# A Phosphorus Credit Trading Program in an Agricultural Watershed

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# Outline

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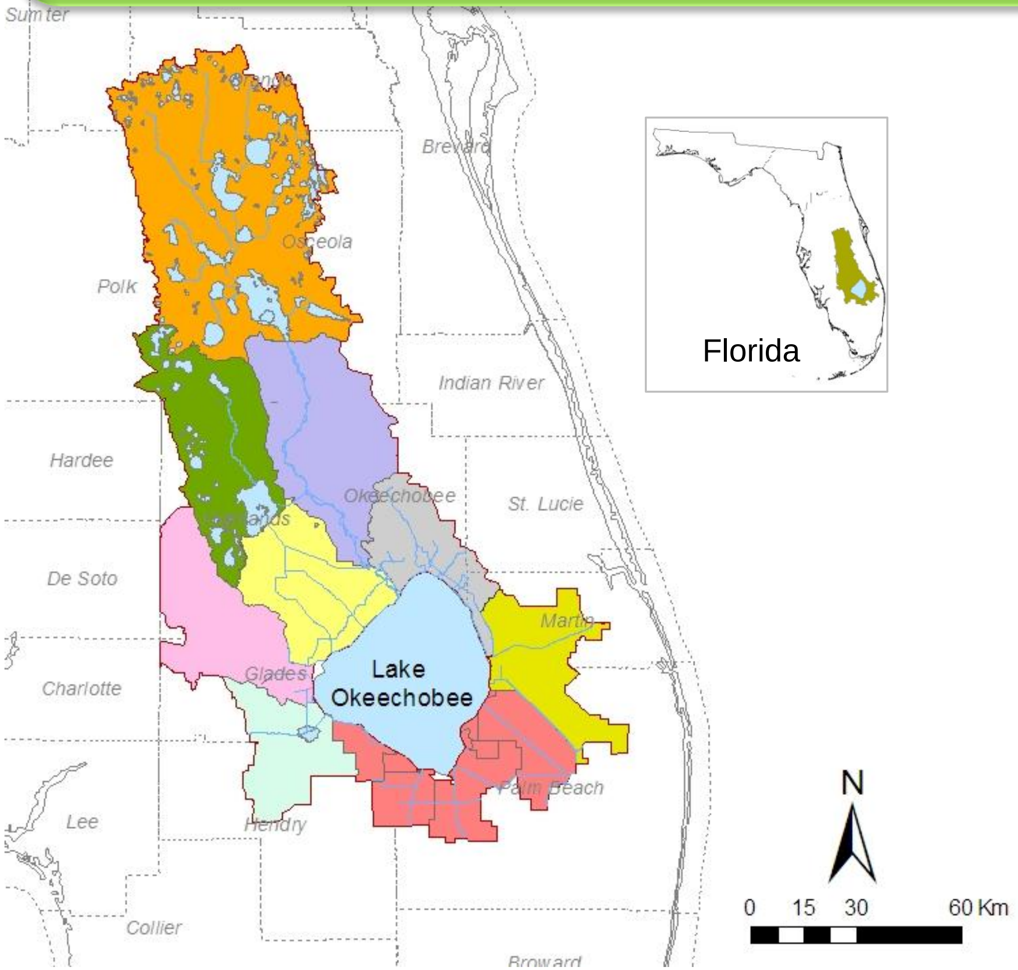
2. Objective
3. Methodology
4. Results
5. Conclusions

# 1. Introduction

## Study Area




**Uses:** water supply, flood control, irrigation, and recreation.

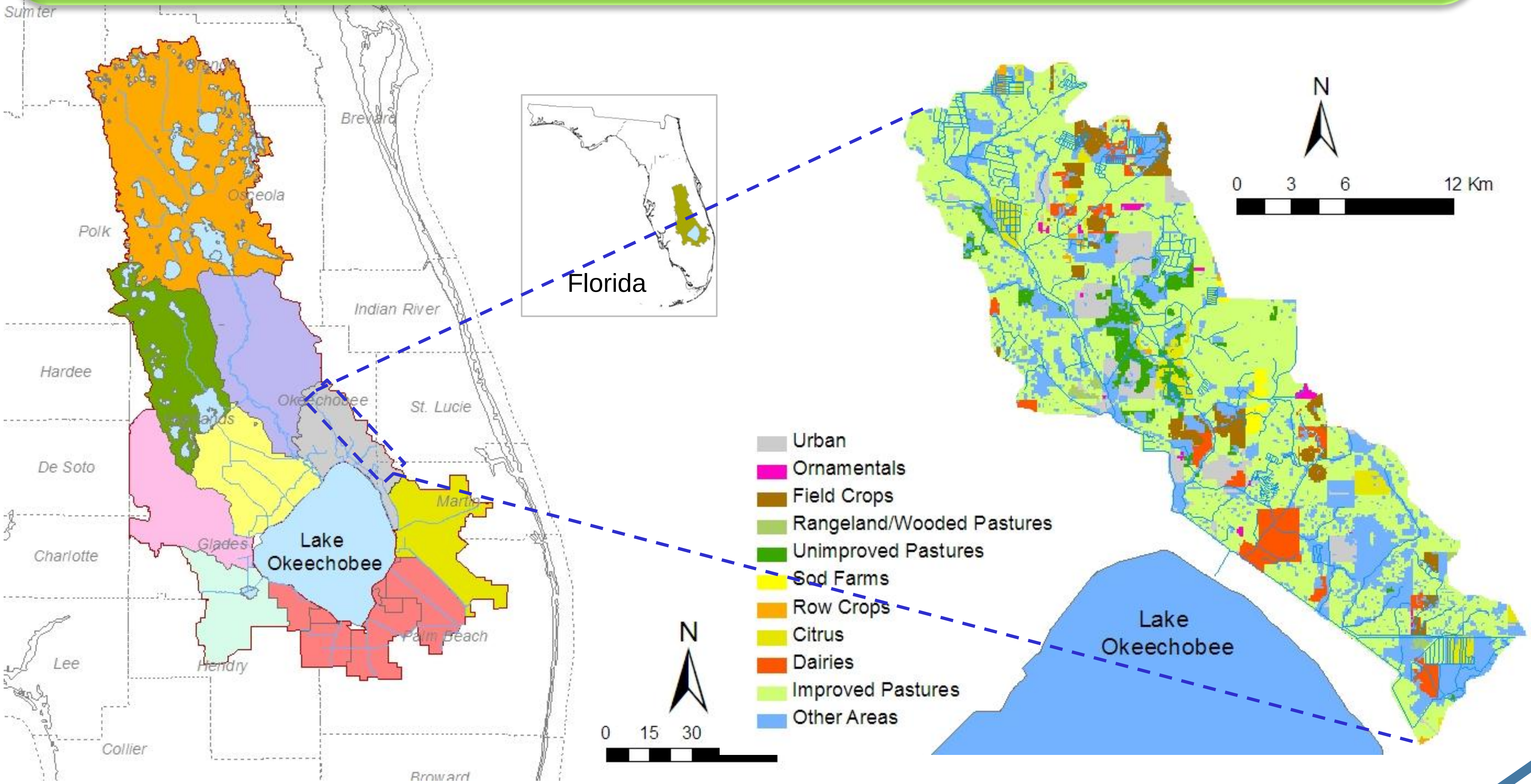
**Threats:** Land use changes and excessive nutrient (phosphorus) loads.

