CFAES

EST. 1870

WE SUSTAIN LIFE

# Bridging Science and Practice: Watershed Modleing for Nutrient Mitigation in Ohio's Agricultural Watersheds, USA

**Asmita Murumkar, Ecosystems Services Field Specialist,**
**Department of Extension**
**Department of Food, Agricultural and Biological Engineering**

The Ohio State University
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

# Outline

- ❑ **Watershed model (Soil and Water Assessment Tool; SWAT)**

- ❑ **High Resolution Watershed models**
  - ❑ **Remote sensing**
  - ❑ **Conservation practices improvements**

- ❑ **Water quality benefits of conservation practices**
  - ❑ **Single Practice - Sensitivity**
  - ❑ **Bundled Practices – Impact**

- ❑ **Watershed Modeling projects**

# WLEB watershed modeling team

CFAES

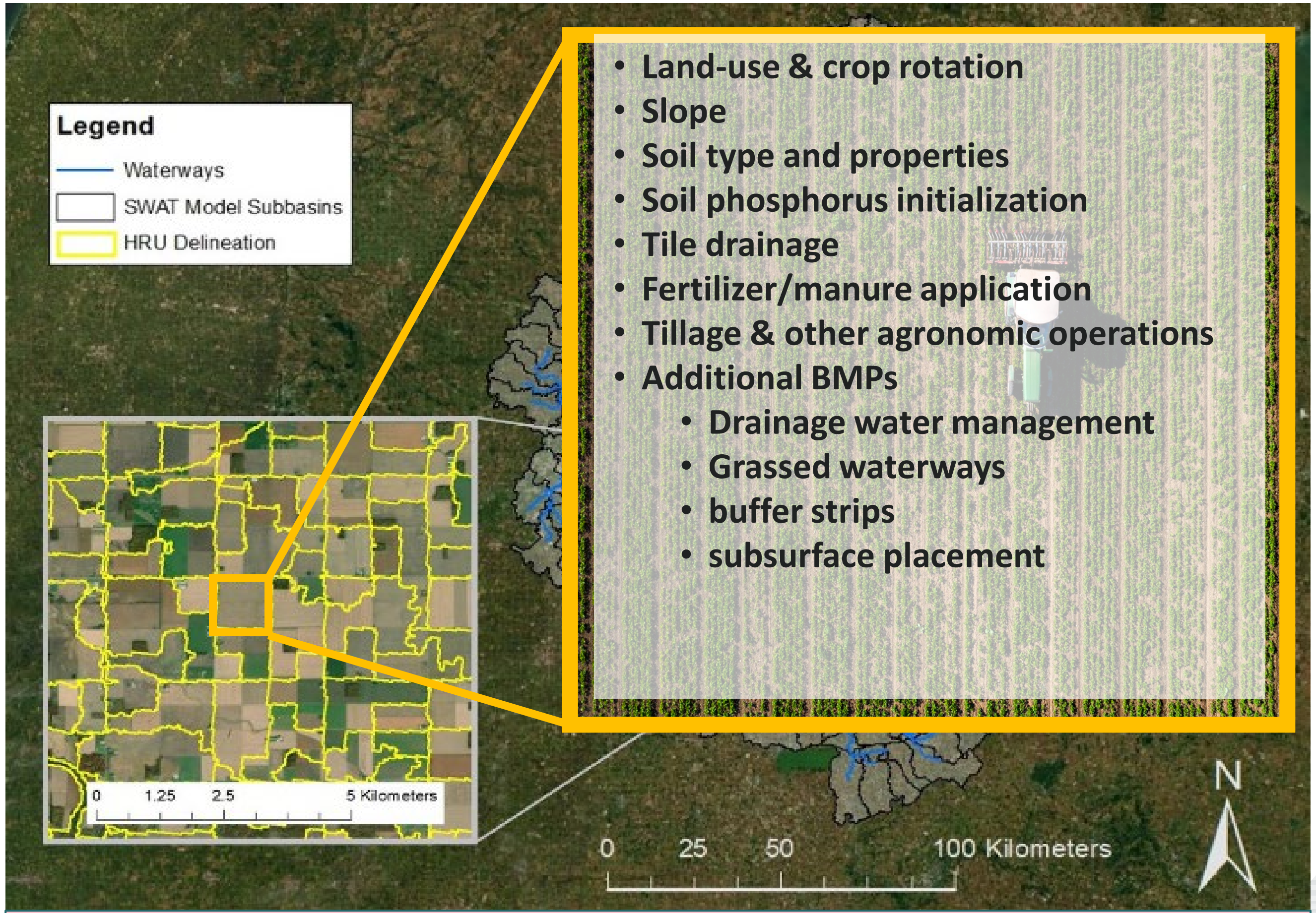
- **The Ohio State University**
  - Jay Martin
  - Asmita Murumkar
  - Vinayak Shedekar
  - Mahesh Tapas
  - Lorrayne Miralha
- **University of Wisconsin-Madison**
  - Margaret Kalcic
  - Anna Apostel
  - Lourdes Arrueta
- **University of Toledo**
  - Kevin Czajkowski
  - Kimberly Panozzo
  - Ishfaq Rahman
- **USDA-ARS**
  - Kevin King
- **Maumee Watershed Modeling Stakeholder Advisory group**

**Funding sources:**

Sea Grant OHIO · Ohio Lake Erie Commission · H2Ohio · NOAA · USDA · NIFA

# Maumee field-scale SWAT model

- **Near-field level resolution:**
  - ~170 acres field
  - Some spatial refinement of management practices (e.g. manure near CAFOs; county-level fertilizer sales)
- **Calibration**
  - Calibrated at the watershed outlet as well upstream gauges
  - Validate at field level




**Published**: Apostel et al. (2021) "Simulating internal watershed processes using multiple SWAT models," *Science of The Total Environment*

# High-resolution watershed model development

**Remote sensing data**
- Crop rotations
- Cover crops
- Tillage practices
- Buffer strips

**Soil Test Phosphorus**

County level STP distributions used to apply a heterogeneous representation of soil P values

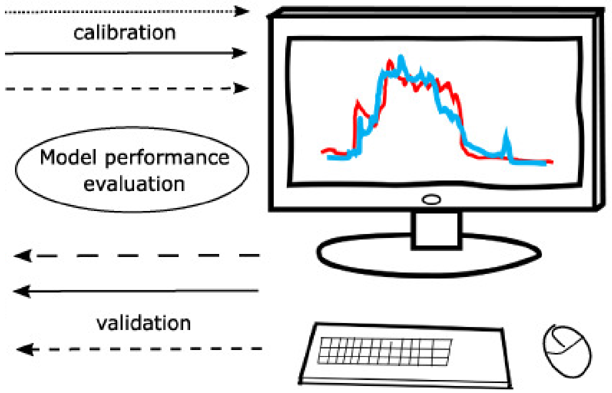
**Manure**
- Locations of permitted and unpermitted facilities
- Kast et al 2020 allocations
- Applied according to STP values and crop needs

**Inorganic Fertilizer**
- County level rates of N and P scaled to meet plant needs
- Applied to field where manure does not meet plant needs

