The Ohio State University

Linking agricultural land management decisions and Lake Erie ecosystem services using integrated ecological economic modeling

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ACES 2014 Morning Workshop 3, December 8, 2014

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Lake Erie human behavior-ecosystem services research

- Focus: Develop a set of models to project how policies influence agricultural land management in the watershed and how land management influences Lake Erie ecosystem services

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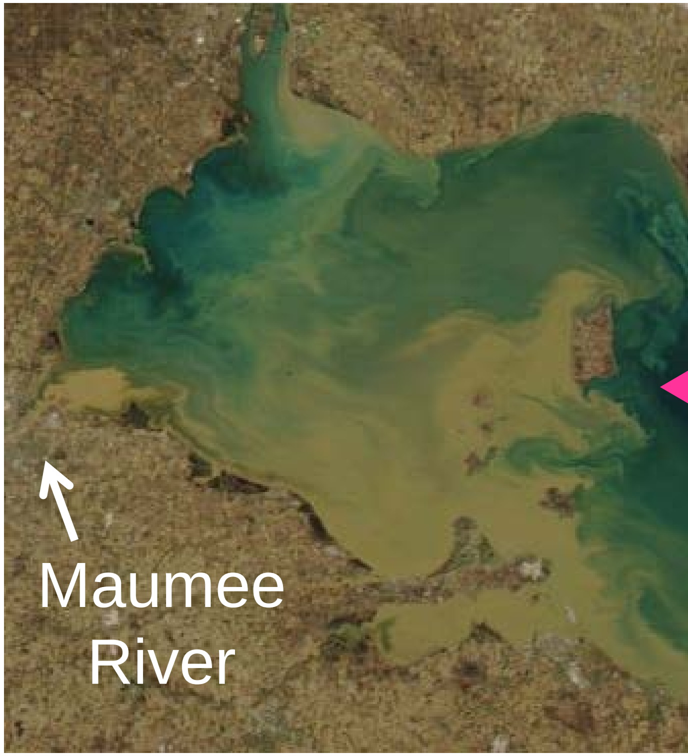
Funding from NSF Coupled Human and Natural Systems Program (GRT00022685) and the NOAA/Ohio Sea Grant Program

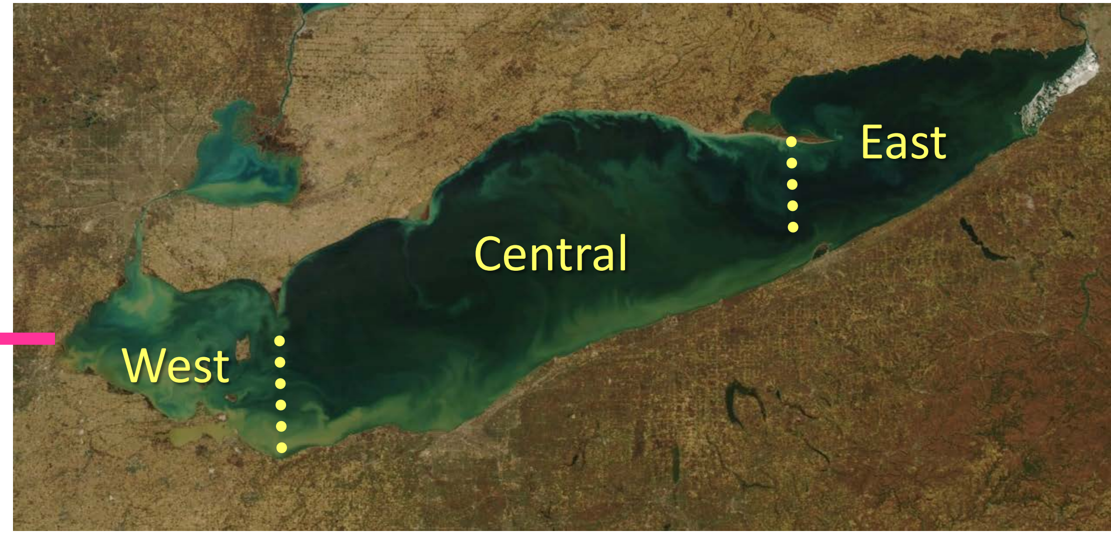
Project Website: http://ohioseagrant.osu.edu/maumeebay