**Solution:** Adoption of a phosphorus Total Maximum Daily Load (TMDL) of 140 mtons/yr.

Drainage area: 11,914 $km^2$

# 1. Introduction (cont.)

## Case Study: S191 Basin

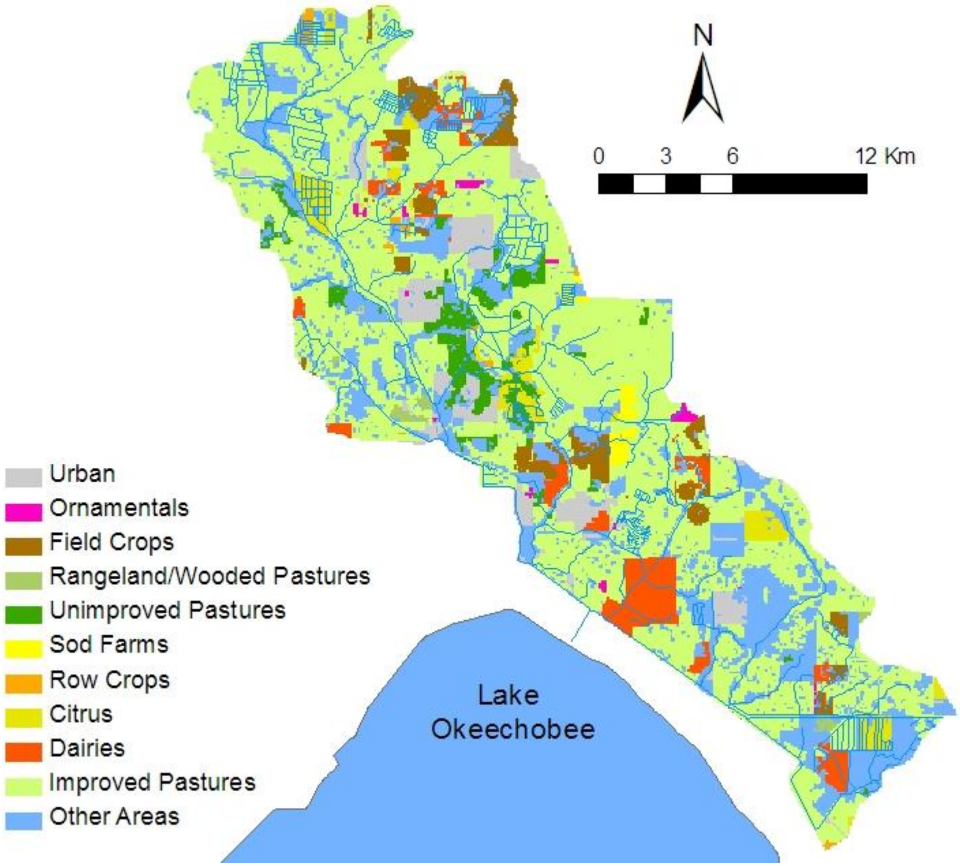


# 1. Introduction (cont.)

## Case Study: S191 Basin

- Direct discharge to Lake Okeechobee.
- **73% of the basin is composed by agricultural land**, 22% natural areas, and 5% urban.
- 485 km$^2$ - **4% of the Lake Okeechobee Watershed (LOW) area**.
- Annual average Total Phosphorus (TP) load of 85 mtons* - **17% of TP load to the Lake**.

*From 2002 to 2009.



# 2. Objective

**Assess the environmental and economic benefits of a phosphorus credit trading program compared with a command-and-control approach**

# 3. Methodology

**Phase 1**

## Hydrology and Water Quality Modeling

Where phosphorus sources are located? How much is their annual average load? What are the trading ratios?

**Phase 2**

## Economic Modeling

What is the optimal cost-effective Best Management Practices (BMPs) to be implemented at each source in order to achieve a basin-load reduction target?

