Costs and Benefits of On-Farm Water Storage Systems

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Overview

- Background
- On-Farm Water Storage (OFWS) Systems
- Part A: Benefits – Objectives, Methods, Results
- Part B: OFWS Systems as a Tool to Reduce Risk – Objectives, Methods, Results
- Conclusions

Background

1. Degradation of water quality:
   - Nitrogen, phosphorus and sediment are the major causes of impairment in Mississippi surface waters.
   - Elevated levels of nutrients can lead to eutrophication.
   - Development of hypoxic zones, loss of amenities provided by surface water.
2. Irrigation needs:
   - Mississippi receives an average 56 (1,422 mm) inches rainfall annually, but 70% of total precipitation is during the winter and spring months.
   - Less rainfall during the growing season; periodic drought
   - East Mississippi – mostly Dryland Production, high cost of drilling wells due to depth to reach water.

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 goals of reducing downstream nutrient loads and providing water for irrigation.

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

Part A, Benefits: Objectives

1. Evaluate OFWS systems for downstream sediment and nutrient loading control.

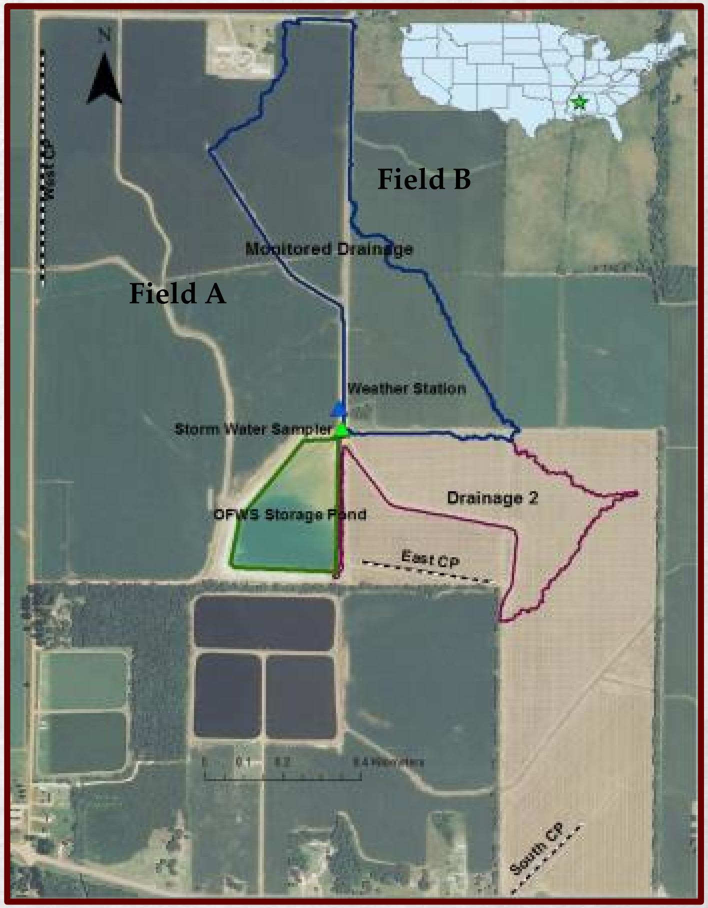
2. Quantify surface water provided by the OFWS system for irrigation.

3. Determine if commercial fertilizer application can be reduced because of the nutrient load in recycled water used for irrigation.

4. Evaluate alternative management practices to reduce nutrient and sediment loading.

Site Description

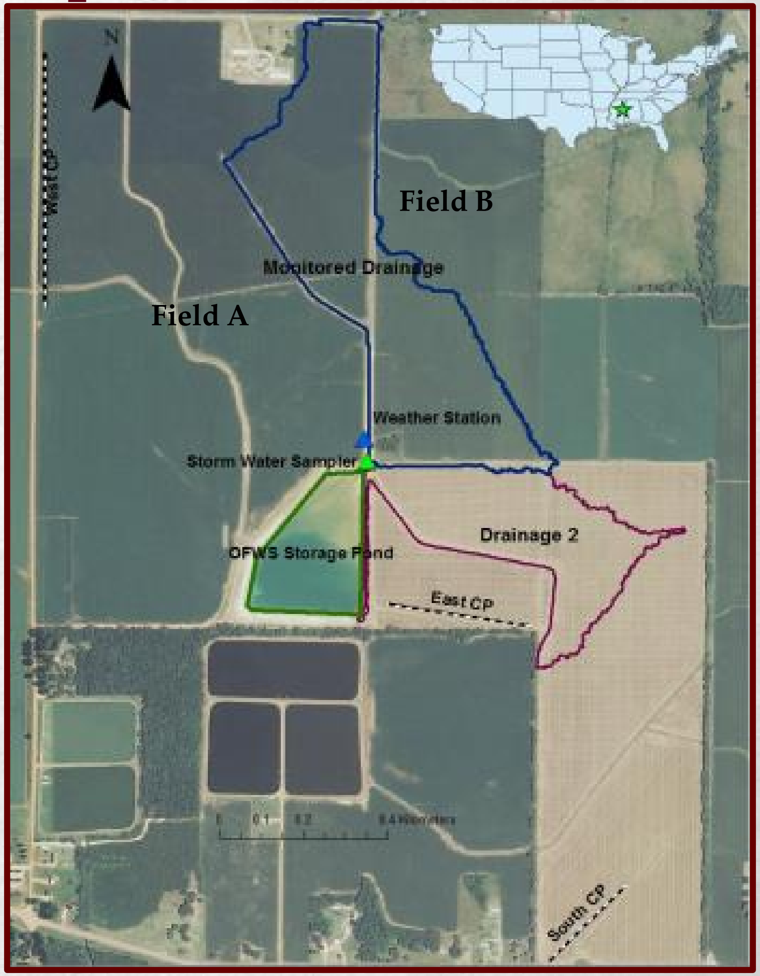
- Located 22 miles southeast of Starkville in Noxubee County in the AL and MS Blackland Prairie.
- In the Middle Tombigbee-Lubbub Watershed.
- Major crops: Corn and soybean.
- Annual precipitation in the region: 54 inches (1,372 mm).
- Fall fertilizer application.
- Conventional tillage.
- An OFWS system constructed in 2012.
- OFWS system storage pond: 17 surface acres (6.8 hectares), 25 ft (7.6m) deep at deepest point.



OFWS system in East Mississippi.

Site Description

- Drainage area: 111 acres (45 hectares).
  - Portions of three fields drain to the pond.
  - Two sub-watersheds.
  - Only northern most watershed monitored for this study.
- Pond feeds 3 center pivot irrigation systems and irrigates approx. 339 acres (137.2 hectares).



OFWS system in East Mississippi.

Methods: Monitoring System

A. Storm runoff samples:

- Collected using ISCO 6712 automated portable sampler.
- Installed at the outlet of the monitored sub-watershed.
- Sample collection: event based on uniform time spacing.
- Triggered when a runoff depth of 7.62 mm was measured in the drainage channel.
- Analyzed for soluble and particulate forms of N and P, and sediment.
- Runoff depth and flow was monitored: 750 Area Velocity Flow Module attached to the sampler.

B. Grab samples from the OFWS system storage pond:

- Collected every 21 days.
- Also analyzed for soluble and particulate forms of N and P, and sediment.
- In-situ measurements for pH, DO, and conductivity were also taken.

ISCO 6712 portable sampler for collecting runoff samples.

OFWS system storage pond.

Methods: Monitoring System

C. Grab samples from the irrigation system:

- Grab samples were collected from the west center pivot during irrigation events and analyzed for soluble and particulate N and P.
- Nutrient levels in the irrigation sample were compared to samples taken from the OFWS storage pond on the same day.

D. Weather Data (Watchdog 2900 ET):

- Precipitation, wind speed, air temperature, relative humidity, and solar radiation every 15 minutes.

E. Water Use Data:

- IM3000 magnetic flowmeters on all three center pivots.

Center pivot irrigation system in the study site.

