Evaluating the Impacts of BMPs on Water Quality Using Privacy-Protected USDA BMP Data in a SPARROW Model

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Purpose

- Quantify effects of BMPs on nutrient loads from agriculture to surface waters using spatially explicit implementation data
- Develop empirical estimates of the effectiveness of specific agricultural BMPs
- Estimate change in fluxes attributable to different practices overall and in different areas of the watershed
- Determine spatial resolution (scale; drainage area) that BMP effects on water quality become quantifiable
- Status to date:
  - Compiled data
  - Adapted NAWQA Northeast SPARROW model to Chesapeake Bay watershed
  - Ran new preliminary SPARROW calibrations
- Guidance: USGS 2019 Workplan, Task 1.3 C

Data

- Geography
  - National Hydrography Dataset (NHD) Plus Version 2 data
  - Assign practice latitude and longitude to the NHD+V2 polygons that intersect the Chesapeake Bay
- Time Period
  - BMPs are those implemented and on-the-ground to remain consistent with the Sparrow 2012 Regional Model
    - Implemented BMPs are the total for 2012 annual practices.
      E.g.: cover crops, nutrient management
    - 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. E.g.: waste management systems, heavy use area protection.
- BMP classifications

Data Source

- USGS and USDA Collaboration

- NRCS data are from the National Planning and Agreements Database (NPAD). NPAD pulls data from Toolkit, ProTracts, NEST, SCIMS, IDEA and PRS
  - BMPs cost-shared by NRCS
  - BMPs funded by FSA but administered by NRCS technical staff
  - NRCS conservation technical assistance

Data Privacy

- Privacy of farmers who receive assistance from USDA are protected by federal law, codified in the Farm Bill
- Personally-identifiable information is protected by restricting release of data that meets all of these requirements:
  - N ≤ 5 or more farmers
  - Same BMP
  - Same geography
- USGS employees who require the data for work that improves water quality may sign a data sharing agreement
- Results of analyses can be published – those do not include the individual records

BMP Classifications

- BMPs are classified into groups
  - NRCS BMP names, could be crosswalked to CAST BMP names
- Groups are not mutually exclusive
- Groups are run in SPARROW independently

1. Have any nitrogen reduction
2. Have a high impact on nitrogen reduction
3. Reduce flow and/or increase infiltration
4. Decrease volatilization of nitrogen (NH4)
5. Reduce runoff to riparian areas and streams

BMPs with a high impact on nitrogen

- Nutrient Management-Right Source, Rate, Time, and Place
  - Nutrient Management Plan – Applied (regular and comprehensive)
  - Precision application technology to apply nutrients/Reduce risks of nutrient losses to surface water by utilizing precision ag technologies
  - Apply enhanced efficiency fertilizer products/Nitrification inhibitors or urease inhibitor/Apply controlled release nitrogen fertilizer
  - Apply nutrients no more than 30 days prior to planned planting date
  - Nitrogen stabilizers for air emissions control
  - Apply split applications of nitrogen based on a pre-sidedress nitrogen test on cropland
  - Split applications of nitrogen based on a PSNT
  - Split nitrogen applications 50% after crop/pasture emergence/green up
  - Using nitrogen provided by legumes, animal manure and compost to supply 100% of the nitrogen needs
  - Improving nutrient uptake efficiency and reducing risk of nutrient losses to surface water
  - Injecting or incorporating manure
- Riparian
  - Riparian buffer, terrestrial and aquatic wildlife habitat
  - Riparian Buffers - Vegetative
  - Riparian Forest Buffer
  - Riparian forest buffer, terrestrial and aquatic wildlife habitat
  - Riparian Herbaceous Cover
  - Manage livestock access to streams/ditches/other waterbodies to reduce nutrients in surface water
  - Manage livestock access to streams/ditches/other waterbodies to reduce pathogens in surface water
- Conversion of cropped land to grass-based agriculture
- Plant an annual grass-type cover crop that will scavenge residual nitrogen

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BMPs with any impact on nitrogen

