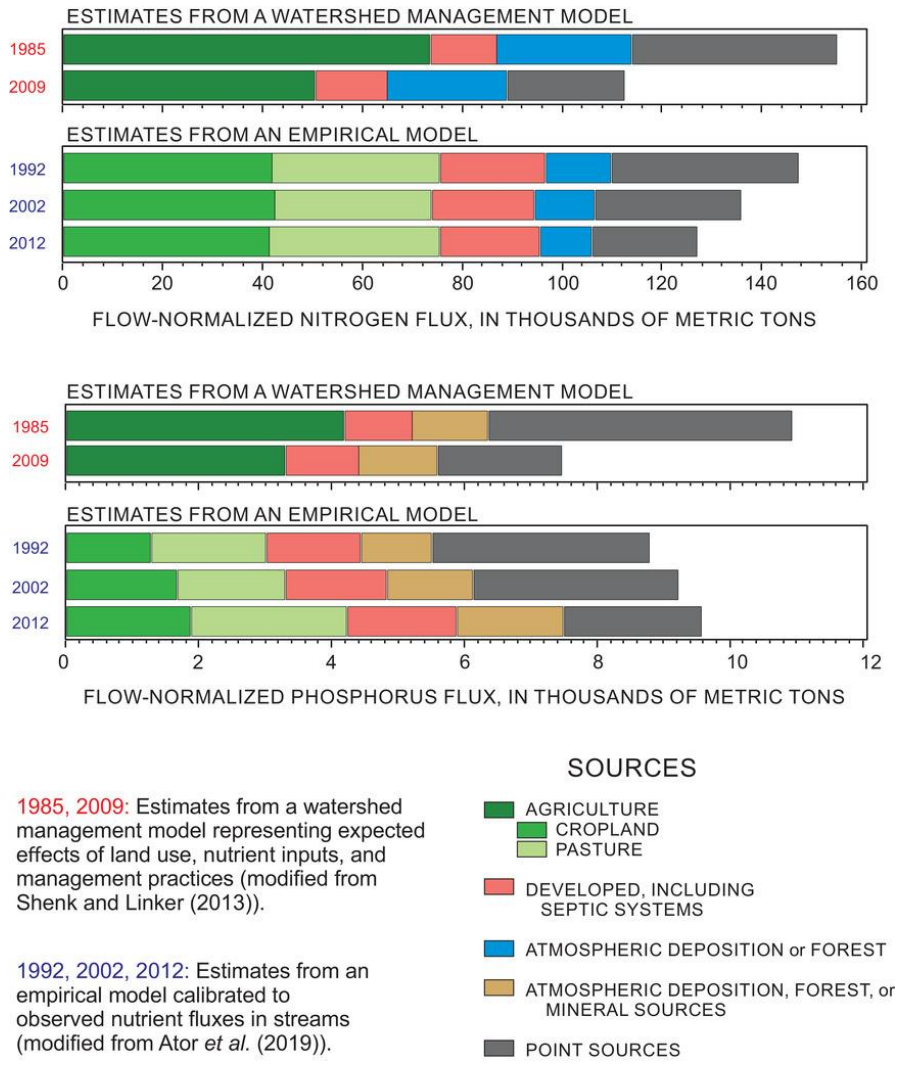
Estimates of nutrient flux to Chesapeake Bay

Toward explaining nitrogen and phosphorus trends in Chesapeake Bay tributaries, 1992-2012

https://doi.org/10.1111/1752-1688.12756



Quantifying Effects of Best Management Practices on Nitrogen in Streams in the Chesapeake Bay Watershed At Regional and Local Scales

October 6th, 2020

Andrew Sekellick, USGS

Olivia Devereux, Devereux Consulting

Scott Ator, USGS

Jeni Keisman, USGS

Project goals

Use ***high-quality spatially explicit*** BMP implementation data in an existing modeling framework to:

- Quantify effects of BMPs on nutrient loads from agricultural sources to local surface waters and delivered to the estuary
- Develop empirical estimates of the effectiveness of specific agricultural BMP categories

Models can improve assessment of progress and establish realistic targets for reductions.

USGS and USDA Data Collaboration

Geography

- BMP locations (latitude and longitude) assigned to National Hydrography Dataset (NHD) Plus V2 catchment polygons (~2 sq km)

Time Period

- BMPs are those implemented and on-the-ground in 2012 to be consistent with the NAWQA NE Regional SPARROW Model
  - On-the-ground, cumulative practices, are a sum of 2006 to 2012. Data prior to 2006 for NRCS are not considered accurate by NRCS because of changes to their data systems.