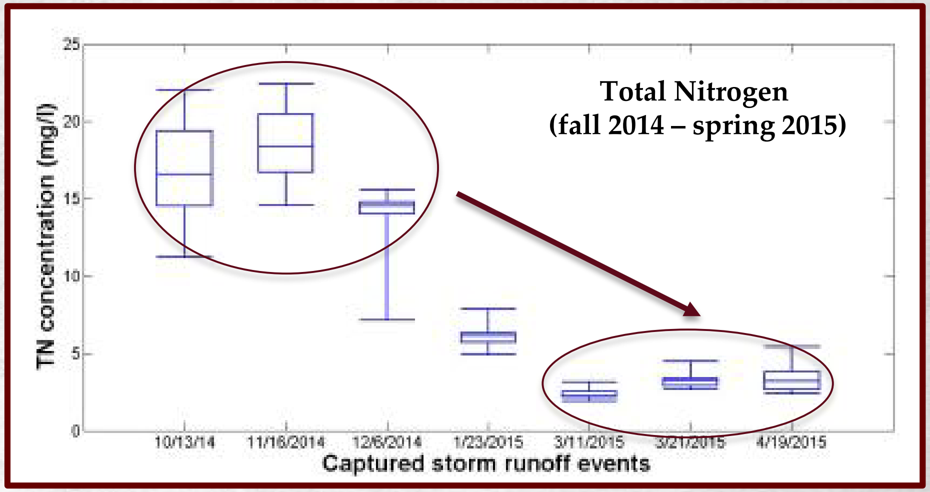
Watchdog 2900 ET weather station.

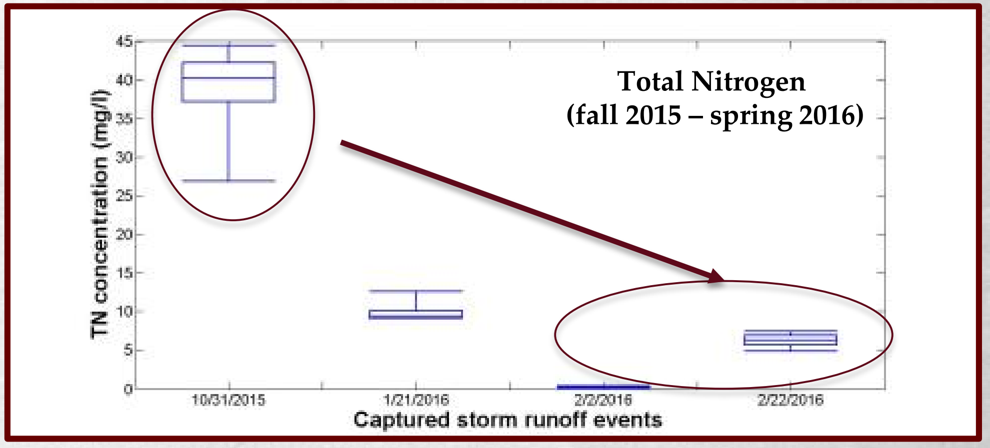
IM3000 magnetic Flowmeter.

Results from Storm Runoff Samples

Results: Total Nitrogen

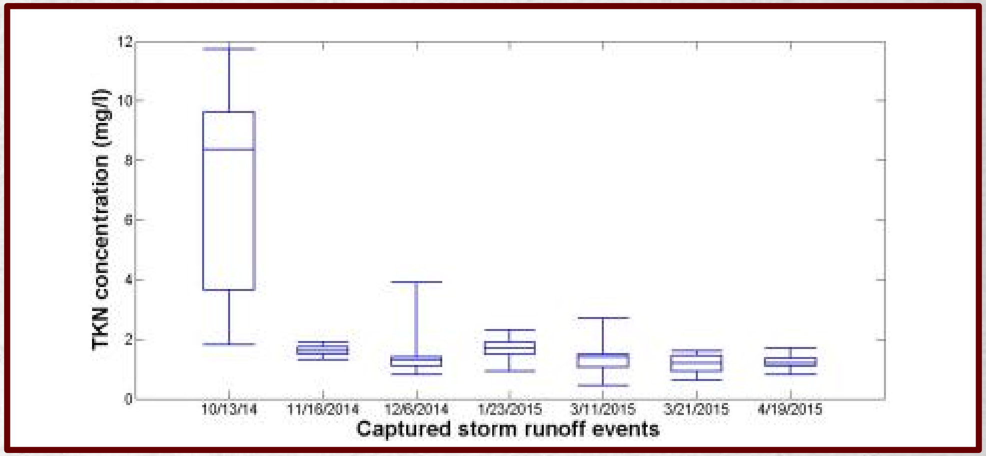
- Site was monitored for 22 months (6/2014 – 3/2016).
- Most runoff events in the winter and spring season.
- Highest nitrogen concentrations: Fall runoff events.
- Lowest nitrogen concentrations: Late spring runoff events.
- Fall application of poultry fertilizer.
- Trend of decreasing nitrogen concentration from fall to spring.

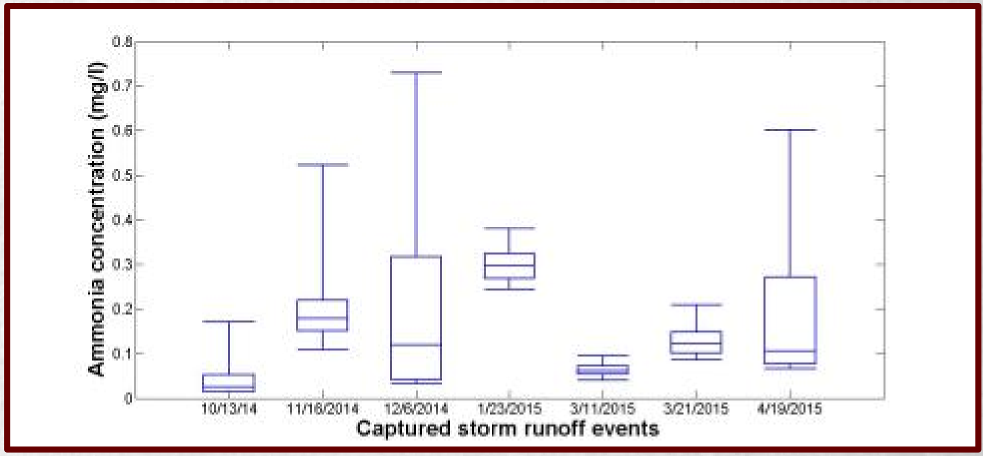




Results: TKN and Ammonia

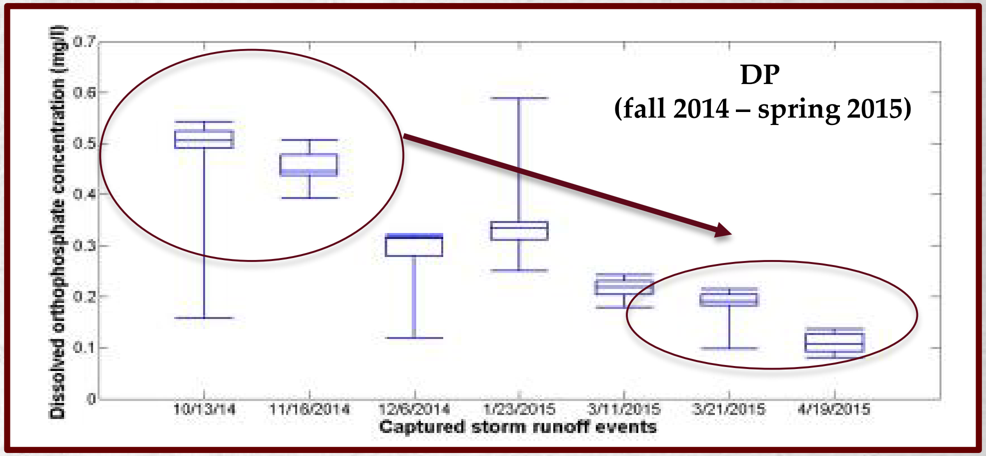
- TKN concentration in the first runoff event was significantly higher than in the remaining storm events captured.
- Fall application of poultry litter fertilizer is likely the reason for high TKN concentrations in fall.
- Ammonia concentration in the same runoff captured was much lower.
- Organic nitrogen was the major constituent of TKN rather than ammonia.
- In Fall 2015 - spring 2016, TKN concentration in the first runoff event was much lower than in fall 2014 – spring 2015, and TKN concentrations stayed around 2 mg/L during the second year of the study