- 76 additional BMPs that have a nitrogen impact, but are not included in the High Impact grouping
- Additional BMPs include
  - Cover crops
  - Vegetative barriers
  - Wetland
  - Animal waste management
- Tillage reduction is excluded because there are studies that show tillage increases TN runoff.
  - Stefani Daryanto, Lixin Wang, Pierre-André Jacinthe. Impacts of no-tillage management on nitrate loss from corn, soybean and wheat cultivation: A meta-analysis. Scientific Reports, 2017; 7 (1) DOI: 10.1038/s41598-017-12383-7

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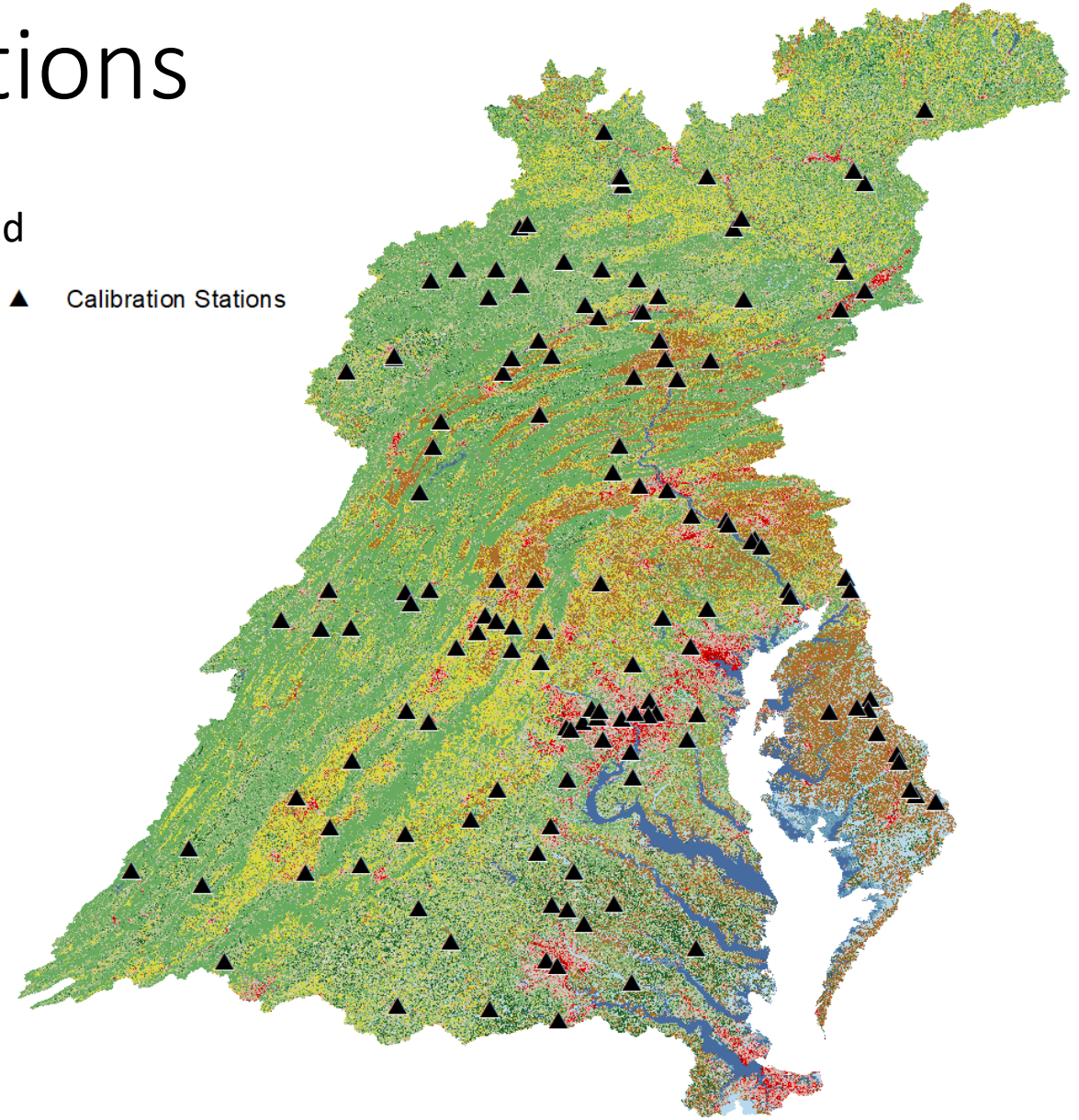
SPARROW model calibrations