**Phase 3**

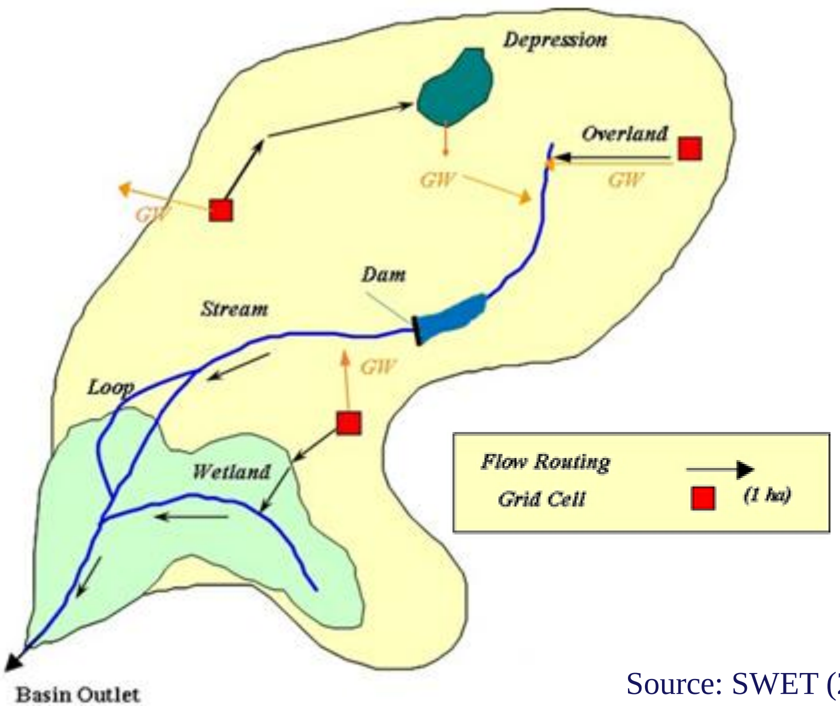
## Phosphorus Credit Trading Scenario Analysis

What is the net cost savings of a trading program compared with a command-and-control approach?

# 3. Methodology (cont.)

## Phase 1: Hydrology and Water Quality Modeling

Watershed Assessment Model




Source: SWET (2011)

WAM is a GIS based model aimed to:

- Simulate the water quantity and quality for existing conditions in a watershed.
- Develop nutrient strategies while identifying existing nutrient sources by land use and region.
- Analyze the impacts of different best management practices on the watershed.

# 3. Methodology (cont.)

## Phase 2: Economic Modeling

### Least-Cost Abatement Model:

$$Min\ Z = \sum_i \sum_k \sum_j c_{i,k,j} \times X_{i,k,j}$$

Subject to:

$$\sum_i \sum_k \sum_j L_{i,j} \times r_{k,j} \times X_{i,k,j} \geq Target\_P_{red}$$

$$\sum_k X_{i,k,j} = 1 \quad \forall i,k,j$$

This optimization model will be solved using the General Algebraic Modeling System (GAMS) software.

**Indices:**
$i$: zones
$j$: land use types
$k$: BMP types

**Given Data:**
$C_{i,k,j}$: annual abatement cost , $/yr
$L_{i,j}$: TP load, kg/yr
$r_{k,j}$: BMP TP load reduction efficiency, %
$Target\_P_{red}$: basin-wide minimum TP load reduction target, kg/yr

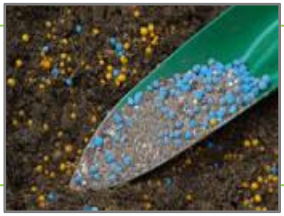
**Decision Variable:**
$X_{i,k,j}$: binary variable, 1 if BMP is implemented, 0 otherwise

# 3. Methodology (cont.)

## Best Management Practices (BMPs) for Phosphorus Reduction

BMP type I – Owner type
- Non-structural

Fertilizer type



Fertilizer amount

Record keeping

BMP type II – Typical type
- Structural

Fencing

Wetland restoration

BMP type III – Alternative type
- Structural

Chemical treatment

# 3. Methodology (cont.)

## Phase 3: Phosphorus Credit Trading Scenario Analysis

**Step 1**
- Determination of the cap
- Allocation of the cap per source

**Step 2**
- Estimation of the costs of the command-and-control and the least-cost abatement approaches

**Step 3**
- Determination of the credit price
- Identification of the buyers and sellers of credits

**Step 4**
- Estimation of the number and cost of the credits traded

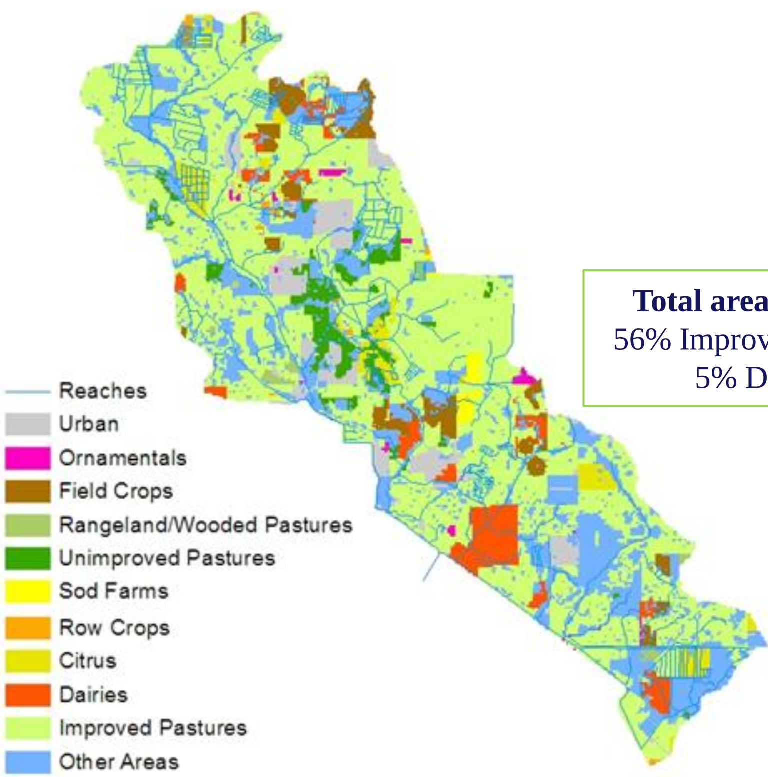
**Step 5**
- Estimation of net costs savings