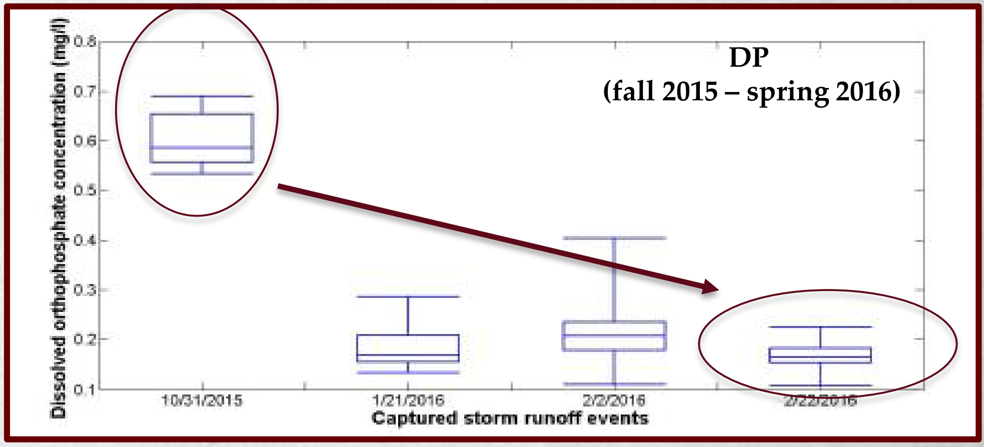




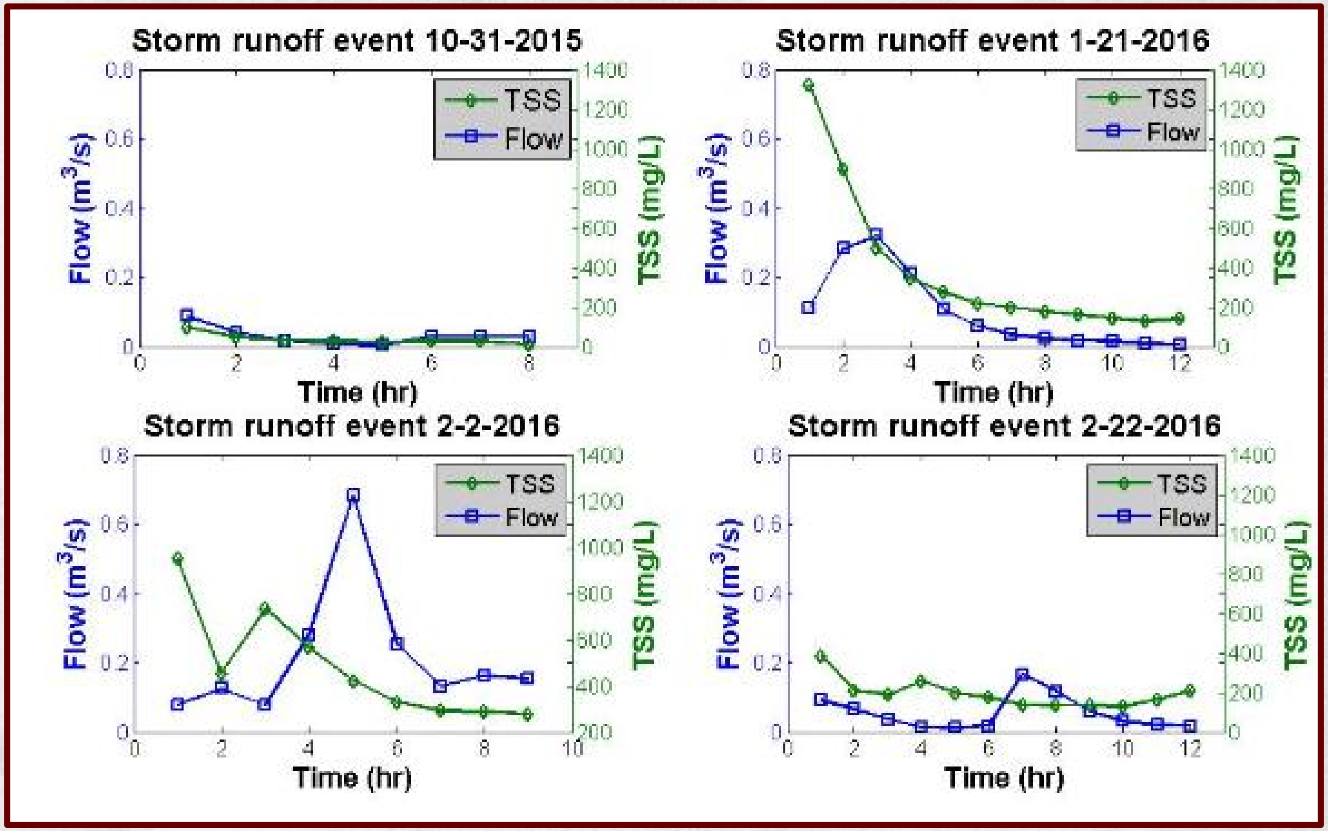
Results: Dissolved Phosphorus

- Highest DP concentrations: Fall runoff events.
- Lowest DP concentrations: Late spring runoff events.
- Relatively small range of difference between high and low concentrations
- Poultry litter fertilizer application could be the reason for higher DP concentrations in early fall runoff events.





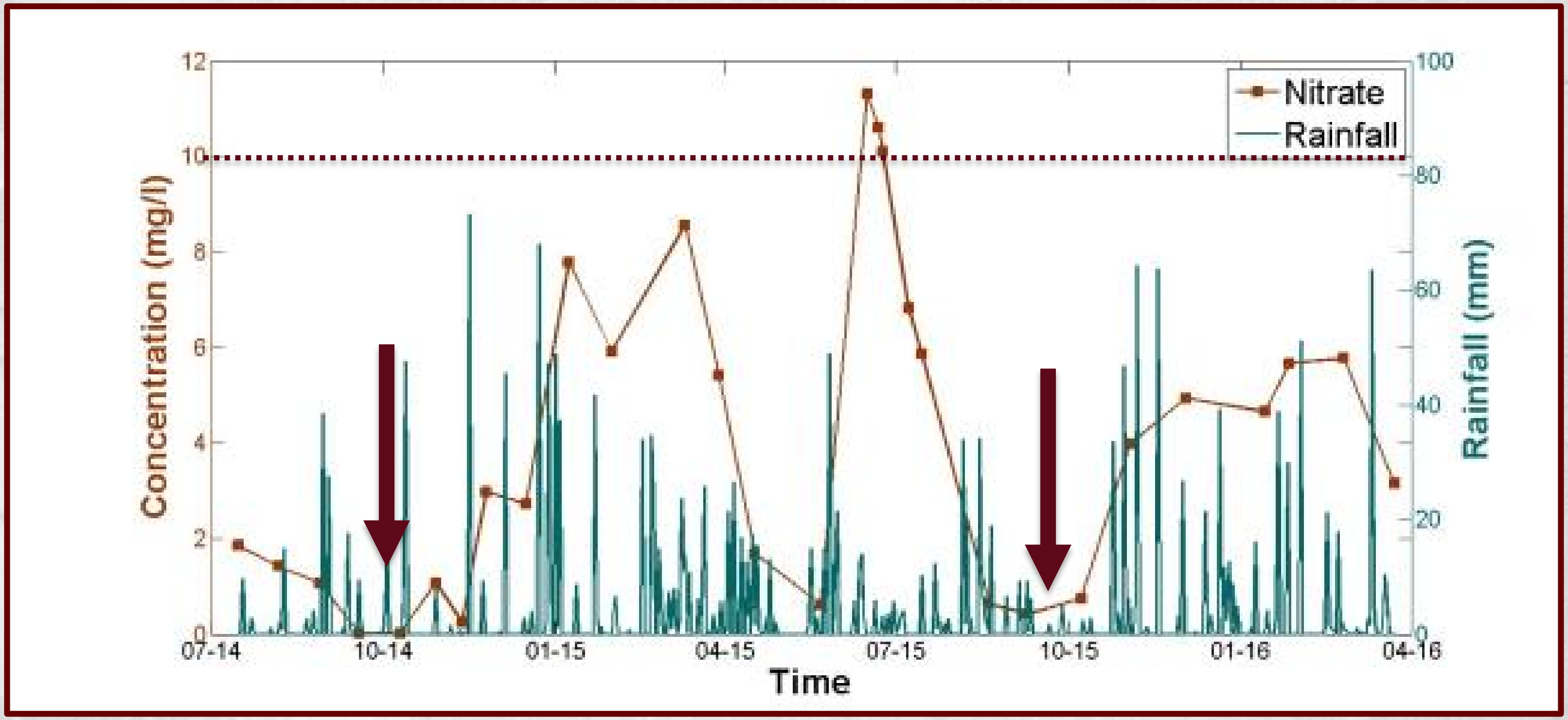
Results: TSS



- Higher TSS concentrations in storm runoff events with the higher flow rates.
- Higher flow rate events also had higher measured TP concentration.

