Application of AnnAGNPS to model an agricultural watershed in East-Central Mississippi for the evaluation of an on-farm water storage (OFWS) system

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Overview

- Background/Motivation
- On-Farm Water Storage (OFWS) System
- Objectives
- Modeling of the OFWS system
  - Research site
  - AnnAGNPS model
  - Model setup
  - Results and Discussion
- Conclusions

Background/Motivation

1. Degradation

- Nitrogen, of water quality impairme
- Elevated l
- Develop by surface water.

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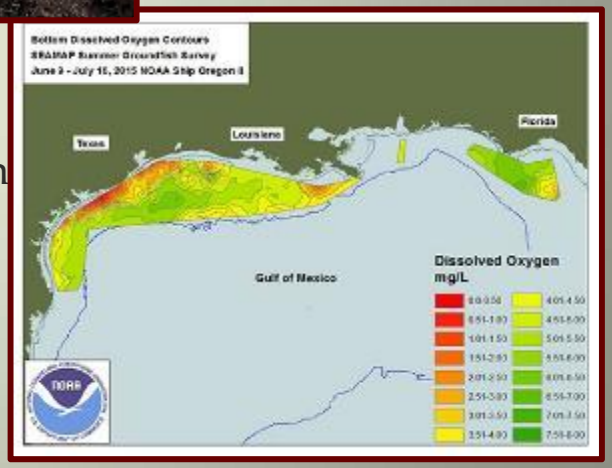
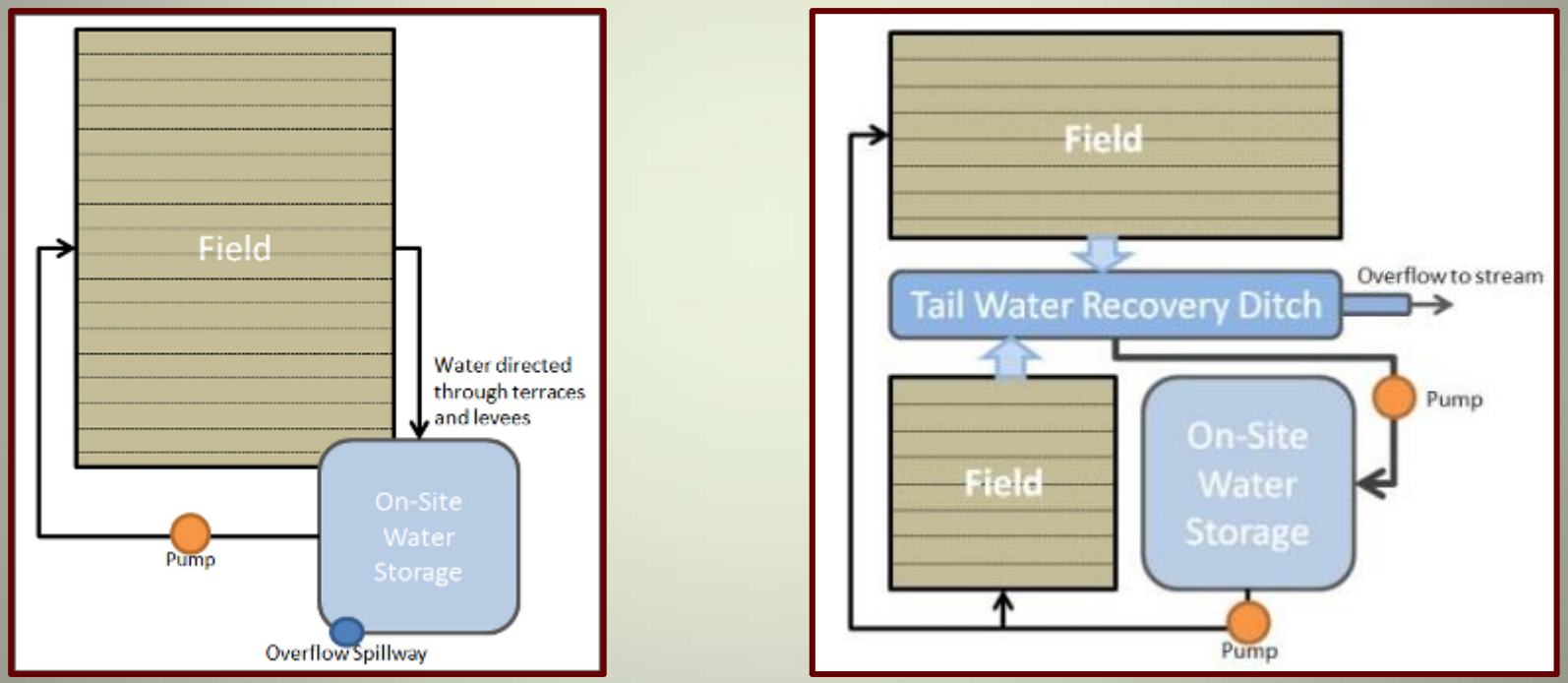
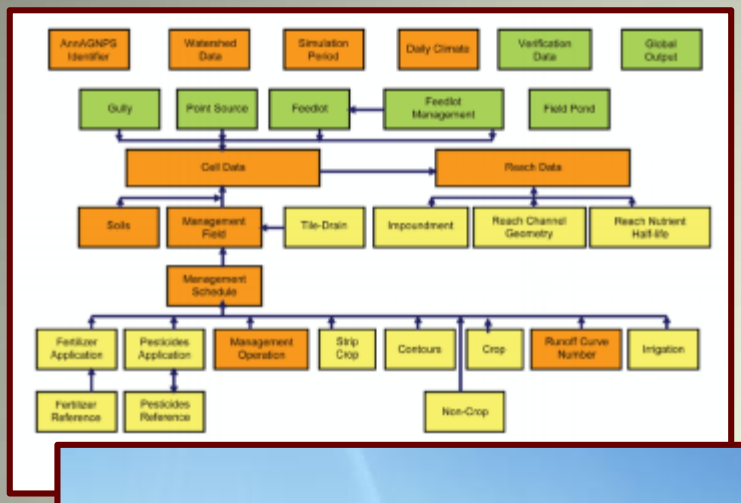