**Additional linked practices**
- Subsurface application
- Tile drainage-spacing
- Wetland locations

**Maumee River Watershed**


**Field-scale SWAT Models**

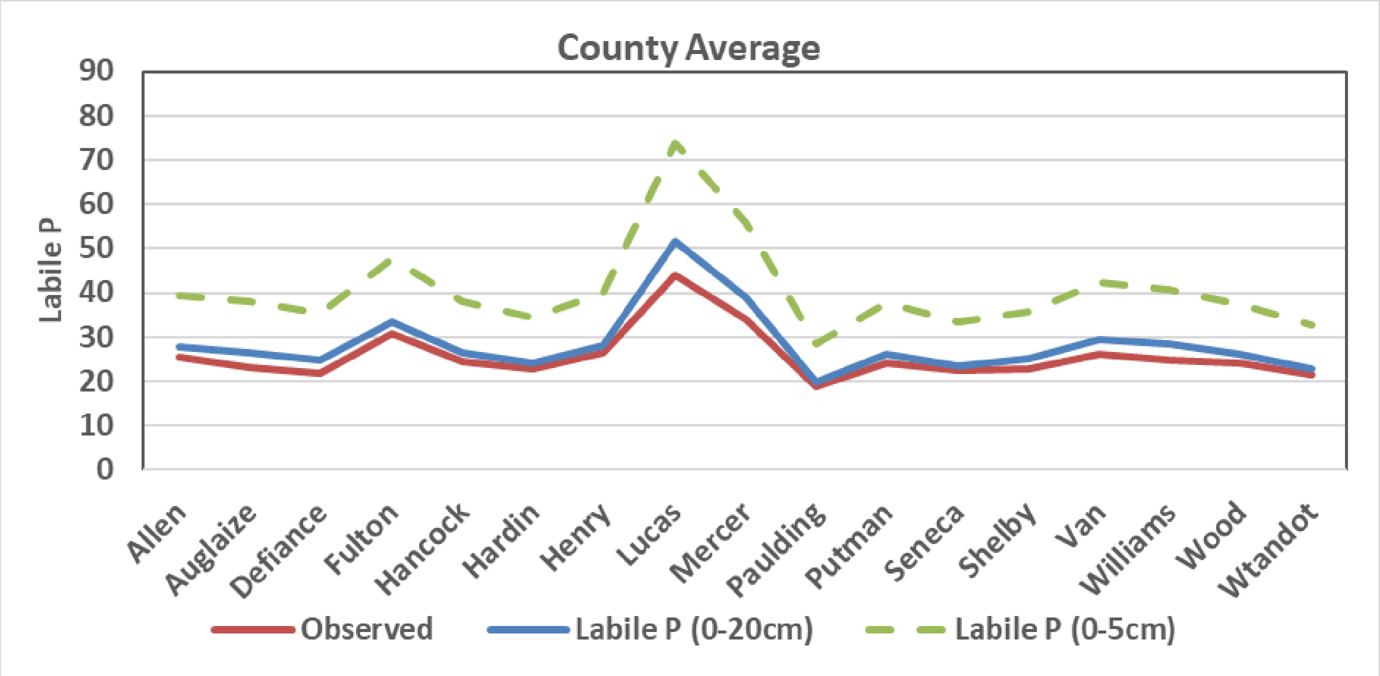



**How do you know model is working?**

# Soil Test Phosphorus (STP)

CFAES

- County data distributions resampled to focus on average, not extreme values.



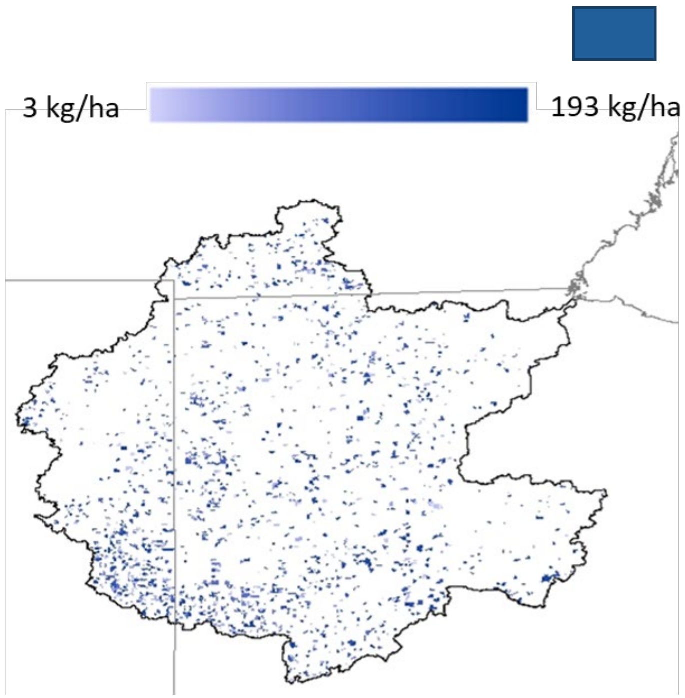

*Dayton et al. 2020*

| | | 0-20 cm | 0-5 cm | 6-20 cm |
|---|---|---|---|---|
| **Labile P (mg P / kg soil)** | Observed | 26 | -- | -- |
| | 2021 Model | 20 | 25 | 15 |
| | **Current Model** | **25** | **35** | **20** |

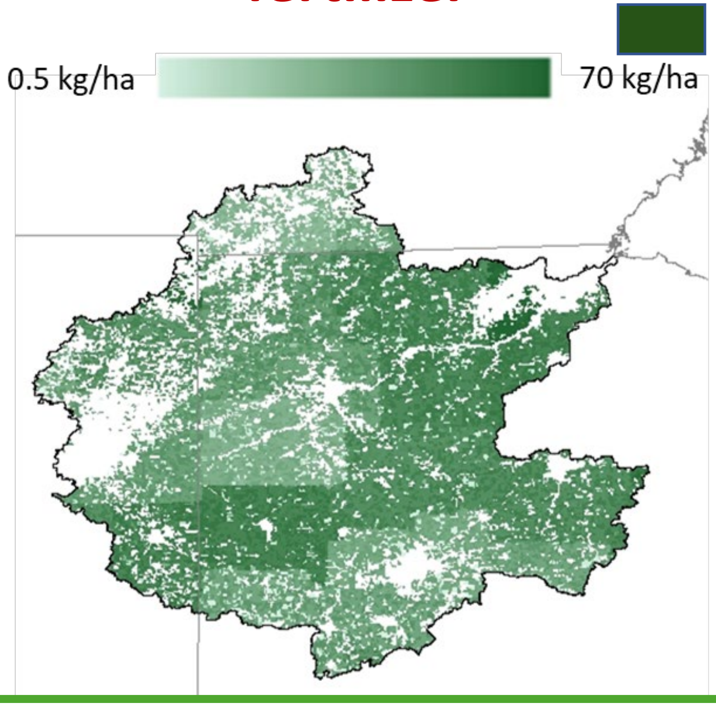
# Nutrient application



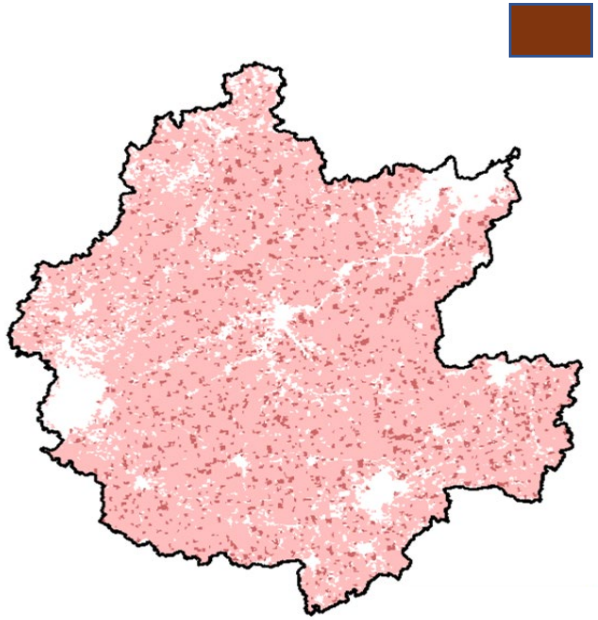
## Phosphorus from manure




## Phosphorus from inorganic fertilizer




## Subsurface fertilizer application



~20% of fields receive manure at least once in 3 years

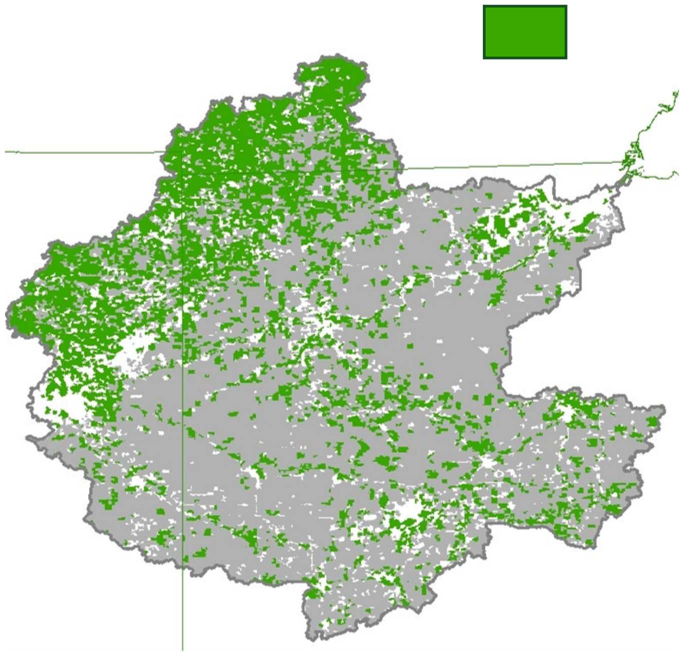
Based on STP value at a field
- 0-25 ppm: Over application
- 25-50 ppm: applied at removal/maintenance range
- >50 ppm: no application