# 4. Results

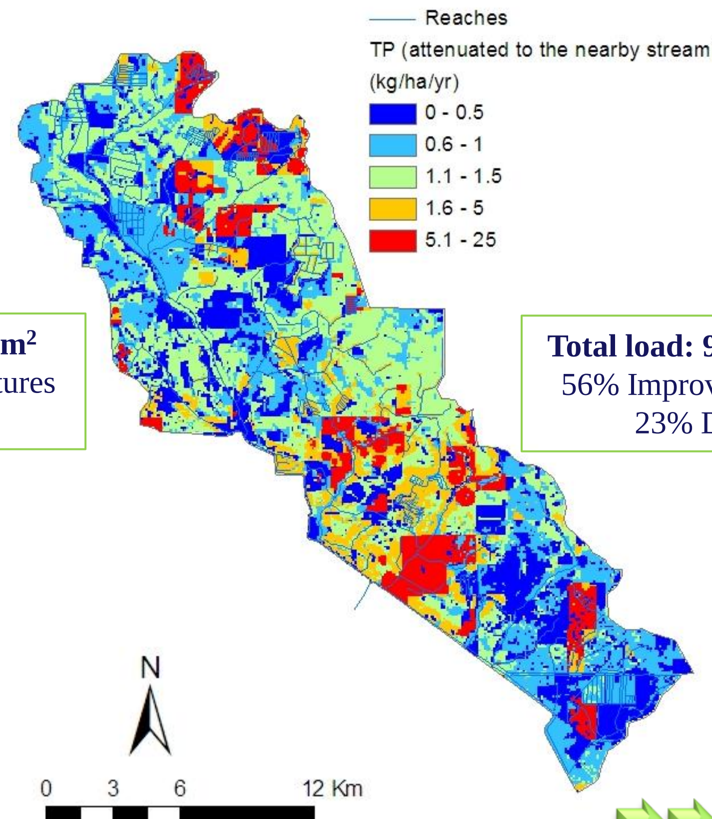
## Phase 1: Hydrology and Water Quality Modeling

### Identification of Total Phosphorus (TP) Sources in the S191 Basin

Land use and TP loads spatial distribution



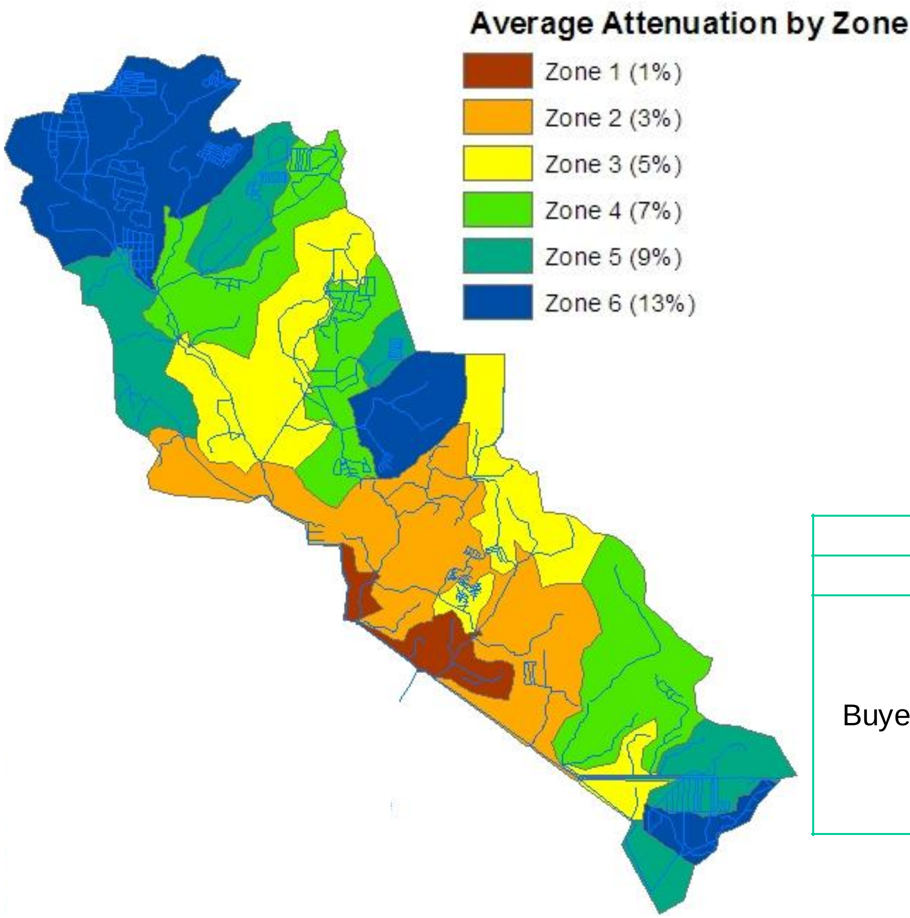

**Total area: 485 km$^2$**
56% Improved Pastures
5% Dairies




**Total load: 91 mtons yr$^{-1}$**
56% Improved Pastures
23% Dairies

# 5. Results (cont.)

## Phase 1: Hydrology and Water Quality Modeling




### Trading Ratios (TR)

TR are used to equalize the TP loads at the basin outlet from trading sources located at different distance from the Lake