Sea Grant
Ohio Sea Grant College Program

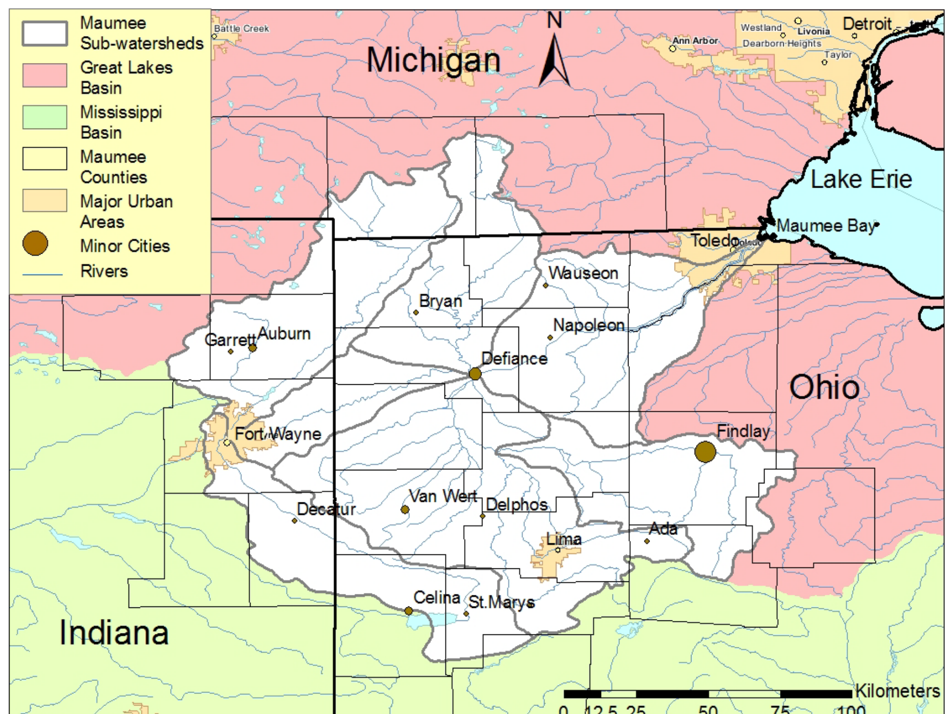
THE OHIO STATE UNIVERSITY

Study System

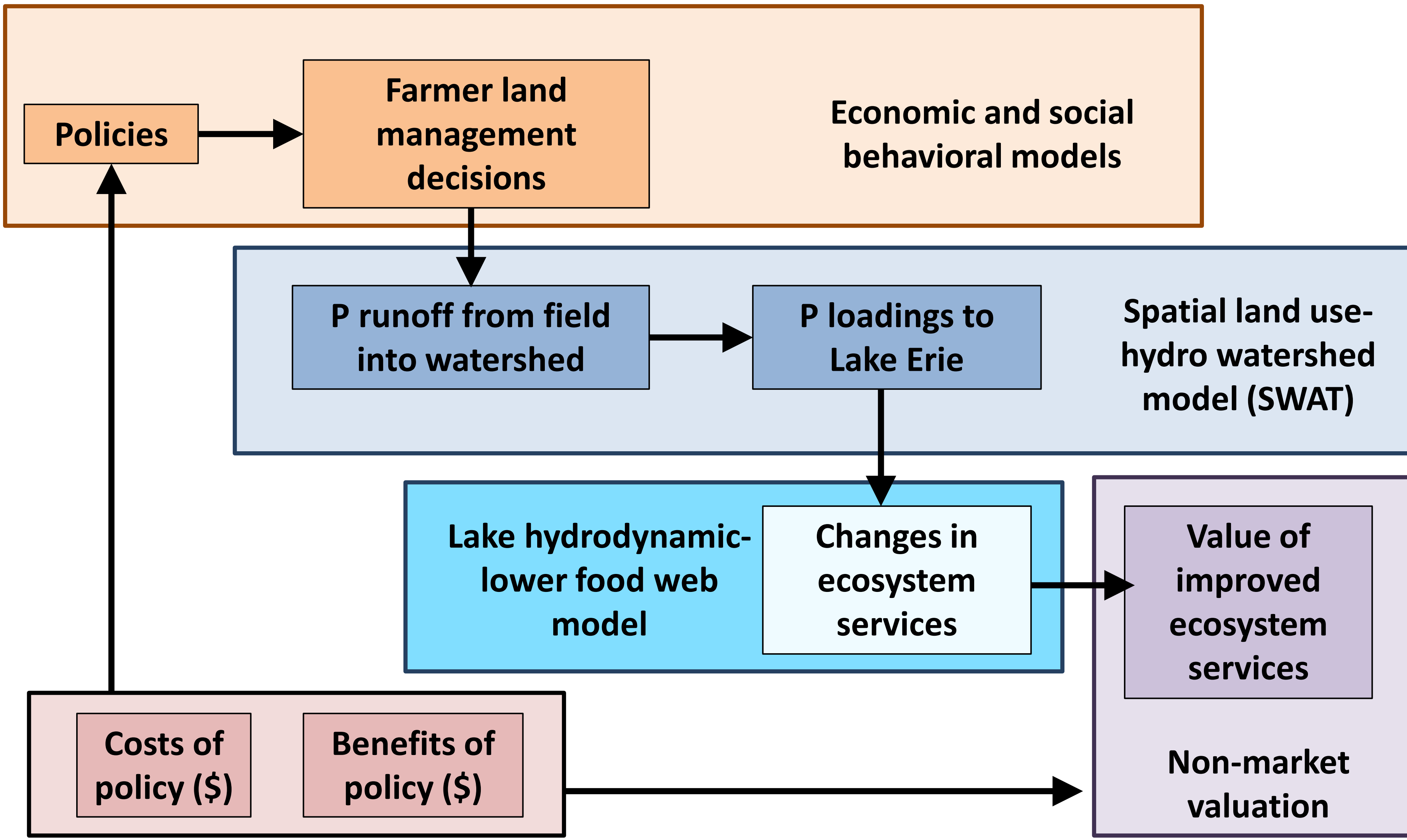




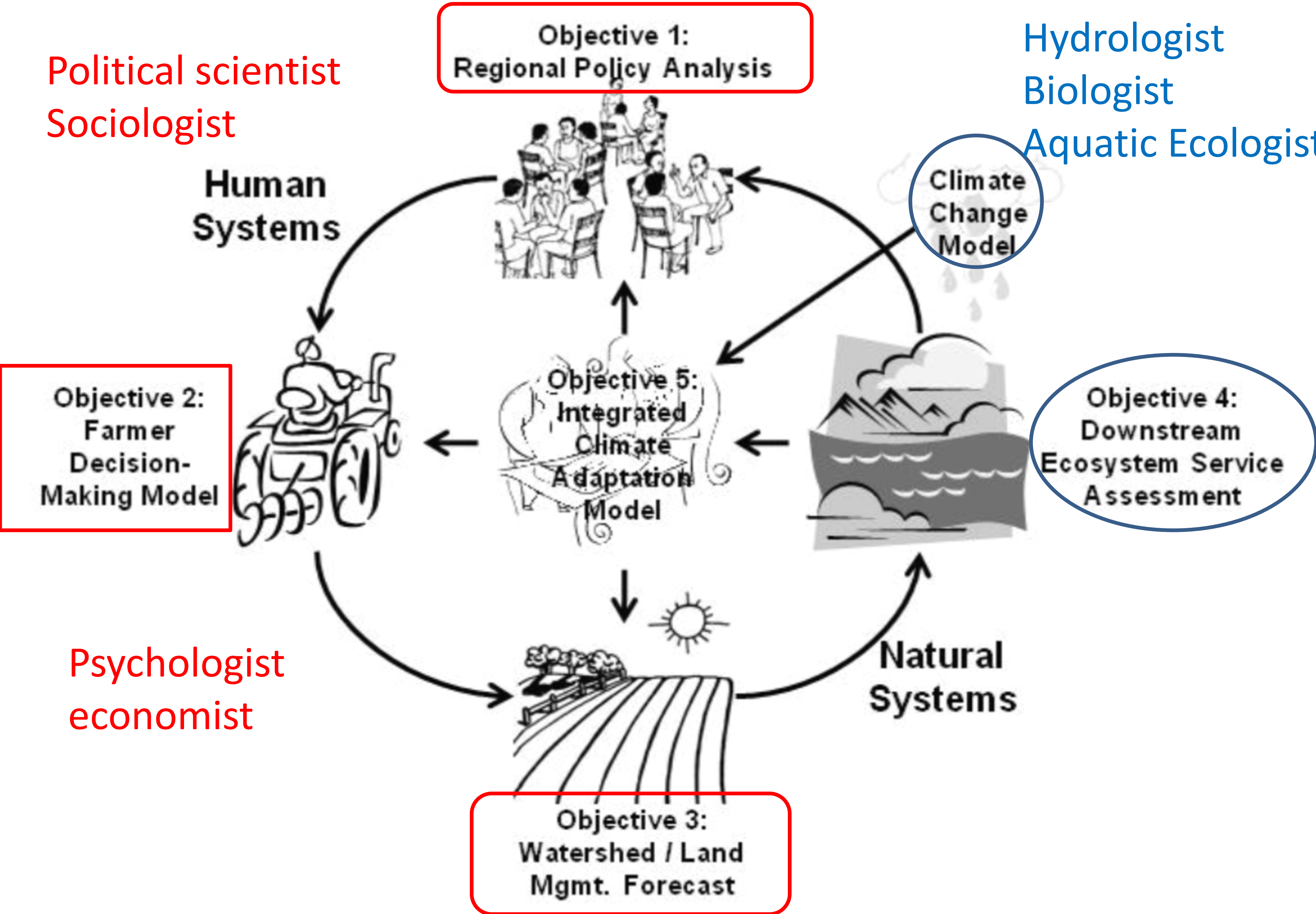
The western Lake Erie basin
And the Maumee River watershed



Lake Erie-land coupled human-natural systems model



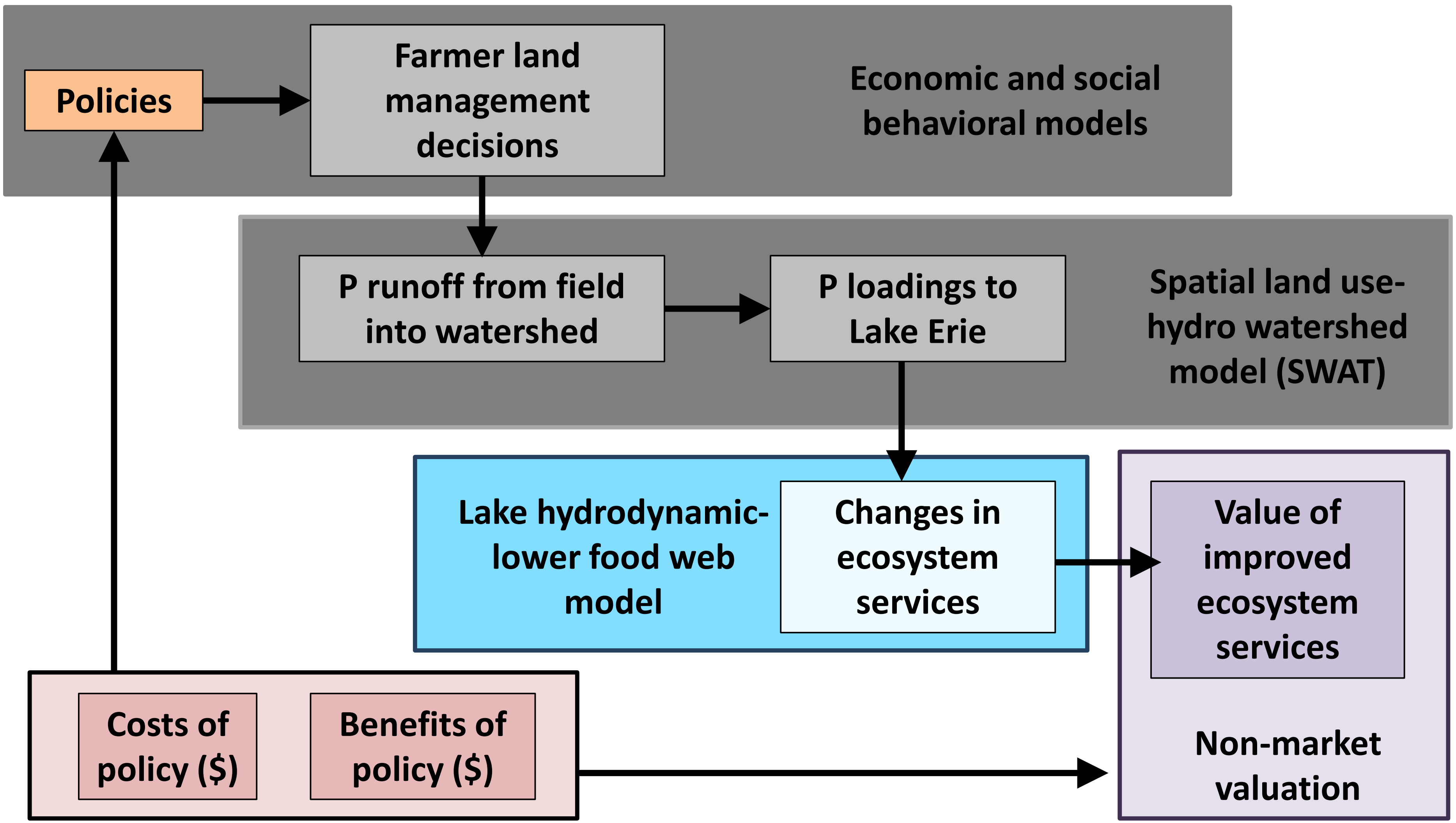
NSF-CHANS Project Methods (2010-2015)