10% of cultivated row crop fields

# Additional linked data

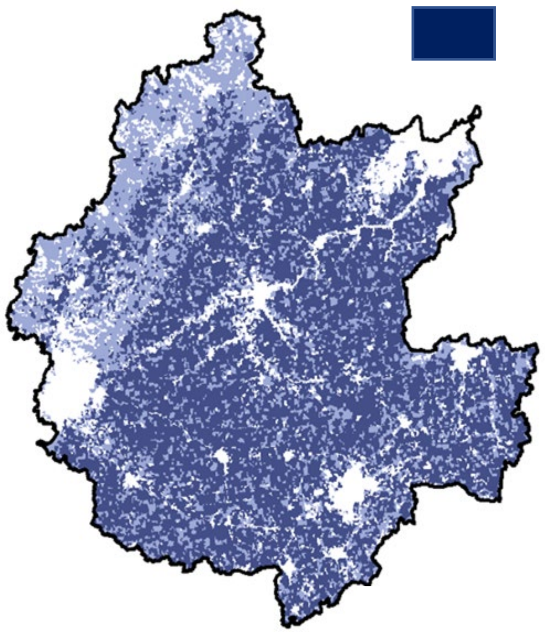
CFAES

## Wetlands



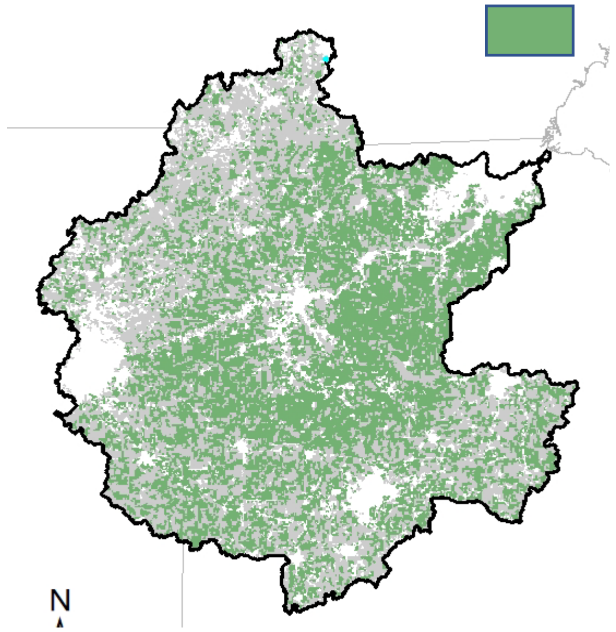
- National Wetland Inventory Data
- N and P removal efficiencies based on regional literature review of wetland effectiveness

## Tile-drainage



- ~62% of total watershed area
- Tile spacing (ft): 30, 35, 40, 50, 60 based on Ohio drainage guide

## Edge-of-field filter strips

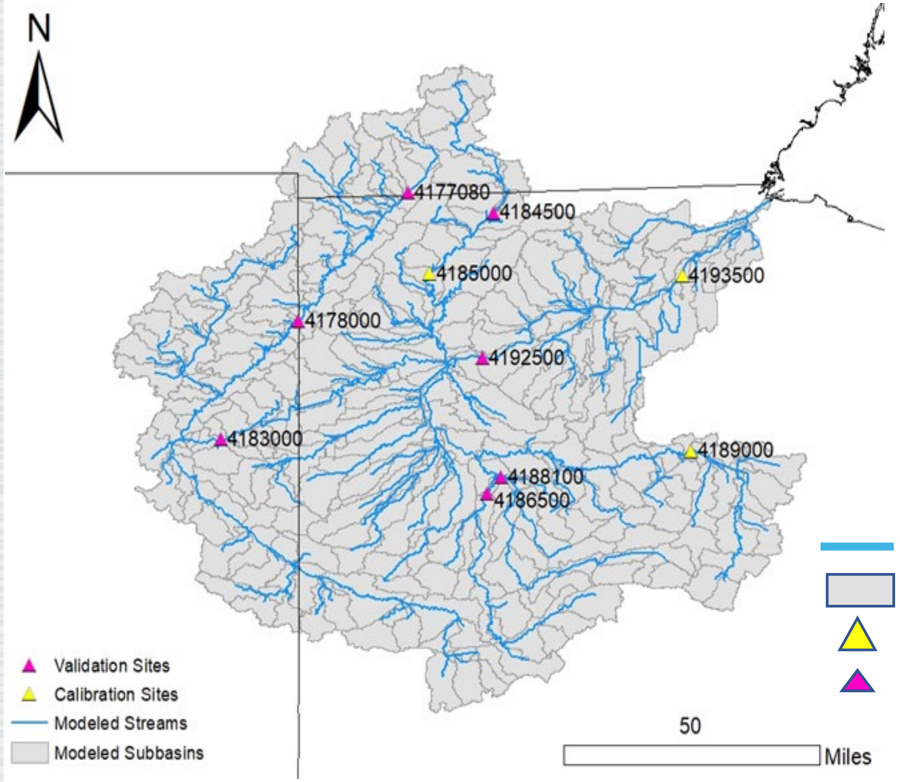



- Remote sensing-based location and size
- More realistic and lower efficiencies

CFAES

# How do you know model is working?

## ❑ Calibration and validation periods




Rivers
Modeled Subbasins
Calibration Gauges (2007-2021)
Validation Gauges (2002-2006)

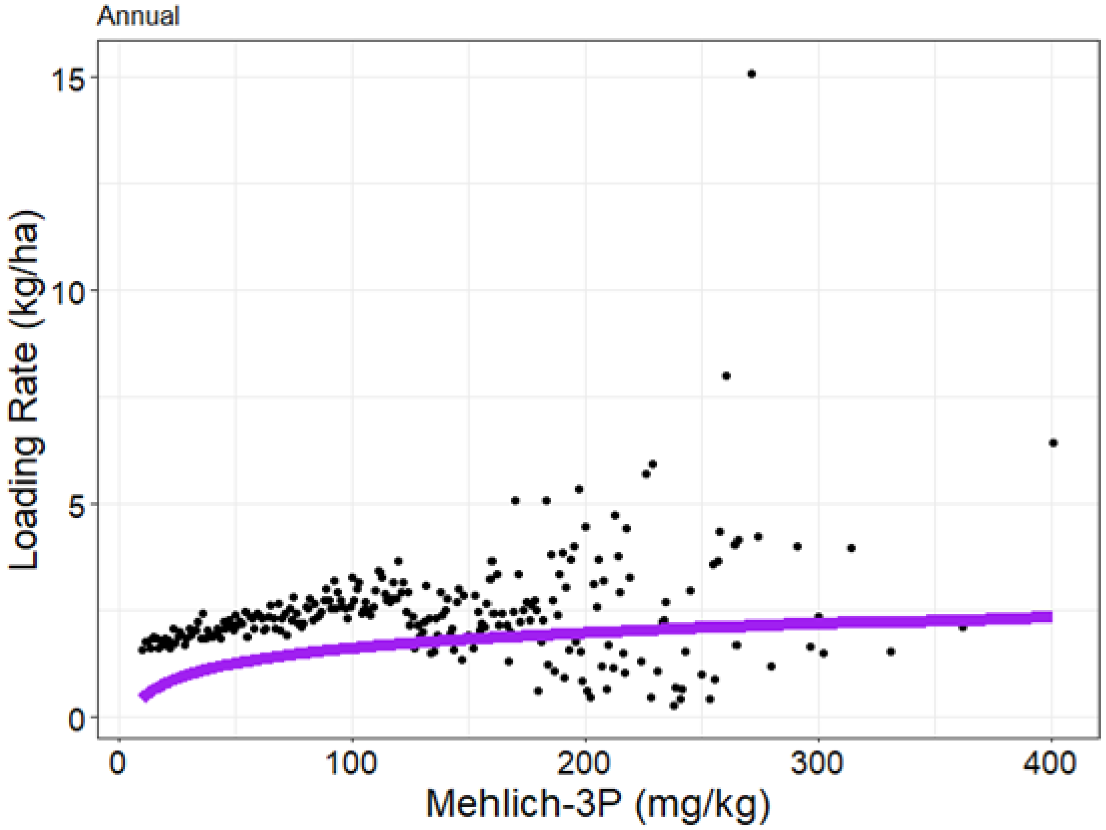
## ❑ Validation of edge-of-field practices

Source: USDA-ARS, Columbus

- **Field-level validation:**
  - USDA-ARS Soil Drainage Research Unit (Williams et al., 2016)
  - OSU edge-of-field monitoring networks (Brooker et al., 2021)

# Calibration and Validation: Results

- **Watershed outlet:** Very good performance
- **Other calibration gages:** Good performance for discharge, mixed nutrient performance
- **Validation stream gages**: Good performance for Discharge and DRP, mixed TP performance
- **Edge-of-field**: Reasonable predictions (significant correlation relationship, tendency to over-predict)



CFAES

# Predicting benefits of conservation practices

- Water quality benefits of conservation -
  - ***Practice sensitivities***
- Bundled Conservation practices i.e.
  - ***Stacking of practices***

**Conservation Practices**

| |
|---|
| *Tri-state Recommended Application Rates* |
| *Subsurface Nutrient Application* |
| *Manure Incorporation* |
| *Cover Crops* |
| *Drainage Water Management* |
| *Edge-of-field Buffers* |
| *Wetlands* |
| *P-filters* |