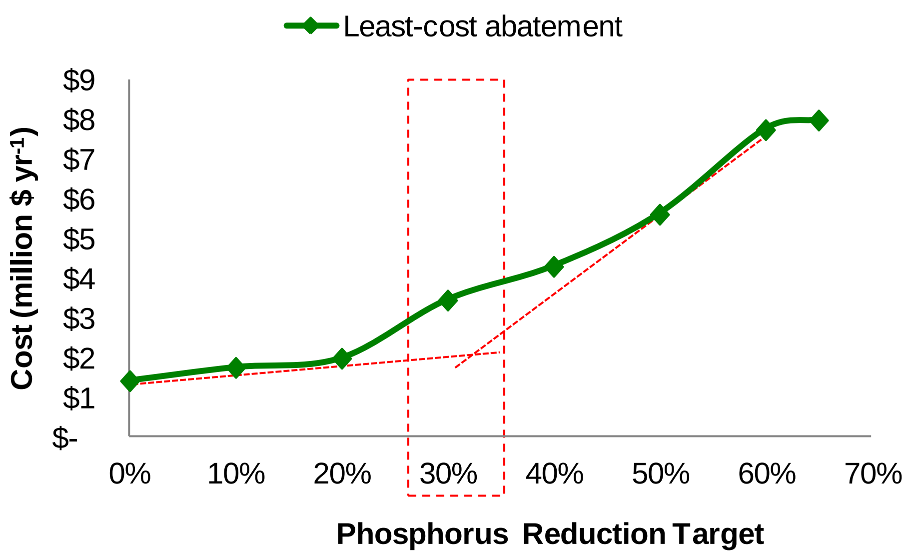
$$TR = \frac{(1 - Buyer's\ attenuation\ factor)}{(1 - Seller's\ attenuation\ factor)}$$

| | | Seller | | | | | |
|---|---|---|---|---|---|---|---|
| | | zone 1 | zone 2 | zone 3 | zone 4 | zone 5 | zone 6 |
| Buyer | zone 1 | 1.00 | 1.02 | 1.04 | 1.06 | 1.09 | 1.14 |
| | zone 2 | 0.98 | 1.00 | 1.02 | 1.04 | 1.07 | 1.11 |
| | zone 3 | 0.96 | 0.98 | 1.00 | 1.02 | 1.04 | 1.09 |
| | zone 4 | 0.94 | 0.96 | 0.98 | 1.00 | 1.02 | 1.07 |
| | zone 5 | 0.92 | 0.94 | 0.96 | 0.98 | 1.00 | 1.05 |
| | zone 6 | 0.88 | 0.90 | 0.92 | 0.94 | 0.96 | 1.00 |

# 4. Results (cont.)

## Phase 3: Phosphorus Credit Trading Scenario Analysis (step 1)

- Trading Program Cap: TP Reduction Target




$$Min\ Z = \sum_i \sum_k \sum_j c_{i,k,j} \times X_{i,k,j}$$

Subject to:

$$\sum_i \sum_k \sum_j L_{i,j} \times r_{k,j} \times X_{i,k,j} \geq Target\_P_{red}$$

$$\sum_k X_{i,k,j} = 1 \quad \forall i,k,j$$

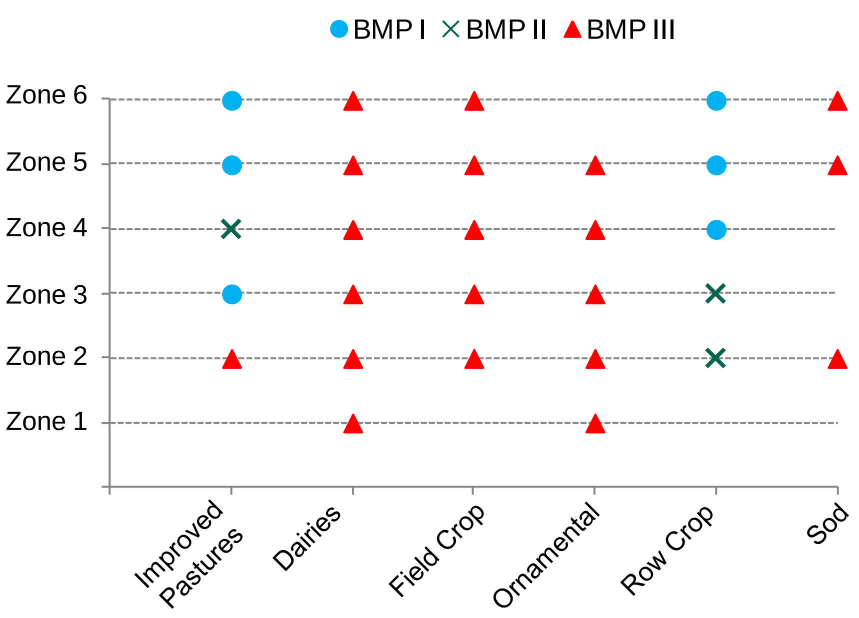
**Current load** (attenuated to the nearby stream): 87.9 mtons $yr^{-1}$ → 30% reduction → **Target load:** 61.5 mtons $yr^{-1}$ → **Individual allocation:** 1.6 kg $ha^{-1}$ $yr^{-1}$