Value-added from the Sea Grant (2014-2016)

process-based lake hydrodynamic-food web model

Non-market valuation of multiple ecosystem services



Main research question: Which policies will lead to a more sustainable outcome?

Change in policy

- Fertilizer tax
- Incentives for best management practices
- Nutrient applicator certification
- Water quality trading

Changes in agricultural land management, production

- Fertilizer type, application rate, placement, timing
- Crop rotation
- Cultivation of new land
- Crop choice
- Tillage
- Cover crops
- Filter strips
- Controlled drainage
- xxx

Is change sustainable?

which policies will lead to more sustainable outcome?

Weak sustainability: Does policy change generate non-decreasing total wealth over time?

$$\Delta W_t = \Delta \text{ Value of } \textbf{produced} \text{ capital}_t + \Delta \text{ Value of } \textbf{natural} \text{ capital}_t + \Delta \text{ Value of } \textbf{human} \text{ capital}_t + \Delta \text{ Value of } \textbf{social} \text{ capital}_t \geq 0$$

$$\Delta W_t = \Delta \text{ Value of } \textbf{produced} \text{ capital}_t + \Delta \text{ Value of } \textbf{natural} \text{ capital}_t + \Delta \text{ Value of } \textbf{institutional} \text{ capital}_t \geq 0$$

$$\Delta W_t = \Delta \textbf{ Agricultural profits}_t + \Delta \text{ Value of } \textbf{ecosystem services}_t + \Delta \text{ Costs of } \textbf{policy}_t \geq 0$$

which policies will lead to more sustainable outcome?

Strong sustainability: Does policy change maintain minimum critical natural capital stocks and flows?

$$NC_{i,t+1} = NC_{i,t} + \Delta NC_{i,t} \geq \overline{NC_i}$$ for each critical NC stock or flow *i*

$$P\,Flow_{t+1} = P\,Flow_t + \Delta\,P\,Flow_t \leq \overline{P\,Flow}$$

specifies a maximum limit for P run-off in given year

$$\Delta\,P\,Flow_{min} = P\,Flow_t - \overline{P\,Flow}$$

specifies minimum reduction in P run-off needed to meet limit

Regional Policy Analysis

survey of Ohio general population,
survey of farmers in western Lake Erie basin,
survey of households in Maumee
focus group interviews with policymakers, ag & envi groups

Nisbet and Toman

800 Ohio voters' views on various regulatory policy options (1 = strongly disagree, 5 = strongly agree)

Place **a fee on residential and business water usage bills** to fund additional regulatory oversight of farmers' fertilizer use and manure disposal	2.41
Create **a special state property levy** on farmland to fund additional regulatory oversight of farmers' fertilizer use and manure disposal	3.11
Charge **a recreational fee** for use (e.g., swimming, boating, fishing, hunting, camping, etc.) of state parks, beaches, and lakes to fund additional regulatory oversight of farmers' fertilizer use and manure disposal	2.85
Create **a special sales tax on agricultural fertilizer** as a means to reduce fertilizer use and increase regulatory oversight of farmers' fertilizer use and manure disposal	3.58
Create a special sales tax on agricultural fertilizer to fund new voluntary financial incentives for farmers to reduce fertilizer, manure, and nutrient runoff	3.85
Require farmers and agribusinesses to create comprehensive management plans to reduce agricultural runoff and water pollution in conjunction with additional regulatory oversight (e.g., **fines** if they do not comply)	4.66

Farmer Behavioral Analysis

- Latent class analysis of farmer BMP adoption
- Ohio Maumee farmer survey 2012

Class	Characteristics
Class I **Envi Stewards** **More willing**	Younger, less rented acreage More likely to think current practices are sufficient, belief that runoff has a lower likelihood of occurring
Class II **Profit Maximizer** **Less Willing**	Older, more rented acreage Less likely to think current practices are sufficient, belief that runoff has a higher likelihood of occurring

FARMERS, PHOSPHORUS AND WATER QUALITY

THE OHIO STATE UNIVERSITY

A DESCRIPTIVE REPORT OF BELIEFS, ATTITUDES AND PRACTICES IN THE MAUMEE WATERSHED IN NORTHWEST OHIO

Authors: Robyn Wilson, Lizzy Burnett, Tara Ritter, Brian Roe and Greg Howard

Funding provided by the National Science Foundation Coupled Human and Natural Systems Program and the Climate, Water and Carbon Initiative at The Ohio State University

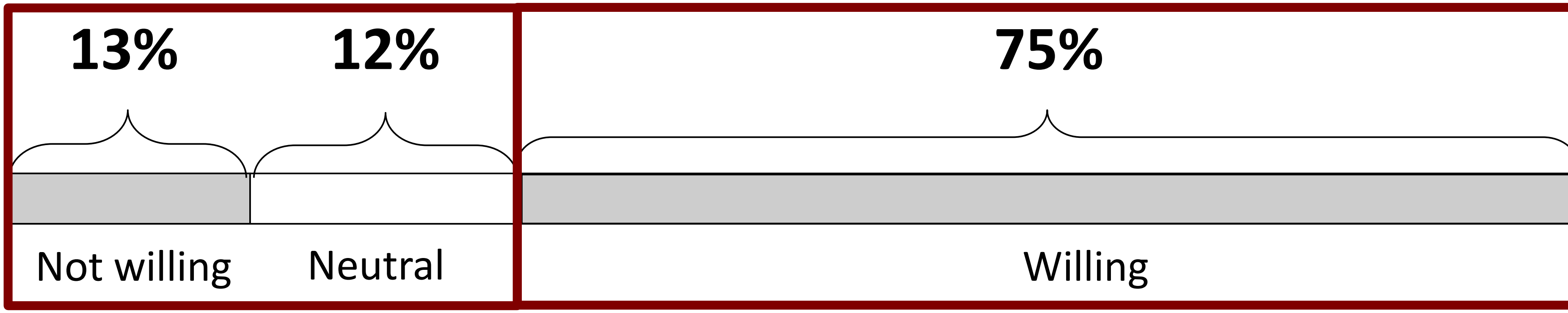
Project Website: http://ohioseagrant.osu.edu/maumeebay/

A study conducted by The Ohio State University College of Food, Agricultural and Environmental Sciences School of Environment and Natural Resources Department of Agricultural, Environmental, and Development Economics

2013

How to encourage BMP adoption rates? – A targeted fix

Wilson 2013



The "less willing" are older with more rental acreage?

