

Climate Change Impacts on Nutrient Runoff and the Effectiveness of Best Management Practices

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Extension

Outline of Today's Talk

1. Research-Education-Extension approach to watershed management
2. Impacts of Climate Change on pollution “hot spots” or Critical Source Areas (CSAs)
3. Impacts of Climate Change on BMP effectiveness

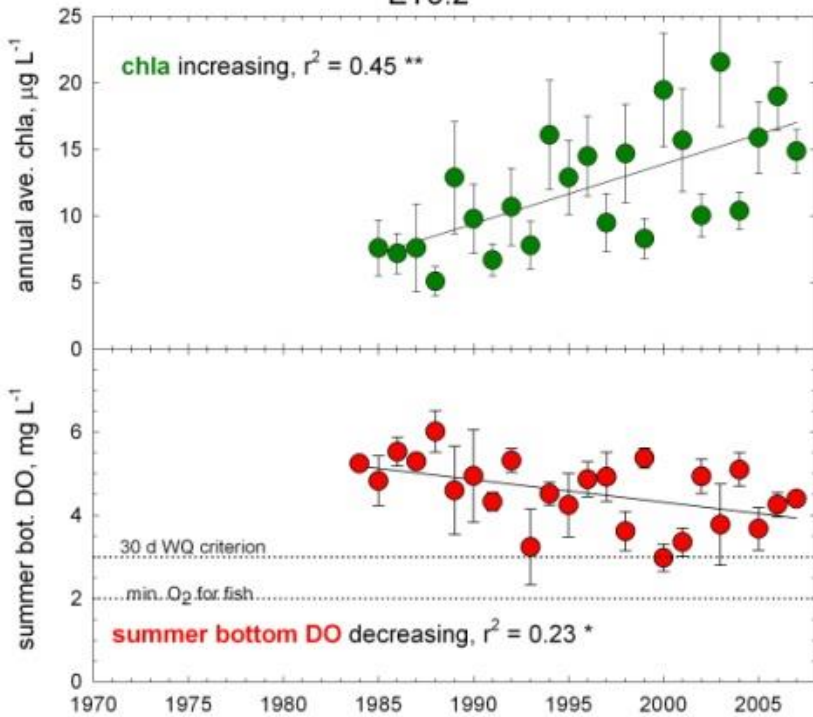
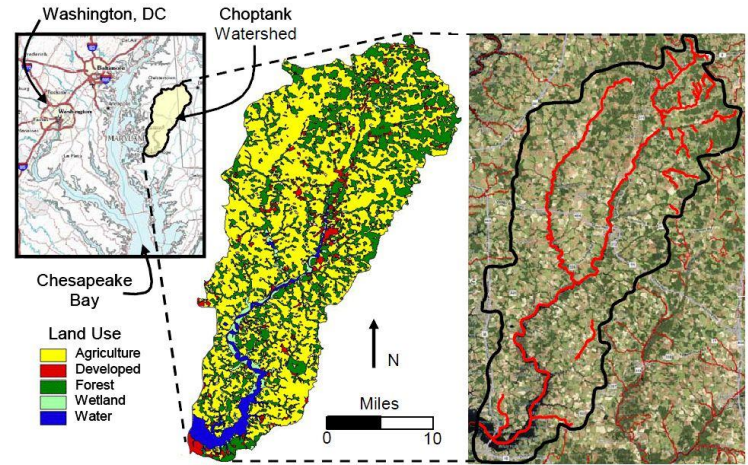
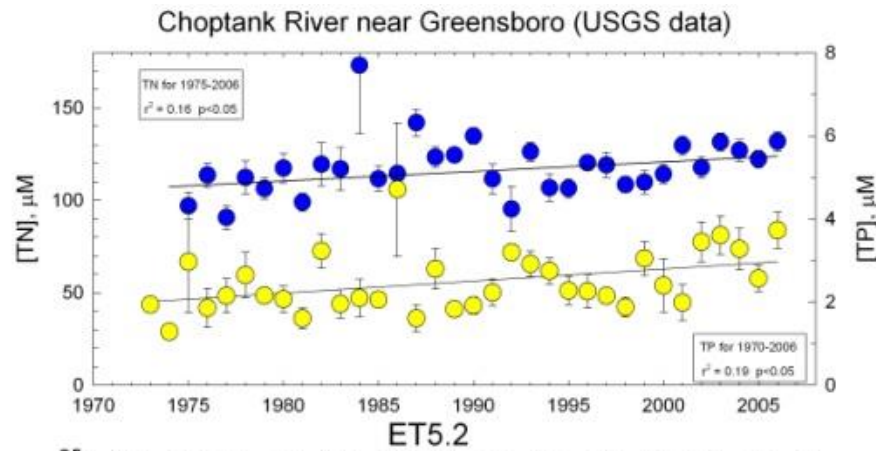
Research-Education-Extension Approach To Watershed Management

Goal

Develop, implement, and evaluate a cross-disciplinary approach for watershed management that considers both technical (biophysical) and social factors

Objectives

1. Evaluate community attitudes towards water resources and identify barriers to BMP adoption
2. Develop a Diagnostic Decision Support System (DDSS) to identify Critical Source Areas and prescribe targeted BMPs
3. Develop and evaluate strategies for increasing awareness and behaviors towards water quality to increase BMP adoption



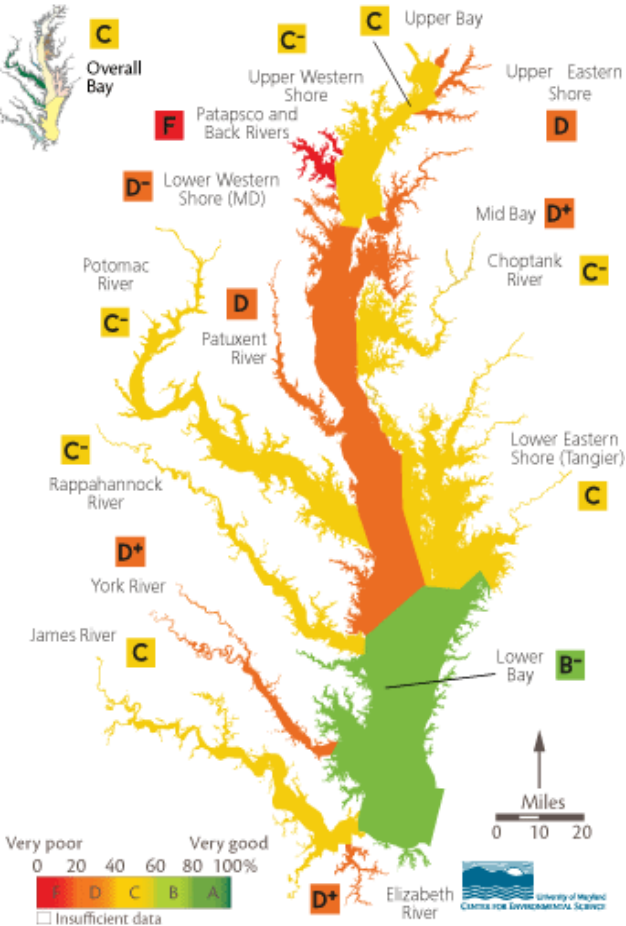
Algae and turbidity are increasing over time, and summer bottom O_2 is decreasing