# 4. Results (cont.)

## Phase 3: Phosphorus Credit Trading Scenario Analysis (step 2)

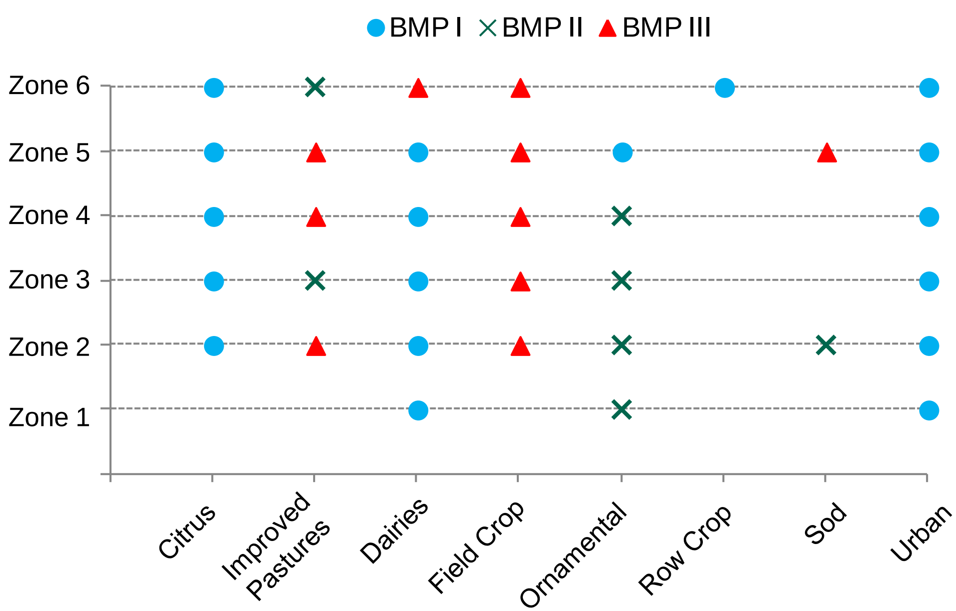
- Identification of Best Management Practices per Land Use and Zone