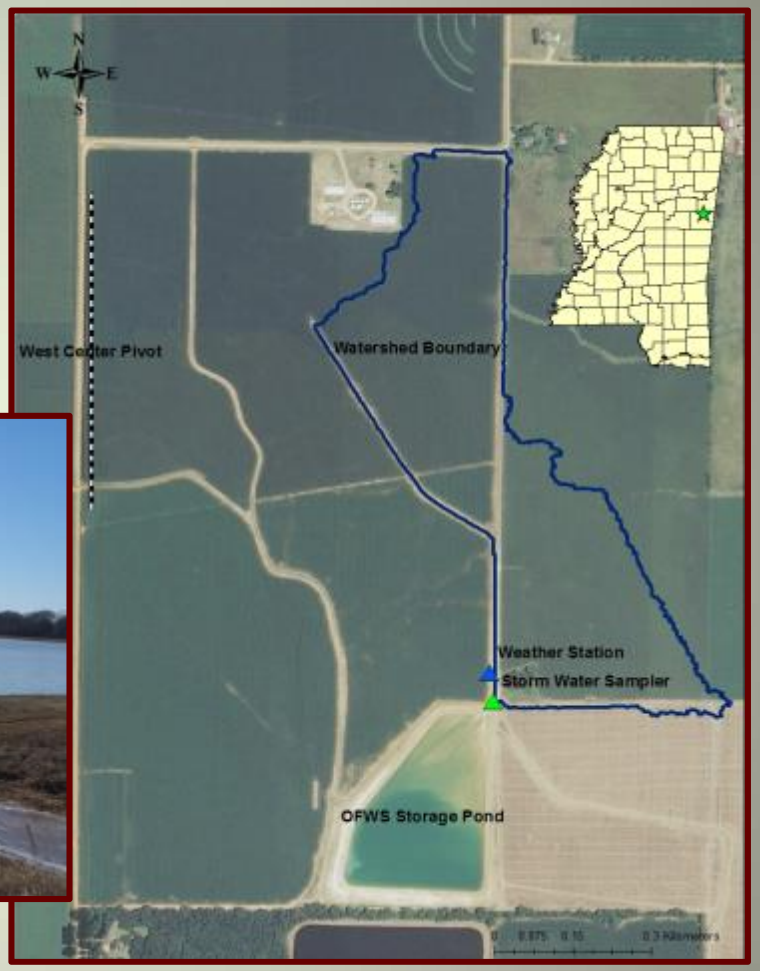
On-Farm Water Storage (OFWS) System

An OFWS system is an agricultural BMP consisting of a tailwater recovery ditch and/or storage pond with the primary goal of nutrient loading reduction.



General designs of OFWS Systems: East Mississippi (left) Mississippi Delta (right).





Modeling Study

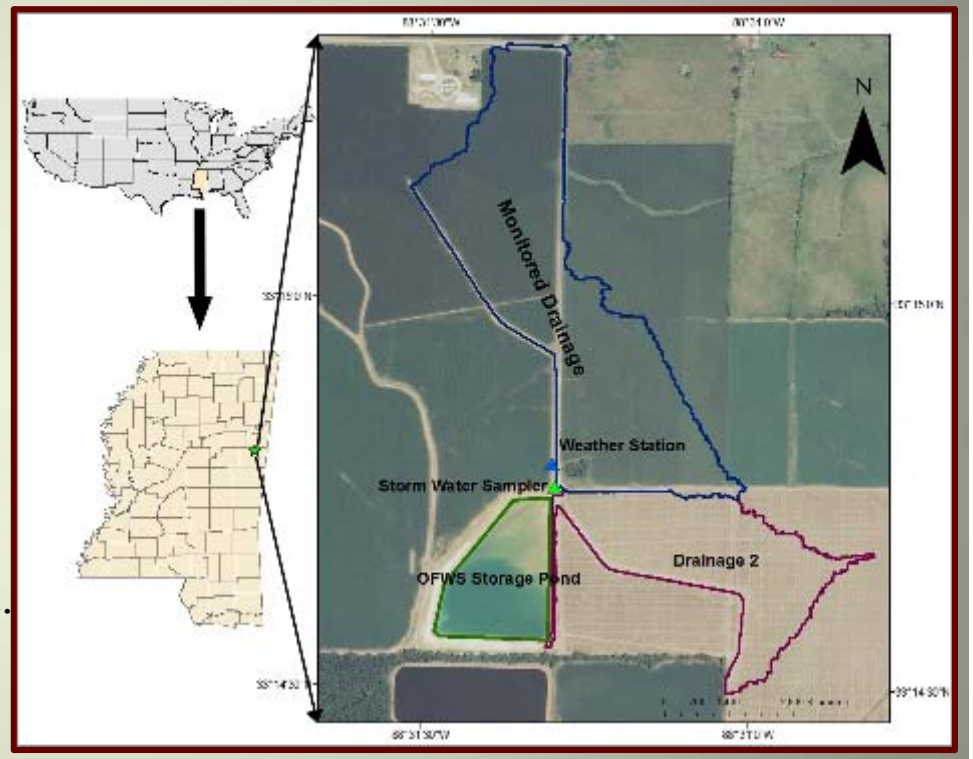
Objectives

- Evaluate AnnAGNPS for simulating runoff sediment, and nutrients in an agricultural watershed in East-Central Mississippi.
- Use AnnAGNPS to evaluate the effectiveness of OFWS systems for reducing downstream nutrient and sediment loading
- Estimate total runoff and nutrient loading under different cropping and management practices to determine if its effect on nutrient loading and runoff.