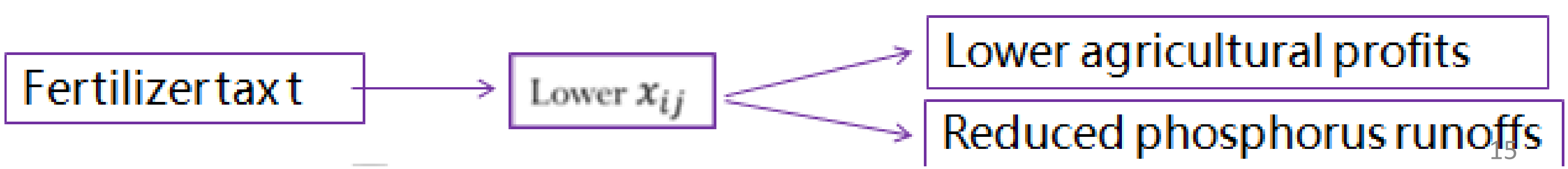
- Focus "structural" fix on the minority/less willing (~25%)
  - e.g. regulation, incentives
- Focus "cognitive" fix on the majority/willing (~75%)
  - e.g., outreach for voluntary adoption (risks-benefits of nutrient loss for a variety of concerns, efficacy/benefits of action)

Behavioral Model - A field-level structural model of farmers' crop use, nutrient input demand and management decisions

Farmer i' field-level profit maximization problem

1) Choose crop j in the first stage
2) In the second stage, farmers choose variable input levels (P fertilizer rate x_{ij}, N fertilizer rate, and manure rate) and BMP (tillage, soil testing) to maximize the profit

- Social welfare given a per-unit fertilizer tax t



Nutrient Management in the Maumee Watershed

A study conducted by:

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

In cooperation with:

MICHIGAN STATE UNIVERSITY
College of Agriculture and Natural Resources

PURDUE AGRICULTURE

Data: Farmer Survey

7,500 farmers
(a mini-Census!)

- two round of mail surveys from Jan – Apr 2014
- farmers in the watershed from Ohio, Indiana and Michigan
- response rate: ~ 38%

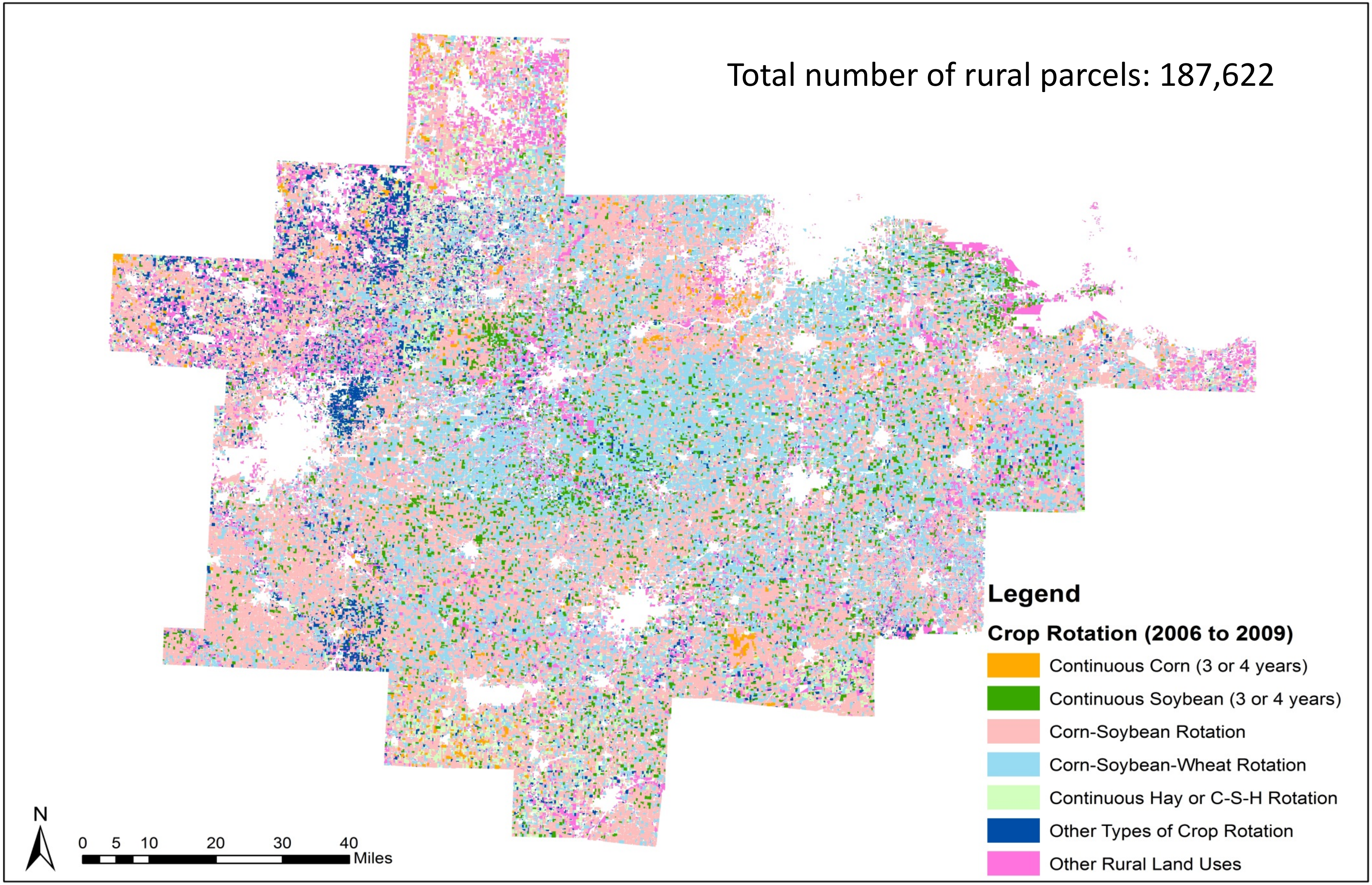
Policy Scenarios

- 1st best emission tax based on edge-of-field P runoff predicted from SWAT
- Uniform input tax (10%, 25% and 50%) on P rate
- Spatially targeted tax based on land characteristics (high slope, near stream)
- Spatially targeted tax based on location – within a high pollution potential subwatershed (zonal tax)

- Combining fertilizer tax with targeted conservation payments to farmers in “hotspot” subwatershed
  - Nisbet et al. (2014): 58% Ohio voters would vote for this policy, 55% farmers agree with this approach, and it is consistently ranked as one of the top three choices

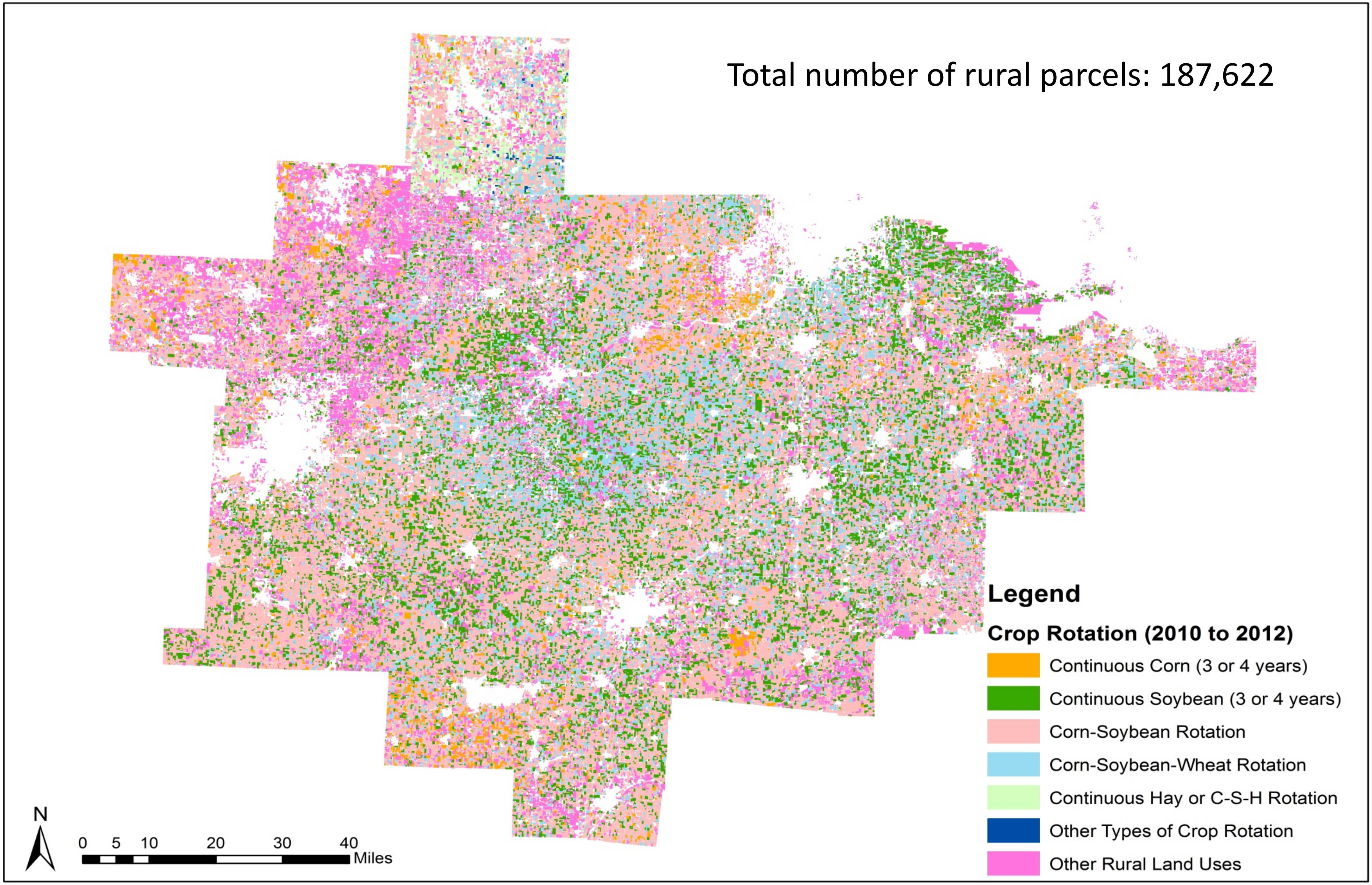
Spatial land use/land management and hydrology watershed modeling