Tom Fisher, Horn Point Laboratory, UMCES

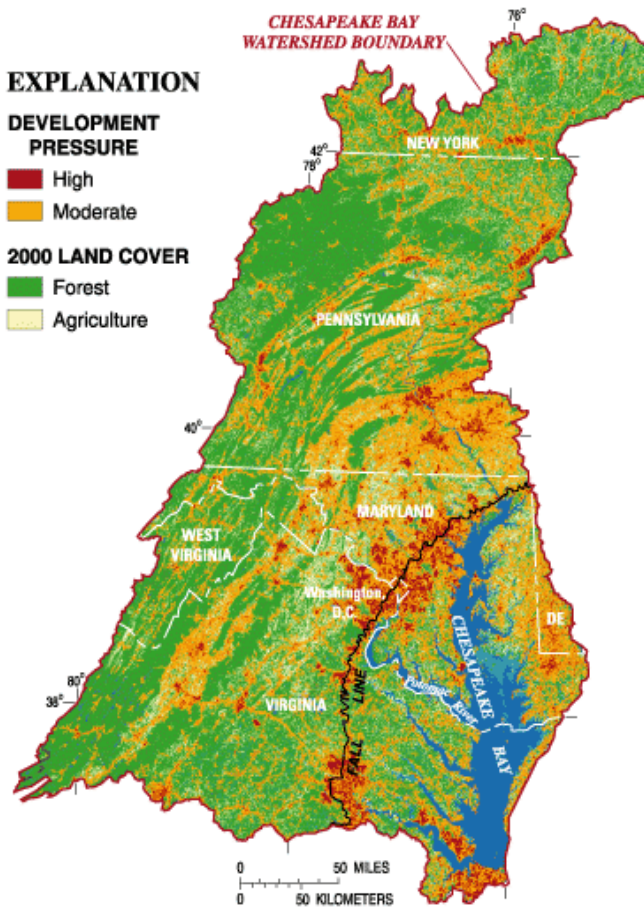
The Chesapeake Bay

Non-Point Sources

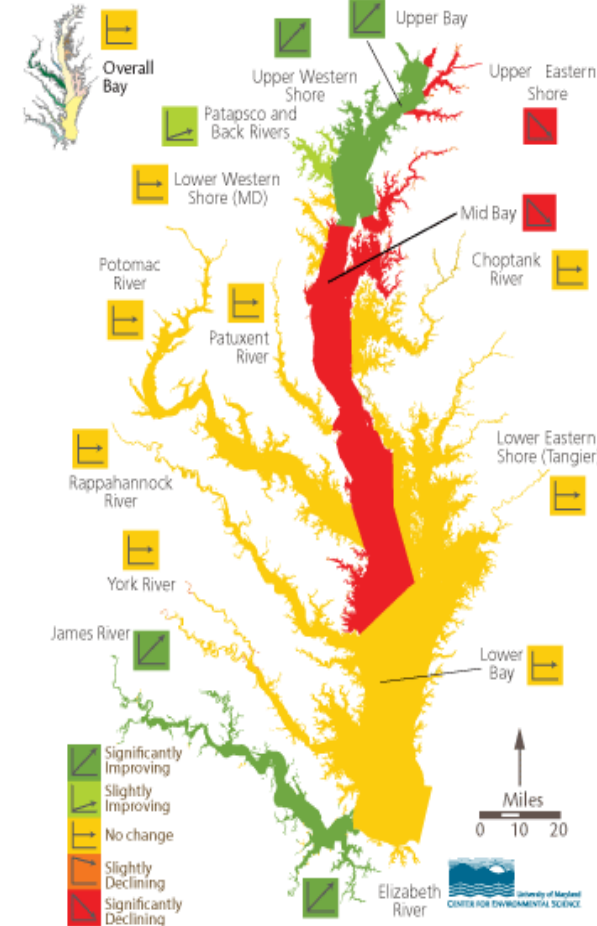
Bay Health Index 2013



CHESAPEAKE BAY WATERSHED BOUNDARY



Bay Health Trends 2013



From: USGS and UMCES

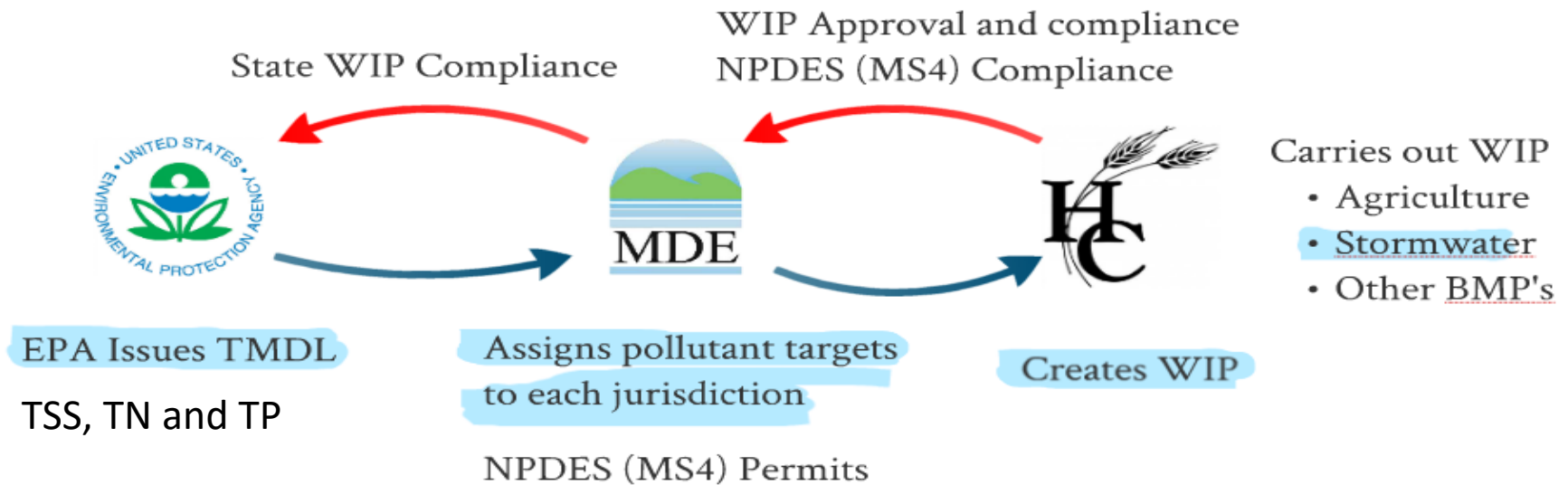
Background

- Little improvement in water quality of Chesapeake Bay over last 40 years
- Focus of previous research and intervention on technological or social components alone
- Need a shift towards **integrative research-extension-education** approach
- Need to better embrace **both biophysical and social dimensions** of pollution transport and Best Management Practice (BMP) adoption

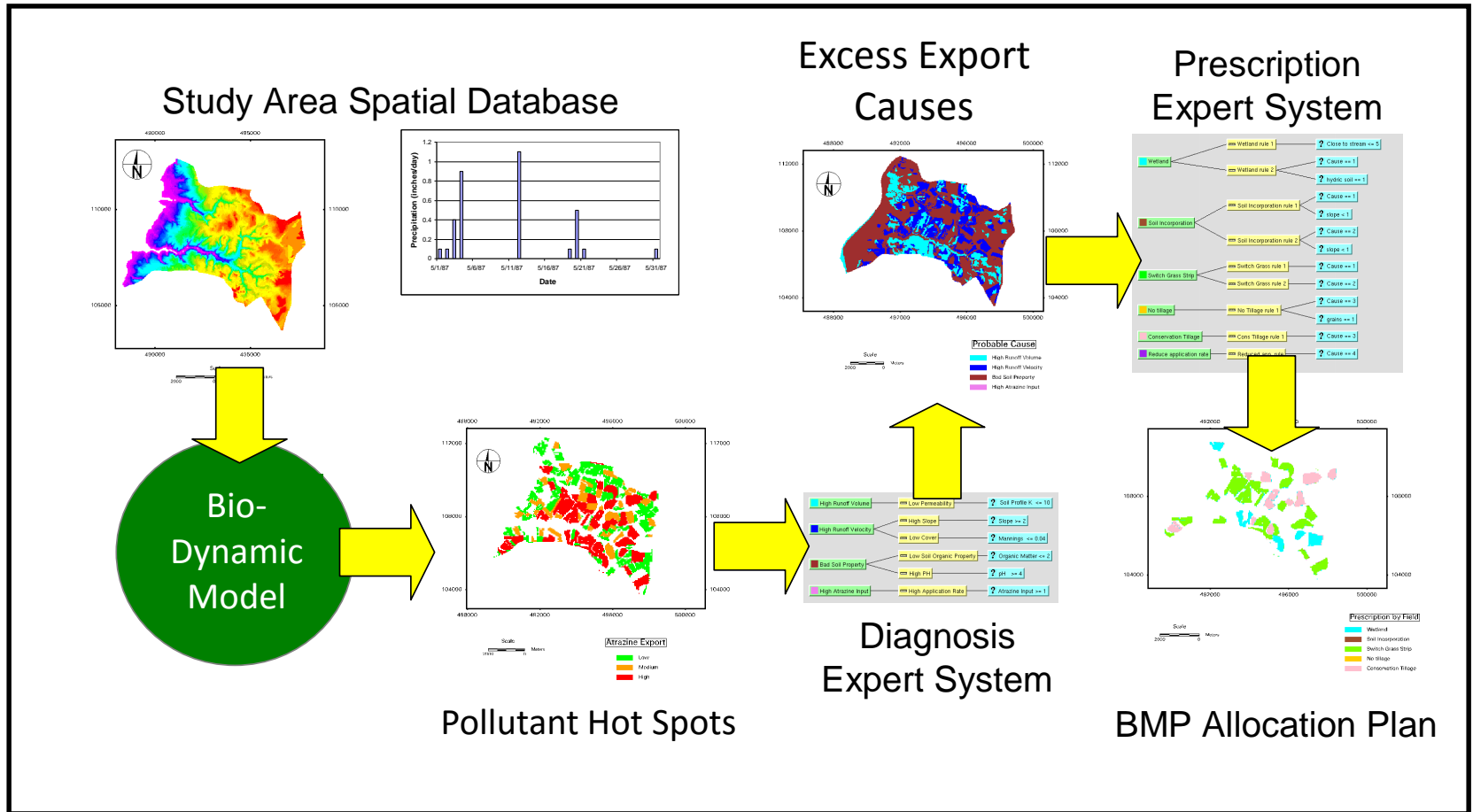
Motivation: EO 13508 and Regulation

$$TMDL = \sum WLA + \sum LA + MOS$$

Point Sources + Non-Point Sources + Margin of Safety



Development of the DDSS

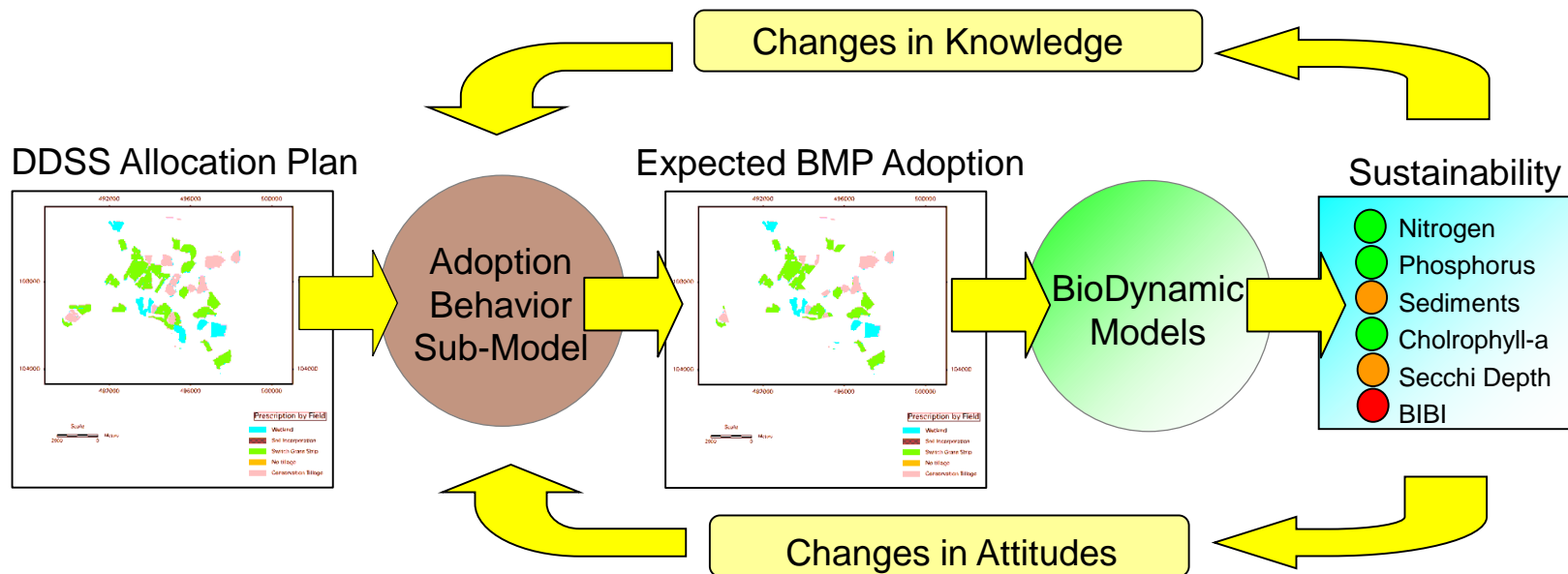


Components: GIS, Models, Expert Systems

Model(s): SWAT (SUSTAIN, AQUATOX, FIBI, EPA BASINS)

Expert Systems: MATLAB (predicate calculus to decision trees)

Integrating Social Dimensions



Evaluate Relationships between Knowledge, Attitudes, BMP Adoption

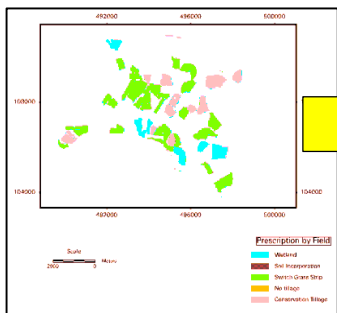
- Community Advisory Committee
- Interviews & Q-sort
- Photovoice
- Focus Groups
- Survey

Increase Awareness & Behaviors To Water Resources & BMPs

- Design & Service Learning
- Town Hall Meetings
- Youth Education Programs
- Education Materials / Media
- BMP Implementation Training