### Command-and-Control




Reduction Target: 30% → Actual Reduction: 41%
**Cost: $ 5.0 million**

### Least-Cost Abatement

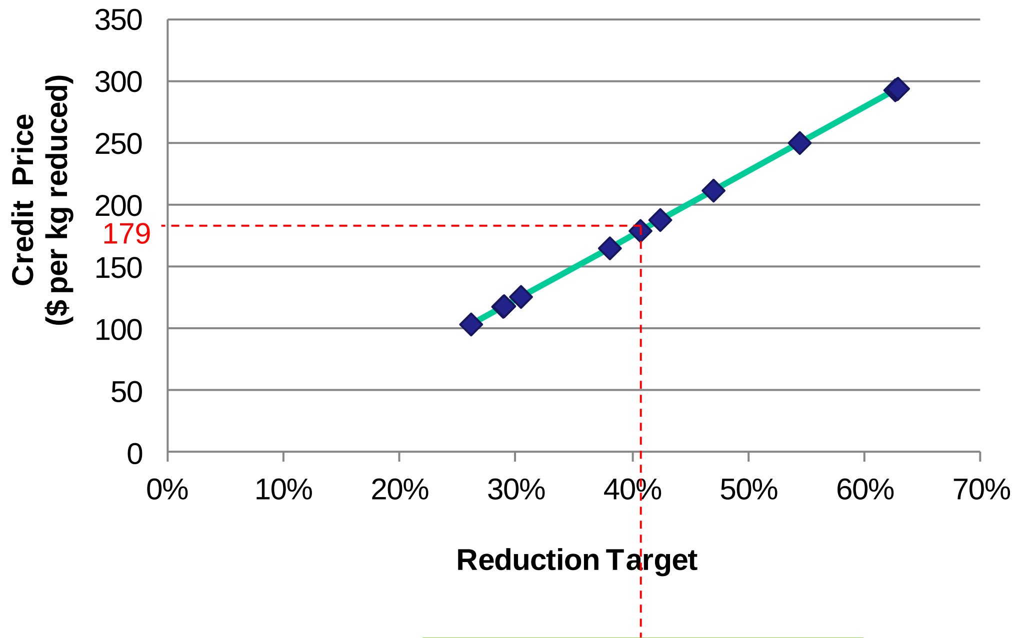



Reduction Target: 30% → Actual Reduction: 41%
**Cost: $ 3.4 million**

# 4. Results (cont.)

## Phase 3: Phosphorus Credit Trading Scenario Analysis (step 3)

- Credit Price: Marginal Abatement Cost (MAC) Curve

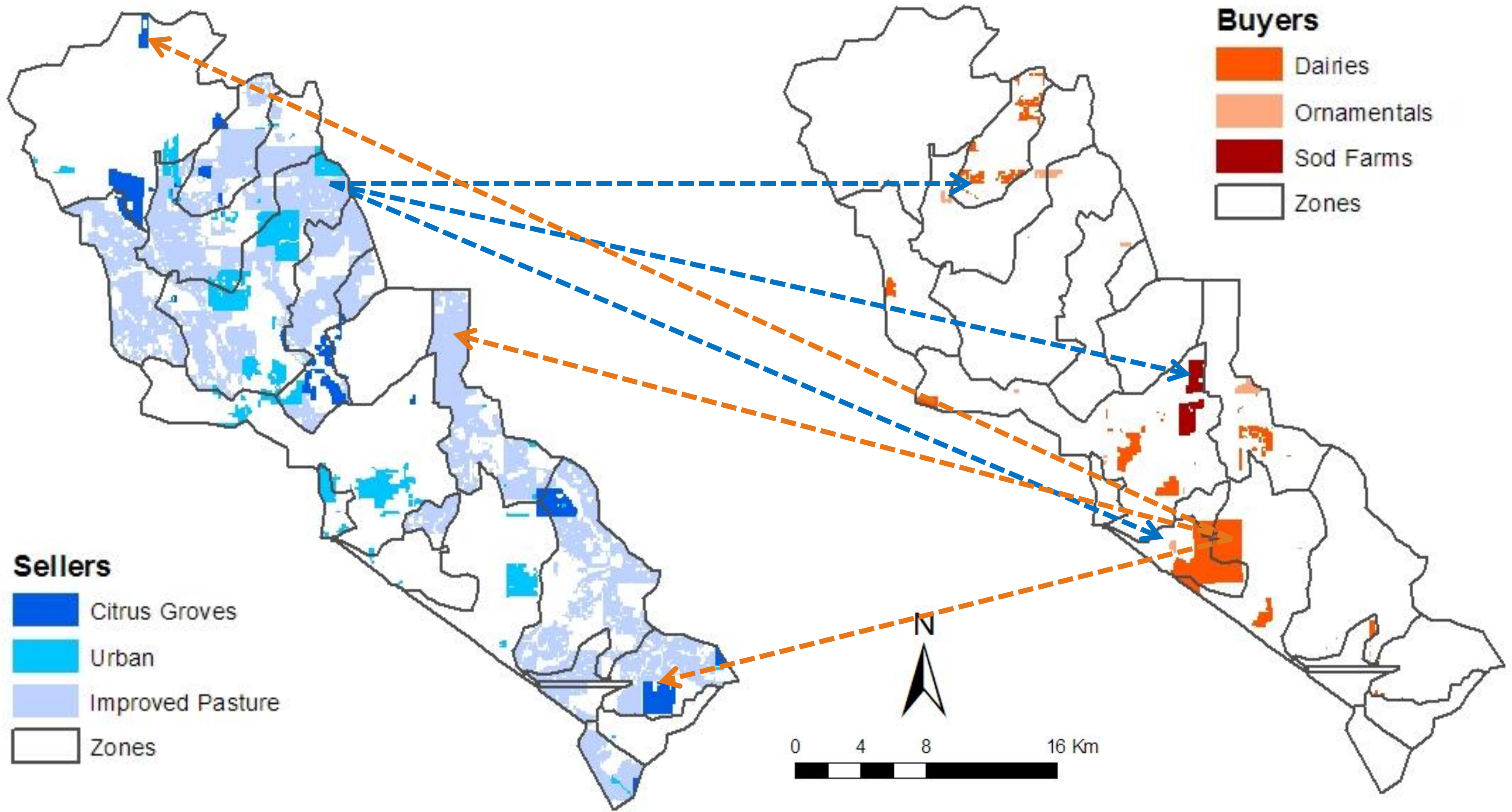



Reduction achieved after BMP implementation (41%)