NAWQA NE regional model simplified for Chesapeake Bay watershed

Sources	Land to water	Decay
Point sources	Carbonate land	Reach time of travel
Septic	Forest/wetland	reservoirs
Atmospheric deposition	runoff	
Land cover		



3 model calibrations executed:

- Base model (no BMPs)
- TN High-Impact BMP model
- TN All-Impact BMP model

BMPs are added to input file as a land to water term.

- BMP intensity = acres of implementation per available cropland and pasture acres (NLCD 2011)
- Intensity can be greater than 1 (overlapping BMPs are possible)
- Can not do High-Impact and All-Impact BMPs concurrently

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Base model

Simplified version of NE NAWQA model

Uses cropland and pasture area instead of fertilizer, manure, and fixation

R^2 = 0.976

Yield R^2 = 0.831

	Parameter	Estimate	t Value	Pr > |t|	VIF (NC)
Sources	Point Sources (N kg)	**0.37**	1.17	0.24	1.30
	Septic (N kg)	**0.55**	2.37	0.02	2.98
	Atmospheric Deposition (N kg)	**0.28**	4.48	0.00	10.59
	Urban land (kg/km^2)	**338.98**	1.82	0.07	4.09
	Cropland (kg/km^2)	**2462.45**	3.96	0.00	6.32
	Pasture (kg/km^2)	**724.30**	2.65	0.01	4.58
Land-to-water	ln(% Carbonate)	**0.09**	3.01	0.00	2.54
	ln(% Forest or Wetland)	**-0.28**	-3.62	0.00	3.12
	ln(runoff mm)	**0.73**	2.63	0.01	2.05
Decay	Reach time-of-travel small	**1.11**	0.60	0.55	8.98
	Reach time-of-travel medium	**0.88**	1.93	0.06	7.75
	Reach time-of-travel large	**0.04**	1.02	0.31	2.06
	Reservoir load	**11.22**	1.90	0.06	1.34

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TN High-Impact model

Negative coefficient for BMP term implies TN High-Impact BMP grouping reduces transport of nitrogen to streams

High VIF implies high correlation –term is significant with correction applied to t statistic

Relates to uncertainty of coefficient estimate. Work we need to resolve.

- Schwarz, G.E., Hoos, A.B., Alexander, R.B., and Smith, R.A., 2006, Section 3. The SPARROW Surface Water-Quality Model—Theory, application and user documentation: U.S. Geological Survey Techniques and Methods, 6–B3, https://pubs.er.usgs.gov/publication/tm6B3.
- sqrt(VIF) = 5.8
- t = 5.8 * 1.14 = 6.61; p < .00001

R^2 = 0.977

Yield R^2 = 0.834

	Parameter	Estimate	t Value	Pr > |t|	VIF (NC)
Sources	Point Sources (N kg)	**0.35**	1.12	0.26	1.30
	Septic (N kg)	**0.56**	2.39	0.02	2.97
	Atmospheric Deposition (N kg)	**0.30**	4.64	0.00	10.85
	Urban land (kg/km^2)	**321.82**	1.73	0.09	4.10
	Cropland (kg/km^2)	**1582.96**	1.92	0.06	26.72
	Pasture (kg/km^2)	**441.97**	1.62	0.11	10.79
Land-to-water	ln(% Carbonate)	**0.08**	2.58	0.01	2.66
	ln(% Forest or Wetland)	**-0.27**	-3.50	0.00	3.17
	ln(runoff mm)	**0.69**	2.54	0.01	1.98
	ln(TN High Impact BMP intensity)	**-0.10**	-1.14	0.26	34.09
Decay	Reach time-of-travel small	**1.22**	0.67	0.50	8.70
	Reach time-of-travel medium	**0.86**	1.90	0.06	7.72
	Reach time-of-travel large	**0.03**	0.77	0.44	2.09
	Reservoir load	**11.55**	1.89	0.06	1.35