Research site

Site/Watershed description:

- Located in East-Central Mississippi
- Modeled watershed: 75 acres.
- Elevation level: 75m to 84 m.
- Soil types: Brooksville silty clay and Vaidan silty clay.
- Warm and humid climate.
- Summer average temperature: 28.1 C.
- Winter average temperature: 7.2 C.

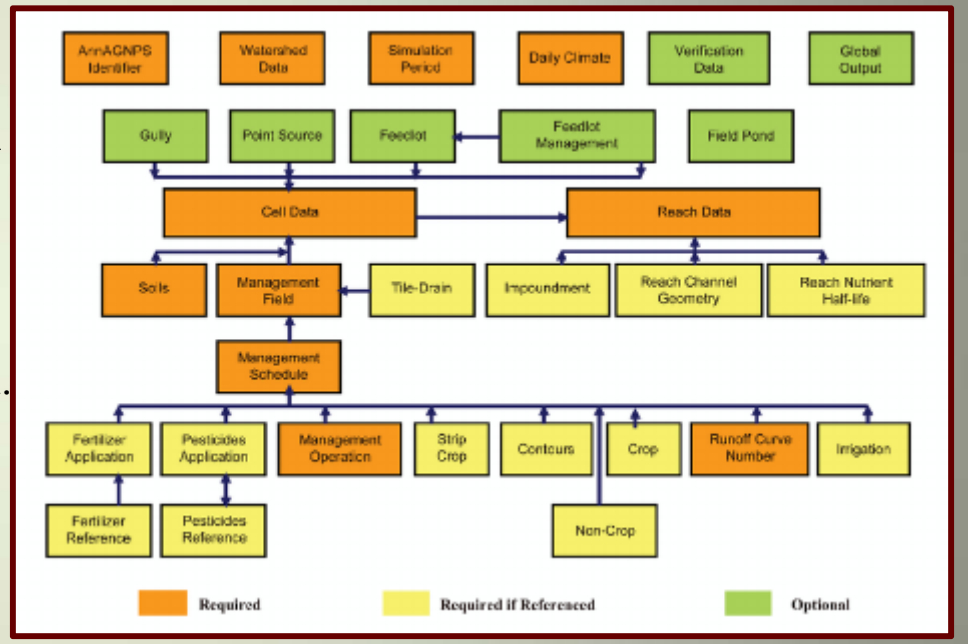


Study watershed, Brooksville, MS.

AnnAGNPS

AnnAGNPS model description:

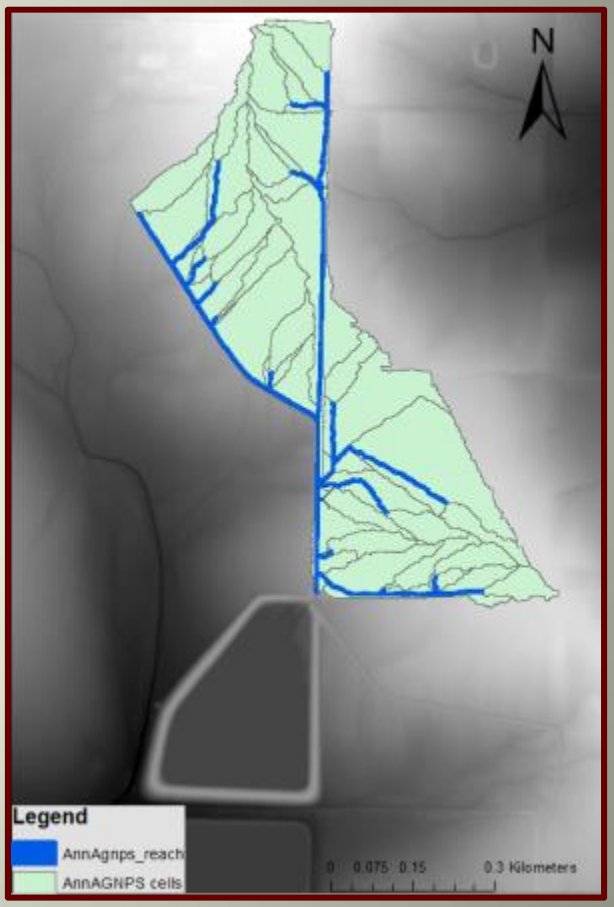
- Continuous simulation, daily time step, watershed-scale, pollutant loading model.
- Simulate runoff, sediments, nutrients, and pesticide transport.
- SCS curve number method to estimate runoff.
- Sheet and rill erosion–the RUSLE method.
- TOPAGNPS–spatial characteristics of the model.
- **Required model input:**
  - **Watershed physical characteristics.**
  - **Land use data.**
  - **Climate data.**



Model setup

Input file preparation: Topography

- LIDAR obtained from MARIS–transformed to a 1m x 1m DEM for model input.
- Important user–defined values for determining stream network and AnnAGNPS cells:
  - Watershed outlet selection.
  - CSA and MSCL values.
- CSA - 0.5 ha and MSCL - 5 m.
- Generated 84 cells with 34 reaches.



AnnAGNPS-determined cells and reaches for the study watershed.