BMP classifications

- Distinct categories of BMPs chosen based on expected impact on nitrogen loads.

BMP Classification

High-Impact Nitrogen

- Conversion of cropped land to grass-based agriculture
- Nutrient management plans
- Various riparian buffer practices
- Wetland creation, enhancement, and restoration

Other-Impact Nitrogen

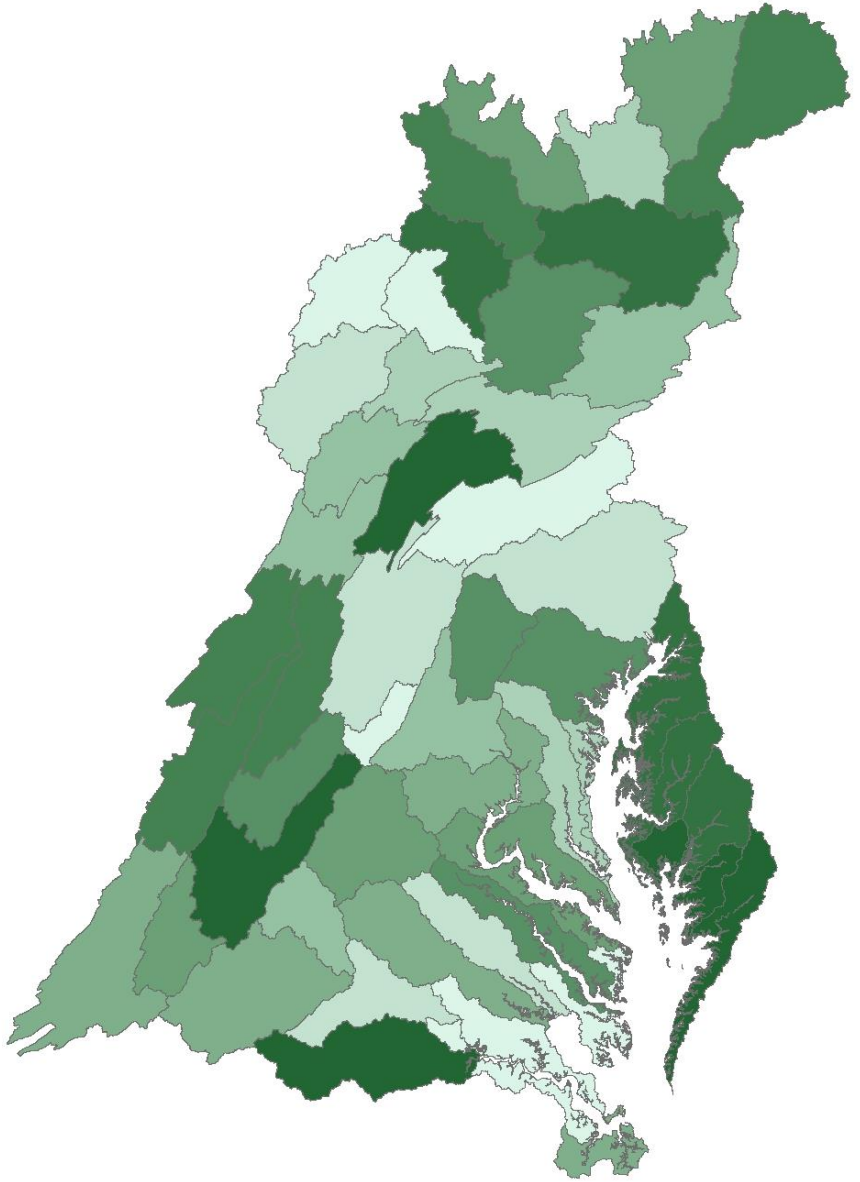
- Cover crops
- Grazing management
- Contour farming controls
- Many other practices