Land use data: field-level crop rotation (2006-2009)



Source: Common Land Unit boundaries overlaid with the Cropland Data Layer (USDA) , 2006-2012

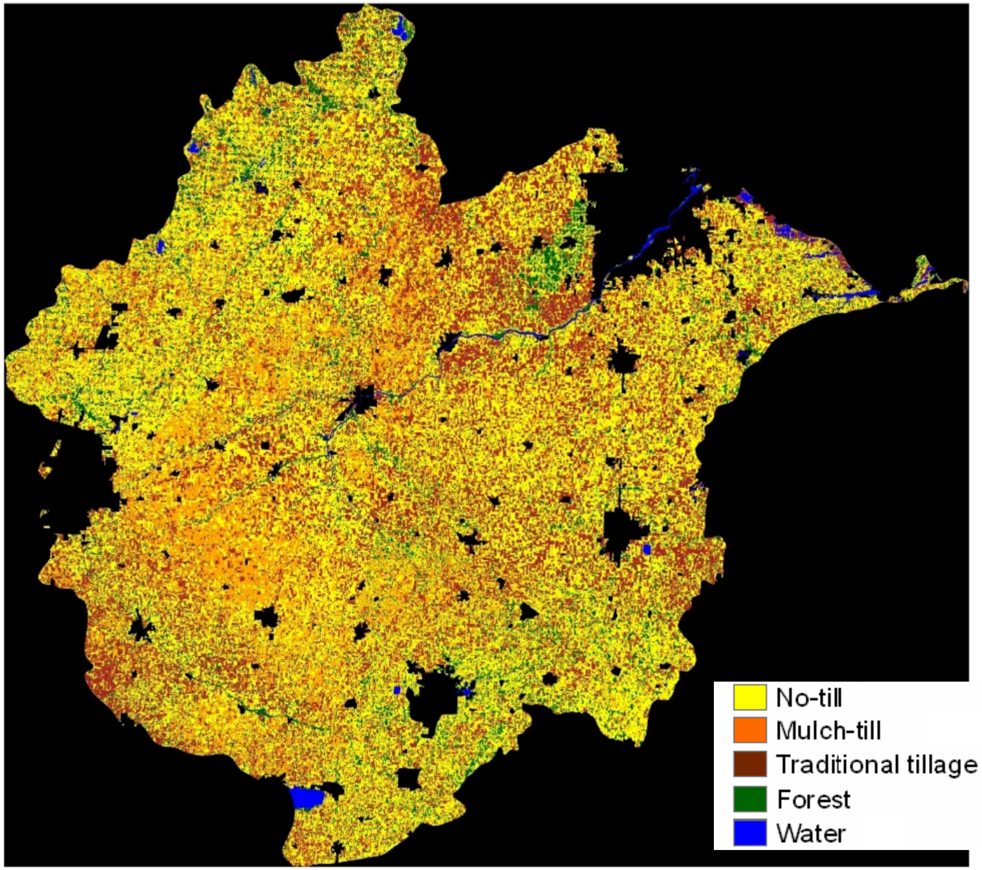
Land use data: field-level crop rotation (2010-2012)



Source: Common Land Unit boundaries overlaid with the Cropland Data Layer (USDA) , 2006-2012

Spatial land use/management model

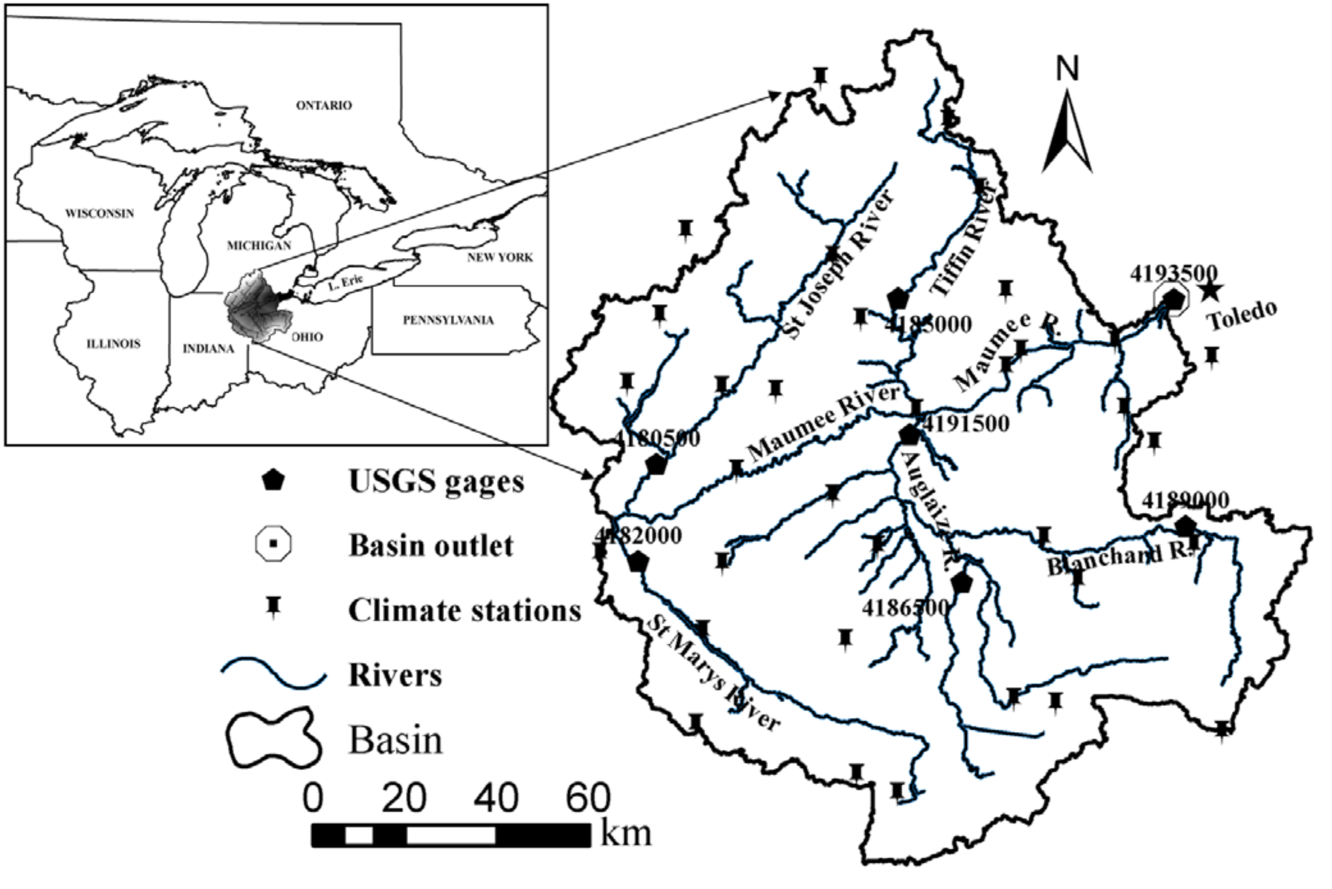
- Land use and management patterns are projected by the economic/social behavioral model
- These projections are inputs into the watershed hydrology model



Example: Tillage choices

Spatial Hydrology Watershed Model
(Gebremarium and Martin, 2014)

SWAT (Soil and Water Assessment Tool, v. 614)



- Basin area 17,000 km^2
- 252 HUC 12 sub-watersheds
- 3,000 HRUs
- Calibrated to basin outlet (into Lake Erie)

Hydrology Watershed Model
(Gebremarium and Martin, 2014)

Use SWAT with climate and land use/management projections to evaluate present conditions and future scenarios.