Model setup

Input file preparation: Climate Data

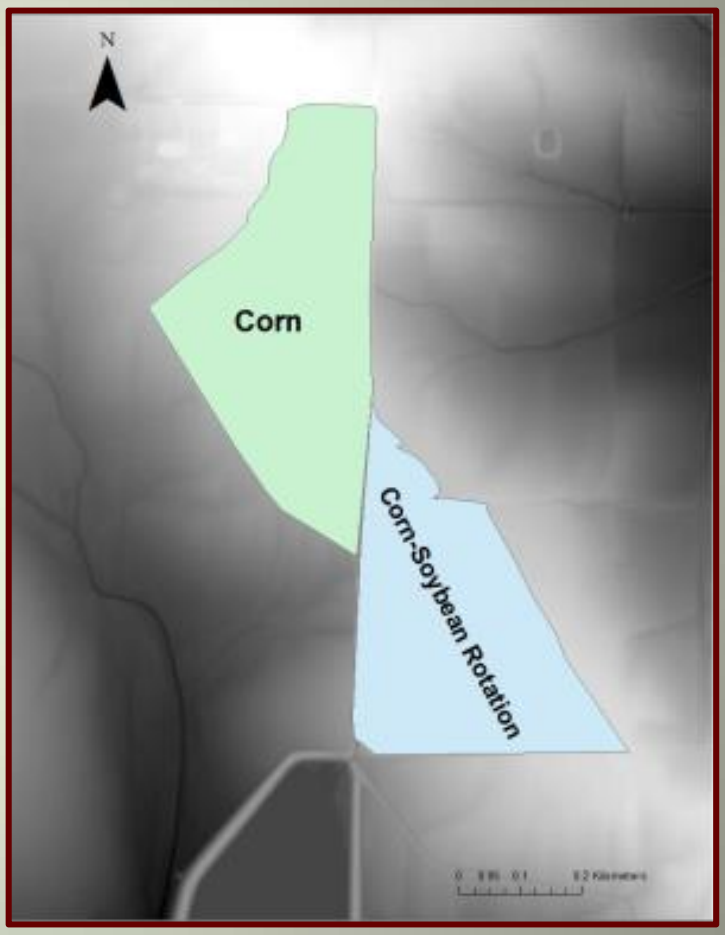
- Minimum weather data inputs required:
  - **Daily maximum and minimum temperature, precipitation, dew point, solar radiation, sky cover, and wind velocity.**
  - Climate data obtained from WatchDog 2900 ET weather station installed at the watershed.
  - Data collection**: September 2014 to March 2016.**
- Two year 24-hr precipitation: 101.6 mm.
- Global storm type ID: Std. SCS Type III distribution.

WatchDog 2900 ET weather station installed at the watershed

Model setup

Input file preparation: Land use and management information

- Watershed – 98% agricultural land.
- Major crops: corn and soybean.
- Detailed management information was obtained from the farmers.
- Land use: manually assigned to each cell.
- Poultry litter application each fall.

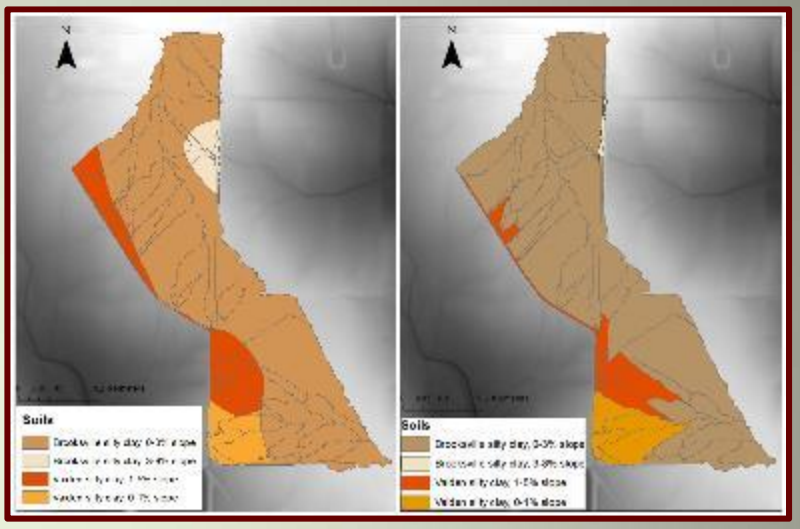


Corn and corn-soybean rotation fields in the monitored watershed.

Model setup

Input file preparation: Soils

- Soil Survey Geographic (SSURGO) soil map – NRCS.
- Soil properties – NRCS Soil Survey Center's National Soil Information System (NASIS) database.



Hydrology, sediment, and nutrient data:

- Runoff and sediment and nutrient loadings acquired from the monitoring study.
- Runoff monitored: September 2014 – March 2016.
- Nutrient in runoff monitored: October 2014 – May 2015, October 2015 – February 2016.
- Sediment in runoff monitored: October 2015 – February 2016.

Model setup

Model assessment:

- Model evaluation was performed at the watershed outlet where the monitoring station was established.
- Assessment methods:
  1. Qualitative method:
     - **Graphical Evaluation.**
  2. Quantitative methods:
     - **Coefficient of determination (R^2).**
     - **Nash-Sutcliffe Efficiency (E).**