- Does not include tillage practices

BMP Intensity

$$\frac{\text{area of implementation}}{\text{area of targeted land use}}$$

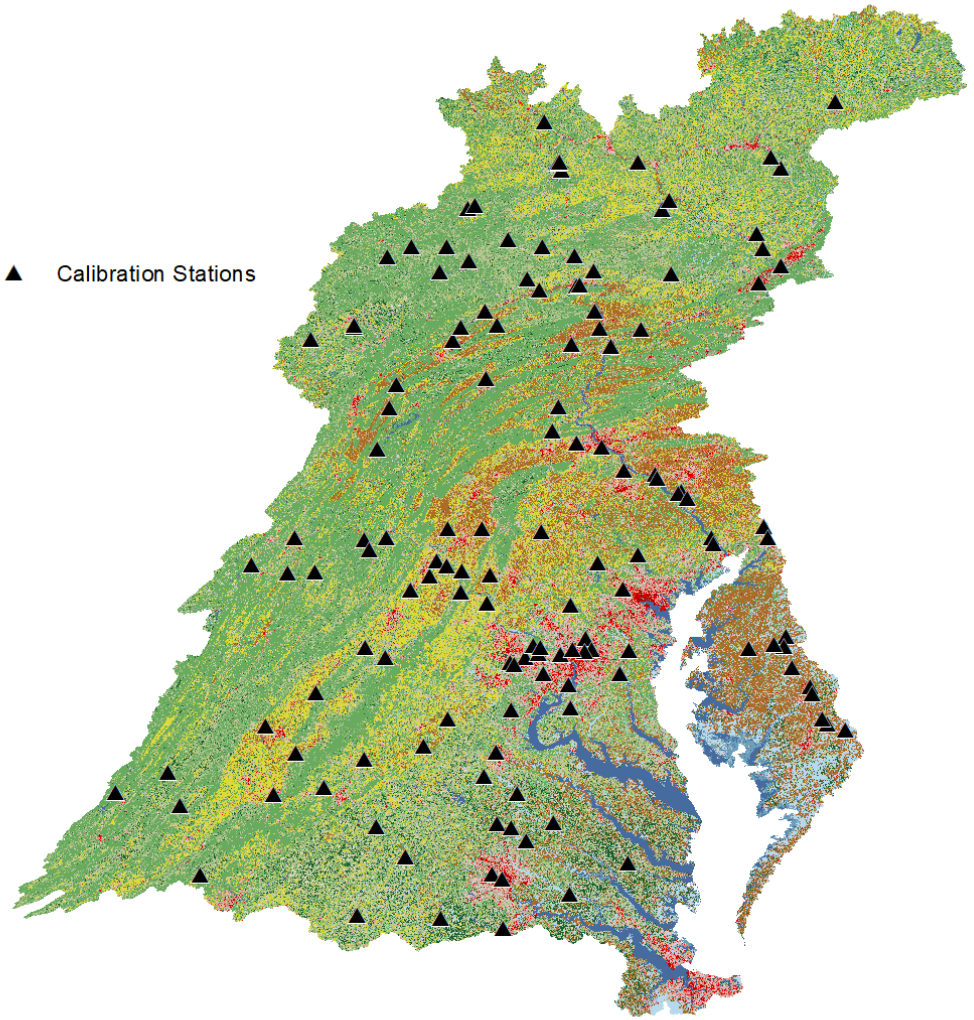
100 acres of cover crop
on
1000 acres of cropland
↓
BMP intensity = 0.1