Example: Preliminary results

1. Changing majority of corn crop from conventional tillage to no-till, had minor impacts on the amount of dissolved phosphorus entering Maumee Bay

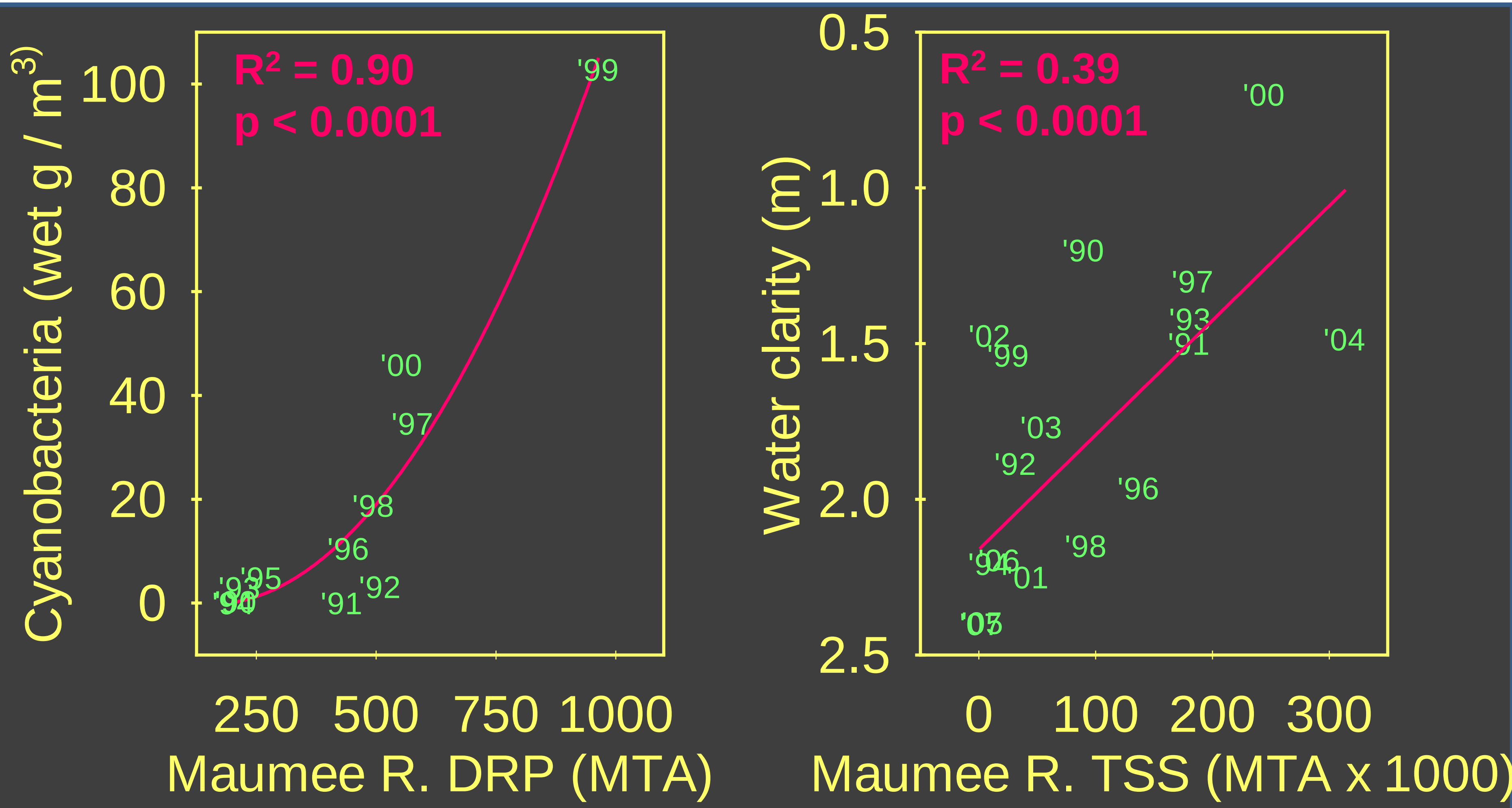
2. Changing from broadcast fertilizer application to incorporating fertilizer in soil for corn crops, resulted in 20% reduction of dissolved phosphorus entering Maumee Bay

Lake Erie hydrodynamic (ELCOM) – lower food web model (CAEDYM)

Fraker and Ludsin
ongoing

Maumee loadings and Lake Erie ecosystem services

Precipitation-driven, non-point source inputs from Maumee R. drive downstream Lake Erie conditions



Ohio Lake Erie P Task Force (2010)

K. Pangle & S. Ludsin, unpub. data

Value of improved ecosystem services

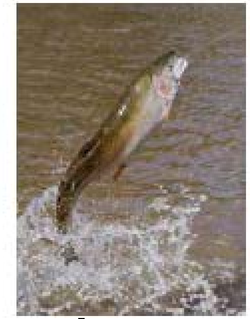
recreational activities (fishing, beach-going, boating)

water clarity – capitalization into lakefront property values

safe drinking water

public health impacts

…



Lake Erie
Angler Survey

- Mailed to 3,000 randomly selected anglers based on ODNR fishing license database
  - 2500 to counties adjacent to Lake Erie, and 500 to other Ohio counties
  - January 2014 – April 2014
  - 2 rounds with reminder card
- Tailored Design Method (Dillman 2007)
- Pilot tested with anglers
- Response rate ≈ 25% (780 responses)
- Incentives: $1; lottery of giftcards to HomeDepot