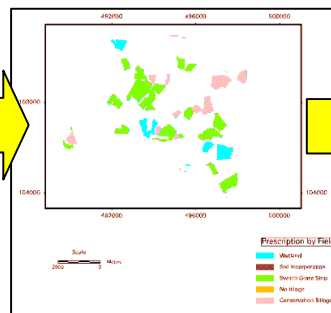
Changes in Knowledge

DDSS Allocation Plan



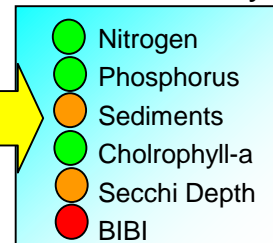
Adoption Behavior Sub-Model

Expected BMP Adoption

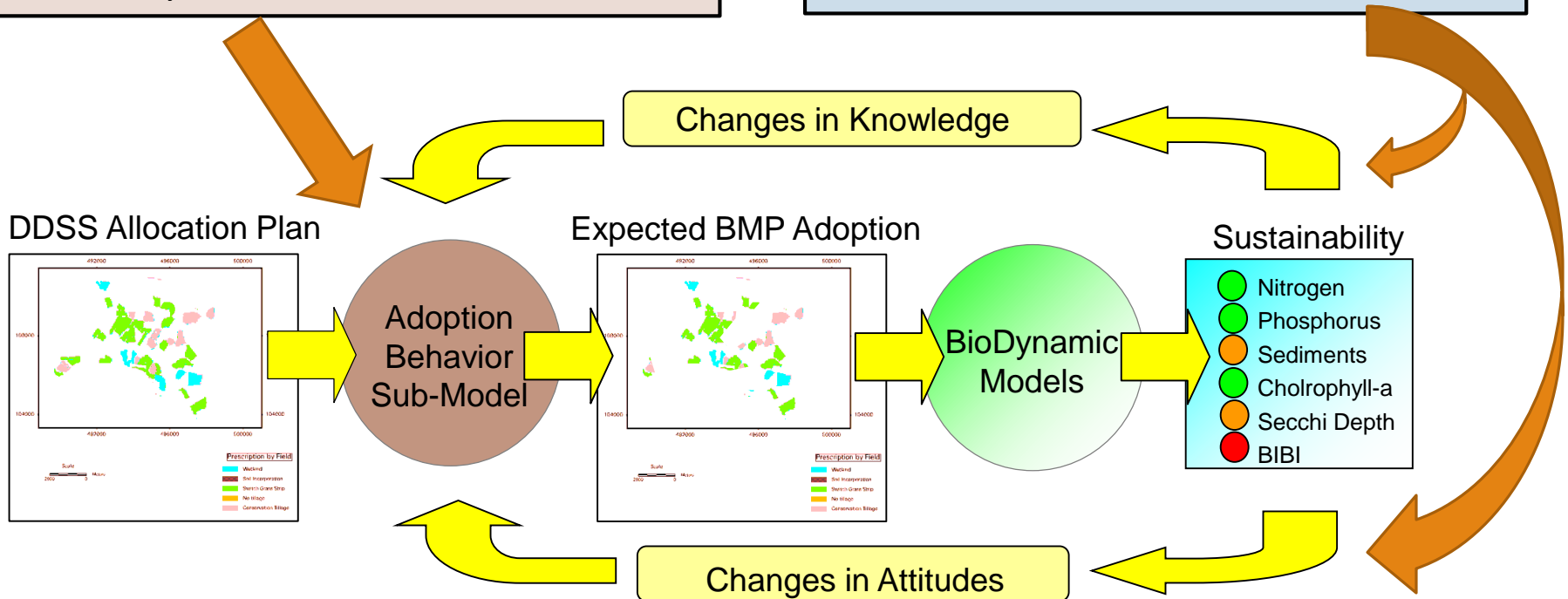


BioDynamic Models

Sustainability



Changes in Attitudes



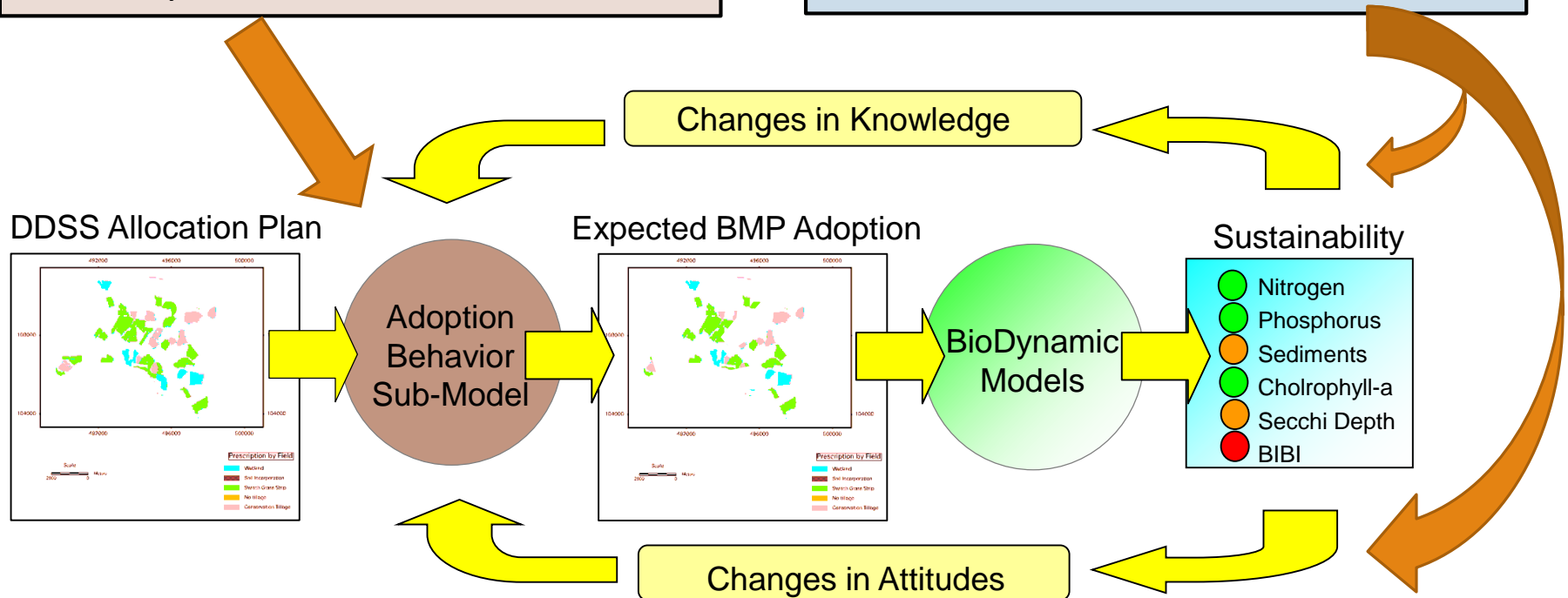
Collaboration with Community Organizations / State Agencies - CBPR

Evaluate Relationships between Knowledge, Attitudes, BMP Adoption

- Community Advisory Committee
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Increase Awareness & Behaviors To Water Resources & BMPs

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Opinion Poll

There is very strong evidence that agriculture is the single largest source of nitrogen, phosphorous and sediment going into the Chesapeake Bay.

Water problems like *Pfiesteria* should not be blamed on chicken manure because of all of the sewage being pumped into the bay right in the port of Baltimore. Pollutants like this in the bay aren't from the farmers.

The most effective regulators are people who came up from the industry of whatever it is they're regulating because they understand what actually happens.

Large companies like Perdue control all aspects of growing chickens, they should pay for Agricultural Best Management Practices for farmers

Precipitation and Temperature Changes

Climate change forecasts for the Northeastern United States:

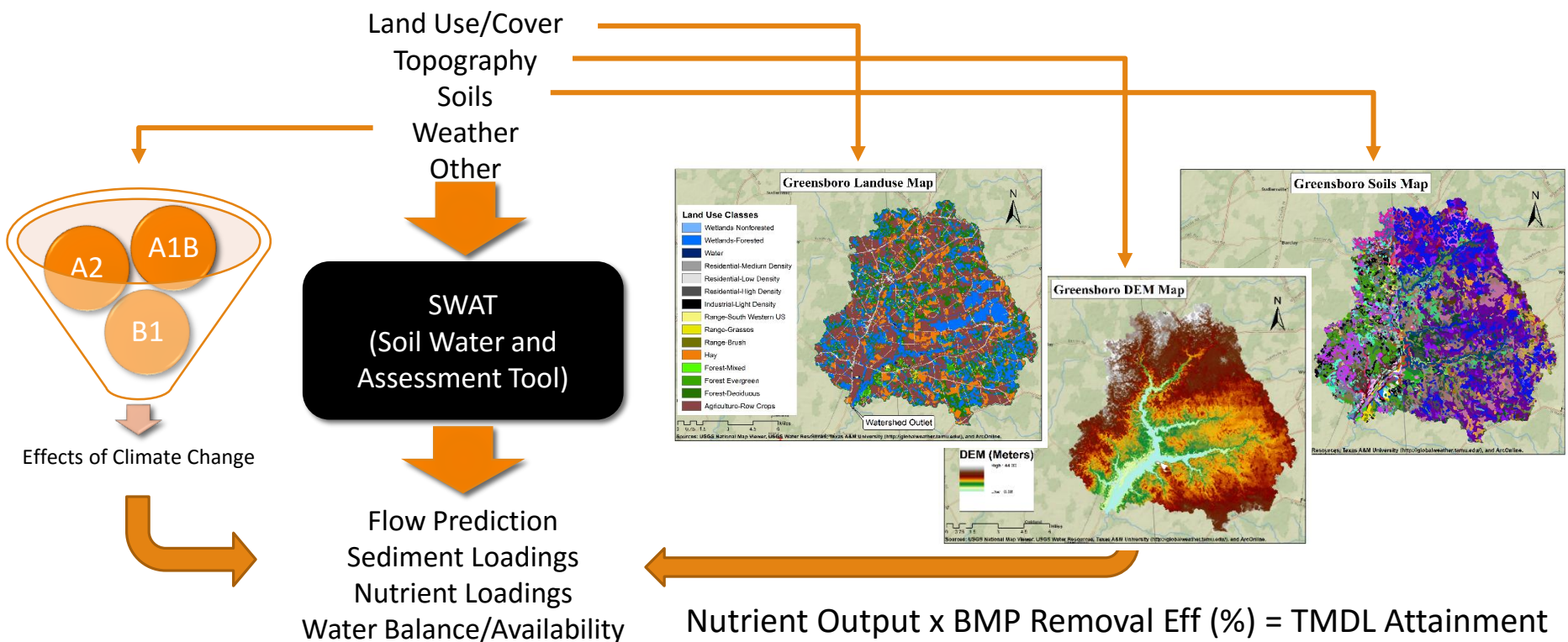
- ↑ Elevated concentrations of atmospheric CO₂
- ↑ Elevated mean temperature
- ↑ Increased mean rainfall
- ↑ Shift in seasonal rainfall patterns
 - Wetter spring
 - Drier late summer
- ↑ Increases in extreme weather events

Impacts of Climate Change on Pollution “hot spots” or Critical Source Areas (CSAs)

Biophysical Modeling

Once we have a working model...

- 1. We can use best available science to find Critical Source Areas (CSAs)
- 2. We don't have to physically install BMPs (now or in the future), saving money
- 3. We can use the model to test BMP configurations that will achieve TMDL targets



Definition of a Critical Source Area (CSA)

An area that exports target constituents at concentrations significantly above average

Quantile Method (Fixed Threshold)

Rank	SurQ (mm H2O)	TSS (tonnes/ha/yr)	TN (kg/ha/yr)	TP (kg/ha/yr)
Top 10%	>406	>1.03	>24	>1.9
Top 20%	>359	>0.73	>16	>1.6

Top 10%: Value for which the top ~770 HRUs is separated from the other 7705 HRUs

Top 20%: Value for which the top ~1540 HRUs is separated from the other 7705 HRUs

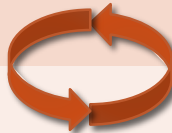
Our Goal is:

A BMP or BMP configuration that will maintain good water quality in the Chesapeake Bay treating the least amount of land area possible.

Model Construction and Analysis

Data Type	Characteristics	
Topography/DEM	10 meter	} HRU
Landuse/Land Cover	NLCD 2006	
Soils	NRCS SSURGO	
Weather (Calibration)	3 stations NCEP CFSR	
Flow, Nutrients and Sediment	1 USGS Gauging Station Greensboro	
Climate Change	CMIP3 (B1, A1B, A2)	
GFDL-CM2.1	(Mid and End Century)	

Software	Purpose and Progression
ArcGIS	Spatial Data Analysis (Graphics and Database)
ArcSWAT	Model development SWAT input file Generation
SWAT-CUP	Model calibration (SUFI-2 Method)
SWAT	Experimental engine (SWAT.exe)



Model Calibration

- Warm-up (3 yrs): 1/1/1990 to 12/31/1992
- Calibration Period (15 yrs): 1/1/1990 to 12/31/2004

Model Validation

- Warm-up (2 yrs): 1/1/2005 to 12/31/2006
- Validation Period (6 yrs): 1/1/2005 to 12/31/2010

Greensboro Watershed

Choptank Watershed



Greensboro Sub-watershed

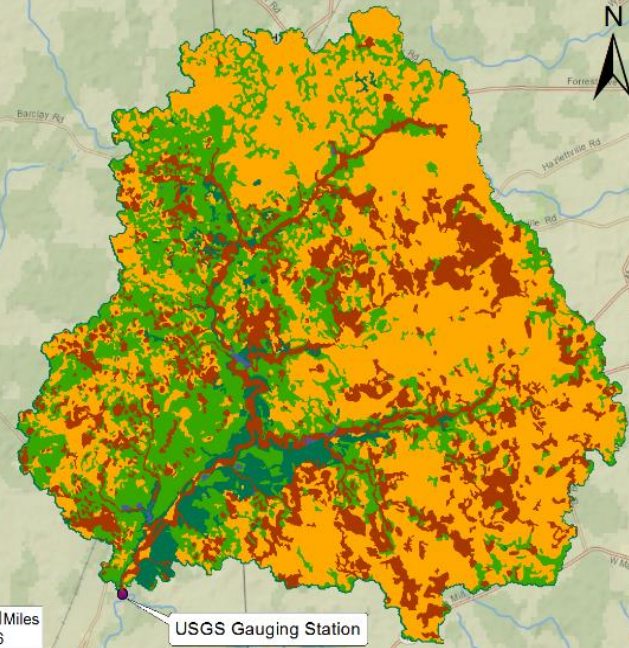
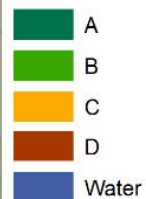


USGS Gauging Station

Sources: USGS National Map Viewer, USGS Water Resources, Texas A&M University (<http://globalweather.tamu.edu/>), and ArcOnline.