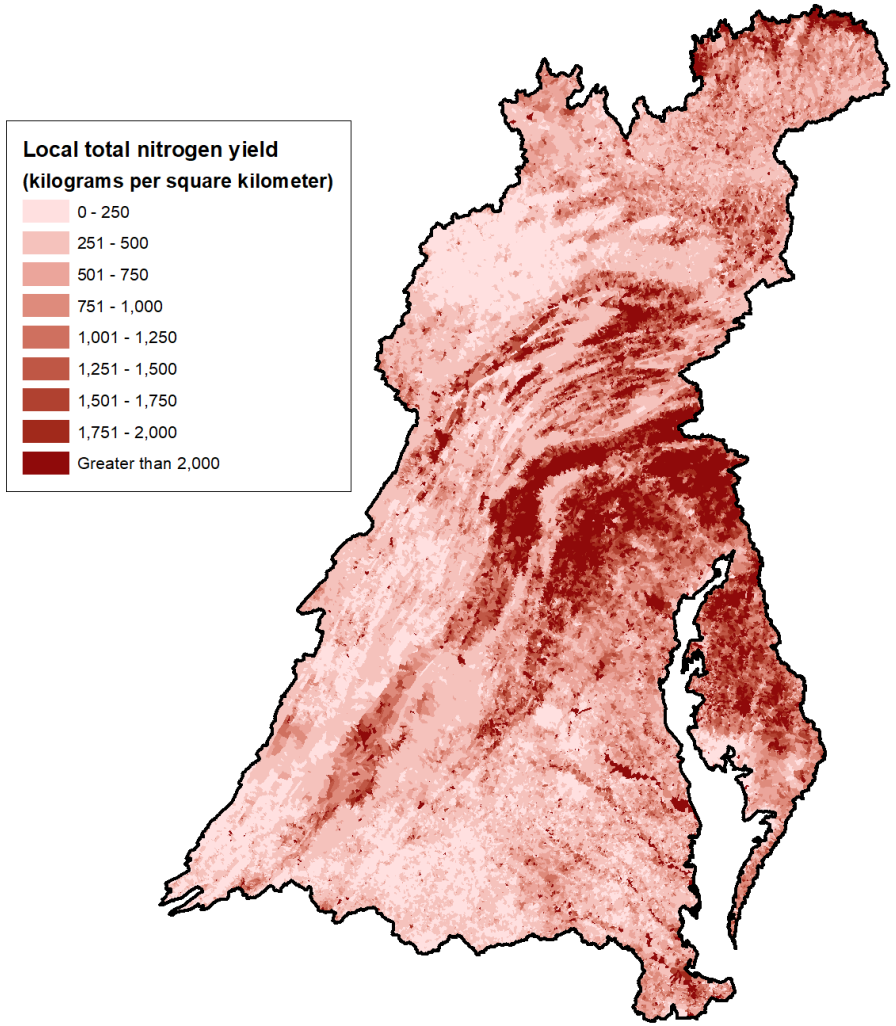
Modeling Total Nitrogen in streams with SPARROW

NAWQA NE regional model adapted for Chesapeake Bay watershed

Sources	Land to water	Decay
Point sources	Forest/wetland	Reach time of travel
Septic	Runoff	Reservoirs
Atmospheric deposition	Soil depth	
Land use	BMP intensity	



Base TN model



Parameter	Unit	Coefficient	p value
Sources			
Point source	kg/yr	1.00	0.14
Septic	kg/yr	0.48	0.04
Atm deposition	kg/yr	0.28	<0.01
Developed land	km2	339.95	0.07
Cropland on carbonate	km2	4847.66	0.01
Cropland on non-carbonate	km2	2626.56	<0.01
Pasture on carbonate	km2	1392.12	0.01
Pasture on non-carbonate	km2	752.66	0.01
Land to water			
Forest/Wetland		-0.34	<0.01
Soil depth		-0.8	<0.01
Runoff		0.82	<0.01
Decay			
Small streams		0.55	0.21
Large streams		0.069	0.10
Reservoirs		8.99	0.04

r^2 : 0.9752

yield r^2 : 0.8395

High-Impact TN model

Negative coefficient for BMP term implies High-Impact BMPs reduce transport of nitrogen to streams

---

If average groundwater age > 14 years than BMP intensity = 0.00001

Parameter	Unit	Coefficient	p value
Sources			
Point source	kg/yr	1.03	0.11
Septic	kg/yr	0.52	0.02
Atm deposition	kg/yr	0.24	<0.01
Developed land	km2	369.29	0.03
Cropland on carbonate	km2	4756.74	<0.01
Cropland on non-carbonate	km2	2104.30	<0.01
Pasture on carbonate	km2	1316.20	<0.01
Pasture on non-carbonate	km2	841.18	<0.01
Land to water			
Forest/Wetland		-0.35	<0.01
Soil depth		-0.59	0.04
Runoff		0.99	<0.01
High-Impact BMPs		**-0.11**	**0.01**
Decay			
Small streams		0.50	0.25
Large streams		0.05	0.20
Reservoirs		7.61	0.05

r^2 : 0.9789

yield r^2 : 0.8492

Other-Impact TN model

Negative coefficient for BMP term implies Other-Impact BMPs reduce transport of nitrogen to streams