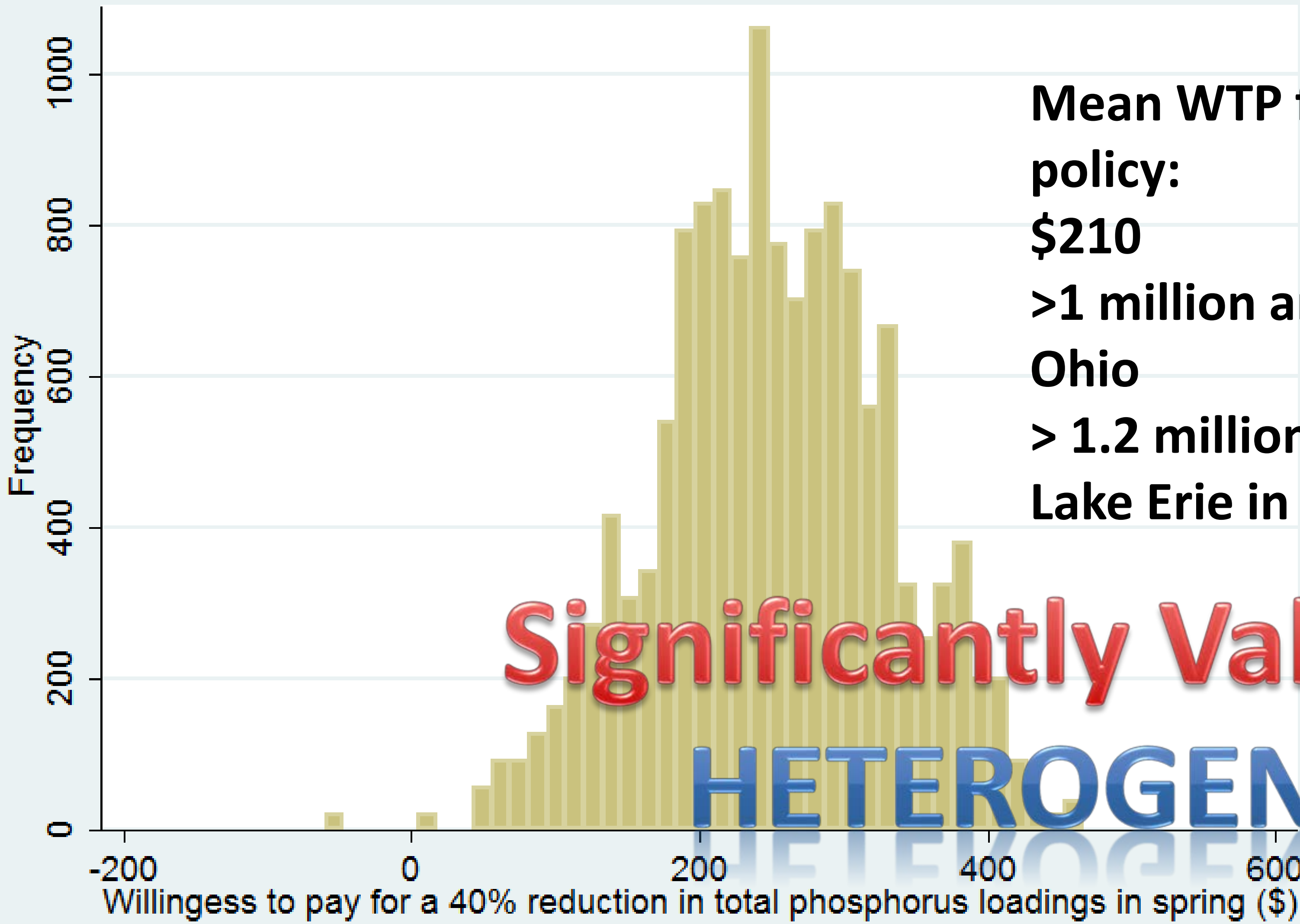
One example hypothetical choice scenario

Scenario 3 :

In the following scenario, two potential sites for walleye fishing are presented. Please review the attribute levels for each site, and decide which site you would prefer. Check the box below the particular site for the one you would choose. You can choose neither by checking the box "Neither".

Attribute	**Site A**	**Site B**	**Neither**
Walleye catch rate at fishing site (# hours needed per fish caught per person)	6 hours	2 hours	
Miles of an algal bloom that you have to boat through before getting to the fishing site (0, 4, 8)	4	0	
Poor water clarity caused by sediments at fishing site (Very murky, somewhat murky, clear)	Somewhat Murky	Very Murky	
Time in boat getting to fishing site (minutes) 15,30,45	45	30	
Distance from house to boat ramp (miles) 20,40,60	20	60	
Which Site do you MOST prefer (Please check the box for your preferred option)	**Site A** ☐	**Site B** ☐	**NEITHER** ☐

Welfare Implications for the policy that leads to 40% reduction in P

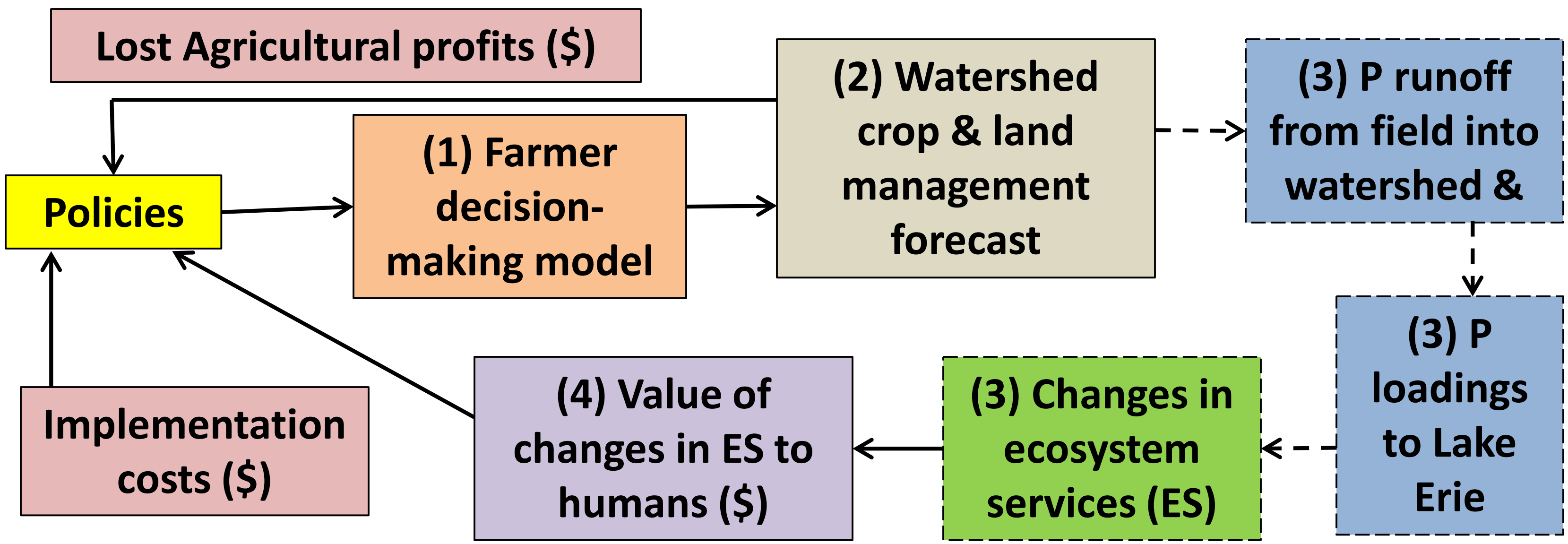


Mean WTP for this policy:
$210
>1 million anglers in Ohio
> 1.2 million hours in Lake Erie in 2013

Significantly Valuable

HETEROGENEOUS

The Big Picture



Goal: The Sustainability of Lake Erie Agro-ecosystems

Thank you!

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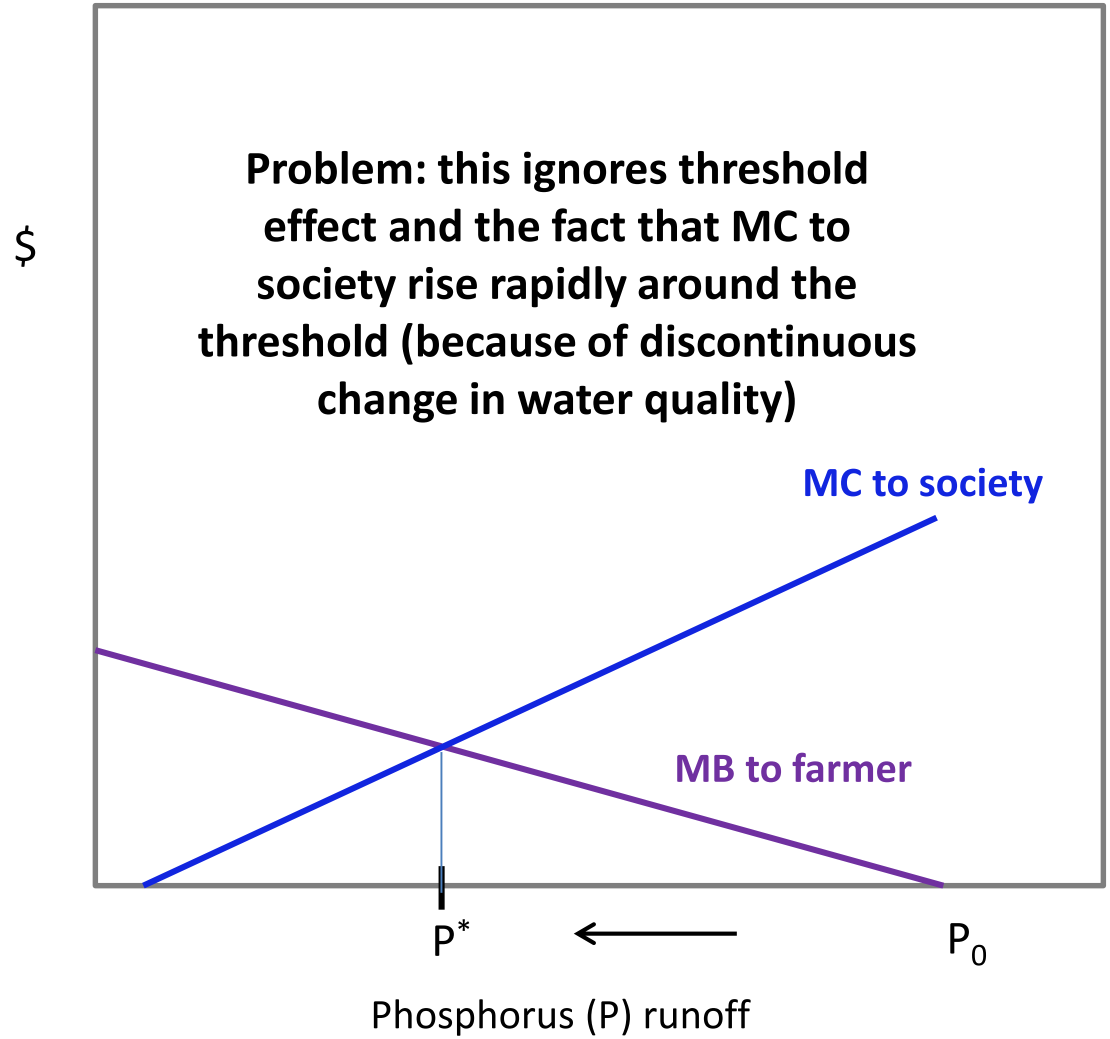
A cautionary note: Marginal trade-offs ignore complex ecosystem dynamics