# Scenario Development

- Scenarios developed with guidance from **Ohio agency** personnel to evaluate individual practices and mitigation program implementation
- Reviewed by the **Maumee Watershed Modeling Stakeholder Advisory group**

# Sensitivity Scenarios: Implementation

CFAES

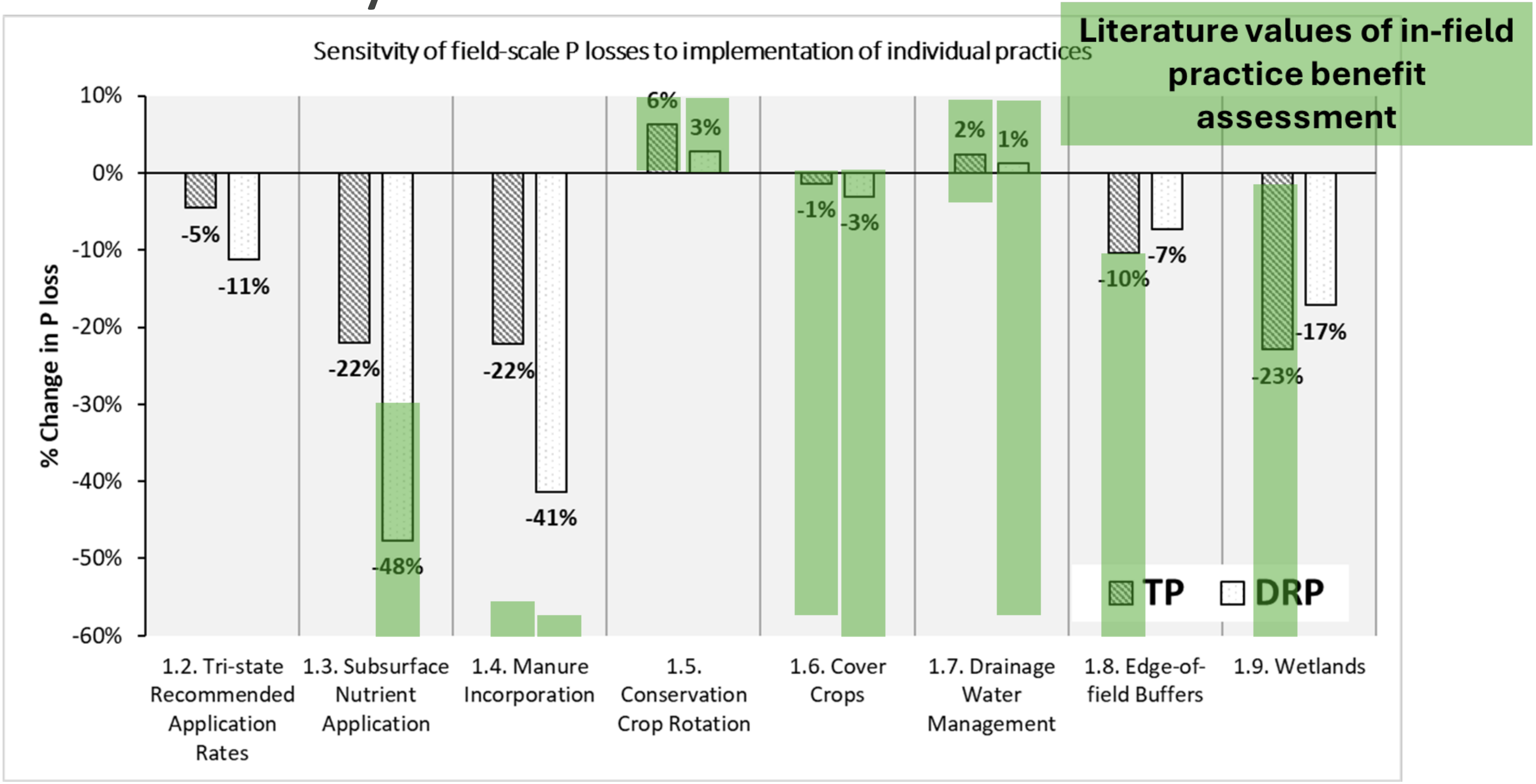
| Management Practice | Implementation | % of all row crop acres in model | |
|---|---|---|---|
| | | Baseline | Scenario |
| *Tri-state Recommended Application Rates** | N and P rates modified to follow application guidance based on soiling testing | 50% | 100% |
| *Subsurface Nutrient Application* | Broadcast fields targeted and modified to receive subsurface inorganic nutrient application | 10% | 23% |
| *Manure Incorporation* | Liquid manure immediately incorporated after application | 12% | 18% |
| *Cover Crops* | Winter rye planted over winter following a corn or soybean harvest | 10% | 30% |
| *Drainage Water Management*** | Depth to tile drain modified throughout year following management guidance | 1% | 9% |
| *Edge-of-field Buffers*** | EOF buffers added at varying efficiencies | 35% | 49% |
| *Wetlands*** | Wetlands implemented on tile drained fields with the guidance of 1.5% of field being removed from production and 25% of tile effluent would be routed through wetland | 20% | 30% |

***Resulted in 5% reduction in P fertilizer across watershed, 10% on changed fields***

*****Percentage of acres impacted by practice***

# Sensitivity Scenarios: Field-scale





CFAES

# Bundled Scenarios: Implementation

## Bundled practice scenarios

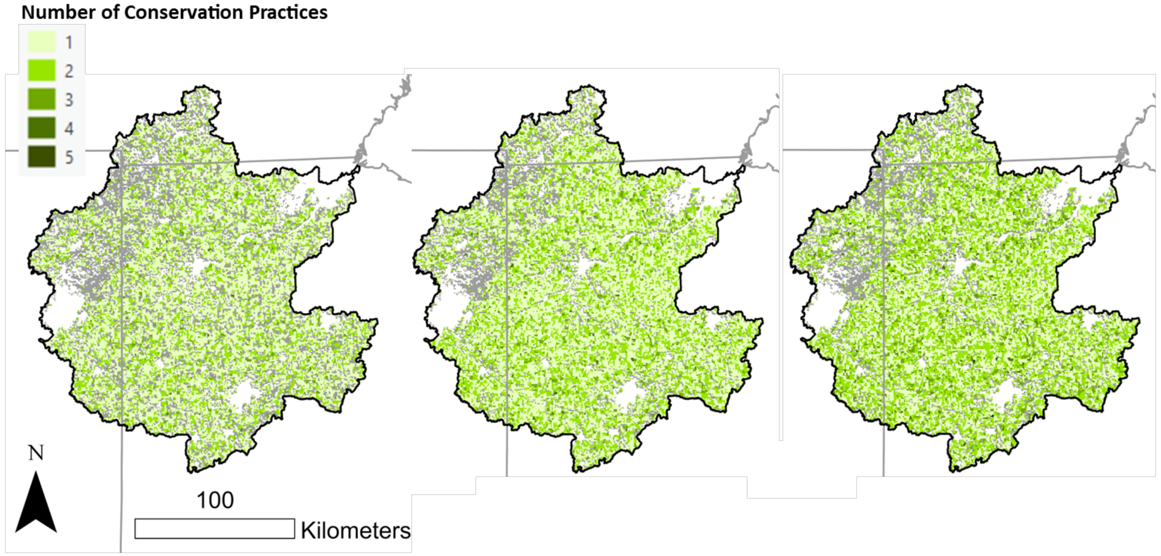
| Management Practice | Baseline | Bundle 1 | Bundle 2 | Bundle 3 |
|---|---|---|---|---|
| *Tri-state Recommended Application Rates* | 50% | 87% | 100% | 100% |
| *Subsurface Nutrient Application* | 10% | 16% | 19% | 36% |
| *Manure Incorporation** | 12% | 14% | 15% | 20% |
| *Cover Crops* | 10% | 17% | 19% | 39% |
| *Drainage Water Management*** | 1% | 2% | 3% | 4% |

| | | | | |
|---|---|---|---|---|
| *% acres impacted above baseline* | - | 53% | 73% | 116%*** |