Coefficient magnitude is lower than High-Impact BMPs

If average groundwater age > 14 years than BMP intensity = 0.00001

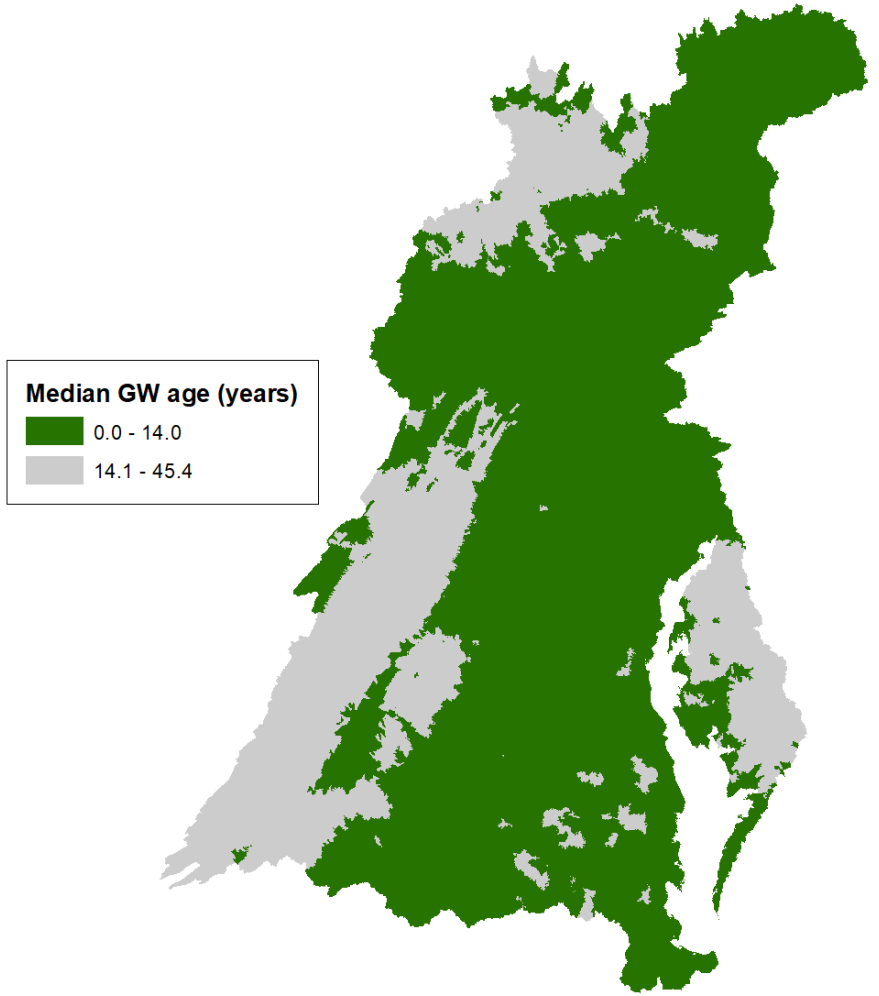
Parameter	Unit	Coefficient	p value
Sources			
Point source	kg/yr	1.13	0.09
Septic	kg/yr	0.53	0.02
Atm deposition	kg/yr	0.26	<0.01
Developed land	km2	320.80	0.07
Cropland on carbonate	km2	4842.31	0.01
Cropland on non-carbonate	km2	2433.32	<0.01
Pasture on carbonate	km2	1464.34	<0.01
Pasture on non-carbonate	km2	851.08	<0.01
Land to water			
Forest/Wetland		-0.36	<0.01
Soil depth		-0.75	<0.01
Runoff		0.93	<0.01
Other-Impact BMPs		**-0.04**	**0.04**
Decay			
Small streams		0.46	0.29
Large streams		0.06	0.11
Reservoirs		7.91	0.04