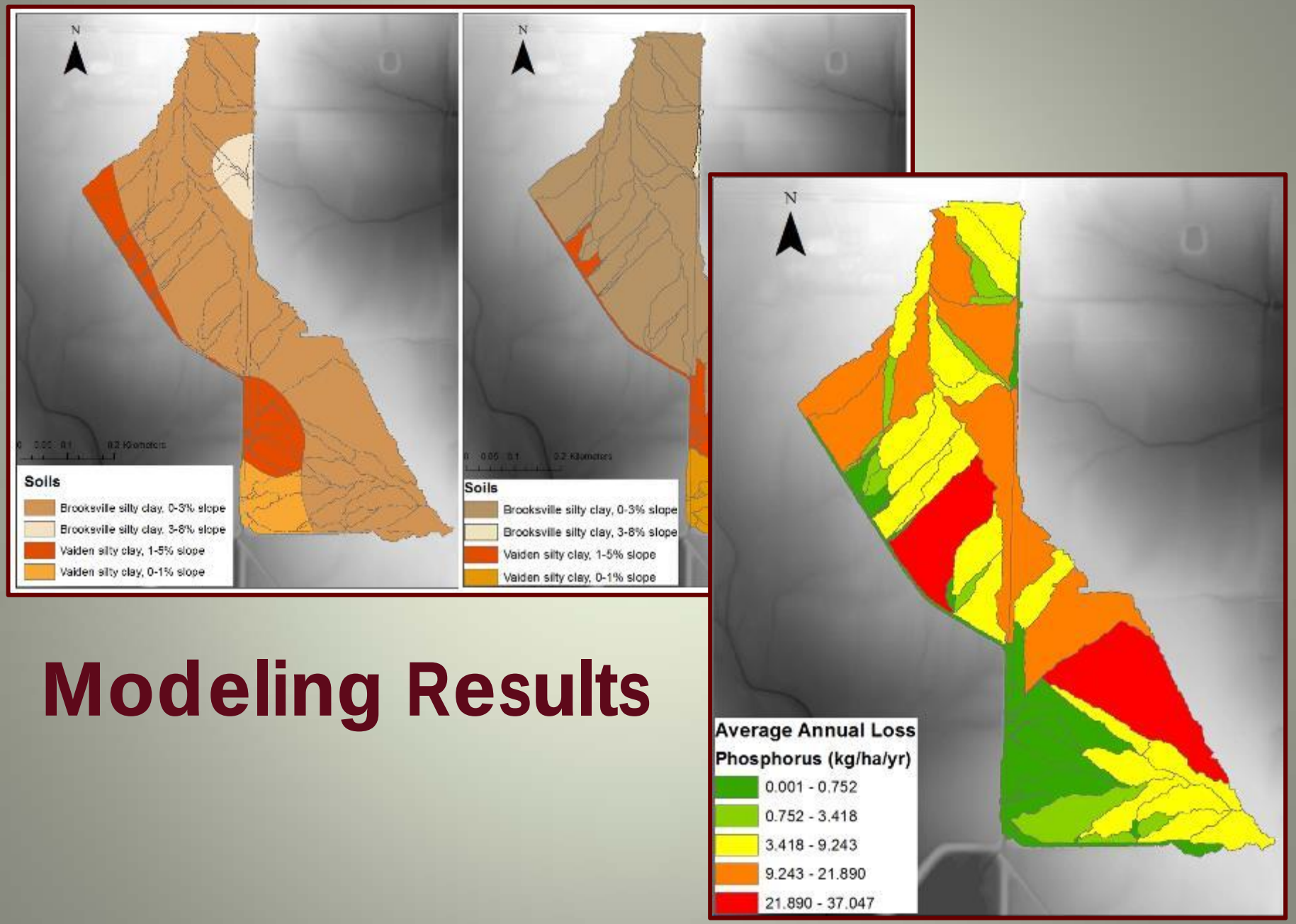
Model calibration and validation

- Calibrated and validated: runoff and sediment.
- Evaluated for model prediction performance: nitrogen, phosphorus.

Model setup

Evaluation of alternative management practices:

- Three scenarios were evaluated:
  1. Poultry fertilizer application and all tillage operations in the spring.
  2. Soybean planted on all agricultural fields in the watershed.
  3. Corn planted on all agricultural fields in the watershed.

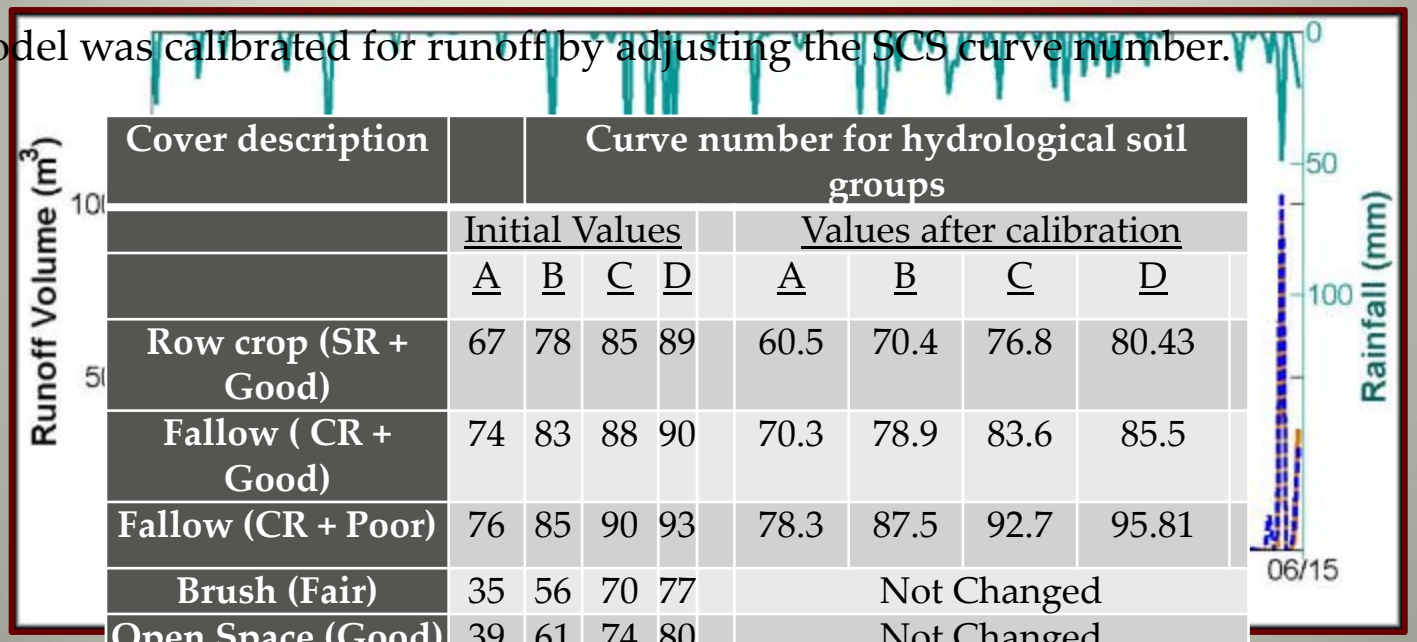


Modeling Results

Results: Runoff

Calibration

- Initial model run without calibration:
  - Daily runoff prediction: $R^2 = 0.73$ and $E = 0.74$.
  - Monthly runoff prediction: $R^2 = 0.66$ and $E = 0.65$.
- Model performance after calibration:
  - Daily runoff estimation: **$R^2 = 0.83$ and $E = 0.83$.**
  - Monthly runoff estimation: **$R^2 = 0.89$ and $E = 0.88$.**
- Model was calibrated for runoff by adjusting the SCS curve number.



