A Prototype System to Evaluate the Potential Benefits of Using Recycled Drainage Water to Irrigate Corn and Soybeans

Laura Bowling, Dept. of Agronomy

In collaboration with:
Dan Quinn, Shaun Casteel, Katy Mazer, Nathaly Vargas Arroyo Agronomy
Keith Cherkauer and Dongseok Yang, Ag and Bio Engineering
Juan Sesmero, Ag. Econ

IN CCA Program
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USDA NIFA

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Today's Presentation

- Background & Motivation
- The ACRE DWR Prototype
- Environmental Impact
- Year 1 Yield Results
- Next Steps

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Background & Motivation

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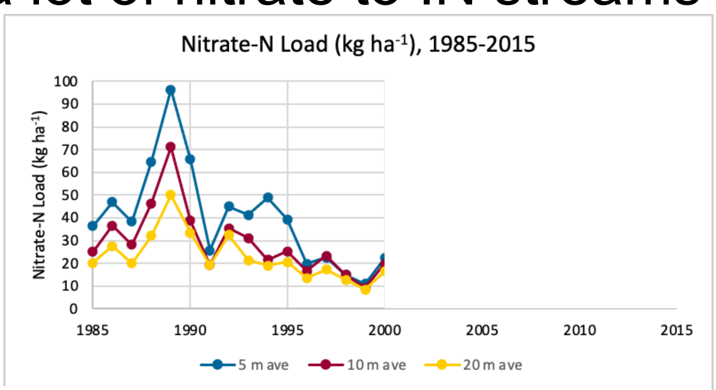
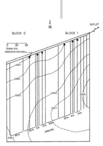
Subsurface drainage releases a lot of nitrate to IN streams





SEPAC long-term drainage experiment
Over 31 years of data!
Bowling and Kladivko (2021)

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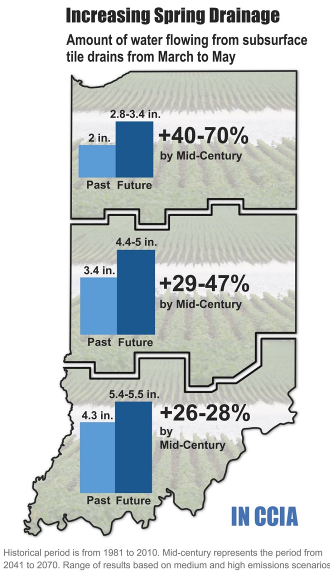
Indiana's climate is changing

- Annual temperature has increased 1.2 °F over the last 100 years
  - 5-6 °F more expected by mid-century
- Annual precipitation has increased over 5.6" over the last century
  - Greatest increase in the spring
  - Little to no change in summer precipitation



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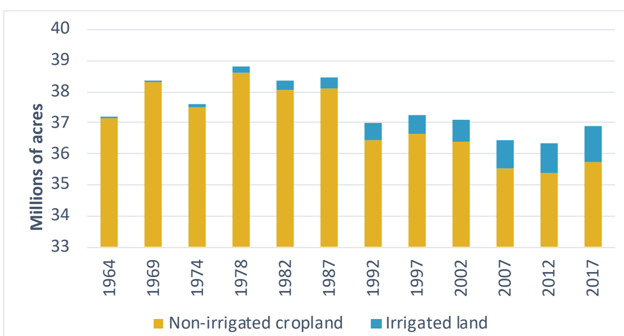
Irrigation Expansion in IN



Cropland acreage in IN and IL

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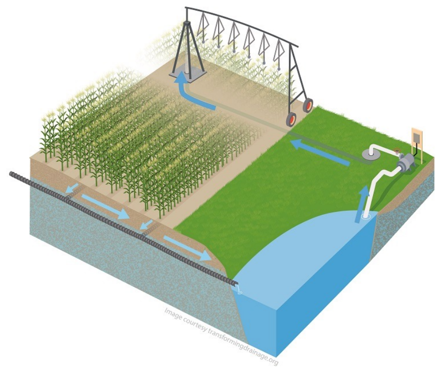
Is drainage water recycling the solution?

No.

But could it be?



Drainage water recycling is the practice of capturing excess water drained from fields, storing the drained water, and using the stored water to irrigate crops when there is a water deficit.