r^2 : 0.9784

yield r^2 : 0.8458

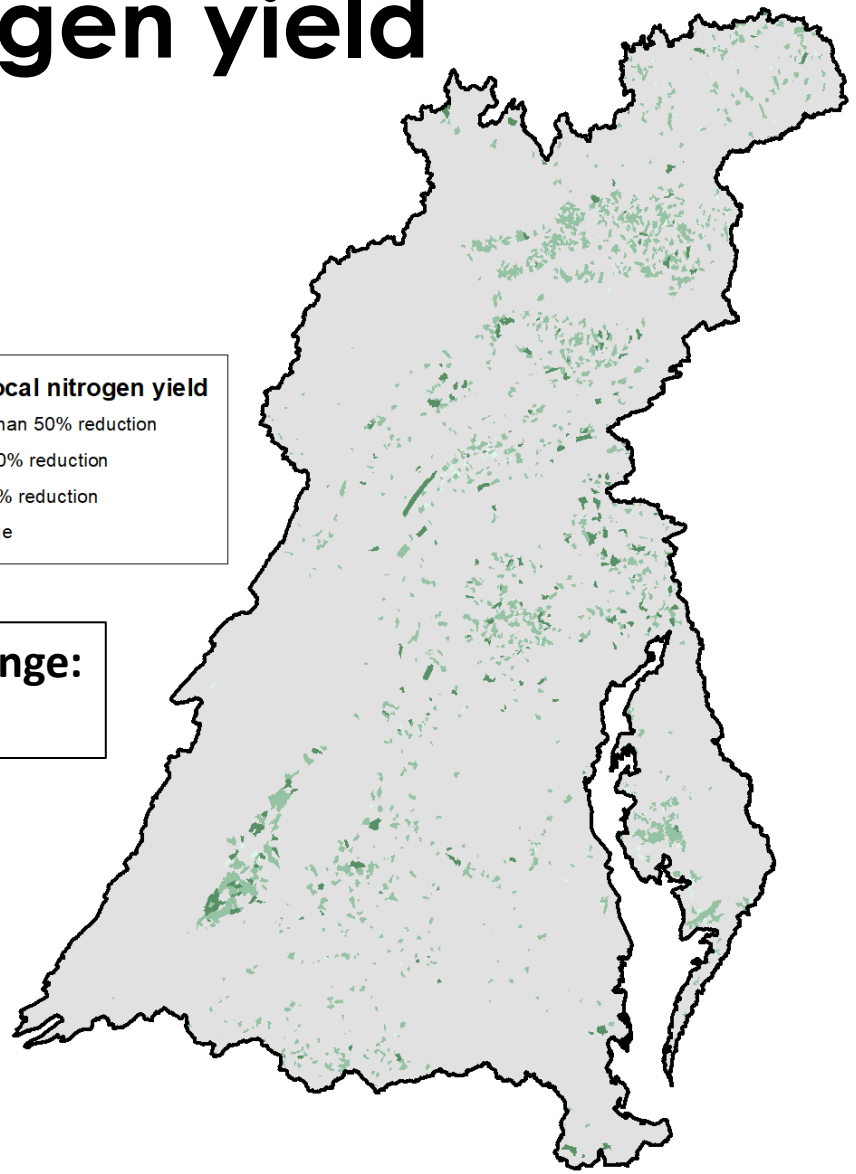
Groundwater Age

Max	45.4 years
90%	19.3 years
75%	14.1 years
Median	10.0 years
25%	7.4 years
10%	5.5 years
Min	0 years



Predicted change in local nitrogen yield

- TN High-Impact model establishes empirical estimate of BMP effectiveness
- Model run in prediction mode with BMP implementation set to 0 acres in input file
- Difference in predicted incremental loads between 2 models can be interpreted as effect of this set of BMPs



Total watershed change:
1.5% TN reduction

Discussion

SPARROW can be a useful tool for BMP evaluation at regional and local spatial scales.

TN models establish empirical estimates of BMP effectiveness

Groundwater age is important!

- For these specific selections of BMPs, effects on nitrogen transport are difficult to detect in areas with older groundwater.
- These results do not mean all BMPs are ineffective in areas with older groundwater.
- This is a 2012 model – results may differ with more recent data.

BMP categorization is important!

- Different signals detected from different BMPs.
- This analysis can potentially be used to isolate effect of different BMPs.

Future work and opportunities

Study unit size

- BMP implementation datasets vary in quality and availability
- Can we calibrate a model with reduced BMP spatial resolution?
- Can we calibrate a model with increased stream network resolution?