Greensboro Hydrologic Soil Group Characterization

Hydrologic Group Soil Classifications

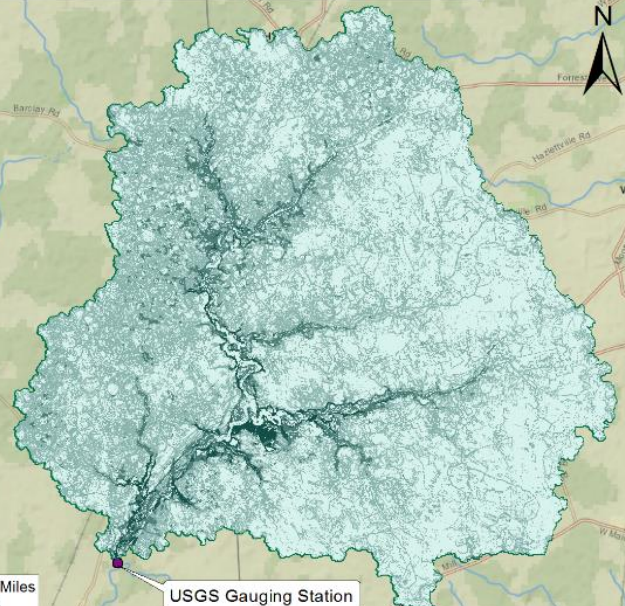


USGS Gauging Station

Sources: USGS National Map Viewer, USGS Water Resources, Texas A&M University (<http://globalweather.tamu.edu/>), and ArcOnline.

Greensboro Slope Classification Map

Mean HRU Slope %

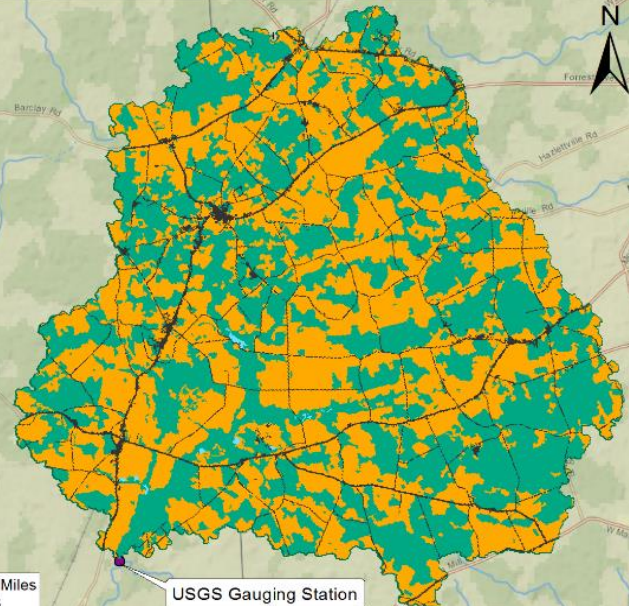
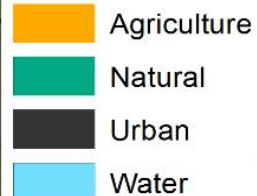


USGS Gauging Station

Sources: USGS National Map Viewer, USGS Water Resources, Texas A&M University (<http://globalweather.tamu.edu/>), and ArcOnline.

Greensboro Landuse Classification Map

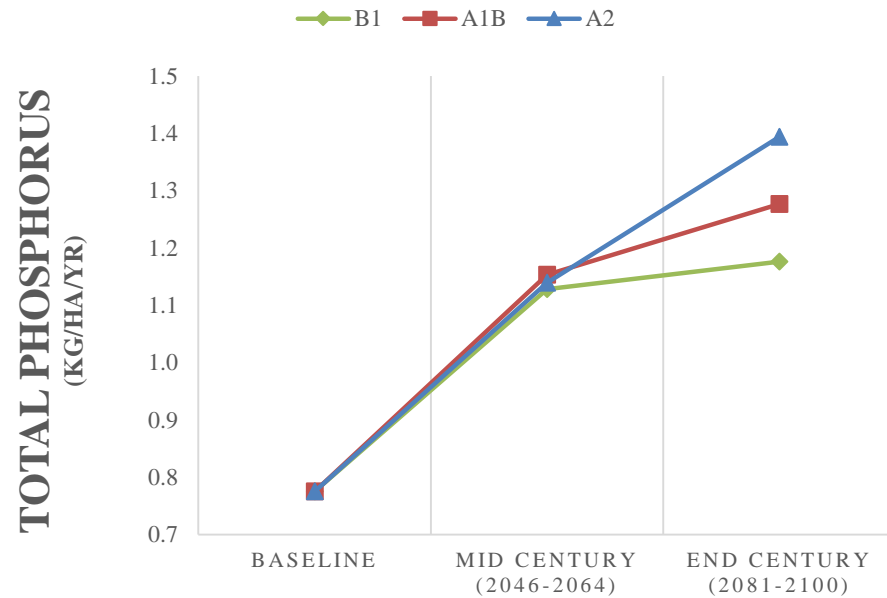
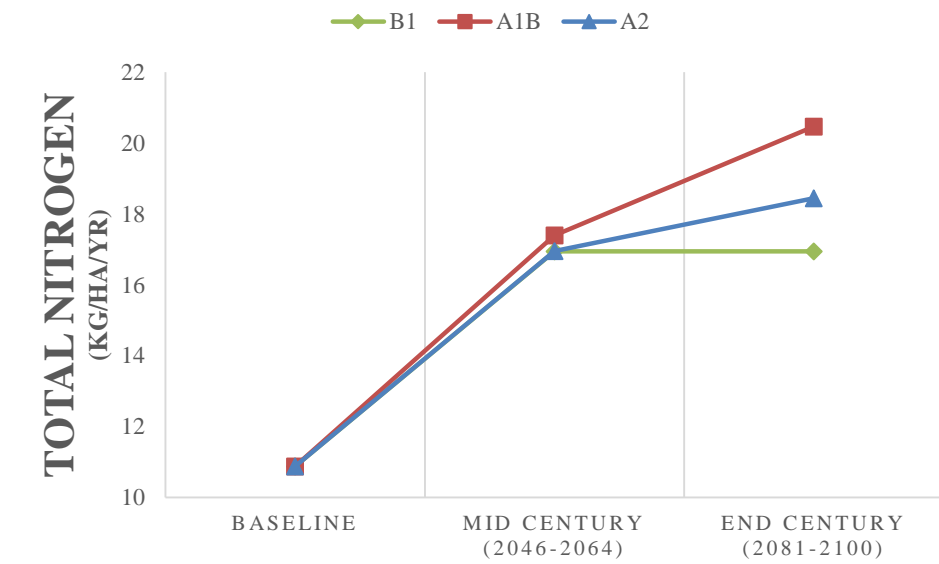
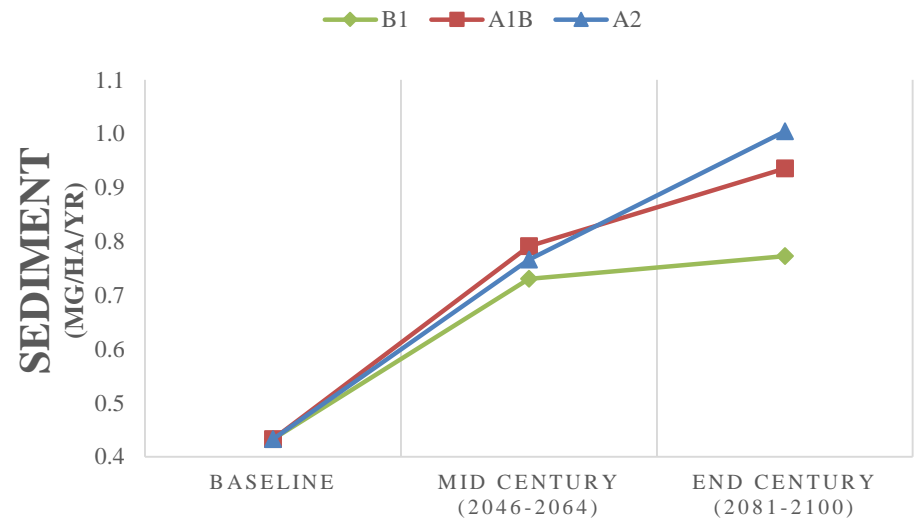
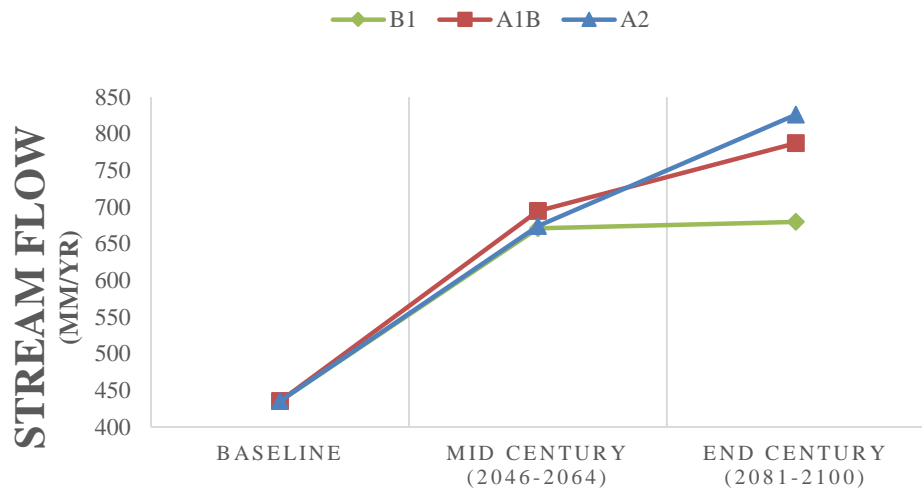
Land Use and Land Cover



USGS Gauging Station

Sources: USGS National Map Viewer, USGS Water Resources, Texas A&M University (<http://globalweather.tamu.edu/>), and ArcOnline.