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Goals and Objectives

Advance knowledge on eco-intensification using drip fertigation from recycled drainage water

- ***Evaluate benefits of intensive management with drip fertigation***
- ***Support impaired wetland ecosystems***
- ***Quantify water quality and quantity improvements***
- ***Evaluate the economic feasibility***

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The ACRE DWR Prototype System

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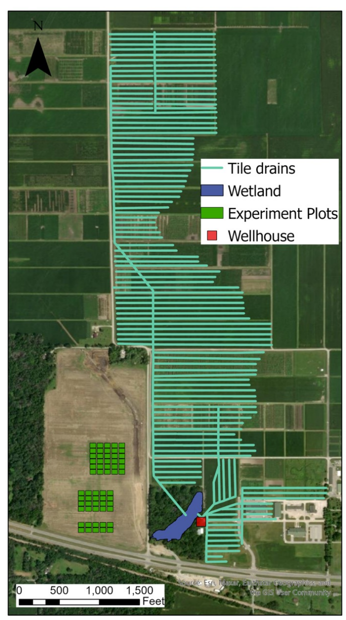
System Overview



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Water Control Structure at Wetland Outlet

- Reconstructed culvert under the access drive prior to US 52
- Replaced old 20" concrete culvert with 30" HDPE
- 6" removeable boards control water level within the wetland

During installation

Buried Structure

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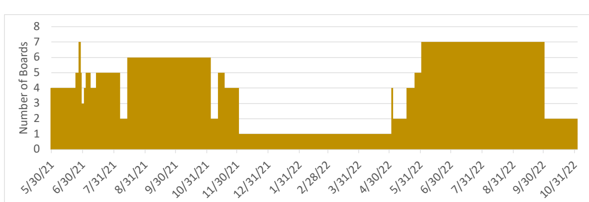
Operational Strategy

- Free-flowing (1 board + weir) during the non-growing season
- Increase storage in early May, watch the weather
- 3 boards is "safe level" during extreme rain – flow rate limited by downstream culvert



Maximum water level in May/June 2022

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Irrigation Water Supply

Passes through water filtration system

Powered by a 6500 W portable generator

2 HP centrifugal pump, provides about 26 psi of pressure at 90 GPM

Inflow from wetland 10’ 2” intake hose with foot valve

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Back up water supply

Ball valve controls water source

PVC elbow to 4” flexible hose to existing ACRE groundwater well

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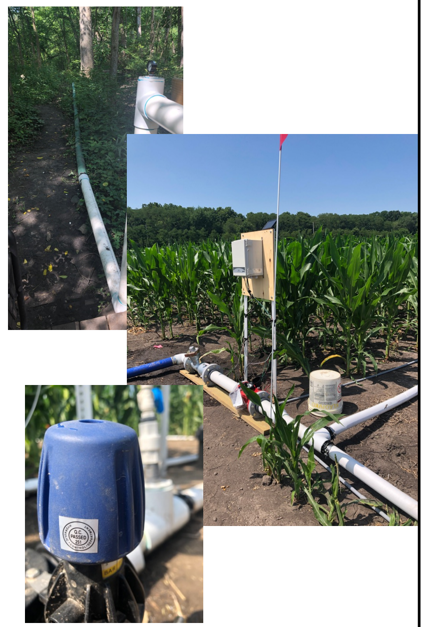
Field Installation

- 4” main extends ~800 ft under county road 500 to Field 70
- Programmable control station in the field: 3 inch sub-mains that extend to corn and soybean treatments
- Pressure control valves control split to 2 inch sub-mains at the fertigation station



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Field Layout

- Sub-mains:
  - 2" Flexnet 30" spacing
    - Every row in corn
    - Every other row in soybean
  - DripNet PC 636 15ml
    - Emitters every 27”
    - 0.16 gallons per hour flowrate
- Netafim covered the cost of all Netafim materials

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Fertigation System

Pump, fertilizer injection line, and separate tanks for fertilizer mixes

Control box for specifying fertilizer injection rate (gpm)

Two Separate Valves and Lines for Fertigation and Irrigation

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Sensors and Irrigation Decision-Making