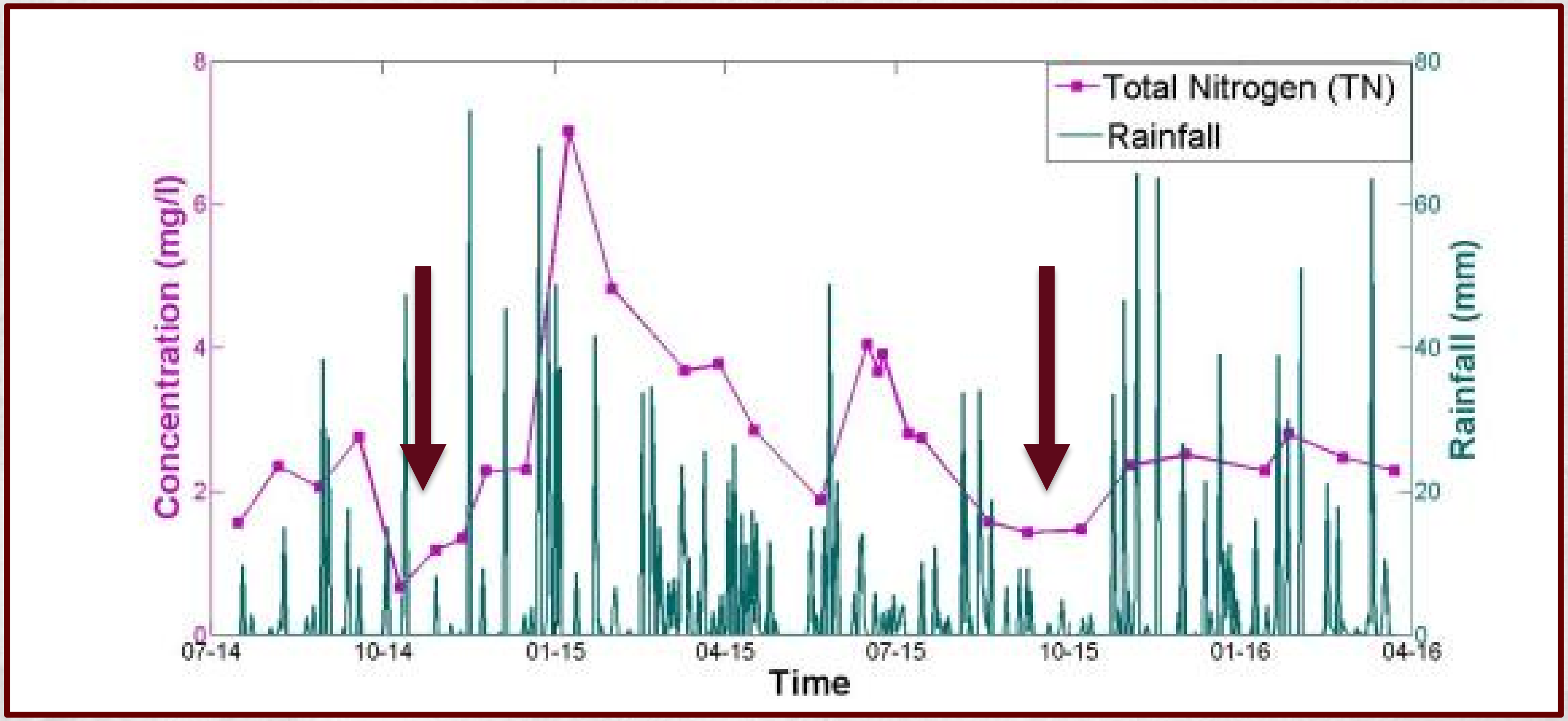
Results from Storage Pond Grab Samples

Results: Nitrate



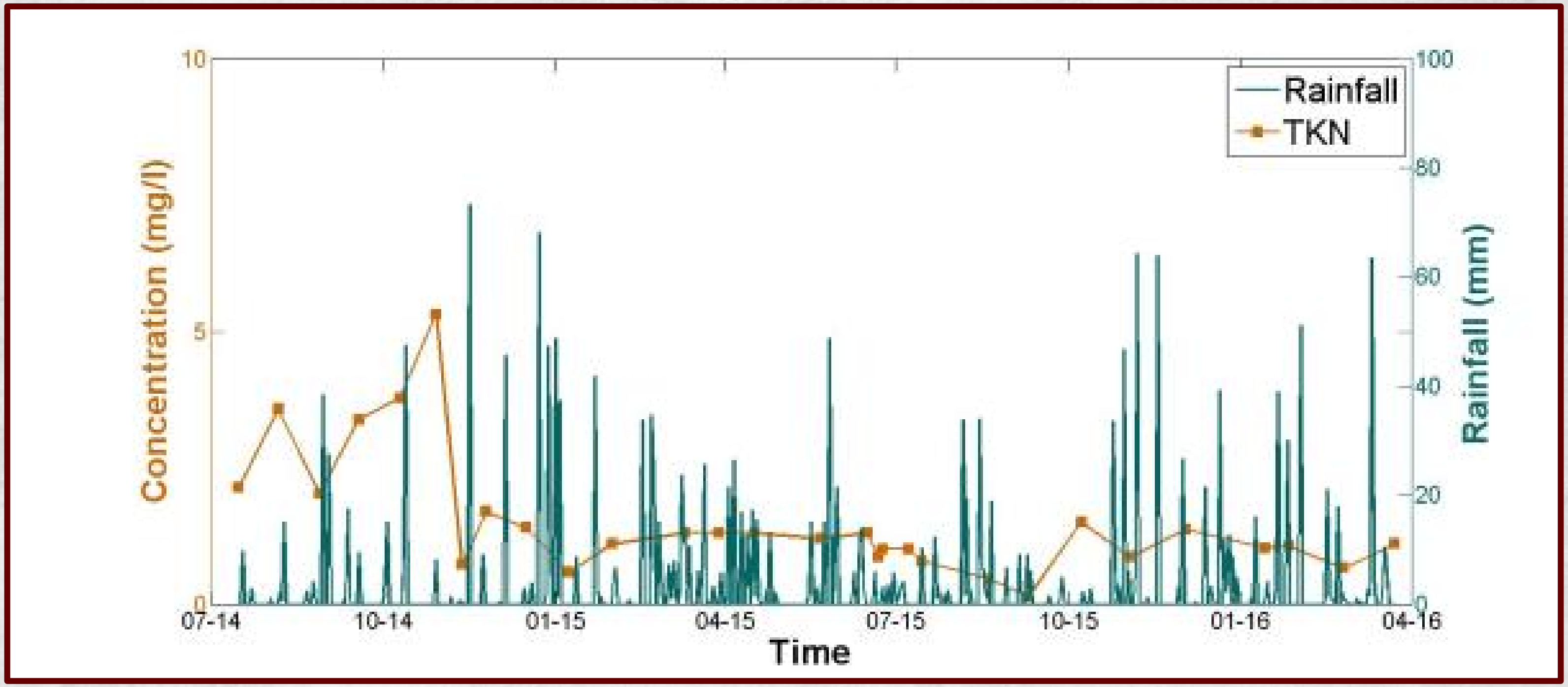
- Nitrate concentrations were considerably lower than in the storm runoff events captured.
- **Lowest concentrations** were measured **in the fall of each year prior to fall fertilizer application** and major rainfall events.
- **Concentration increased after the fall runoff events**, and started decreasing in the spring in both years of study.

Results: Total Nitrogen



- TN followed a similar trend to nitrate.
- Lowest concentrations were measured in the fall of both years of study.
- Concentration in the pond was lower than in the storm runoff events.