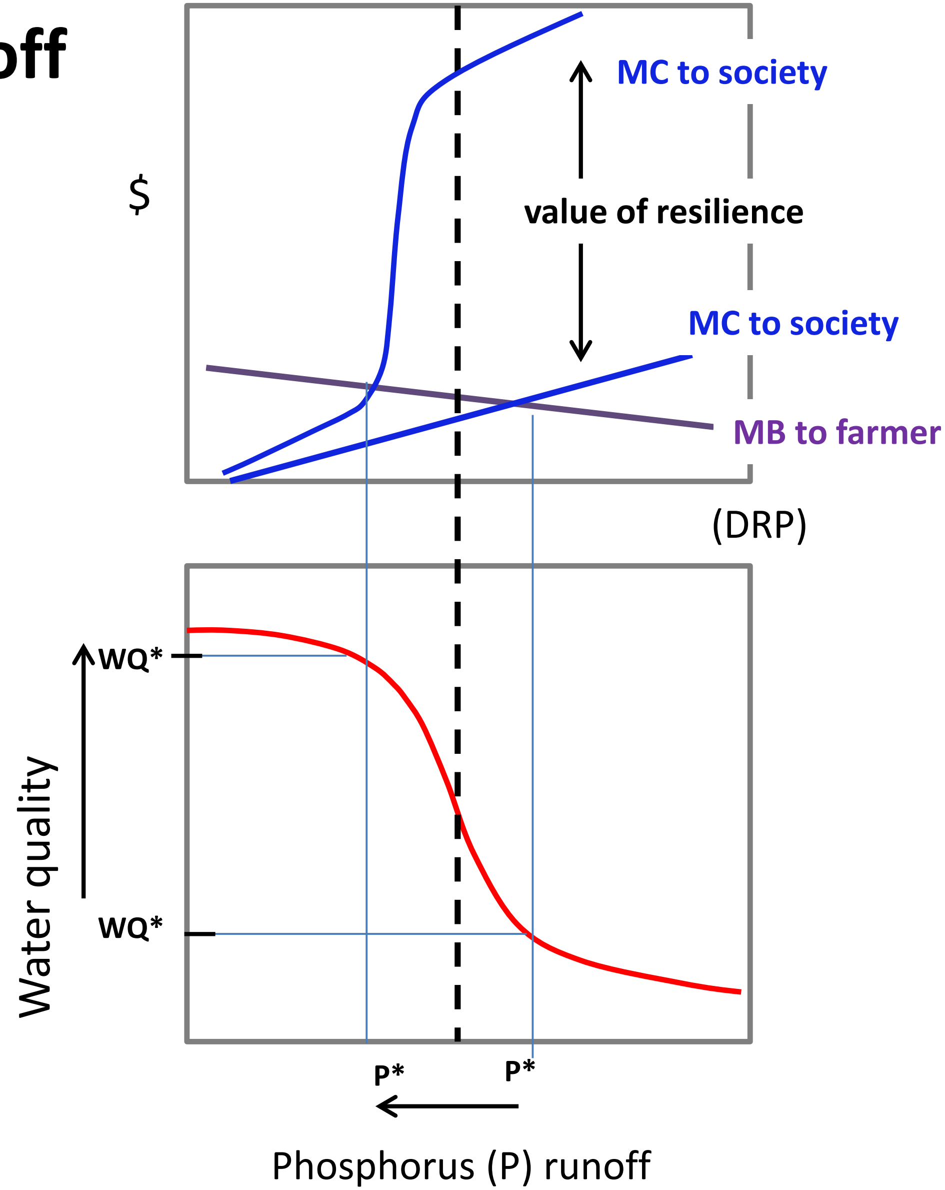
- Eutrophication process exhibits "regime shifts"
- Threshold level of P causes additional P in sediments to be recycled
- This can cause lake to flip "suddenly" and remain in eutrophic state for long time



Optimal P runoff

Accounting for economic trade-offs…

…AND ecosystem dynamics



Optimal outcome incorporates value of resilience associated with the good state

- **National Science Foundation Coupled Human and Natural Systems program Project: "Co-Evolution of Upstream Human Behavior and Downstream Ecosystem Services in a Changing Climate."**. Amount: $1.5 million. Dates: 9/2011– 8/2015.
  - SWAT: calibrated
  - Farmer survey, general population survey, focus group interview: done
  - Farmland parcel data: collected
  - Lake hydrodynamic-lower food web model: developing
- **NOAA/Ohio Sea Grant: "Linking Agricultural Production and Great Lakes Ecosystem Services: Modeling and Valuing the Impacts of Harmful Algal Blooms in Lake Erie",** $198,955, Feb 2014-Feb2016.
  - Angler survey, beach-goer survey: done
  - Lakefront property values (water clarity): ongoing
  - Public health impacts of HAB: ongoing
  - Value of safe drinking water: ongoing

Discrete choice experiment on the adoption of filter strips

Please circle your preferred ranking for each program at the bottom of each column.

	Program A	Program B	Your Current Situation
Length of Program	10 years	10 years	--
Maintenance	Mowing allowed	Mowing allowed	--
Inspection frequency	Annual, announced	Annual, announced	--
Paperwork burden	~ 10 hours/year	~ 5 hours/year	--
Width of Filter Strip	25 feet	75 feet	--
Annual Rental Payment	$200/acre	$125/acre	--
Please rank each program. *Circle one 'Best', one 'Middle' and one 'Worst'*	Best Middle Worst	Best Middle Worst	Best Middle Worst

Results: Marginal Effects

Independent Variable	Pooled Sample	Latent Class Analysis	
		Env. Active (62%)	Others (38%)
Payment	0.0014***	0.0005***	0.0015***
FS Width	-0.0037***	-0.0059***	-0.0014
Paperwork	-0.0129***	-0.0046**	-0.0162***
Years	-0.0024	0.0002	-0.0057
Status Quo	0.0688	0.0500	0.3148**
FS Efficacy	0.0037	0.0411***	-0.0017
BIC	2286.77	2188.22	

*, **, and *** denote statistical significance at the 90%, 95%, and 99% levels.

Implications

- Ignoring heterogeneity may result in inaccurate estimates of WTA payments
- How do we improve adoption rates?
  - Target those most likely to be "Environmentally Active"
  - Educate farmers on value of filter strips
    - Average efficacy for farmer in "Other" class for 25 foot filter strip: 15.6 percentage points (49% reduction)
    - Actual efficacy found in research: 70-90% (sediments), 50-70% (nutrients)
    - Change in beliefs from 49% to 60% → 3.5 percentage points → 14.35% increase in probability of enrollment