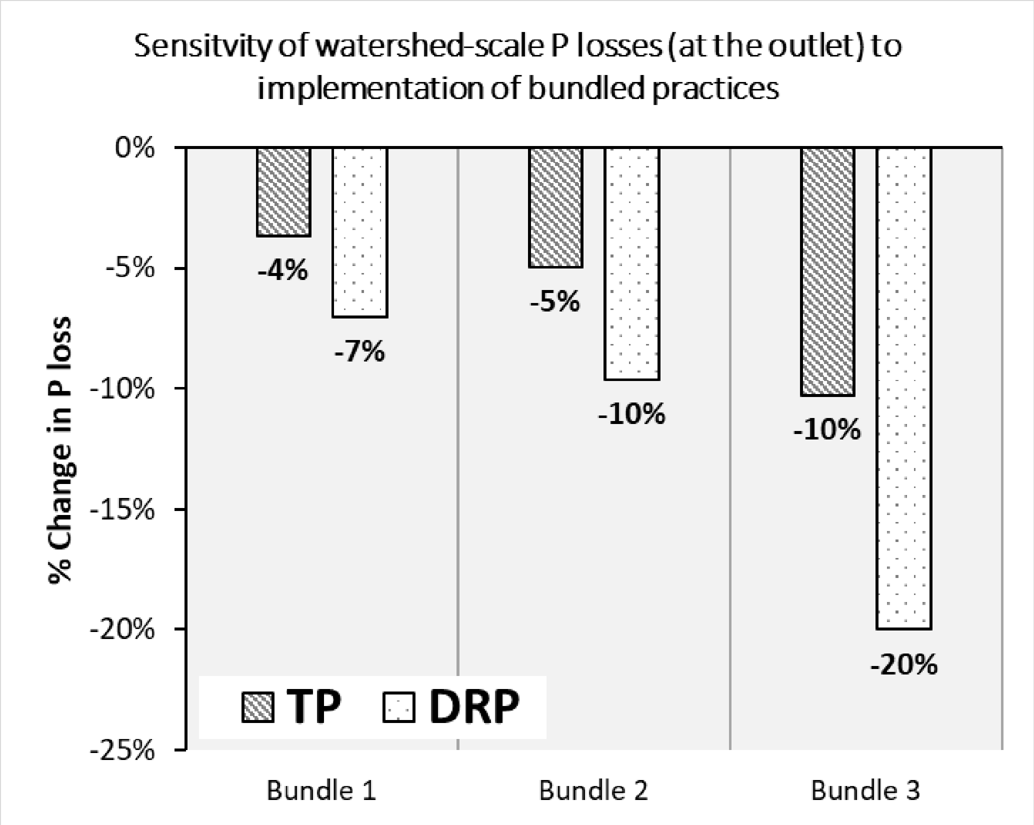
**Manure percentages calculated as a percent of manure fields*
***Drainage water management implemented as a number of structures*
****Values over 100% possible because of stacked practices*

# Bundled Scenarios: Implementation






| Number of Practices | Bundle 1 | Bundle 2 | Bundle 3 |
|---|---|---|---|
| 1 | 1,792,521 | 1,891,491 | 1,571,424 |
| 2 | 750,705 | 1,118,051 | 1,275,605 |
| 3 | 101,848 | 214,465 | 351,885 |
| 4 | 5,552 | 13,860 | 37,135 |
| 5 | 0 | 298 | 1,861 |



# Sensitivity Results: Key Findings

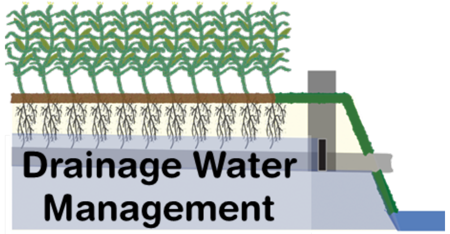
CFAES

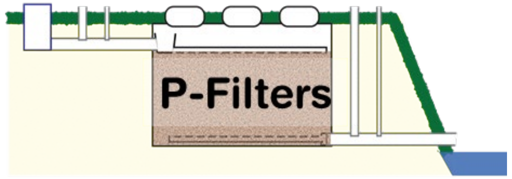
- Better bank for a buck

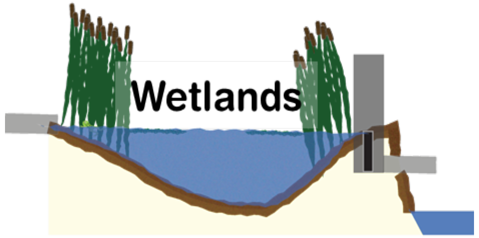
  - Consideration 1: Increase adoption rates of the most effective practices.
    - Greater and targeted adoption = greater impact.
  - Consideration 2: Implement strategic land management if possible.
    - Implementing the most effective practices on strategic acres (areas with greater P runoff), if they can be identified, showed greater impact than random adoption.

CFAES

# Evaluating dynamics of Legacy P field nutrients




**Practice identification**

Drainage water management
P-filter
Wetlands
Combined practices

**Criteria for BMPs**

- DWM criteria (STP>100 mg/kg, Slope < 1%, Poorly drained soils)
- P-filter (STP>100 mg/kg, % Silt > 40)
- Wetlands (STP>100 mg/kg, Hydric soils)

**Scenarios (Current and Future Climates)**

- ❑ Single practice
- ❑ Stacking of practices
  - ❑ Two practices
  - ❑ Three practices

**Team**

- ❑ *The Ohio State University*
- ❑ *University of Wisconsin-Madison*


**Funding: ODHE HABRI**

## Pilot Watershed Project 2023-2028: Can we move the needle in a small watershed to demonstrate how to reach target P reductions?

CFAES

**PI Jay Martin,**
*The Ohio State University*

**Practice Implementation**

70% of the watershed in conservation practices aimed to reduce dissolved P loads

***First year adoption of Subsurface P Placement = 24% of acres***
***Second year tracking towards greater adoption rates***

Practices include:

- Voluntary nutrient management plans
- Subsurface P placement
- Manure incorporation
- Overwintering Cover
- Drainage water management
- P removal structures
- Blind inlets
- Wetlands
- Buffers

### Three Research Areas:

**Social Science**

Measure the effect of interventions on drivers of adoption and persistence

**Water Quality**

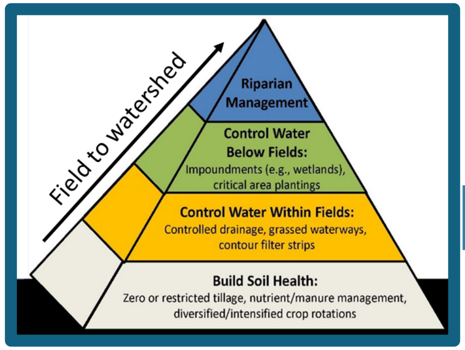
Measure the effect of practices on reducing loads from field to watershed

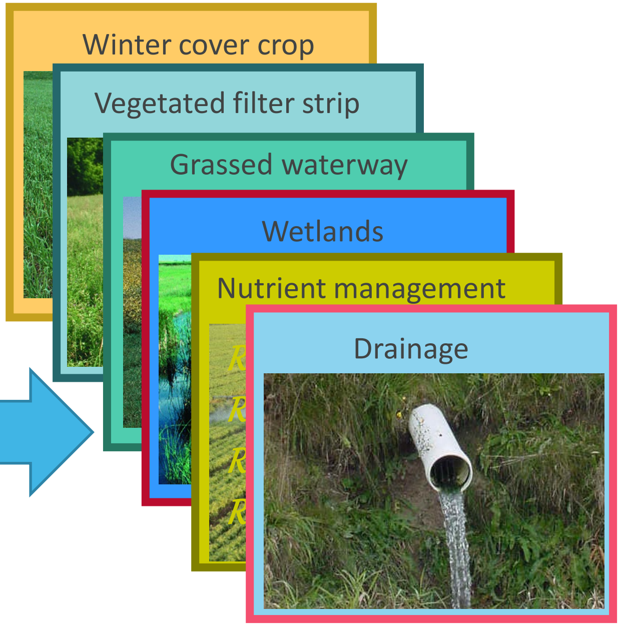
**Soil Health**

Investigate changes in soil health resulting from practice implementation

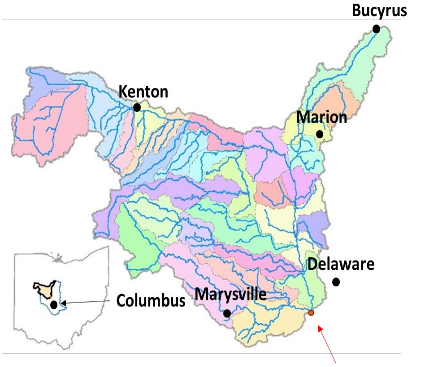
# High-resolution watershed model: Upper Scioto River Watershed

## ACPF

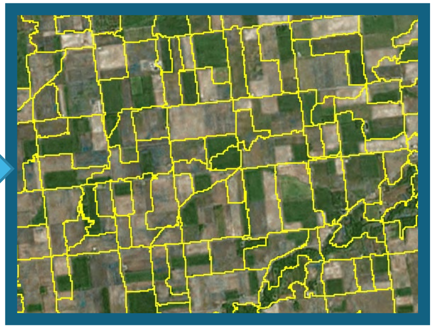



## Implement practices




## Field-scale SWAT+



## Test outcomes

*Overall reductions of TP, DRP, TN, sediment*

CFAES

# Project Funders and Collaborators: Upper Scioto River Watershed

**Current Investment** $1.75M

**Modeling team members:**

Asmita Murumkar
Jay Martin
Margaret Kalcic
Mahesh Tapas
Haley Kujawa
Emmitt Higgins
Brian Brandt
Mark Wilson