Results: TKN

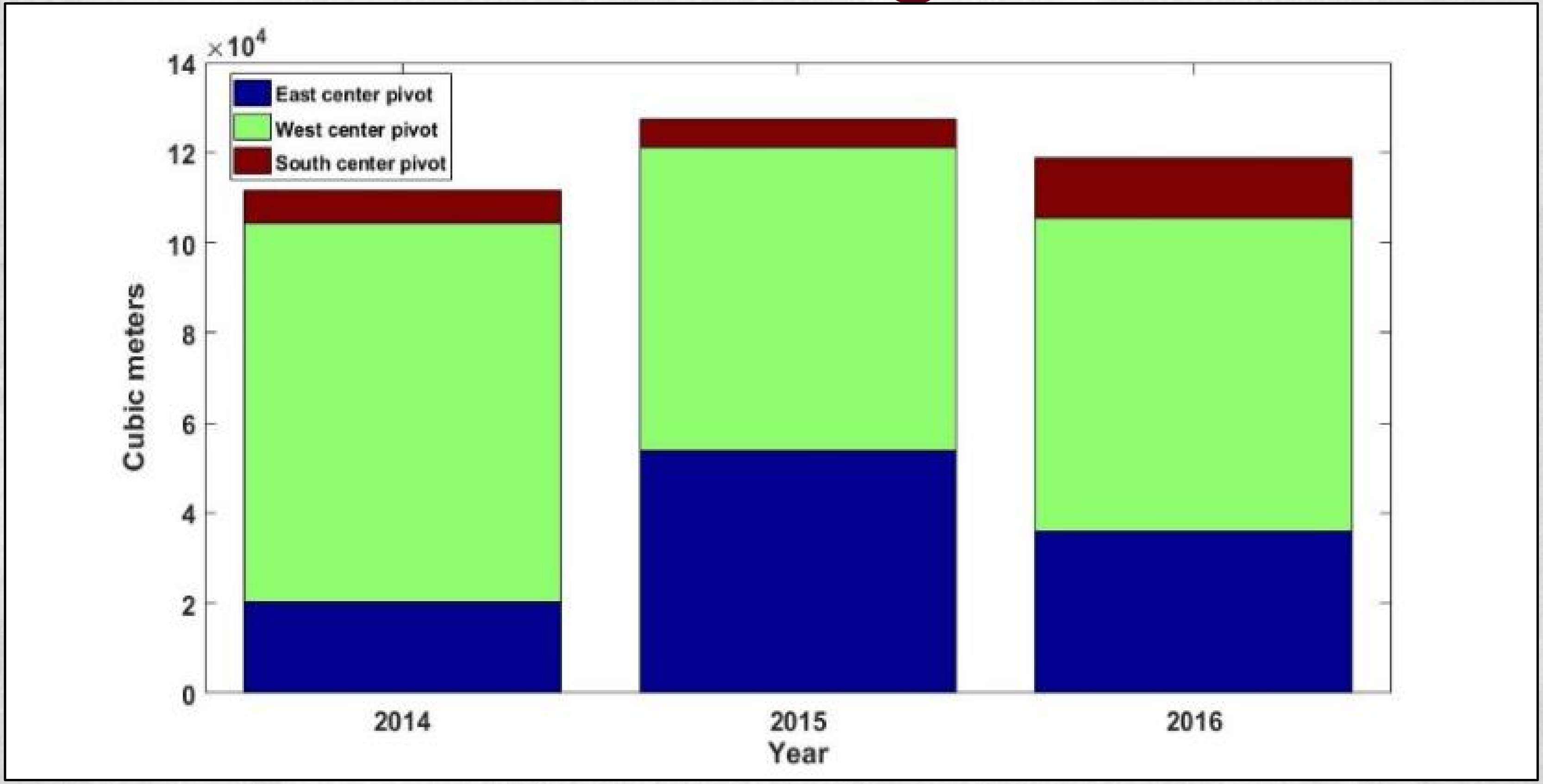


- Highest TKN concentration measured was 5.31 mg/L on October 9, 2014 which coincided with the first runoff event after poultry fertilizer application.
- Unlike 2014, TKN concentration did not increase after poultry litter application and runoff events in fall 2015.

Results: DP and TP

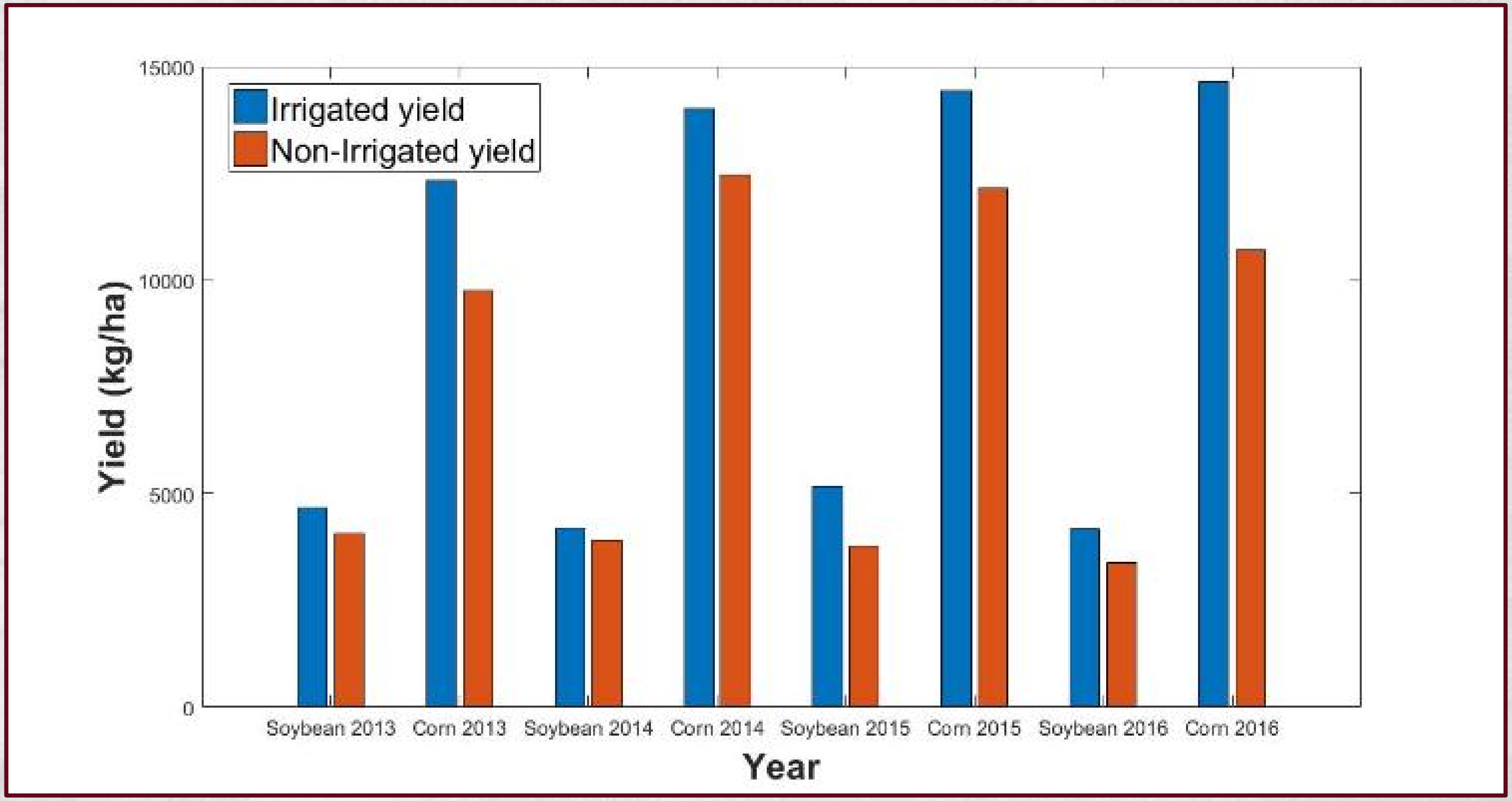
- DP concentration was **below the detection limit of 0.05 mg/L** in 24 of the 29 samples collected and analyzed throughout the study period.
- TP was **below the detection limit in most samples** during the **growing season** in both years of study, but **detectable in most samples (up to 0.425 mg/L) during the non-growing season** for both years of study.
- DP and TP concentrations in the storage pond were lower than the concentrations recorded in the storm runoff samples.