Cover description		Curve number for hydrological soil groups							
		Initial Values				Values after calibration			
		A	B	C	D	A	B	C	D
Row crop (SR + Good)		67	78	85	89	60.5	70.4	76.8	80.43
Fallow (CR + Good)		74	83	88	90	70.3	78.9	83.6	85.5
Fallow (CR + Poor)		76	85	90	93	78.3	87.5	92.7	95.81
Brush (Fair)		35	56	70	77	Not Changed			
Open Space (Good)		39	61	74	80	Not Changed			

Graphical comparison between predicted and observed runoff after calibration.

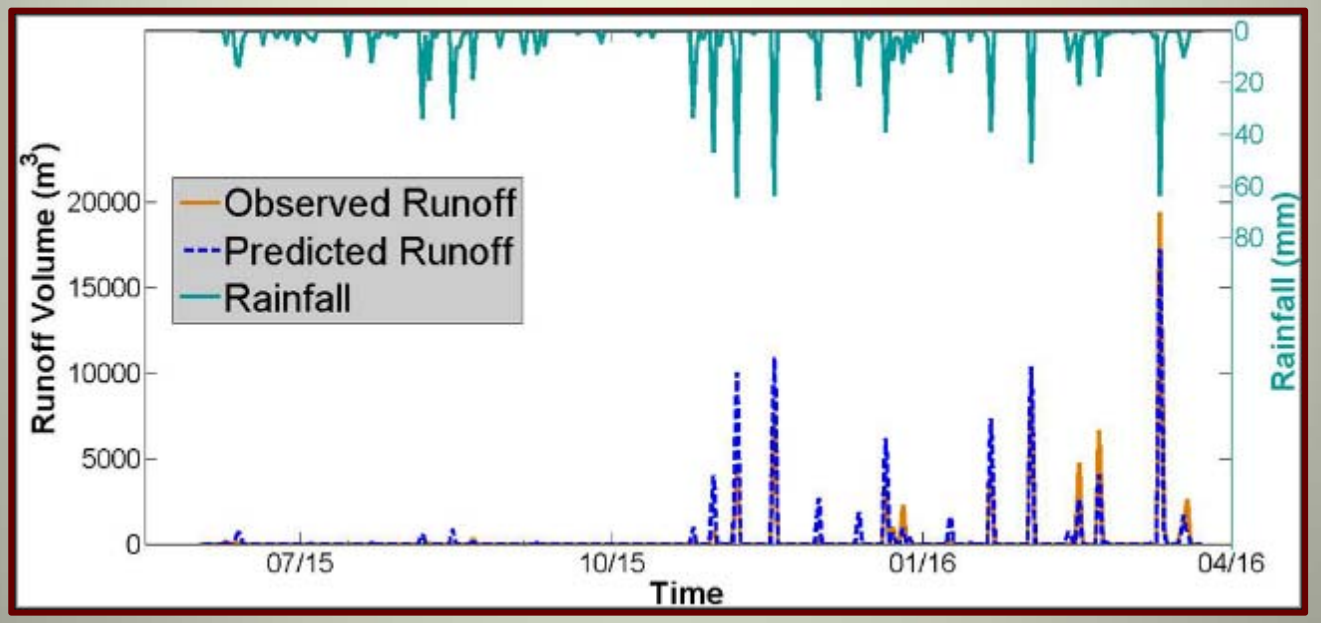
Results: Runoff

Validation

- AnnAGNPS can model runoff from agricultural watersheds in East Mississippi.
- AnnAGNPS can predict potential runoff amount and associated drainage areas to aid in planning of OFWS systems.

Model performance for validation phase:

- Daily runoff estimation: $R^2 = 0.85$ and $E = 0.82$.
- Monthly runoff estimation: **$R^2 = 0.90$ and $E = 0.66$.**



Graphical comparison between predicted and observed runoff for validation phase.

Results: Sediment

Calibration and Validation

- Sediment calibration parameters:
  - RUSLE-P, Manning's sheet and reach coefficient, and crop residue.
- Calibration: **R^2 = 0.73 and E = 0.43.**
- Validation: **R^2 = 0.88 and E = 0.67.**
- **AnnAGNPS can estimate sediment loss from agricultural watersheds in East Mississippi.**
- **It can estimate sediment loading captured by the OFWS systems.**

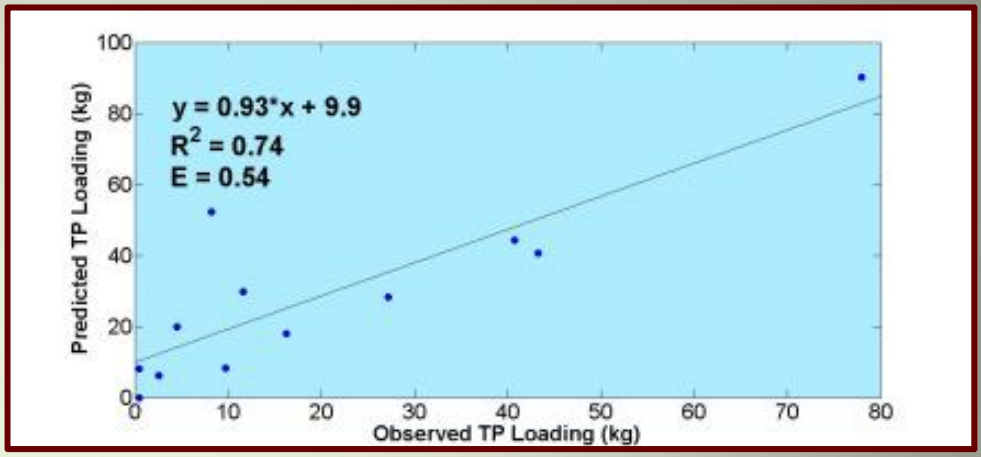
Model Parameters	Initial Values	Values after calibration
RUSLE-P	1	0.4
Manning's sheet n	0.15	0.175
Manning's reach n	0.15	0.2
Crop residue	Default	10% increase