**Stay toned**

**Webpage-Story Map**

https://farmland.org/project/usrw/

# SWAT Model Improvement Projects

## ❑ Phosphorus transport via tile drainage

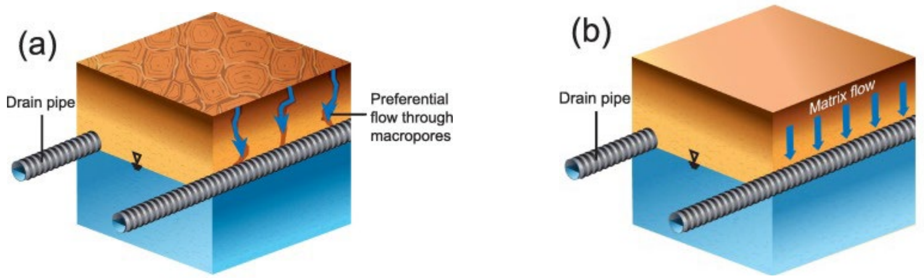
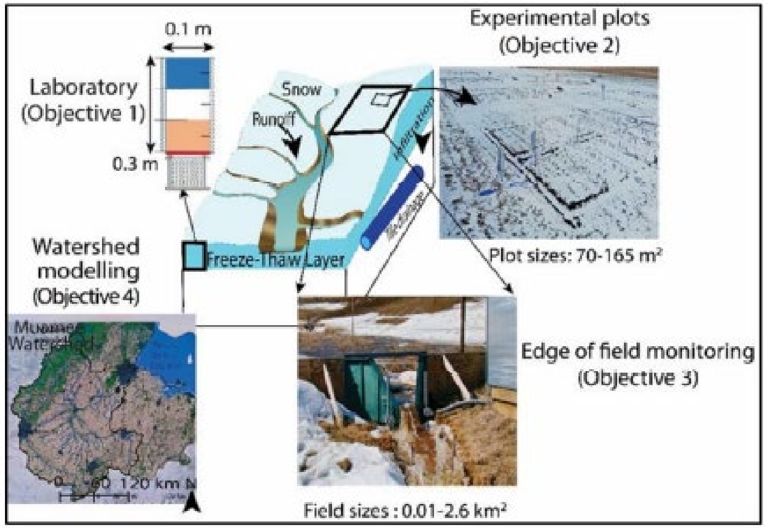



Figure from Dialameh and Ghane 2023

## ❑ Cold Season Process Hydrology




## ❑ Soil Health

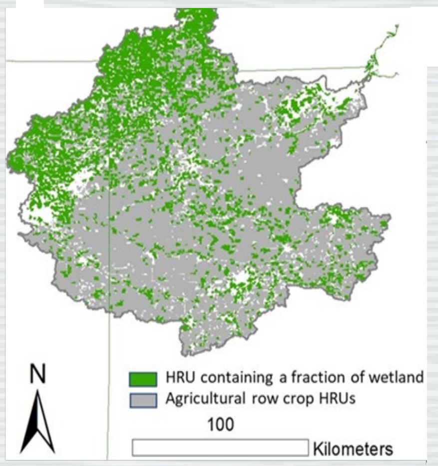
**Team**

- ❑ *The Ohio State University*
- ❑ *University of Wisconsin-Madison*
- ❑ *USDA-ARS (Columbus)*
- ❑ *USDA-ARS (National Soil Erosion Research Laboratory)*