Results: Irrigation



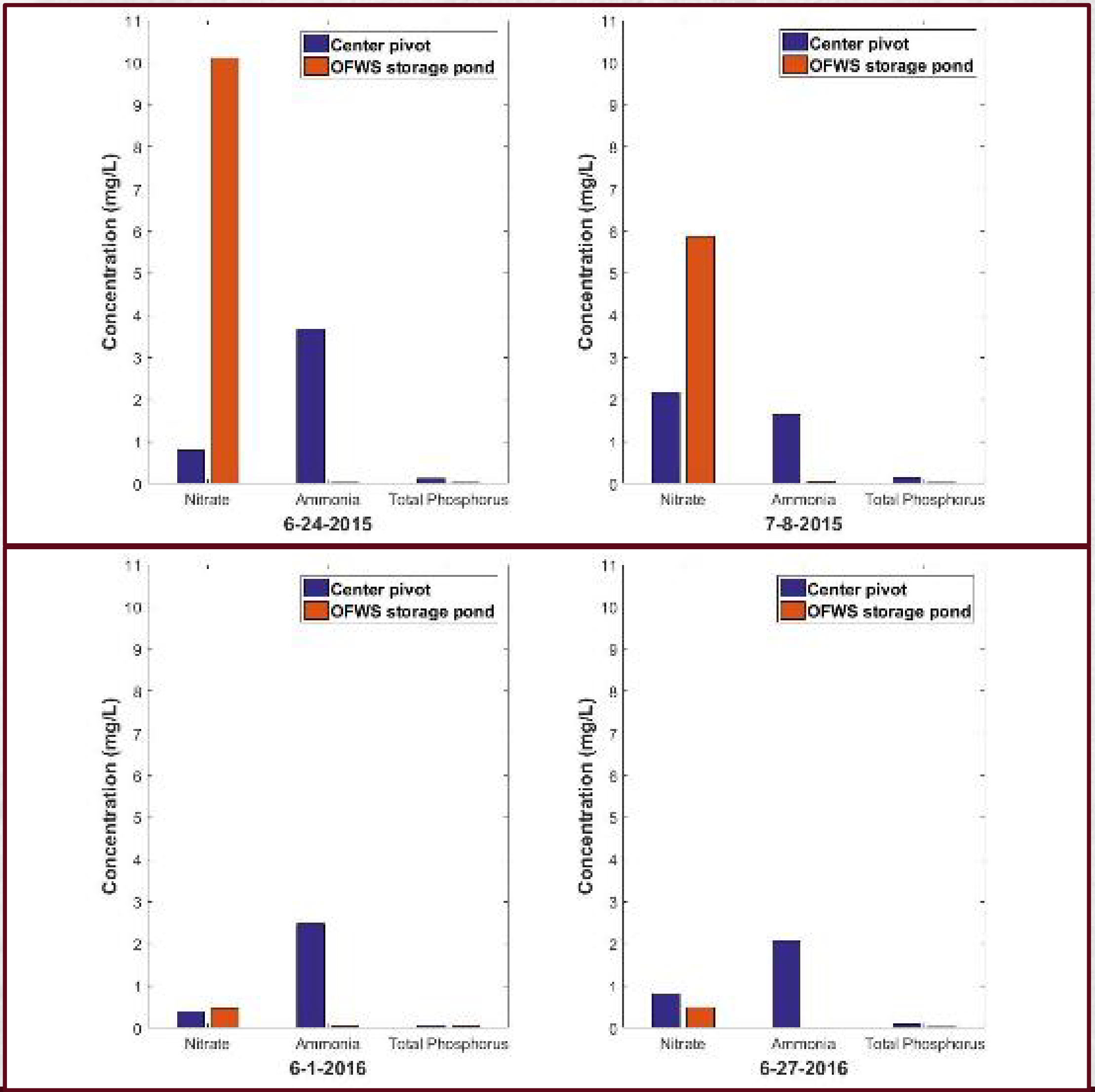
- 29.4 million gallons (90.8 ac-ft), 33.6 million gallons (103.4 ac-ft), and 31.4 million gallons (96.5 ac-ft) for irrigation in 2014, 2015, and 2016, respectively.
- Irrigated 339 acres each year.

Results: Yield



- Irrigated corn yield was higher by an average of **39, 23, 34, and 59 bushels per acre,** in 2013, 2014, 2015, and 2016, respectively.
- Irrigated soybean yield was higher by an average of **9, 5, and 21, and 12 bushels per acre** in 2013, 2014, 2015, and 2016, respectively.

Results: Nutrient Recycling



Conclusions from Monitoring

- Nutrient and sediment concentrations in storm runoff samples were considerably higher than in grab samples collected from the storage pond, demonstrating how OFWS systems can be effective in controlling downstream nutrient and sediment loading.
- Even if water is lost downstream through the pond's overflow pipe when the pond is at maximum capacity, **nutrient concentrations are considerably lower in the pond than in storm runoff events**.
- These systems can be an effective irrigation source – **63 million gallons of water for irrigation in 2014 and 2015**.
- **Higher yields were obtained for irrigated acres for both soybean and corn**, highlighting the importance of irrigation in East Mississippi where OFWS systems can be effective.
- Although some **nutrients** are being recycled, levels in applied irrigation water are **not high enough or consistent enough to allow a reduction in commercial fertilizer application.**

Part B, OFWS as a Tool to Reduce Risk: Objectives

- ✓ Determine net present value of OFWS over the investment period
- ✓ Determine feasibility of irrigating from an OFWS vs. rain-fed production

Study Site and Data

- **Site**
  - ✓ Noxubee County, Brooksville, located in the Mississippi Blackland Prairie
  - ✓ Field size is about 408 acres with about 339 irrigated acres
  - ✓ Pond size: 17 acres, 25 feet deep
  - ✓ 3 Center pivot irrigation systems
- **Crop prices**
  - ✓ Projected baseline prices
    - Food and Agriculture Policy and Research (FAPRI)
  - ✓ Futures prices
    - Livestock Marketing Information Center (LMIC)
- **Noxubee County Crop yields**
  - ✓ Risk Management Agency (RMA)
- **Weather**
  - ✓ PRISM
- **Budgets**
  - ✓ From MSU Planning Budgets, 2016

Additional Scenarios

- Also looked at typical 80 acre field and 160 acre field
  - Applicable to more producers
  - 80 acre- 1/4 mile pivot making a half circle
  - 160 acre: 1/4 mile pivot making a full circle

Methods

- Creating Budgets
  - Price*Yield – Costs = Profit
- Mississippi State University Planning Budgets
  - Assume a Corn/Soybean Rotation

Methods Continued

- Prices are simulated from historical futures market data
- Yields are simulated from de-trended historical Mississippi yield data
- Weather is simulated from historical Mississippi weather data

The Simulation

- Simulated net returns over 25 years with random prices, yields, and weather
  - Used to calculate the Net Present Value
    - Accumulated over 25 years while accounting for the time-value of money (Money is worth more now than later.)
- Looked at 80 acre, 160 acre, and 408 acre fields

Simulated Mean Yields, Temperature, and Precipitation

	Average
Non Irrigated Soybean Yield	41.7
Non Irrigated Corn Yield	140.2
Irrigated Corn Yield	176
Irrigated Soybean Yield	51.49
Temperature	75
Precipitation (Accumulated March – August)	22.8

Net Present Value with Up-Front Payment for 80 Acre Field

		4%		6%		8%	
		I	**R**	**I**	**R**	**I**	**R**
NI	Mean($)	(122)	518	(347)	424	(517)	353
	Min($)	(1,537)	(2,788)	(1,723)	(2,245)	(1,835)	(1,926)
	Max($)	1,600	4,141	1,063	3,453	658	2,931
70%	Mean($)	198	873	(85)	715	(296)	597
	Min($)	(883)	(604)	(1,038)	(517)	(1,151)	(446)
	Max($)	1,756	4,068	1,186	3,392	756	2,878
75%	Mean($)	270	918	(25)	751	(246)	627
	Min($)	(739)	(455)	(915)	(395)	(1,050)	(344)
	Max($)	1,808	4,030	1,233	3,359	798	2,850
80%	Mean($)	331	938	26	767	(296)	641
	Min($)	(596)	(350)	(793)	(308)	(1,151)	(271)
	Max($)	1,831	3,957	1,253	3,298	756	2,797
85%	Mean($)	364	917	53	750	(179)	626
	Min($)	(473)	(280)	(707)	(249)	(884)	(221)
	Max($)	1,809	3,849	1,235	3,206	802	2,717

Net Present Value with Up-Front Payment for 160 Acre Field

		4%		6%		8%	
		I	**R**	**I**	**R**	**I**	**R**
NI	Mean($)	376	518	151	424	(18)	353
	Min($)	(1,018)	(2,788)	(1,204)	(2,245)	(1,317)	(1,926)
	Max($)	2,062	4,141	1,528	3,453	1,127	2,931
70%	Mean($)	696	873	415	715	204	597
	Min($)	(354)	(604)	(509)	(517)	(628)	(446)
	Max($)	2,228	4,068	1,660	3,392	1,233	2,878
75%	Mean($)	768	918	474	751	255	627
	Min($)	(210)	(455)	(387)	(395)	(526)	(344)
	Max($)	2,279	4,030	1,706	3,359	1,273	2,850
80%	Mean($)	831	938	526	767	306	641
	Min($)	(67)	(350)	(265)	(308)	(338)	(271)
	Max($)	2,302	3,957	1,726	3,298	1,216	2,797
85%	Mean($)	864	917	554	750	322	626
	Min($)	58	(280)	(178)	(249)	(356)	(221)
	Max($)	1,809	3,849	1,711	3,206	1,280	2,717