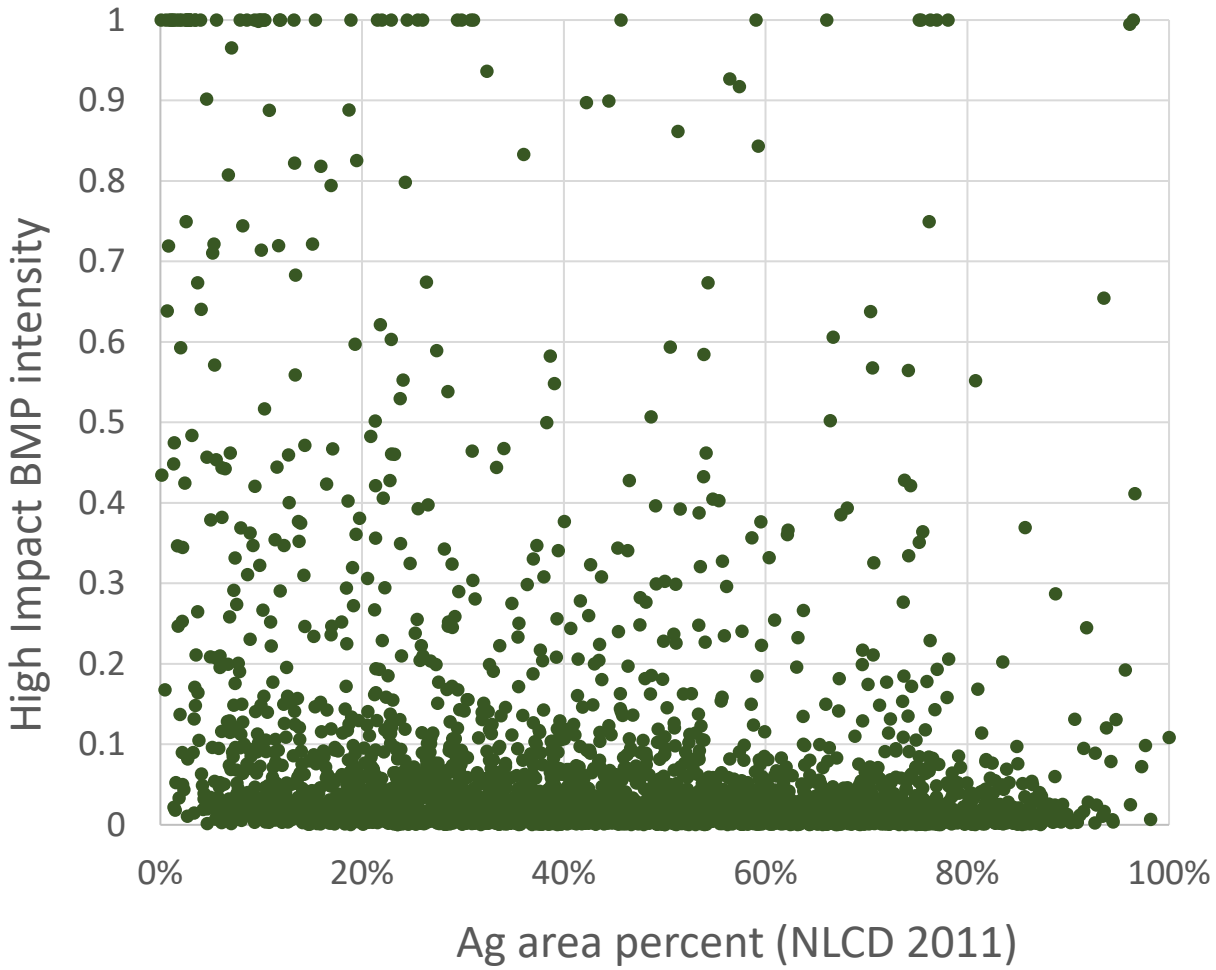
Bootstrapping and confidence intervals on predictions

Other BMP categories/datasets

Alternative approaches for addressing groundwater age

Thinking beyond nitrogen!