# Enhancing ecosystem models to guide selection and placement of wetlands in the Western Lake Erie Basin

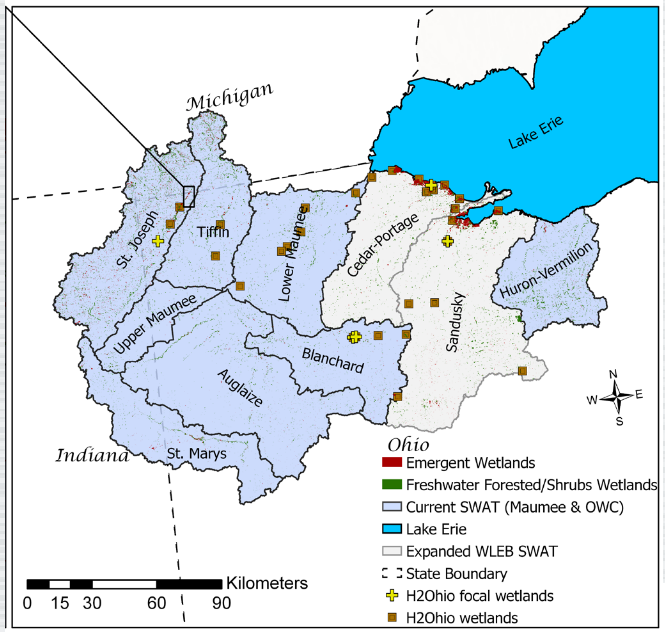
CFAES

**(1)** **Identify wetland locations** throughout WLEB and investigate temporal patch dynamics.

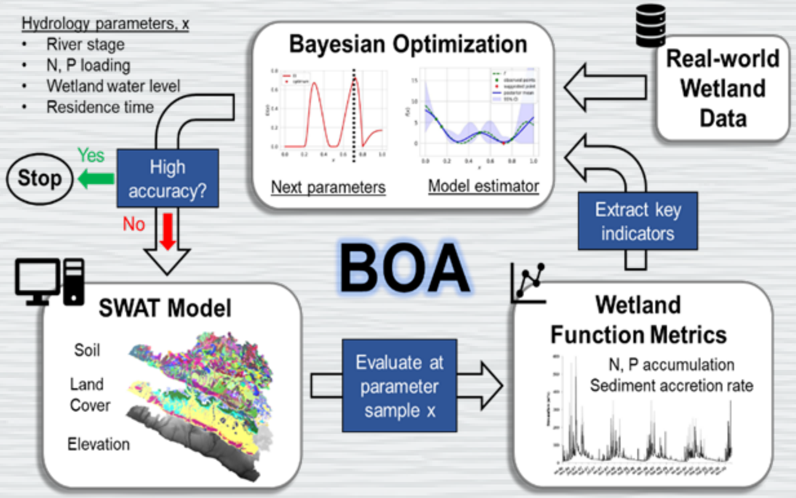



**(2)** Update the Maumee watershed field-scale **SWAT to the SWAT+** version.

**(3)** Compile a **whole WLEB SWAT+ model**




**(4)** Use **data-driven optimization** for automatic calibration in WLEB SWAT+

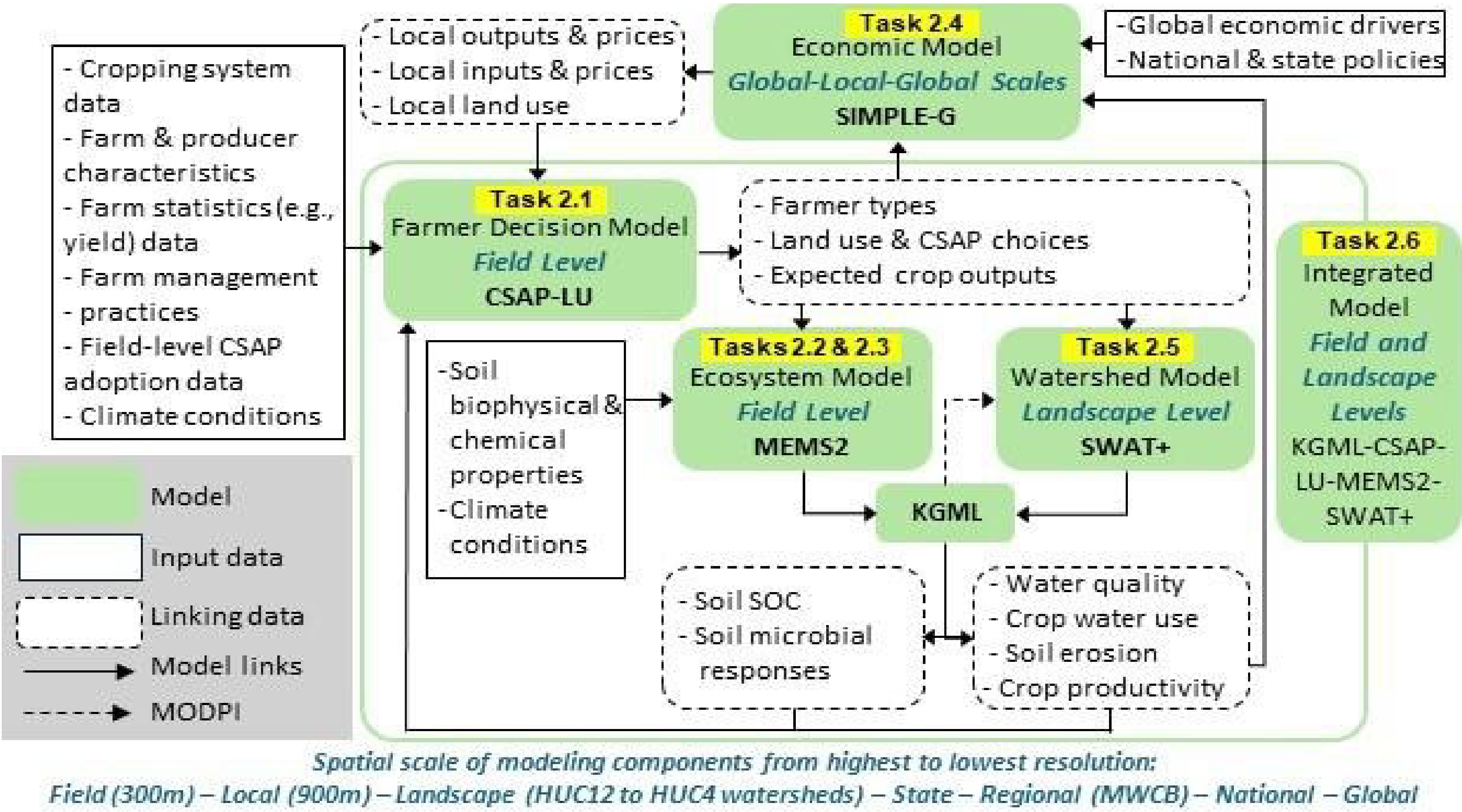



**(5)** Work with a **stakeholder advisory group to evaluate wetlands** for optimal nutrient reduction under current and projected conditions.

**(6)** Expand a **web-based graphical user interface** for application of SWAT+ to test wetland designs under current and future climate scenarios.

**HABRI-ODHE**
**2024 - 2026**
**Team:** *Paulson, Bohrer, Miralha, Murumkar, Kalcic*

# Enabling Farmer Discovery and Managing Critical Tradeoffs with the Emergence of National Scale Carbon Markets




**Team**

- ❑ *The Ohio State University*
- ❑ *Colorado State University*
- ❑ *Central State University*
- ❑ *Purdue University*
- ❑ *Virginia Tech*
- ❑ *University of Minnesota*

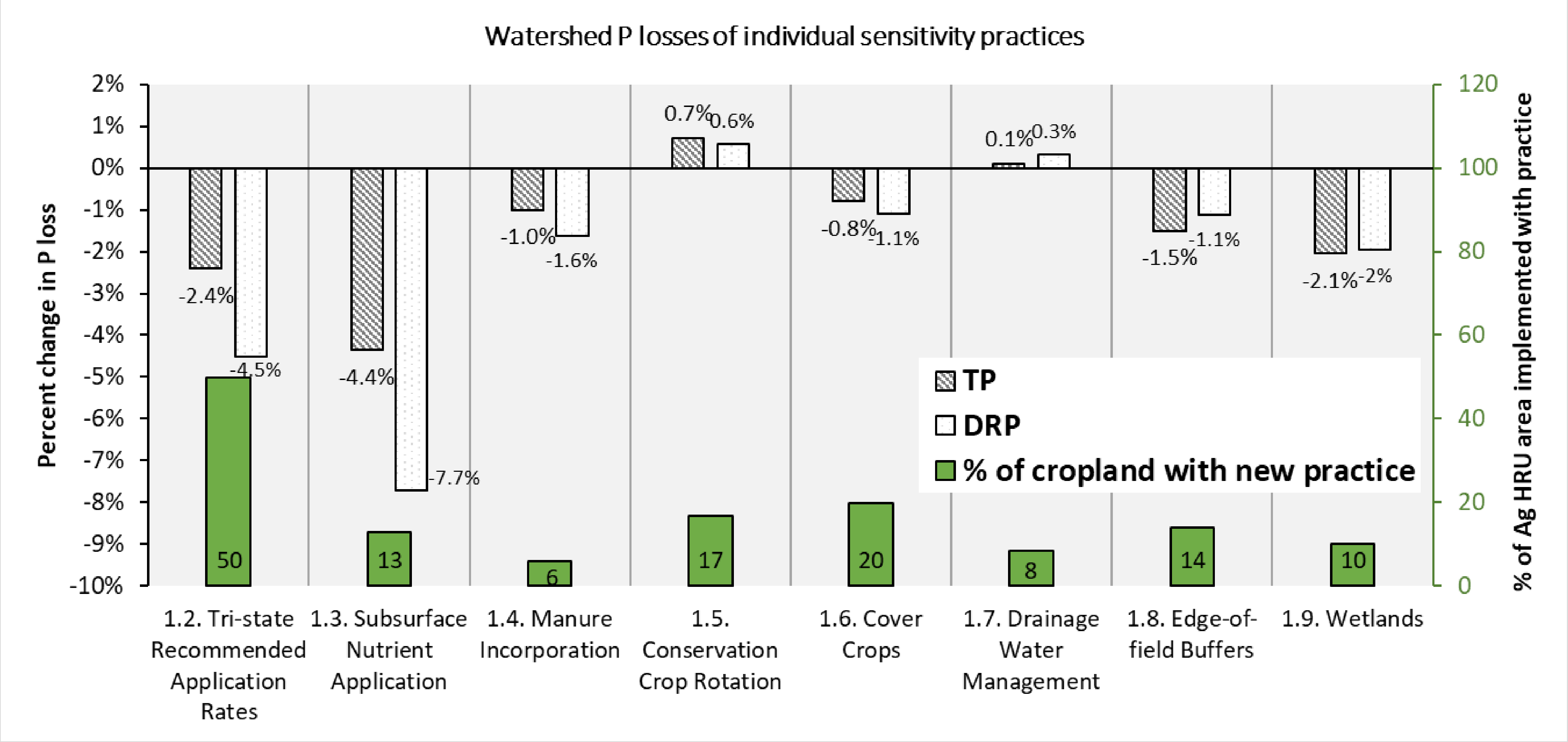
# Thank you!

CFAES

**Asmita Murumkar, PhD,**
Ecosystems Services Field Specialist
Department of Extension
Department of Food, Agricultural and Biological Engineering
**murumkar.1@osu.edu**

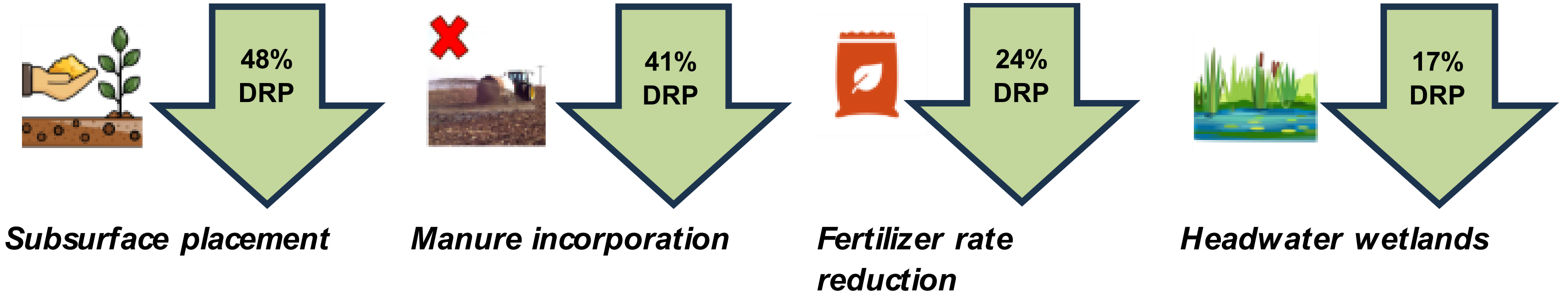
# Sensitivity Scenarios: Watershed-scale