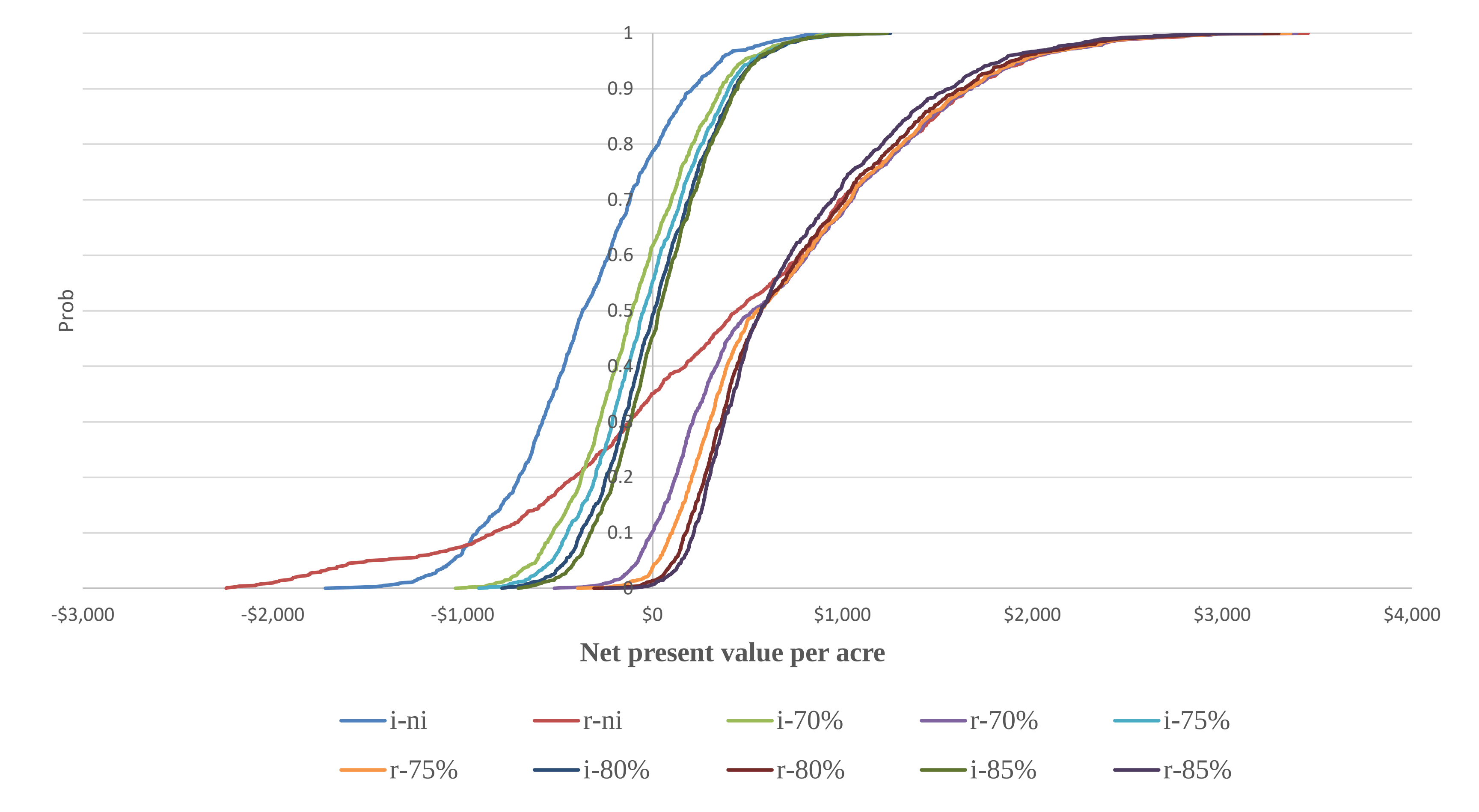
Net Present Value with Up-Front Payment for 408 Acre Field

		4%		6%		8%	
		I	R	I	R	I	R
NI	Mean($)	248	518	22	424	(148)	353
	Min($)	(1,156)	(2,788)	(1,342)	(2,245)	(1,456)	(1,926)
	Max($)	1,980	4,141	1,439	3,453	1,032	2,931
70%	Mean($)	571	873	287	715	75	597
	Min($)	(498)	(604)	(654)	(517)	(767)	(446)
	Max($)	2,143	4,068	1,569	3,392	1,136	2,878
75%	Mean($)	644	918	347	751	126	627
	Min($)	(352)	(455)	(530)	(395)	(665)	(344)
	Max($)	2,194	4,030	1,615	3,359	1,177	2,850
80%	Mean($)	706	938	399	767	170	641
	Min($)	(208)	(350)	(407)	(308)	(569)	(271)
	Max($)	2,216	3,957	1,634	3,298	1,195	2,797
85%	Mean($)	739	917	427	750	194	626
	Min($)	(85)	(280)	(320)	(249)	(499)	(221)
	Max($)	2,193	3,849	1,615	3,206	1,179	2,717

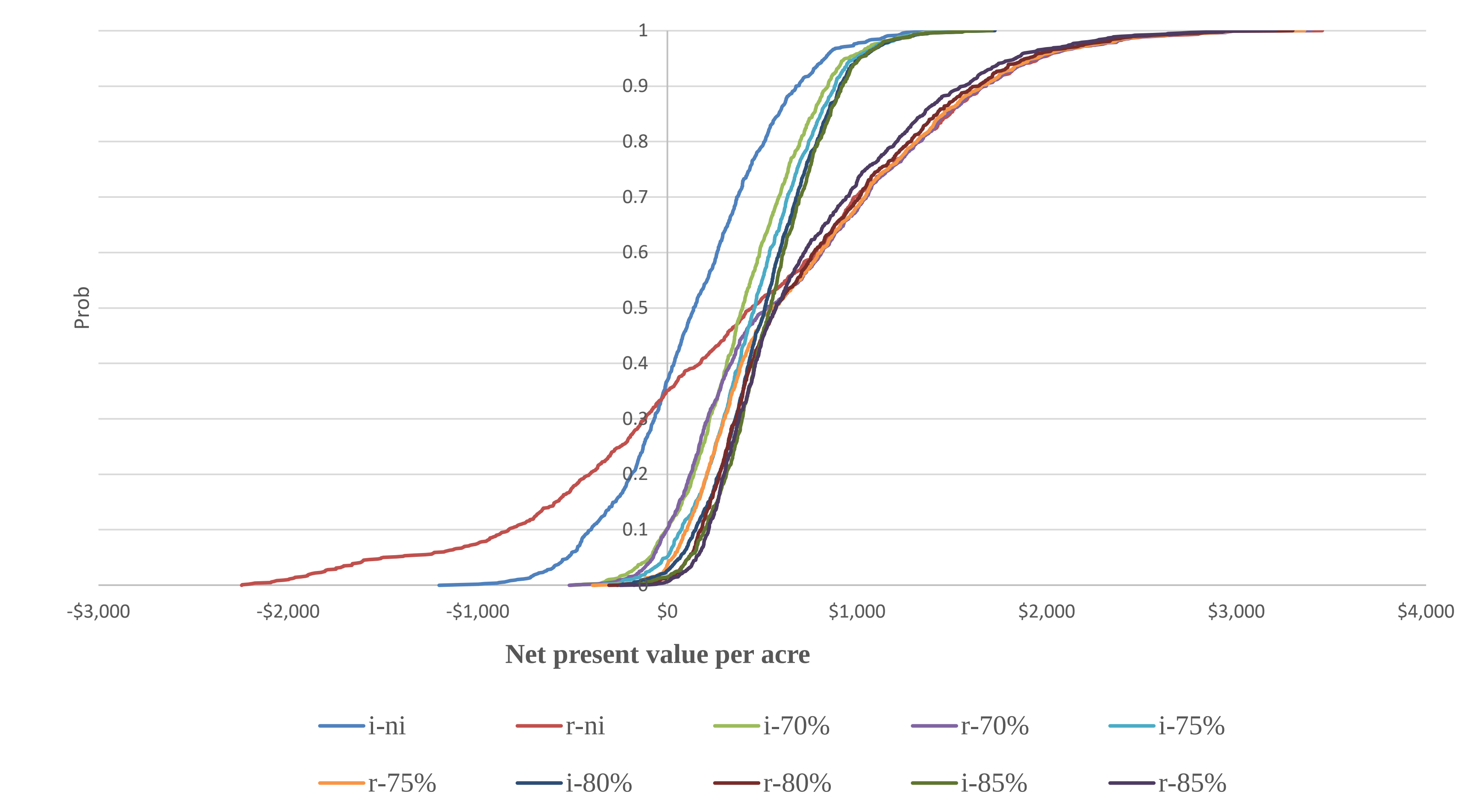
Net Present Value with Financing for OFWS on a 160 Acre Field