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TN All-Impact model

Positive coefficient for BMP term implies TN Impact BMP grouping increase transport of nitrogen to streams

Estimate is opposite of TN High-Impact term

R^2 = 0.978

Yield R^2 = 0.841

	Parameter	Estimate	t Value	Pr > |t|	VIF (NC)
Sources	Point Sources (N kg)	**0.46**	1.39	0.17	1.33
	Septic (N kg)	**0.60**	2.42	0.02	3.22
	Atmospheric Deposition (N kg)	**0.31**	4.56	0.00	11.57
	Urban land (kg/km^2)	**391.99**	1.92	0.06	4.44
	Cropland (kg/km^2)	**2254.24**	3.45	0.00	8.33
	Pasture (kg/km^2)	**629.47**	2.28	0.02	5.18
Land-to-water	ln(% Carbonate)	**0.11**	3.46	0.00	2.57
	ln(% Forest or Wetland)	**-0.27**	-3.46	0.00	3.23
	ln(runoff mm)	**0.75**	2.70	0.01	2.16
	ln(TN Impact BMP intensity)	**0.10**	2.36	0.02	3.71
Decay	Reach time-of-travel small	**1.43**	0.76	0.45	9.28
	Reach time-of-travel medium	**1.15**	2.39	0.02	8.19
	Reach time-of-travel large	**0.03**	0.81	0.42	2.07
	Reservoir load	**10.01**	1.90	0.06	1.32

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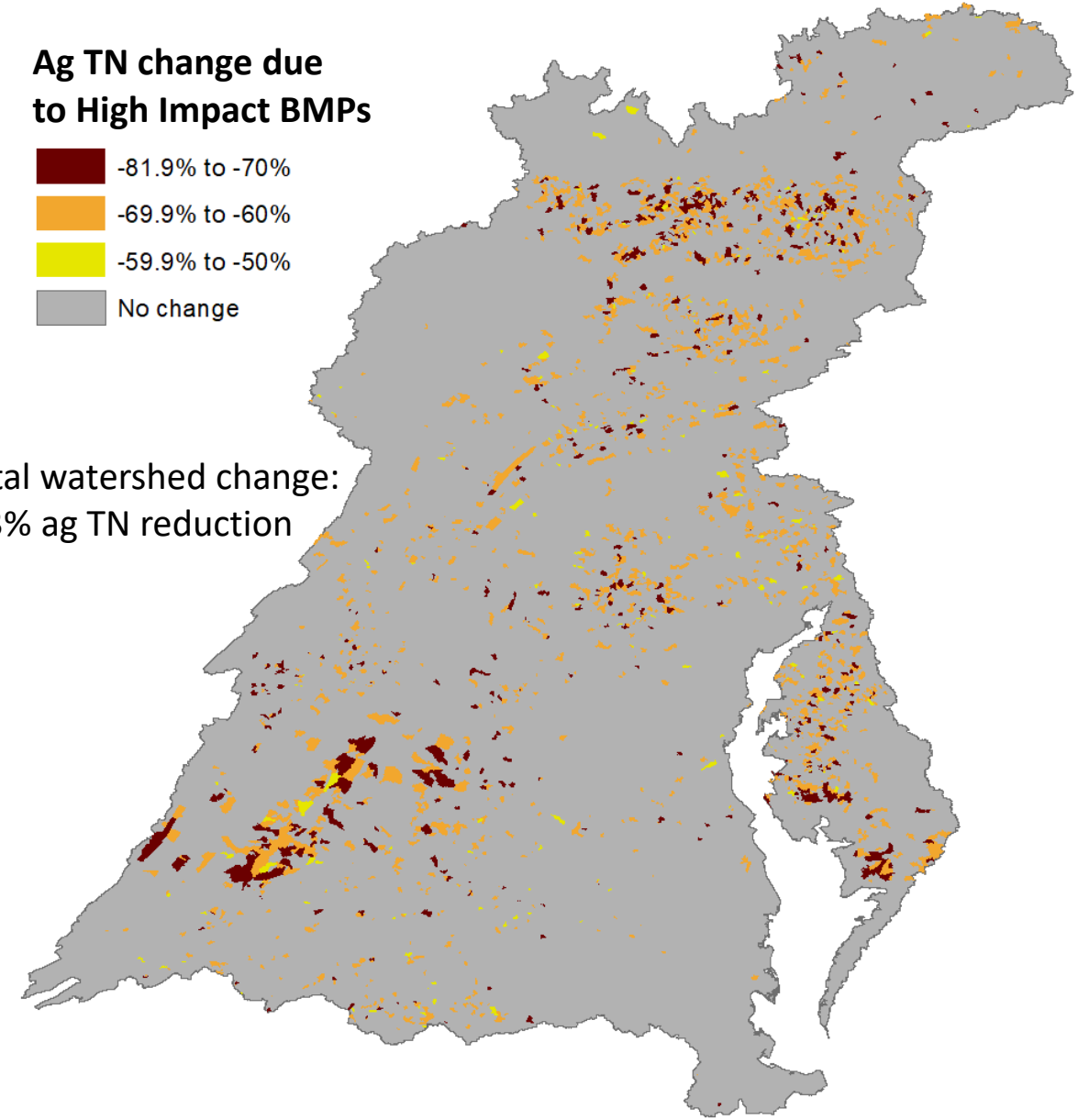
TN High-Impact model: Prediction mode