Watershed Response: Baseline and Climate Change Scenarios



Results: CSA Distribution and Characterization

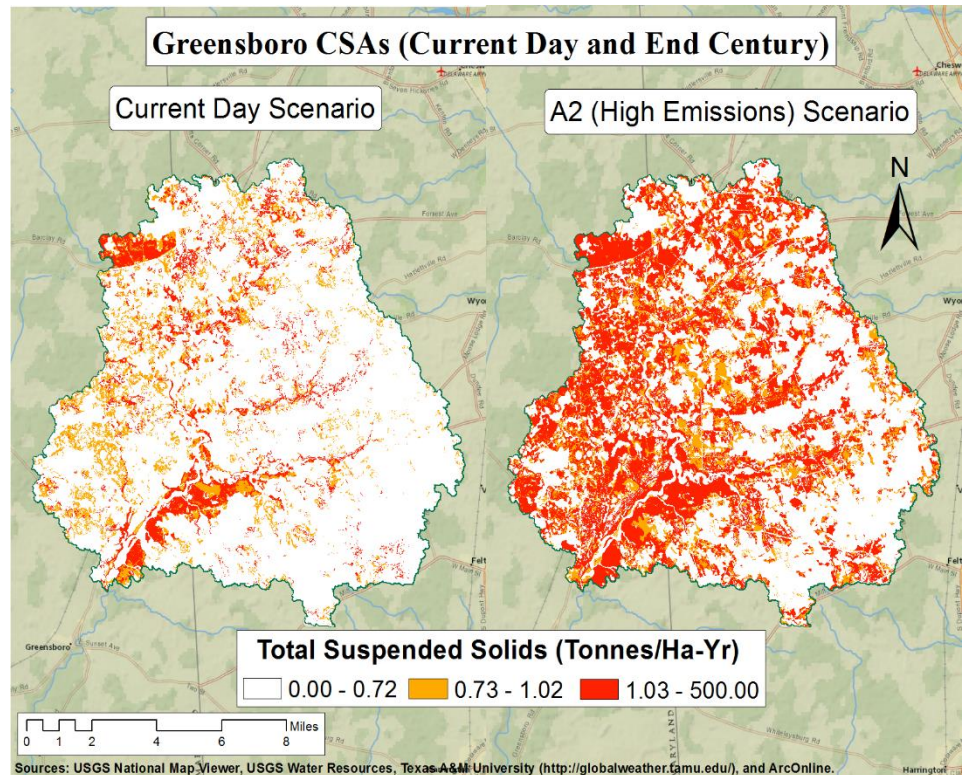
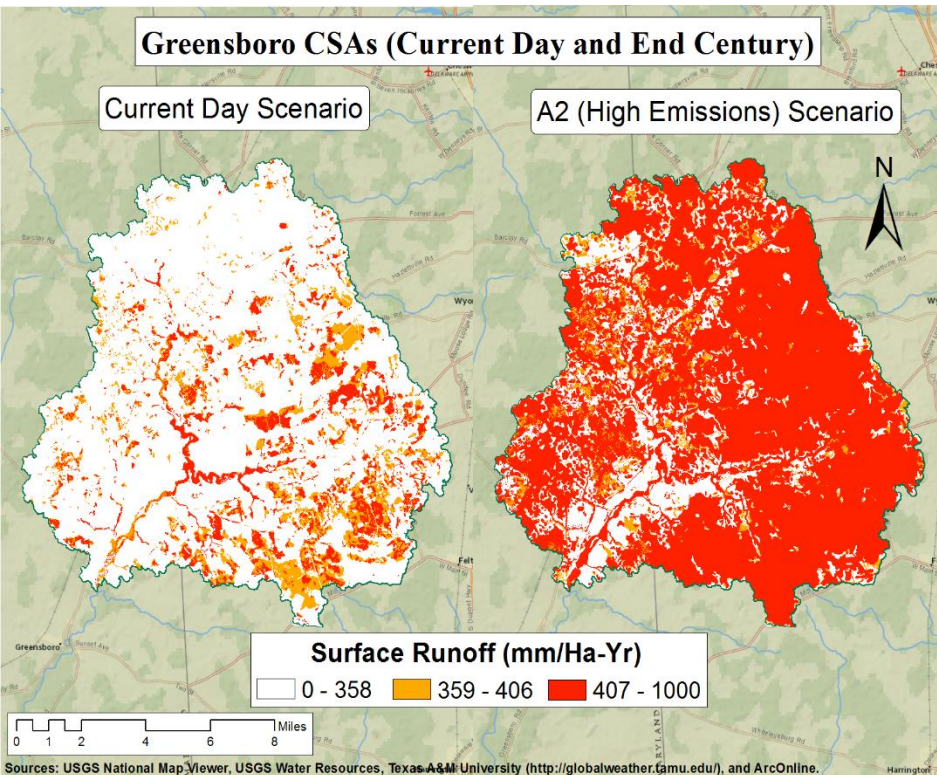
Present Day CSAs



SRES A2



End Century CSAs



Results Cont.: CSA Distribution and Characterization

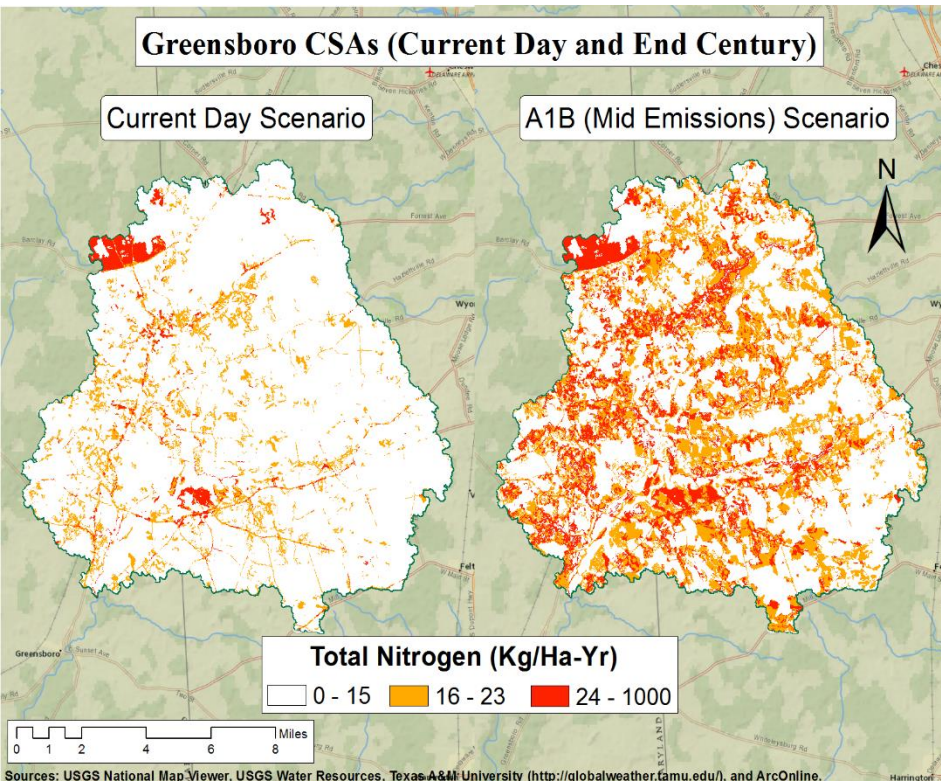
Present Day CSAs



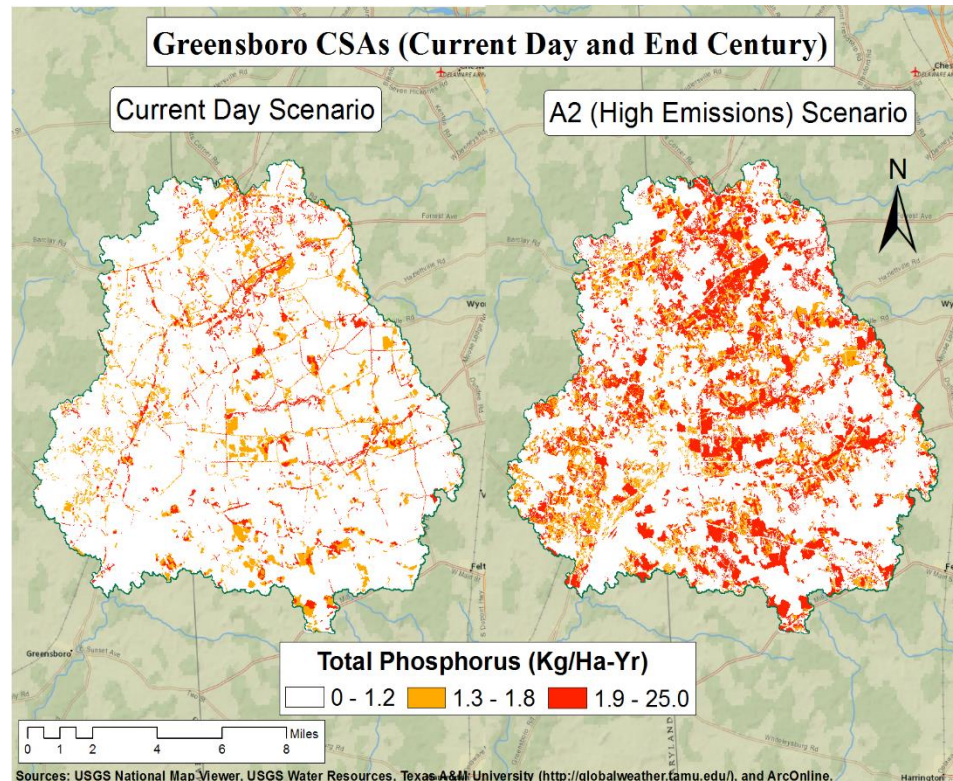
SRES A2/A1B



End Century CSAs



Sources: USGS National Map Viewer, USGS Water Resources, Texas A&M University (<http://globalweather.tamu.edu/>), and ArcOnline.



Sources: USGS National Map Viewer, USGS Water Resources, Texas A&M University (<http://globalweather.tamu.edu/>), and ArcOnline.

CSAs: Summary and Conclusions

CSA IDENTIFICATION

CSAs can be successfully targeted

Watershed response to climate change (+30% precipitation) shows increases in all constituents by mass (154% to 167%)

Hotspot area increases for TSS, TN and TP under climate change (2.5 to 4.0 times larger)

Questions?

Impacts of Climate Change on BMP Effectiveness

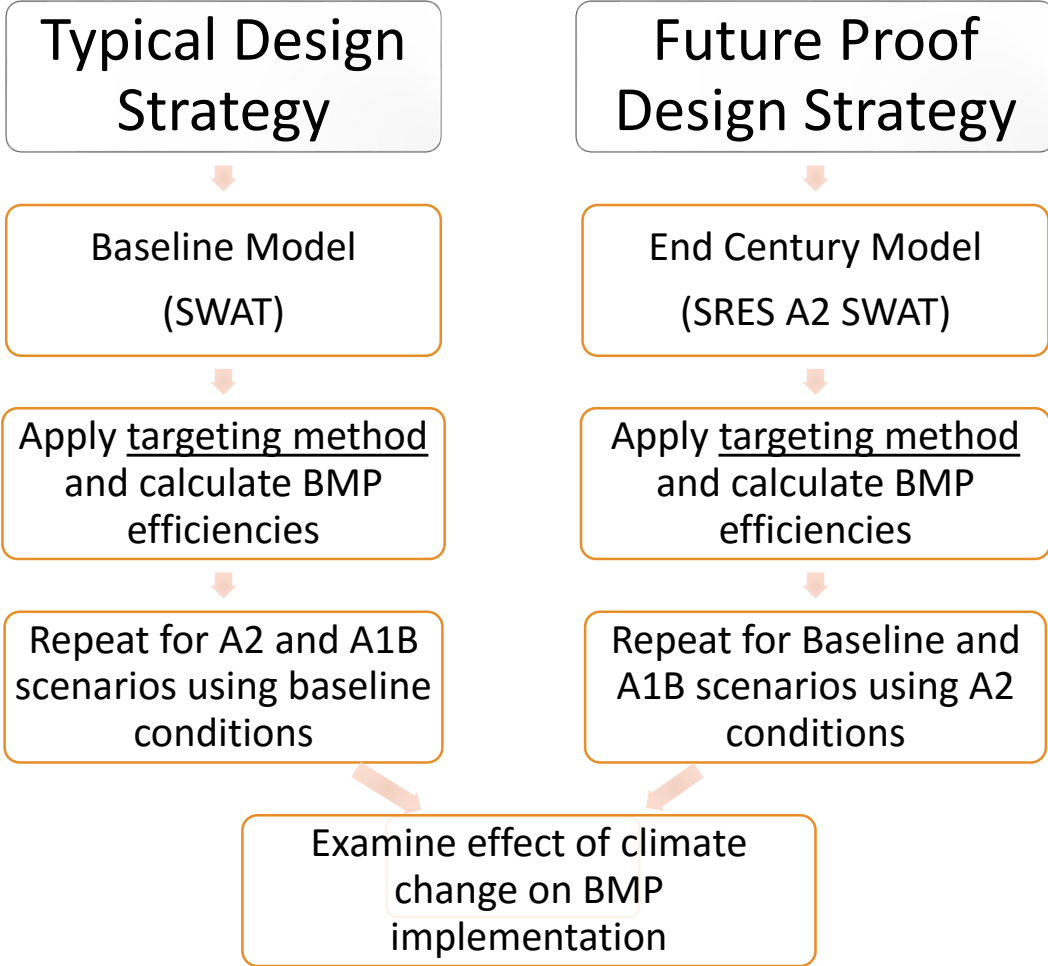
BMP Design and Targeting Methods

Compare/Evaluate Two Targeting Methods:

- CSA Based (Dense CSAs)
- Non-CSA Based (Land Use)

Apply Generic SWAT BMP

Removal Required to Meet Bay TMDL Targets			
Scenario	TSS	TN	TP
Baseline	33%	45%	23%
B1	63%	64%	49%
A1B	69%	70%	53%
A2	71%	67%	57%



BMP Application Methods

Method #1: BMP → Watershed

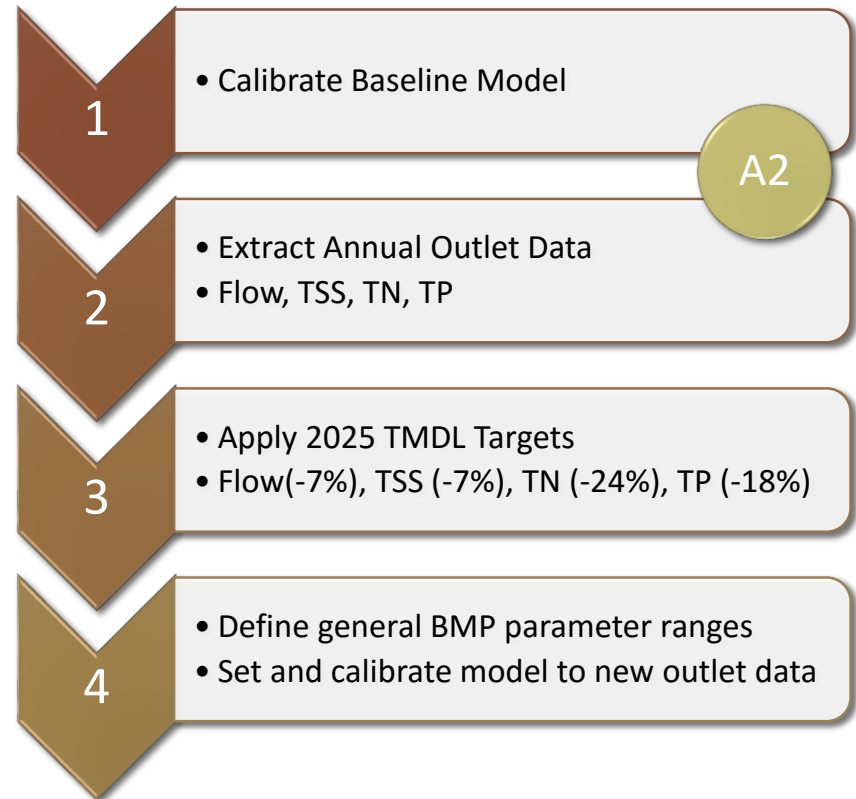
SWAT has “built in” BMP models

- Filter strips, grassed waterways, no till, strip cropping and etc...
- Flexible enough to model other user defined BMPs

Method #2: Watershed needs → BMP(s)

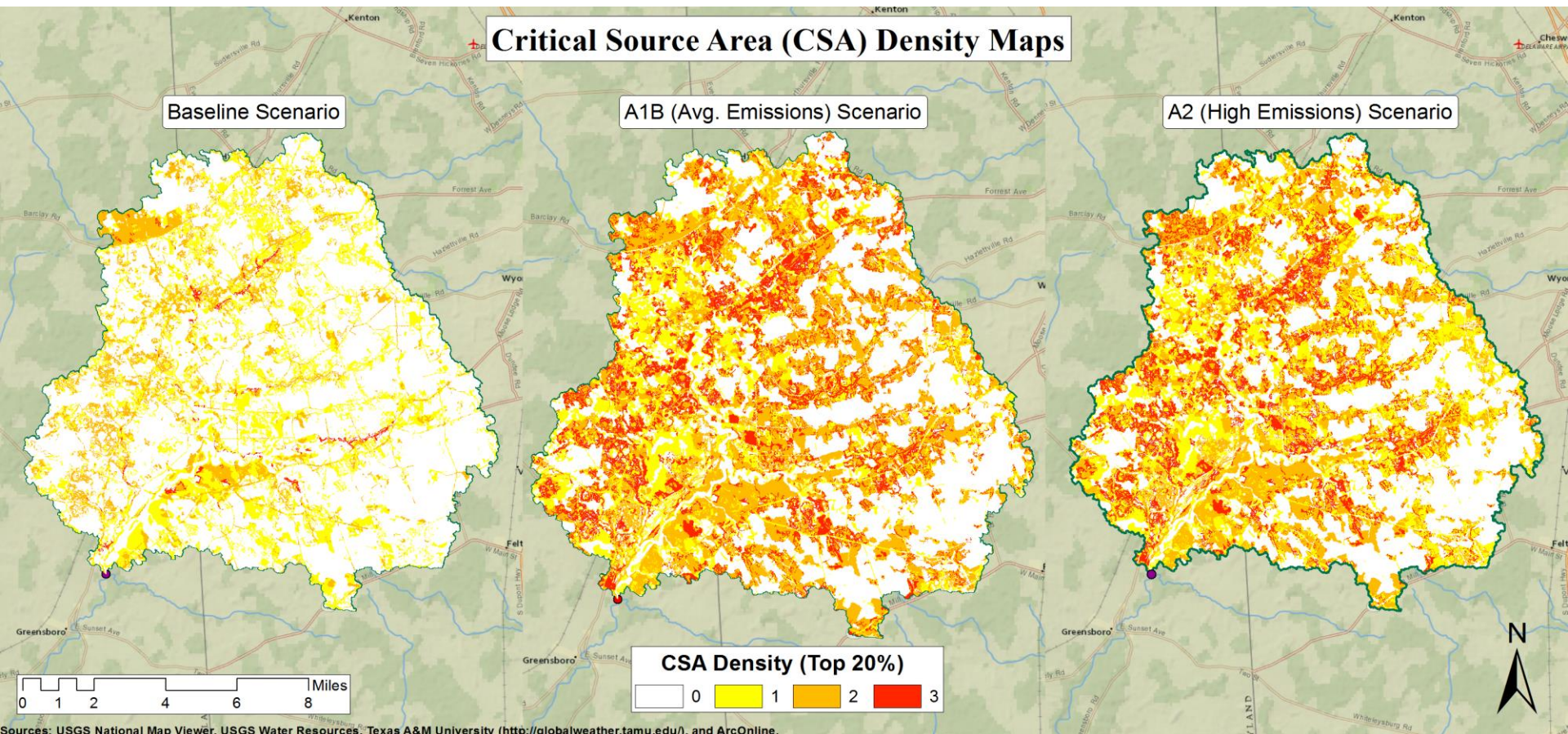
Characterize BMP efficiencies using a generic practice

Parameterization is flexible with efficiencies, land uses, soil classes, sub-basins and etc...



Targeting Method 1: Dense CSAs

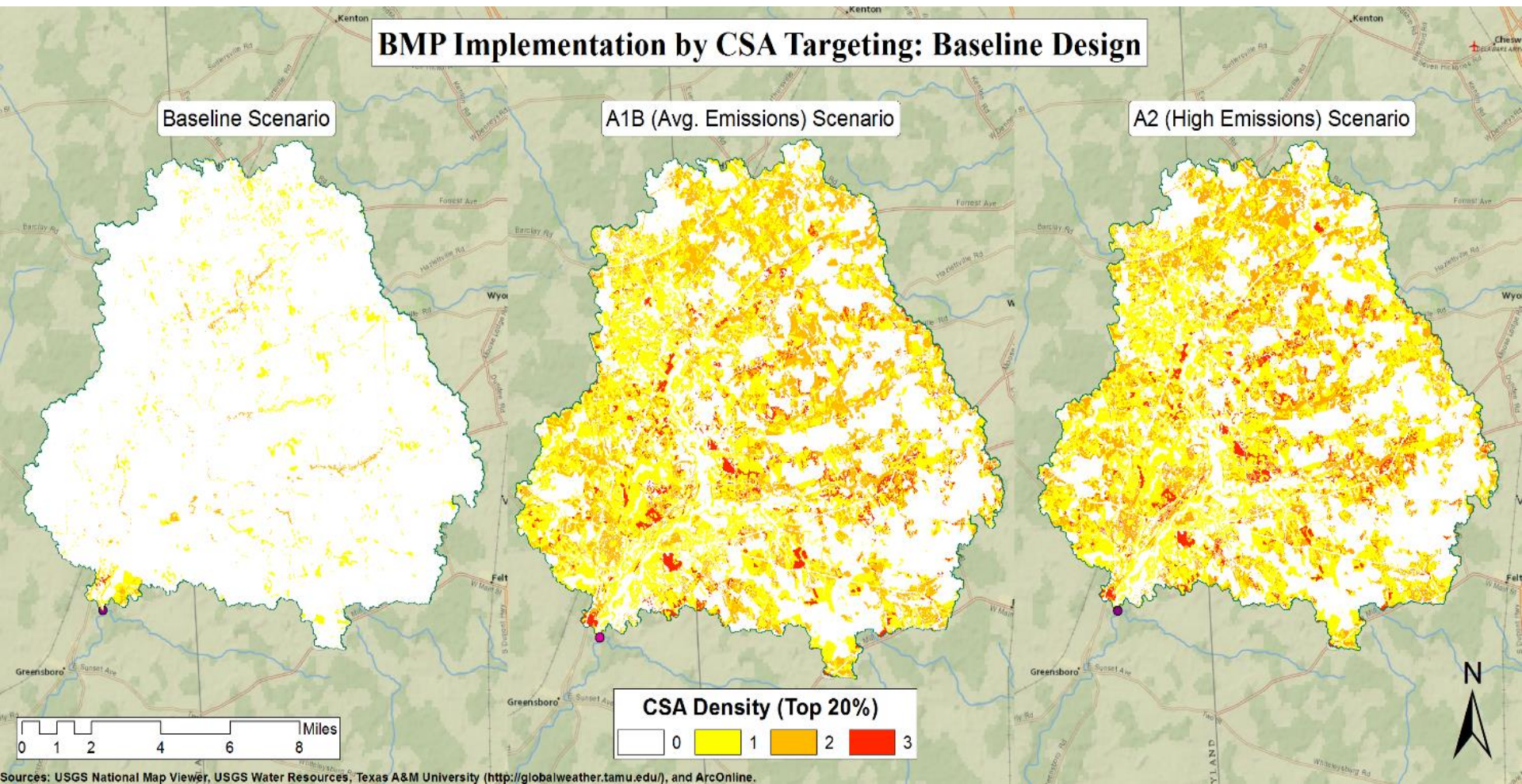
Critically Dense Area at the top 20% Break Value



Rank	SurQ (mm H2O)	TSS (tonnes/ha/yr)	TN (kg/ha/yr)	TP (kg/ha/yr)
Top 10%	>406	>1.03	>24	>1.9
Top 20%	>359	>0.73	>16	>1.6