		4%		6%		8%	
		I	**R**	**I**	**R**	**I**	**R**
NI	Mean($)	445	518	299	424	203	353
	Min($)	(1,053)	(2,788)	(1,149)	(2,245)	(1,024)	(1,926)
	Max($)	2,201	4,141	1,739	3,453	1,399	2,931
70%	Mean($)	774	873	570	715	427	597
	Min($)	(354)	(604)	(425)	(517)	(493)	(446)
	Max($)	2,358	4,068	1,863	3,392	1,497	2,878
75%	Mean($)	850	918	633	751	480	627
	Min($)	(206)	(455)	(299)	(395)	(387)	(344)
	Max($)	2,417	4,030	1,916	3,359	1,545	2,850
80%	Mean($)	915	938	688	767	527	641
	Min($)	(58)	(350)	(173)	(308)	(285)	(271)
	Max($)	2,441	3,957	1,937	3,298	1,565	2,797
85%	Mean($)	**951**	**917**	717	750	552	626
	Min($)	65	(280)	(80)	(249)	(204)	(221)
	Max($)	2,420	3,849	1,920	3,206	1,551	2,717

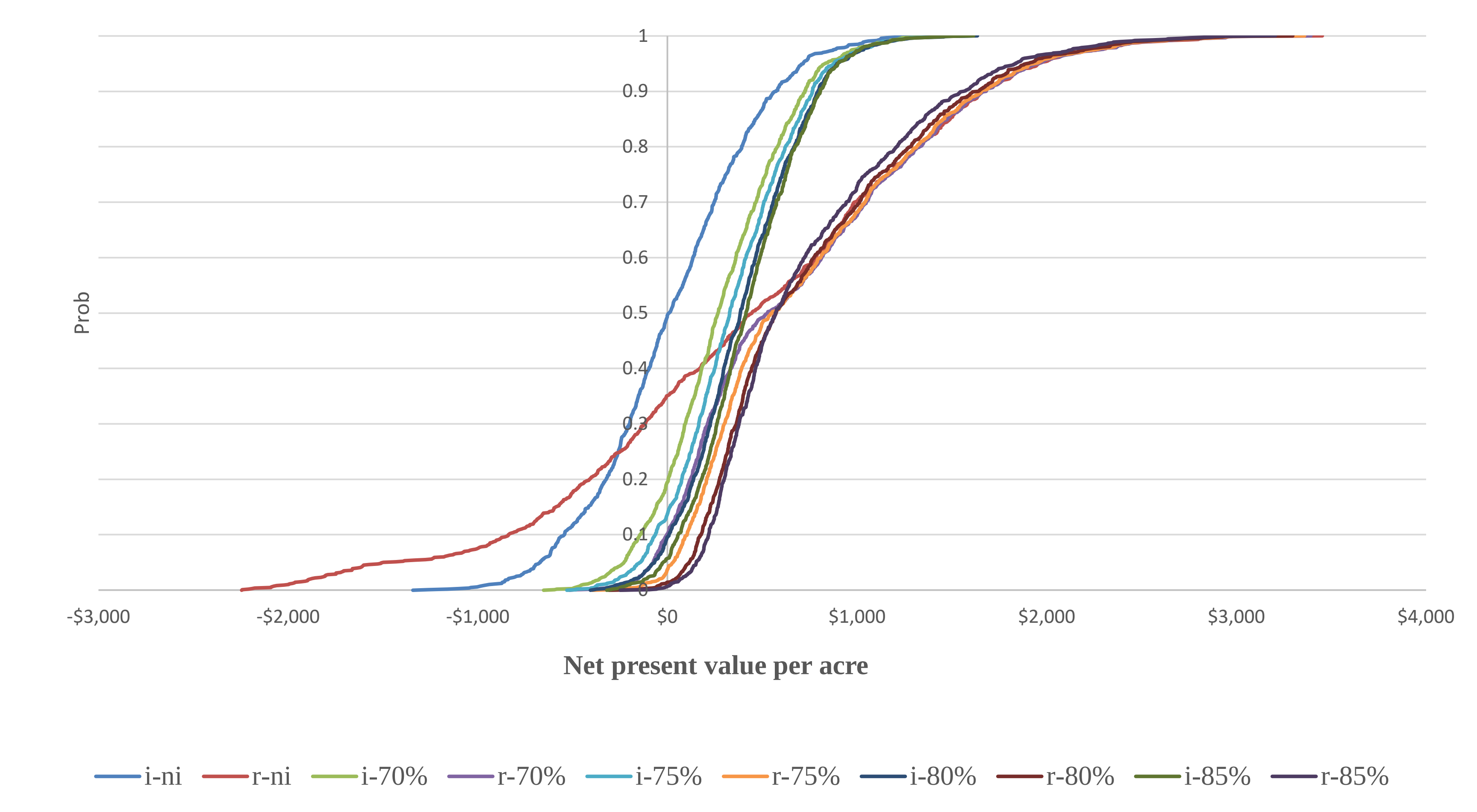
CDF at 6% discount rate on 80 acre field and OFWS costs paid up-front



CDF at 6% discount rate on 160 acre field and OFWS costs paid up-front



CDF at 6% discount rate on 160 acre field and OFWS costs financed



What about Cost-Sharing

- Reduced cost of the construction of the reservoir
  - 20% Cost Share
  - 40% Cost Share
- Available from NRCS in Delta, but not in Non-Delta Areas

Net Present Value with Cost Share on 160 acre field and up-front payment

	% Cost Share	4%	6%	8%
NI	20	453 (518)	229 (424)	61 (353)
	40	**530 (518)**	306 (424)	139 (353)
70%	20	**942 (873)**	632 (715)	400 (597)
	40	**1,018 (873)**	709 (715)	478 (597)
75%	20	908 (918)	604 (751)	377 (627)
	40	**984 (918)**	681 (751)	454 (627)
80%	20	846 (938)	552 (767)	333 (641)
	40	923 (938)	629 (767)	410 (641)
85%	20	774 (917)	493 (750)	283 (626)
	40	851 (917)	570 (750)	360 (626)

NPV for Rainfed in parentheses.

Net Present Value with Cost Share on 160 acre field and OFWS System Financed

	% Cost Share	4%	6%	8%
NI	20	**523 (518)**	370 (424)	191 (353)
	40	**600 (518)**	**440 (424)**	249 (353)
70%	20	852 (873)	641 (715)	385 (597)
	40	**928 (873)**	711 (715)	443 (597)
75%	20	**928 (918)**	704 (751)	431 (627)
	40	**1,004 (918)**	**773 (751)**	489 (627)
80%	20	**993 (938)**	758 (767)	471 (641)
	40	**1,069 (938)**	**827 (767)**	528 (641)
85%	20	**1,029 (917)**	**788 (750)**	493 (626)
	40	**1,105 (917)**	**857 (750)**	551 (626)

NPV for Rainfed in parentheses.

Conclusions

- Estimated NPV of OFWS depends heavily upon the scenario in which it is used
  - Costs must be spread out over as many acres as possible
    - Maximize efficiency
  - Better to take out a loan than to pay upfront
  - Lower discount rates are better (depends on alternative)
- Government incentives will make irrigation more attractive
  - Cost share program is instrumental
- When combined with crop insurance, OFWS dramatically reduces income variability and is an effective risk management strategy

Acknowledgements

- Farmers: Mr. Dale Weaver and Mr. Paul Good
- Dr. Dennis Reginelli, Regional Extension Specialist, Northeast Region

SIP Sustainable Irrigation Project

MSPB MISSISSIPPI SOYBEAN PROMOTION BOARD