# 4. Results (cont.)

## Phase 3: Phosphorus Credit Trading Scenario Analysis (step 4)

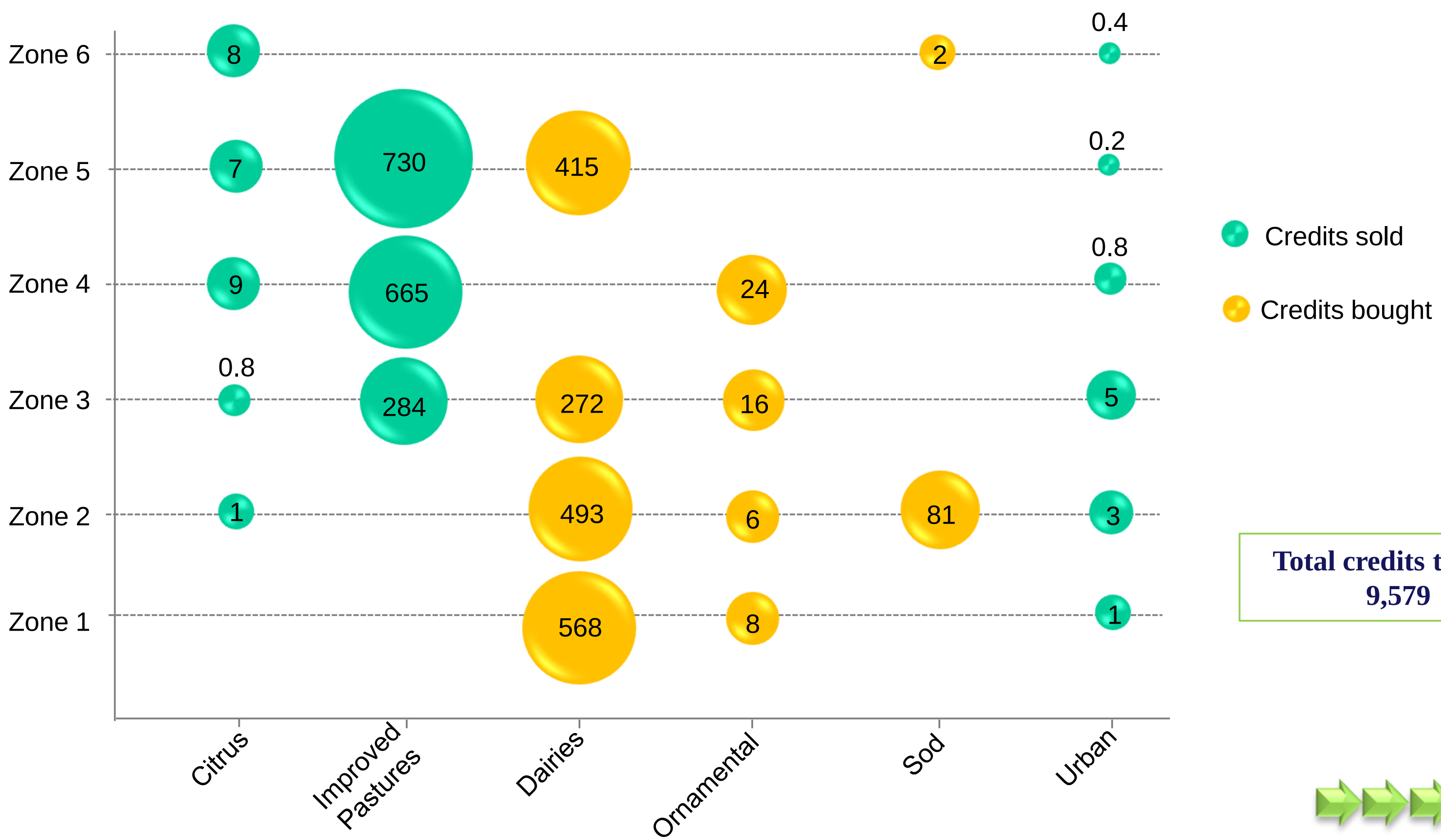
- Identification of Sellers and Buyers



# 4. Results (cont.)

## Phase 3: Phosphorus Credit Trading Scenario Analysis (step 5)

- Cost of Credits Sold/ Bought per Land Use and per Zone ($ in thousands)

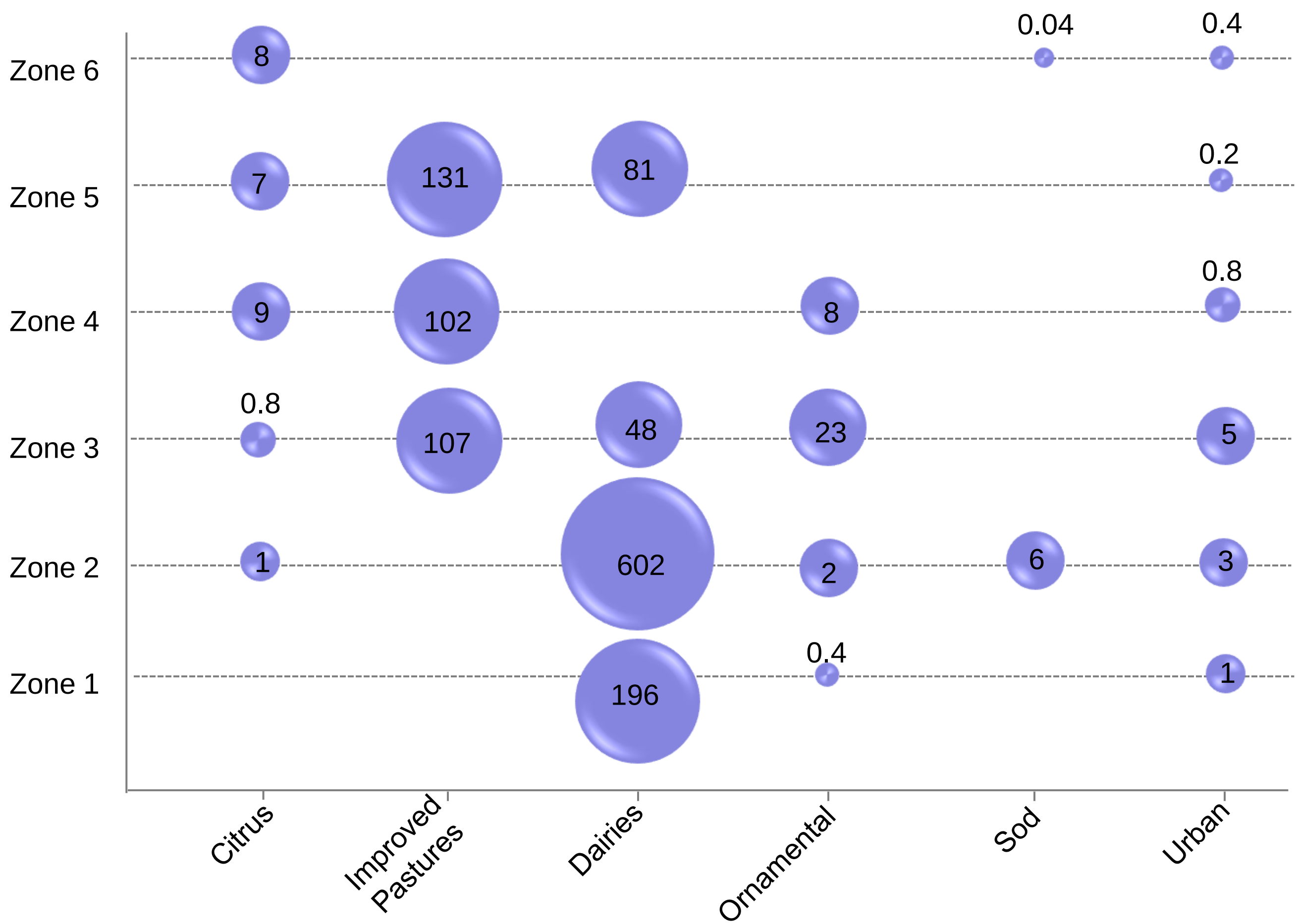



**Total credits traded: 9,579**

# 4. Results (cont.)

## Phase 3: Phosphorus Credit Trading Scenario Analysis (step 5)

- Cost Savings per Land Use and per Zone ($ in thousands)




**Total cost savings:**

**$ 1.3 million (27%)**

# 5. Conclusions

- Phosphorus Credit Trading in the S191 Basin would provide **41% reduction** in TP loads into Lake Okeechobee with a **27% in cost savings when compared to a command-and-control approach**.
- This TP load reduction represents **10% of the total reduction needed** to meet Lake Okeechobee TMDL.
- Higher TP reductions could be achieved by implementing a trading program to other sub-watersheds.

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# Thank you!

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