- TN High-Impact model establishes empirical estimate of High-Impact 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 BMPs

Average estimated reduction in TN loads due to TN High-Impact BMPs	
Pasture	**Cropland**
0.85 kg/ha	3.01 kg/ha



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Pasture	**Cropland**
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Total **2012** watershed-wide TN change due to ag BMPs (SPARROW):

9.3% reduction

Total **2014** watershed-wide TN change due to ag BMPs (Phase 5.3.2):

9.4% reduction

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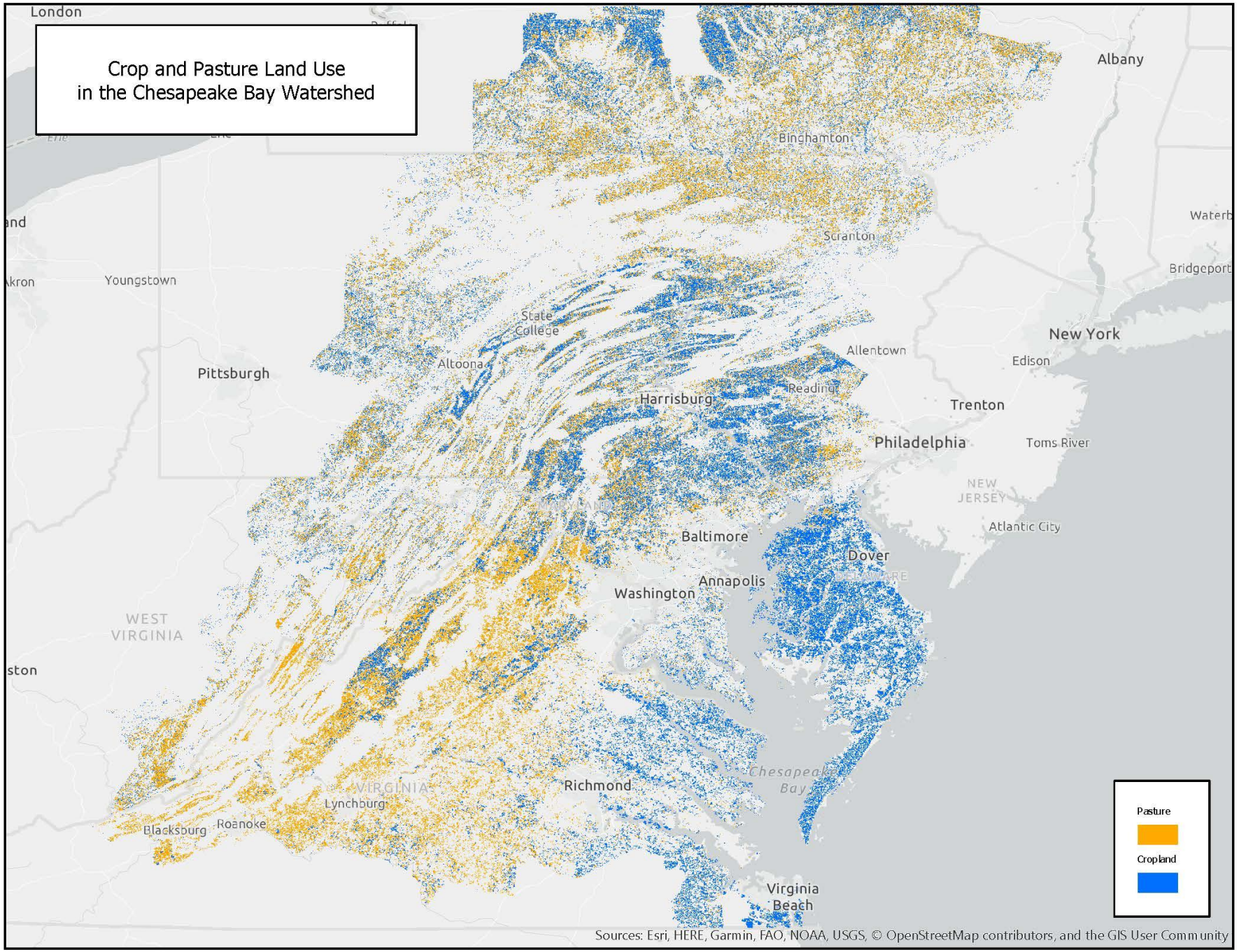
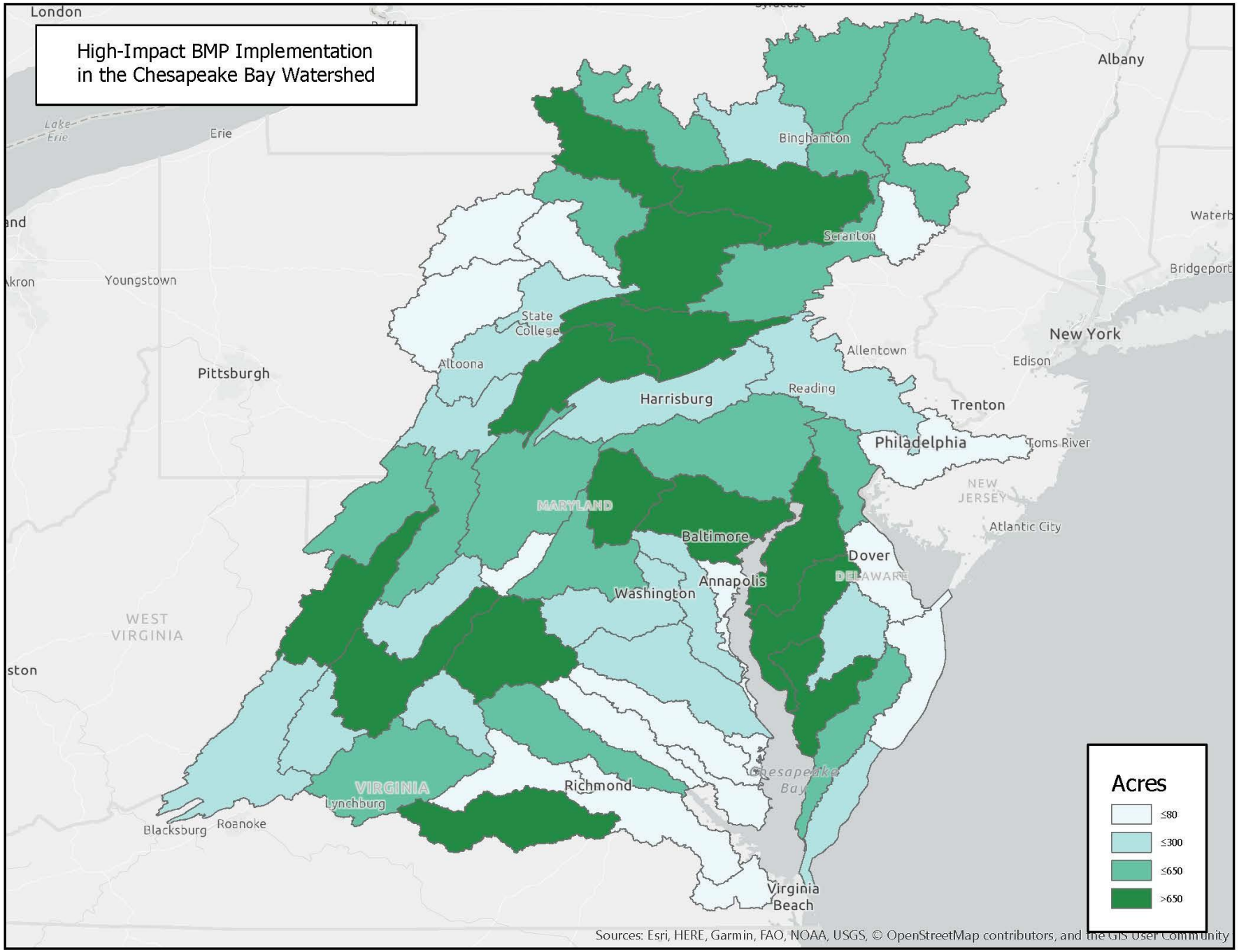