Date	Rainfall (mm)	Predicted sediment load (kg)	Observed sediment load (kg)
CALIBRATION			
10/31/2015	46.74	1463.28	91.83
11/2/2015	6.1	0	1.16
11/7/2015	64.26	3649.60	1219.88
11/18/2015	63.75	3792.03	3649.05
12/1/2015	26.67	459.03	19.49
12/13/2015	21.34	271.24	0
12/21/2015	39.12	1334.46	874.43
12/23/2015	11.68	55.33	418.05
12/25/2015	3.81	0.22	0
12/26/2015	12.7	76.20	645.89
12/28/2015	8.64	25.40	30.57
12/30/2015	4.83	9.97	0
VALIDATION			
1/9/2016	16.0	149.68	52.72
1/15/2016	4.06	4.53	0
1/21/2016	38.86	1315.42	1690.81
2/2/2016	51.05	2394.97	4812.75
2/13/2016	11.94	57.15	0
2/14/2016	6.6	13.61	0
2/16/2016	21.08	271.25	2099.98
2/18/2016	1.02	0	6.99
2/22/2016	17.78	205.93	234.53

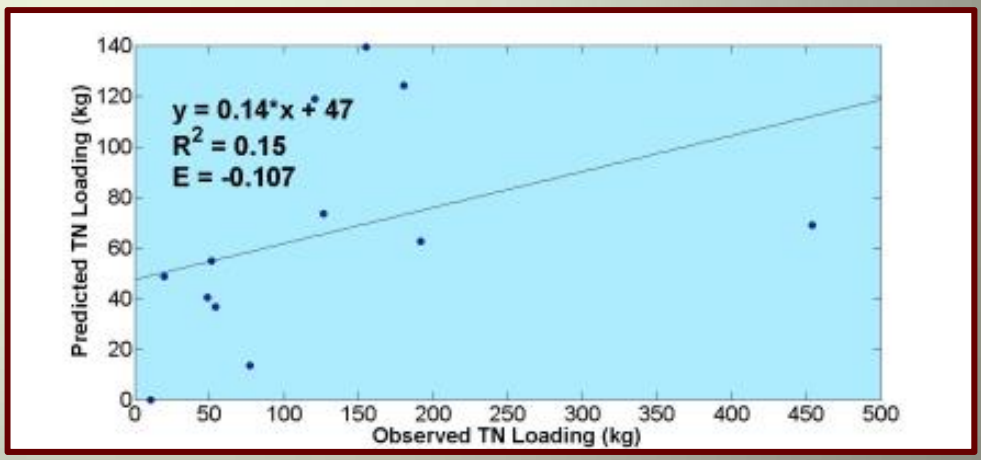
Observed rainfall and predicted and observed sediment load for storm runoff events.

Results: Nutrients

- Only evaluated for total nitrogen and total phosphorus.
- Phosphorus estimation: **R^2 = 0.74 and E = 0.54.**
- Nitrogen estimation: **R^2 = 0.15 and E = -0.107.**
- **Model can satisfactorily estimate phosphorus losses from agricultural watersheds in East Mississippi.**
- **Model did not satisfactorily estimate nitrogen loadings.**



Evaluation of total phosphorus (TP) loading estimation for AnnAGNPS in East MS.