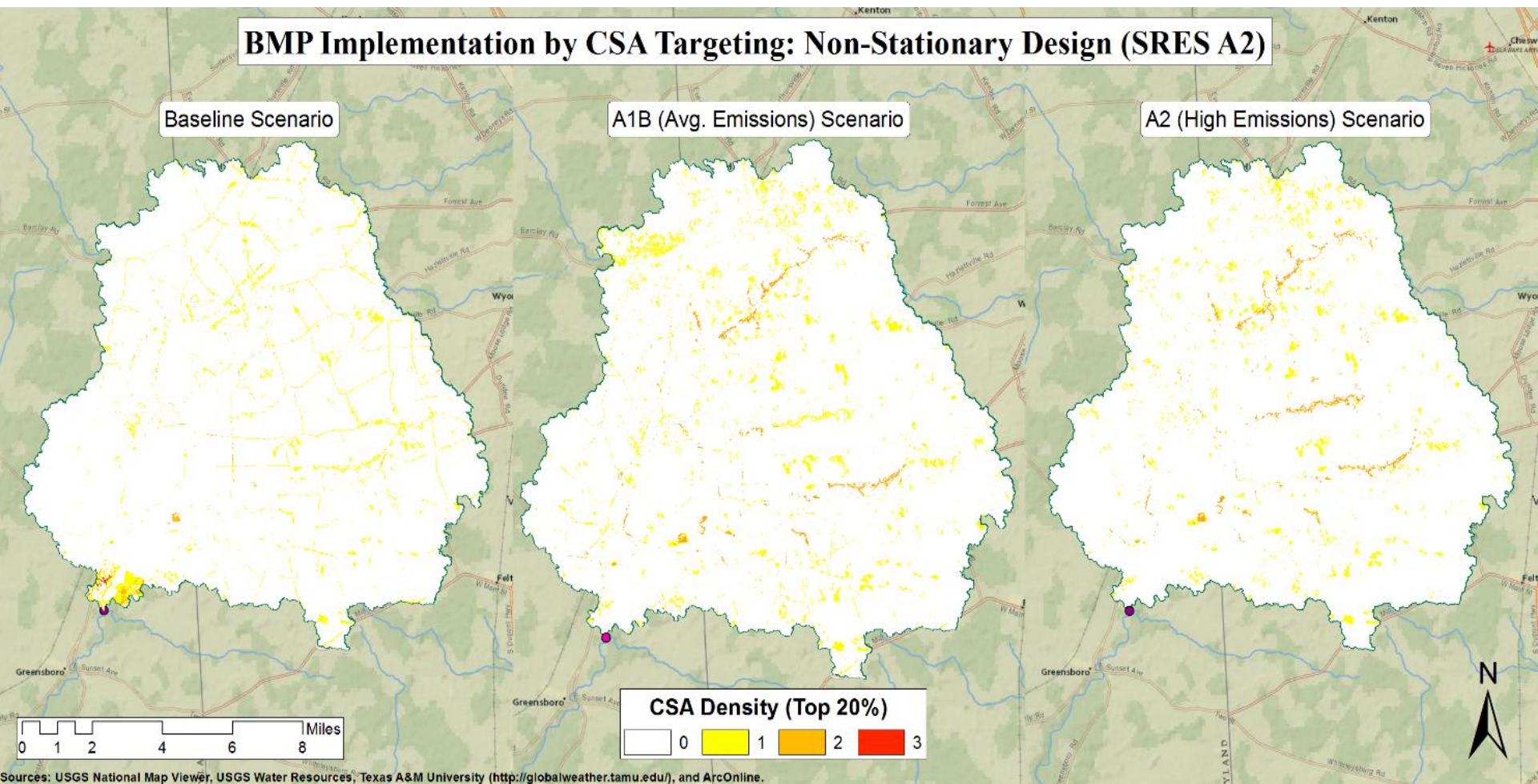
Typical Design Strategy: Targeting Dense CSAs

Residual CSA Density with Baseline BMP Design Subjected to Current, A1B and A2 Climate Conditions



Future Proof Design Strategy: Targeting Dense CSAs

Residual CSA Density with A2 BMP Design Subjected to Current, A1B and A2 Climate Conditions.



Targeting Method 2: Non-CSA Targeting

Inverse Modeling Approach

Targeting Method: Land Use

- Agriculture
- Urban and Suburban

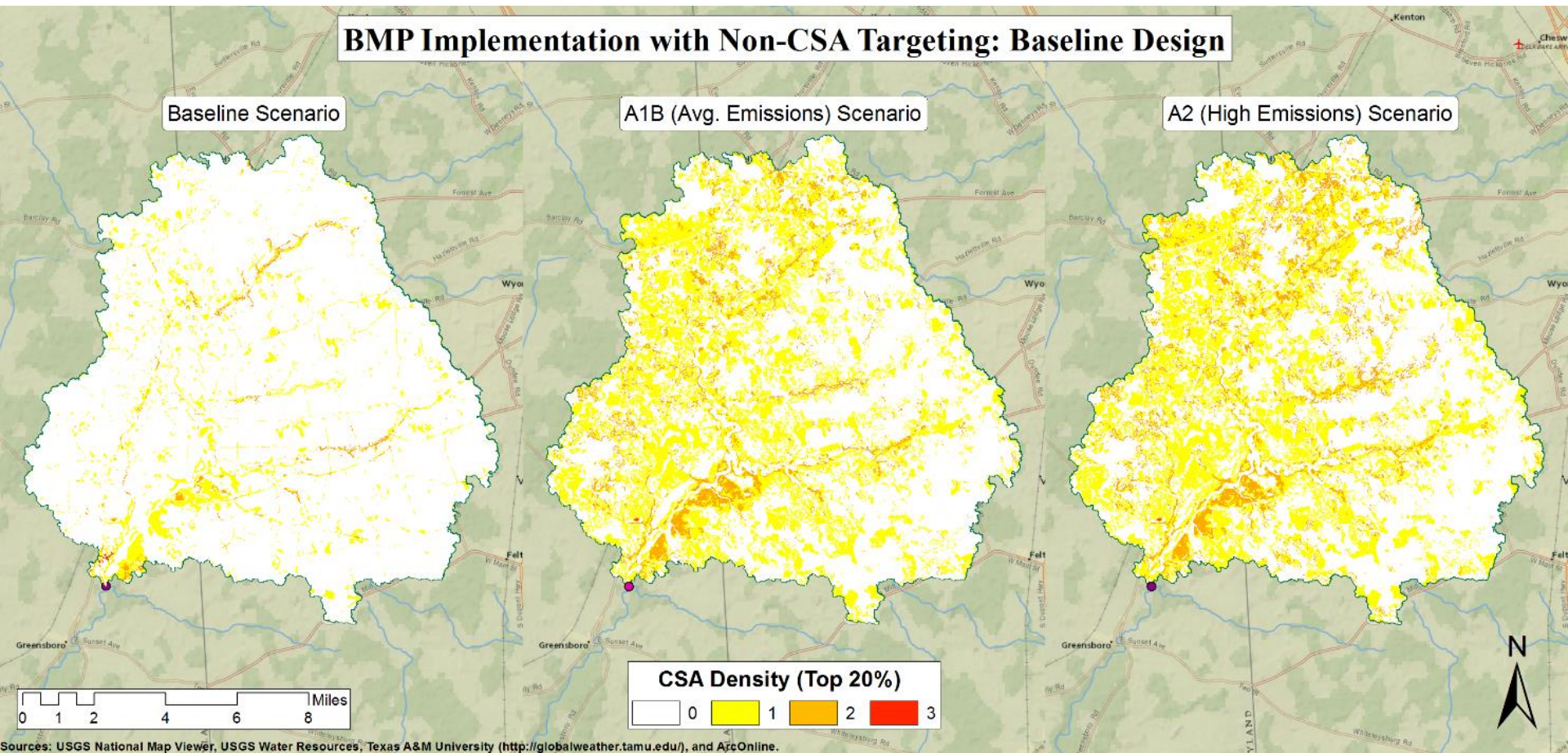
Includes in-stream attenuation

- Minimizes land area and BMP EFF(%)
- Computationally intensive



Typical Design Strategy: BMP Parameterization

Residual CSA Density with Baseline BMP Design for Agricultural and Urban Land, Subjected to Current, A1B and A2 Climate Conditions.



BMPs: Summary and Conclusions

BMP IMPLEMENTATION

BMP efficiencies range from 30%-100% (TMDL for TN not met)

Non-stationarity must be considered in BMP design to address climate change

Tiered Approach with CSA Density, for changing climate

Community-based participation will be necessary

Questions?

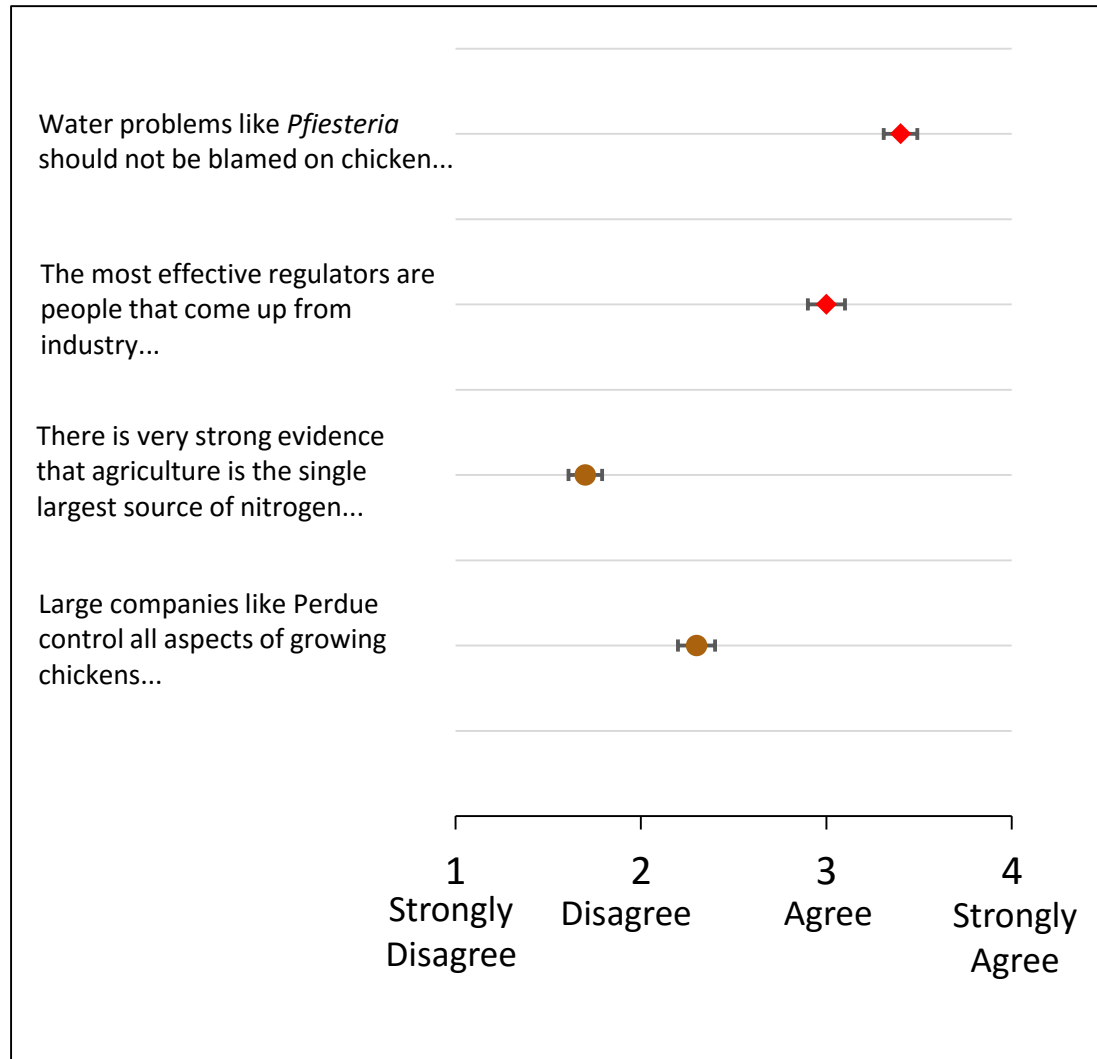
Dense CSA Contribution (%)					
	CSA		Export		
Scenario	Density	Area	TSS	TN	TP
Baseline	1+2+3	31	54	57	53
A2	1+2+3	58	86	86	79

Removal Required to Meet Bay TMDL Targets			
Scenario	TSS	TN	TP
Baseline	33%	45%	23%
A2	71%	67%	57%