Crop and Pasture Land Use
in the Chesapeake Bay Watershed
London
Albany
Binghamton
Scranton
Youngstown
Akron
Bridgeport
State College
New York
Allentown
Edison
Pittsburgh
Altoona
Reading
Harrisburg
Trenton
Philadelphia
Toms River
NEW JERSEY
Atlantic City
Baltimore
Dover
Annapolis
Washington
WEST VIRGINIA
Chesapeake Bay
Richmond
VIRGINIA
Lynchburg
Blacksburg
Roanoke
Virginia Beach
Pasture
Cropland
Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community


High-Impact BMP Implementation
in the Chesapeake Bay Watershed
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Harrisburg
Trenton
Philadelphia
Toms River
MARYLAND
NEW JERSEY
Atlantic City
Baltimore
Dover
DELAWARE
Annapolis
Washington
WEST VIRGINIA
Chesapeake Bay
VIRGINIA
Richmond
Lynchburg
Blacksburg
Roanoke
Virginia Beach
Acres
≤80
≤300
≤650
>650
Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Conclusions

- **These are initial results of model testing.**
- Proposed approach is capable of detecting a signal of BMP effects in stream monitoring data.
- Further effort required to validate and refine these results.
- BMP classifications groupings matter (signal can be complicated with too many BMP types).
  - TN High-Impact BMPs are estimated to ***reduce*** nitrogen loads to streams.
  - TN All-Impact BMPs are estimated to ***increase*** nitrogen loads to streams.
- TN High-Impact BMPs on cropland are estimated to have a greater impact on TN loads than BMPs on pasture.
  - Possible to isolate which specific BMPs are more effective.
  - Possible to isolate which specific BMPs increase TN loads.
- Geography where BMPs are predicted to be reducing TN loads are easily identifiable.

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Possible Future analyses

- Investigate positive TN All-Impact coefficient
  - Spatial distribution of implementation
  - Catchment characteristics
  - Isolate BMPs and refine groupings
- Investigate urban BMPs
- Investigate manure transport effect
- Explore co-linearity among factors and refine model
- Investigate varying time scales of BMP implementation e.g., pre and post 2012
- Use dynamic model to predict signal lags with non-flow adjusted data
- Determine if different geographic scales of inputs affect results (county, HUC12, HUC8)
- Investigate ROI on BMP implementation
- Evaluate BMP effects under varying hydrological regimes, informing possible climate change analysis
- Modify approach to explain impacts on fish and habitat

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