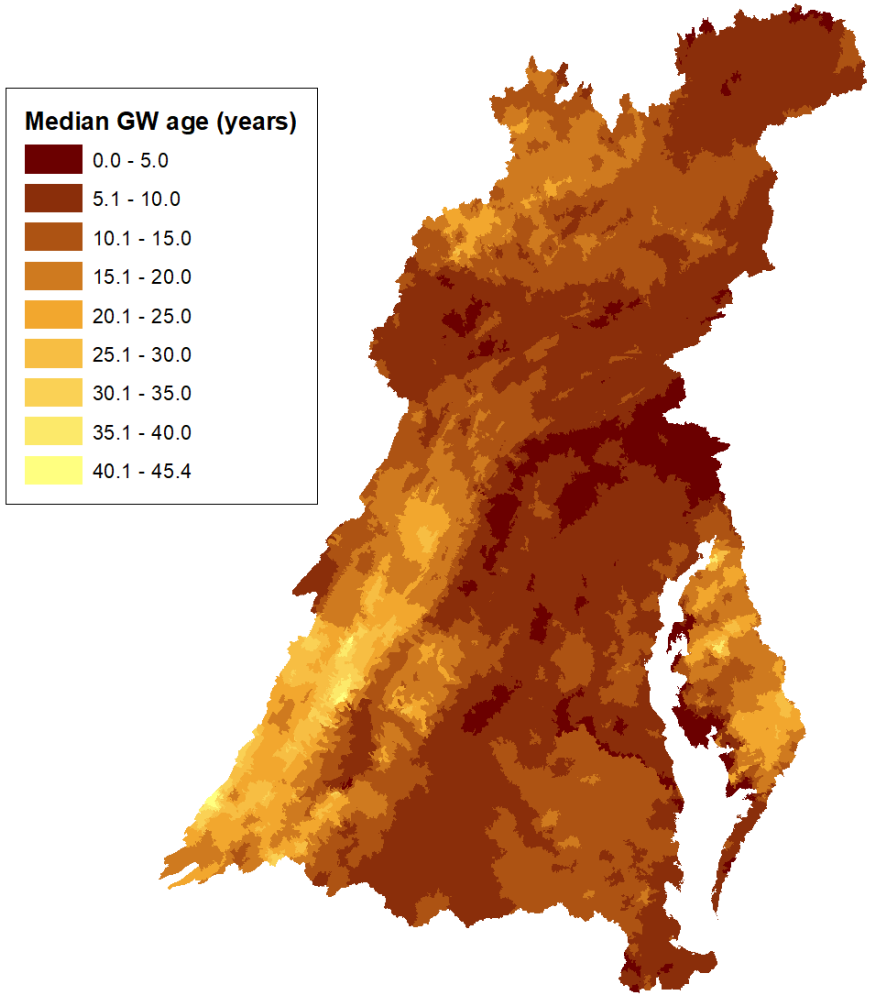
Correlations



Variable	By Variable	Spearman's ρ	Kendall's τ
Ag area percent	High Impact BMP intensity	-0.2714	-0.1846
Ag area percent	Average GW age	-0.1627	-0.1100
High Impact BMP intensity	Average GW age	0.0996	0.0671

Groundwater Age

Max	45.4 years
90%	19.3 years
75%	14.1 years
Median	10.0 years
25%	7.4 years
10%	5.5 years
Min	0 years



High-Impact model – GW Age effects

Median catchment groundwater age (years)	BMP coefficient	Model r^2	BMP p value	% of watershed captured	% of BMPs captured
7	-0.0190	0.9775	0.7438	24%	18%
8	-0.0226	0.9776	0.6100	34%	29%
9	-0.0187	0.9776	0.6671	44%	36%
10	-0.0545	0.9778	0.2146	52%	42%
11	-0.0726	0.9781	0.1037	60%	52%
12	-0.0897	0.9784	0.0357	66%	61%
13	-0.0937	0.9786	0.0221	73%	66%
14	**-0.1076**	**0.9789**	**0.0084**	**77%**	**71%**
15	-0.1088	0.9788	0.0086	81%	75%
16	-0.1047	0.9786	0.0145	84%	79%
17	-0.0805	0.9782	0.0620	87%	84%
18	-0.0770	0.9781	0.0744	90%	88%
19	-0.0647	0.9780	0.1321	92%	90%

Other-Impact model – GW Age effects

Median catchment groundwater age (years)	BMP coefficient	Model r^2	BMP p value	% of watershed captured	% of BMPs captured
7	0.0010	0.9775	0.9697	24%	24%
8	-0.0096	0.9776	0.6695	34%	35%
9	-0.0070	0.9776	0.7544	44%	43%
10	-0.0184	0.9777	0.4150	52%	50%
11	-0.0246	0.9778	0.2864	60%	58%
12	-0.0342	0.9780	0.1329	66%	65%
13	-0.0363	0.9781	0.0978	73%	70%
14	**-0.0431**	**0.9784**	**0.0449**	**77%**	**75%**
15	-0.0426	0.9784	0.0471	81%	79%
16	-0.0399	0.9782	0.0729	84%	83%
17	-0.0268	0.9778	0.2160	87%	87%
18	-0.0285	0.9779	0.1983	90%	89%
19	-0.0256	0.9778	0.2576	92%	91%