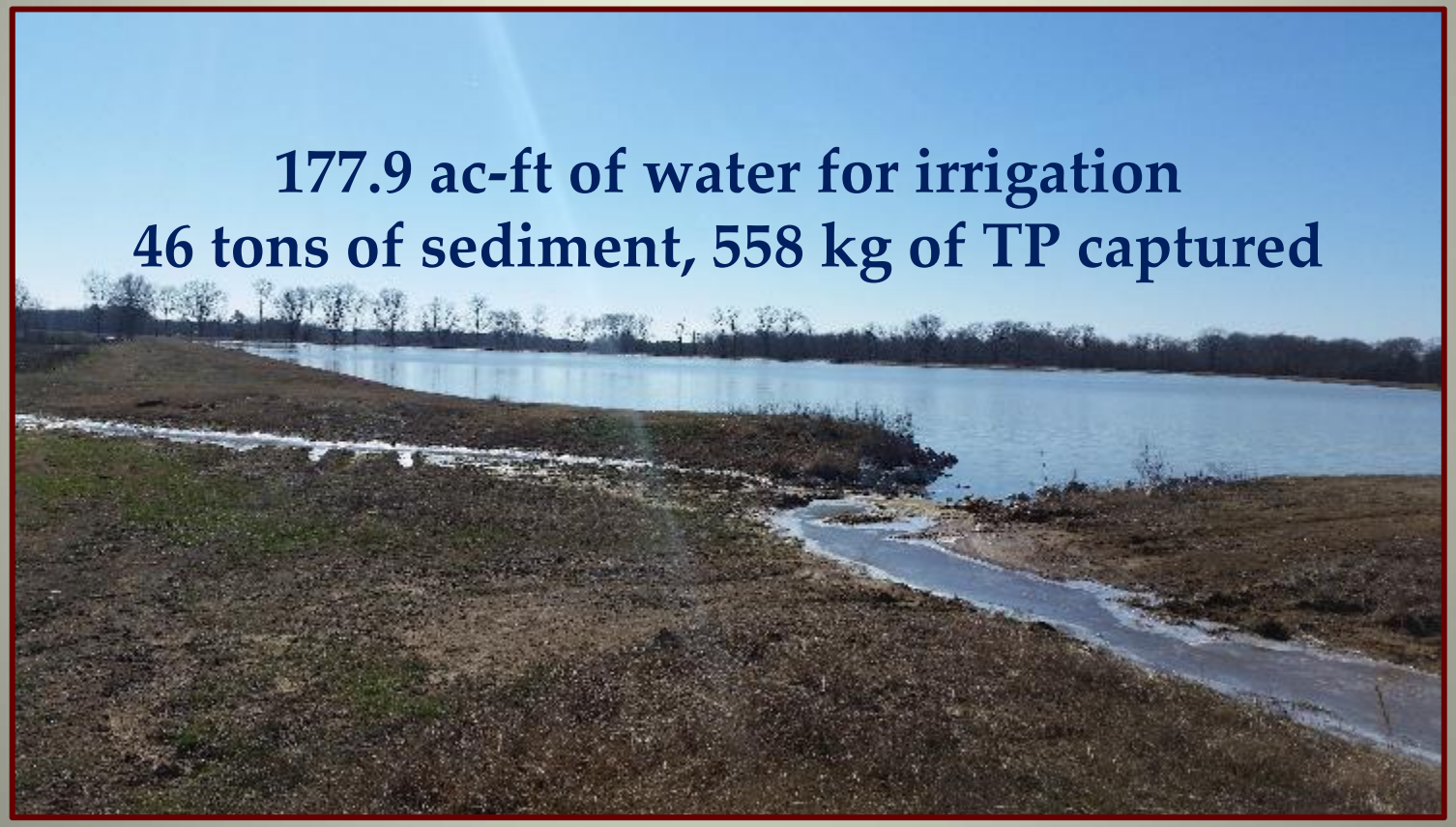


Evaluation of total nitrogen (TN) loading estimation for AnnAGNPS in East MS.

Results

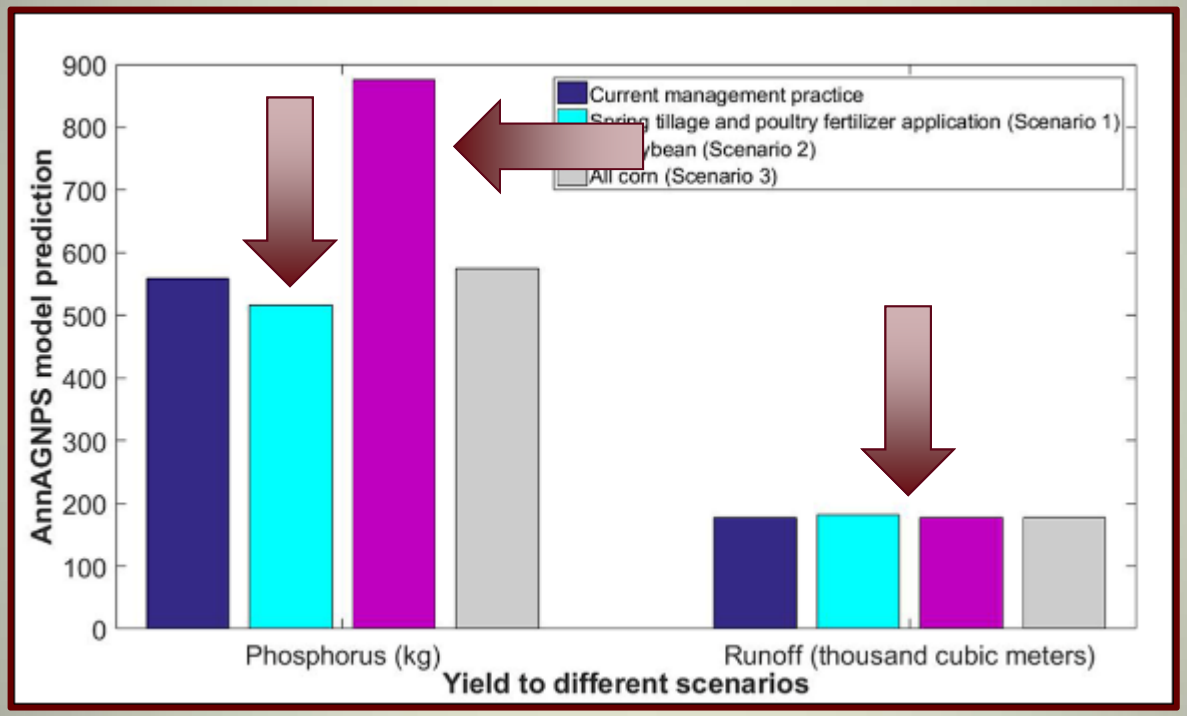
Evaluation of the OFWS system using AnnAGNPS

OFWS system in East Mississippi:



Results

Evaluation of alternative management practice using AnnAGNPS



- Poultry and tillage in spring: **7.5% phosphorus loss reduction**.
- All soybean acreage: **56.8% phosphorus loss increase**.
- **No change in runoff under different cropping practice.**

General Conclusions

- AnnAGNPS can be successfully used to estimate runoff (**R^2 = 0.85, E = 0.82**), sediment (**R^2 = 0.88, E = 0.67**), and phosphorus loadings (**R^2 = 0.74, E = 0.54**) from watersheds in East Mississippi.
- AnnAGNPS can help **evaluate potential sites for the establishment of OFWS systems:**
  - **Estimate potential runoff** that can be captured for irrigation.
  - **Estimate phosphorus and sediment that can captured** to prevent downstream nutrient and sediment loading.
- OFWS systems can be effective in controlling downstream nutrient and sediment loading; **AnnAGNPS predicted 46 tons of sediment and 558 kg of phosphorus were captured during the evaluated period.**

Acknowledgements

- Farmers: Mr. Dale Weaver and Mr. Paul Good
- Dr. Dennis Reginelli
- Research team

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