Poll Results

Farmer (n = 66) responses as part of a survey

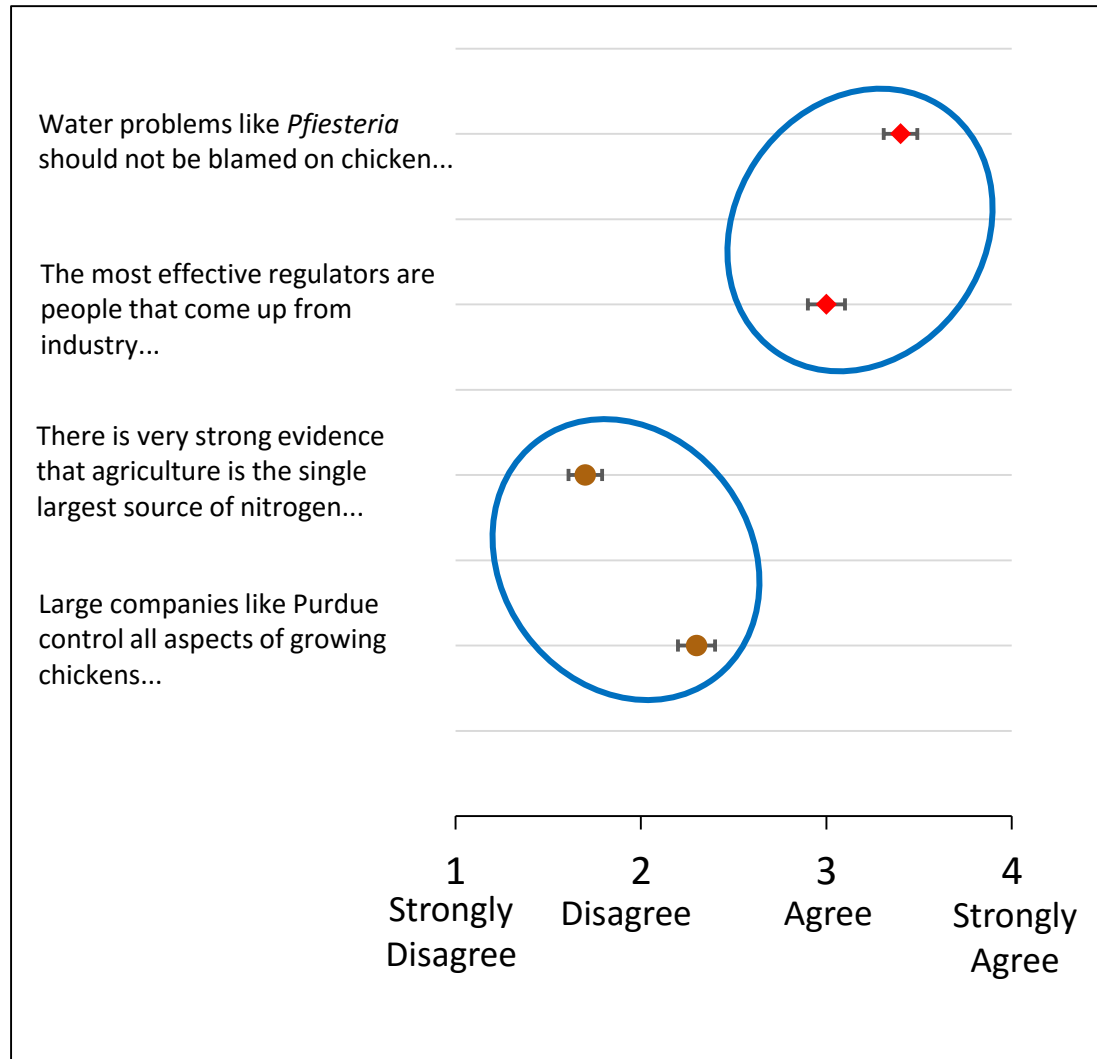
These statements stimulated the strongest responses and were the most polarizing, from 26 stakeholder interviews and Q-sort analysis



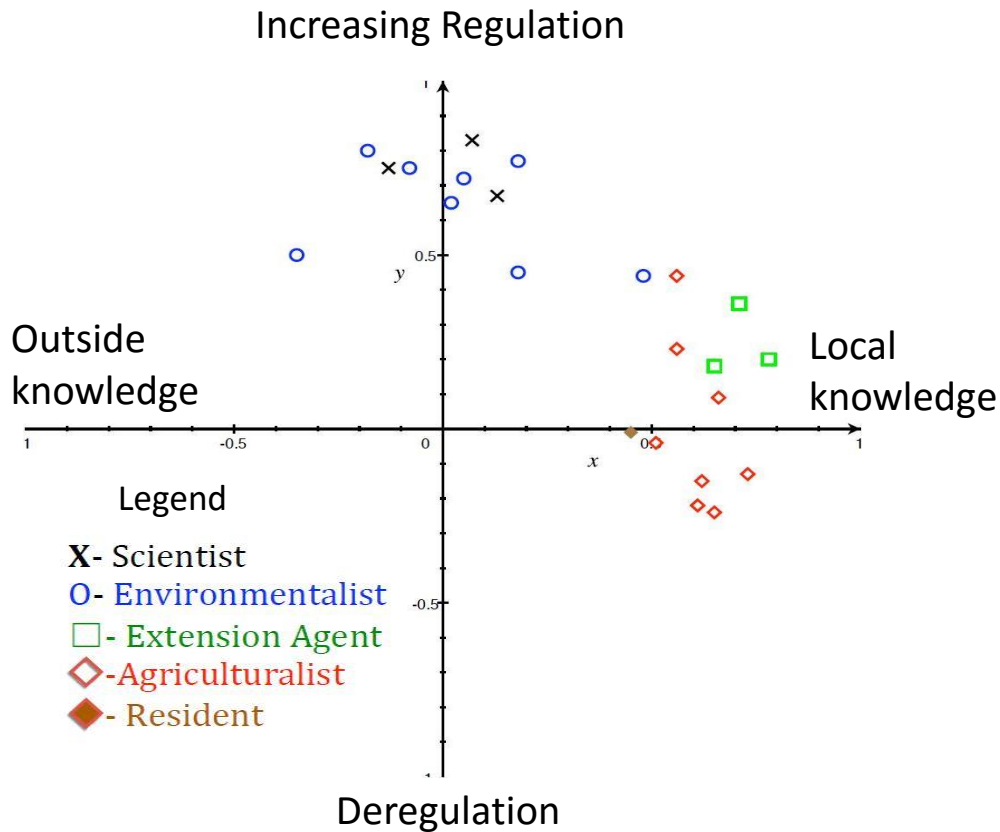
Paired T-TEST: $T = -11.60, p < 0.0001$

Farmer (n = 66) responses as part of a survey

These statements stimulated the strongest responses and were the most polarizing, from 26 stakeholder interviews and Q-sort analysis



Axes of Regulation and Cultural Knowledge

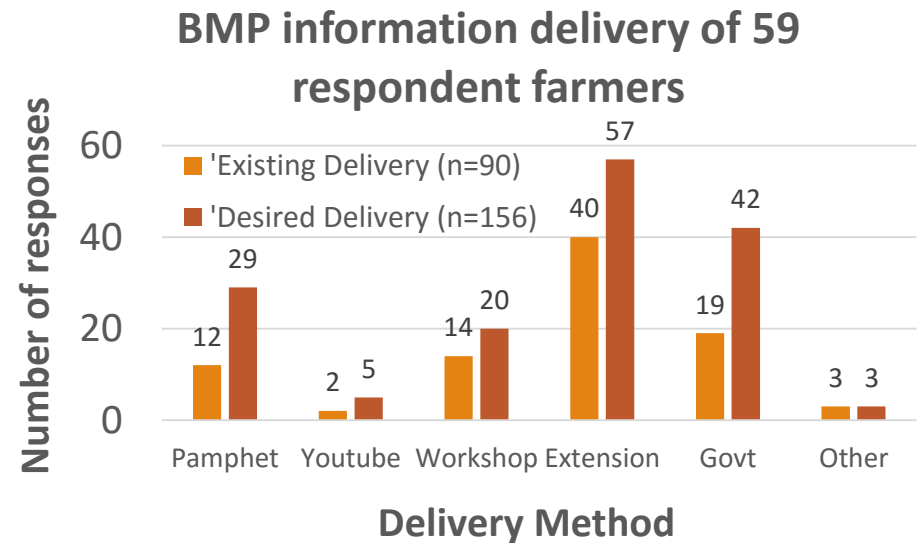
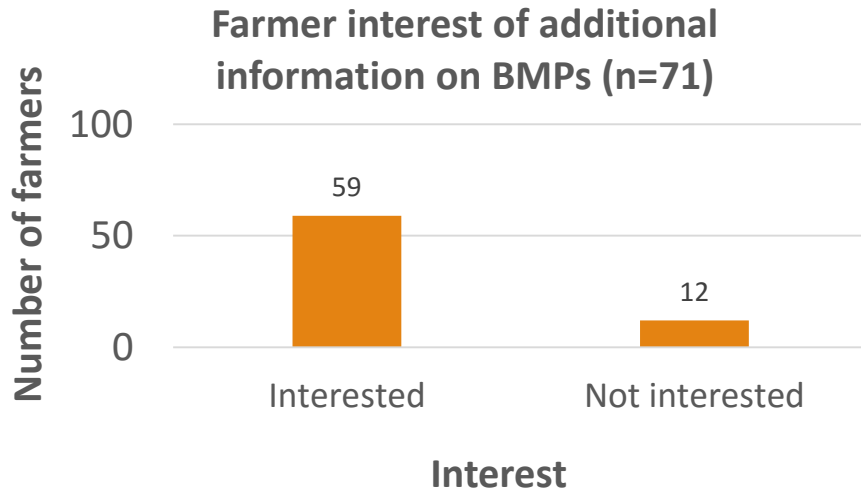


Two dominant discourses from Interviews and Q-sort

Scientists and environmental professionals: Stressed the importance of regulating land-use practices that degrade water.

Farmers and agricultural extension agents: Stressed the importance of local knowledge and were skeptical of “outside” knowledge, including science.

Extension Outreach



Improving awareness



Leveraging connections with trusted knowledge sources (Extension & State agencies)

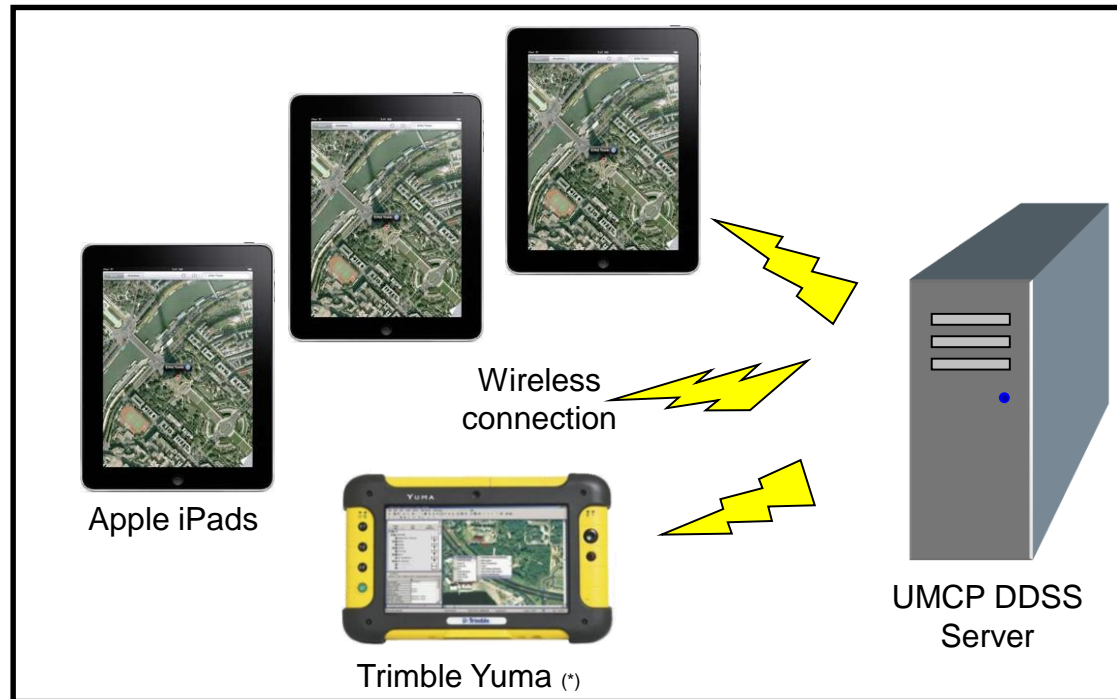
4-H youth programs

County fair exhibits

Town-hall meetings



Mobile platforms for remote access to DDSS



Feature: Provide access watershed boundary, soils, topography, hydrography from GPS coordinates

Goal: Apply DDSS to evaluate BMPs, on-site

Questions?

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