CFAES



# Sensitivity Results: Key Findings

- **Field-scale:**



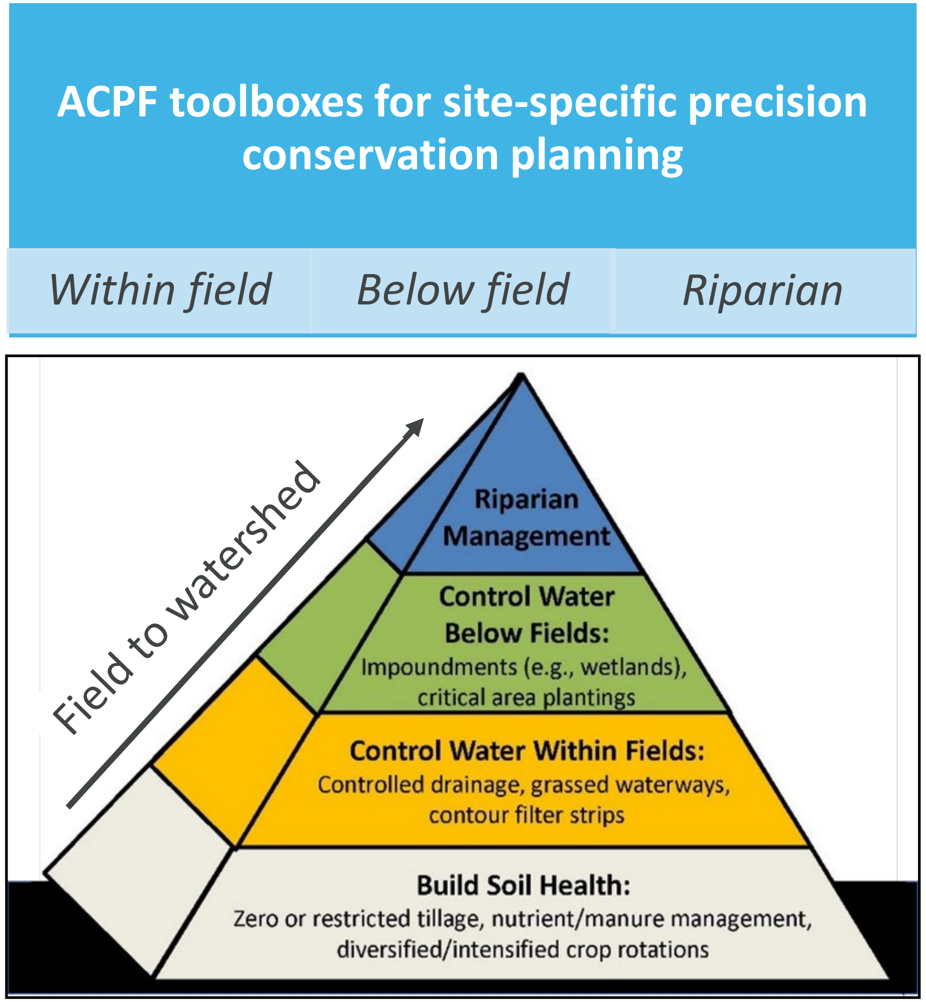

  - **At the watershed scale**, roughly doubling the implementation of multiple conservation practices (from pre-2018-2019 levels) is predicted to reduce both, dissolved reactive P **(DRP)** and total P **(TP)** loading at the watershed outlet by **20% and 10%,** respectively.

- **Results reinforce most effective conservation practices.**
  - **Subsurface Placement, Manure Incorporation, Fertilizer Rate Reduction, Headwater Wetlands.**

  - Co-benefits (e.g. DWM and cover crops help **reduce nitrate losses**).

CFAES

# Agricultural Conservation Planning Framework (ACPF)




**Conservation pyramid for ACPF**

(Tomer et al. 2013).

- Identifies locations suitable for best management practices (BMPs) to address soil and water quality needs.
- Recognizes that farms and watersheds are unique and heterogeneous.
    - Identifies localized areas of potential resource concern.
    - Sites suitable, potential BMPs in in-field, edge-of-field, and downstream locations.

# Model Scenarios – Bundled Scenarios

CFAES

**Bundled scenario practice selection and adoption rates:**

- ❑ Conservation practices were selected using H2Ohio program adopted practices as guidance
  - ❑ Based on H2Ohio program current adoption acres, a 5% yearly increase in acreage was extrapolated to the entire watershed area.
  - ❑ The acres among practice were distributed according to trends in practice adoption distribution
  - ❑ Total increased acres were implemented in the scenarios assuming a 5, 10 and 20-year steady state adoption rate of 5%.
- ❑ Run for climate years 2008-2021
- ❑ Nutrient and discharge outputs produced for Maumee outlet

# SWAT model

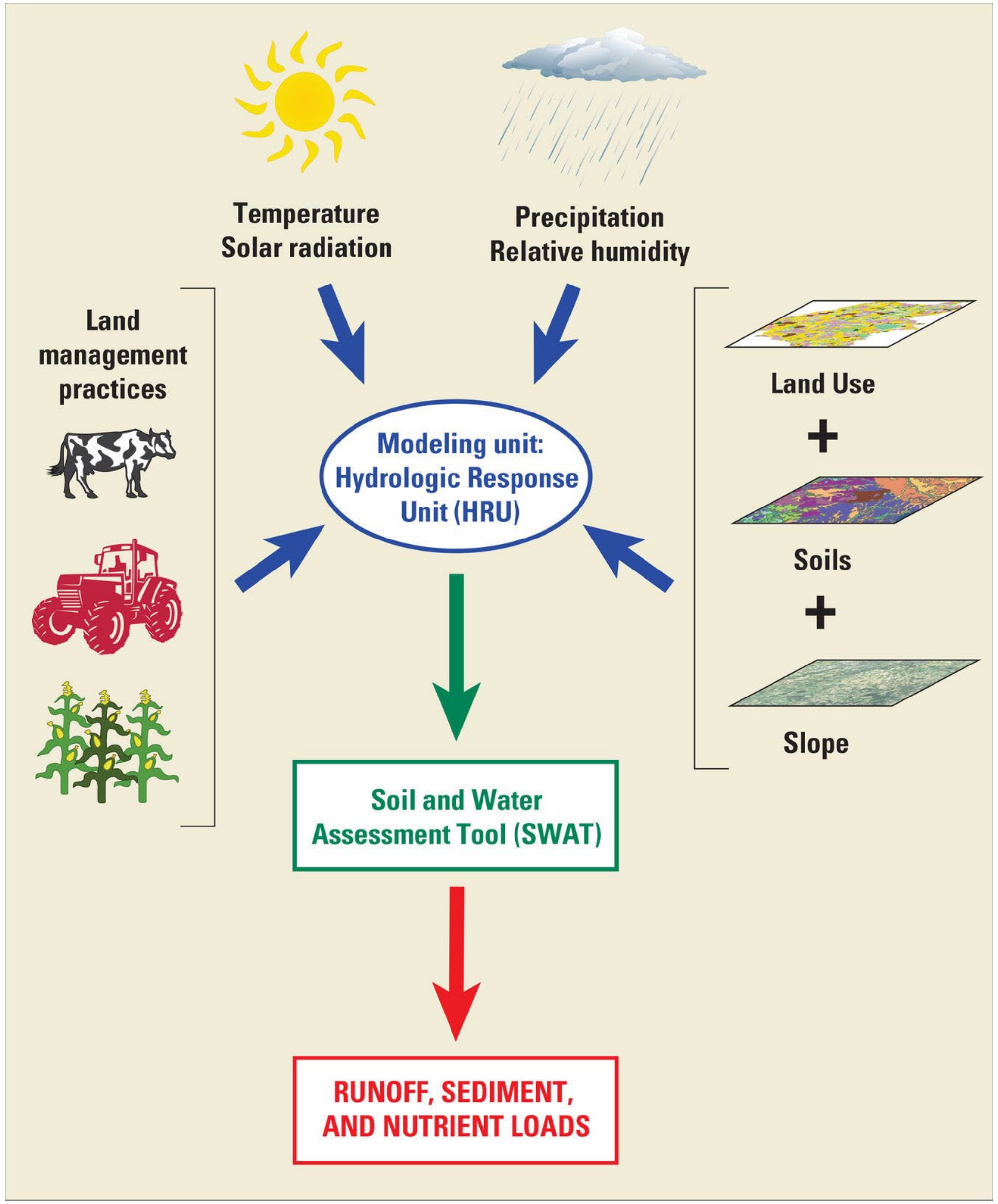
**Can predict water quantity, water quality (Nitrogen, phosphorus, sediment)**

***SWAT takes data inputs:***

Streams
Topography
Soils
Land use
Land management
Climate

***SWAT can test scenarios:***

Conservation practices
Targeting/prioritization




usgs.gov

# High-resolution watershed model development



**Remote sensing data**

- Crop rotations
- Cover crops
- Tillage practices
- Buffer strips

**Soil Test Phosphorus**

County level STP distributions used to apply a heterogeneous representation of soil P values

**Manure**

- Locations of permitted and unpermitted facilities
- Kast et al 2020 allocations
- Applied according to STP values and crop needs

**Inorganic Fertilizer**

- County level rates of N and P scaled to meet plant needs
- Applied to field where manure does not meet plant needs

**Additional linked practices**

- Subsurface application
- Tile drainage-spacing
- Wetland locations

# Key Message

- Models like SWAT are a critical tool in the evaluation and adaptive guidance of programs targeting land management improvements.
- When guiding policy, effectively validating at the implementation scale is needed.
- Guided stakeholder modeling helps assess true policy concerns while uncovering innovation needs within the model.