- Soil moisture is measured using a GroPoint Air from Dranigo Technology Co., LTD connected to a 60 cm GroPoint Profile from RIOT Technology Corp.
- The Dranigo transmitters communicate directly with the farm's LoRaWAN Gateway, the central hub in a low-power, wide area network that encompasses all of ACRE.
- One sensor in a single replicate of each treatment
- Provides real-time average volumetric water in 15 cm intervals down to 60 cm

LoRaWAN

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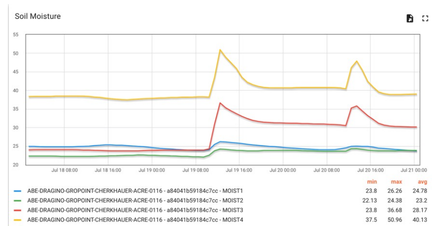
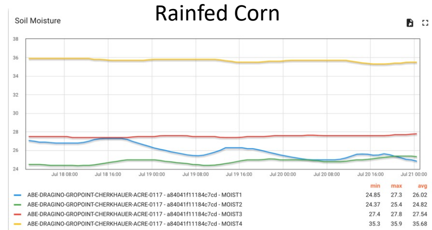
Soil Moisture Sensing

Irrigated Corn



Rainfed Corn



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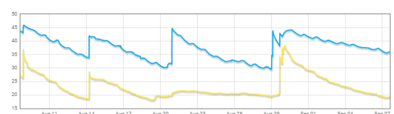
When and how much do we irrigate?

- Both irrigation checkbook and soil moisture sensors are used to determine soil water deficits.
- Both methods are compared, and if soil moisture deficit of irrigated plots is greater than 30%, we irrigate.
- Irrigation depth is based on 3 day average ET losses



Date	Week Past Emer-	Penman Eto	Kc	Crop ET (ET)	Effective Rain ®
-	-	in		in.	in.
6/19/2022	2	0.65	0.23	0.15	0.00
6/20/2022	2	0.70	0.23	0.16	0.00
6/21/2022	3	0.78	0.33	0.25	0.00
6/22/2022	3	0.63	0.33	0.21	0.00
6/23/2022	3	0.72	0.33	0.24	0.00

Observed Corn		
Date	Avg Rainfed Deficit	Average Irrigated Deficit
9/1/2022	65%	31%

Checkbook Corn		
Date	Avg Rainfed Deficit	Average Irrigated Deficit
9/1/2022	60%	35%

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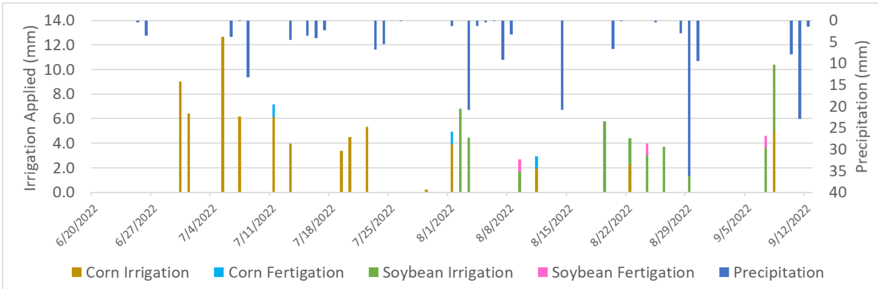
Irrigation Applied



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Quantifying Ecosystem Benefits

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Wetland Habitat

- Wetland already home to some amphibians and crustaceans
- Hydroperiod defines the portion of year that a wetland holds water
- Disturbance regimes lead to either very short or very long hydroperiods

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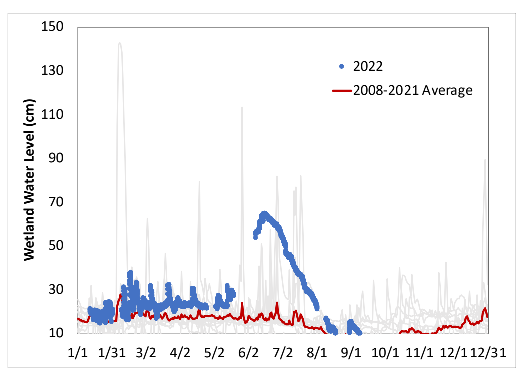
Wetland Hydroperiod

- Drainage water management in 2022 extended the continuous hydroperiod by ~60 days from the 2008-2021 average
- Many amphibians in Indiana need the hydroperiod to extend into mid-July for reproductive success



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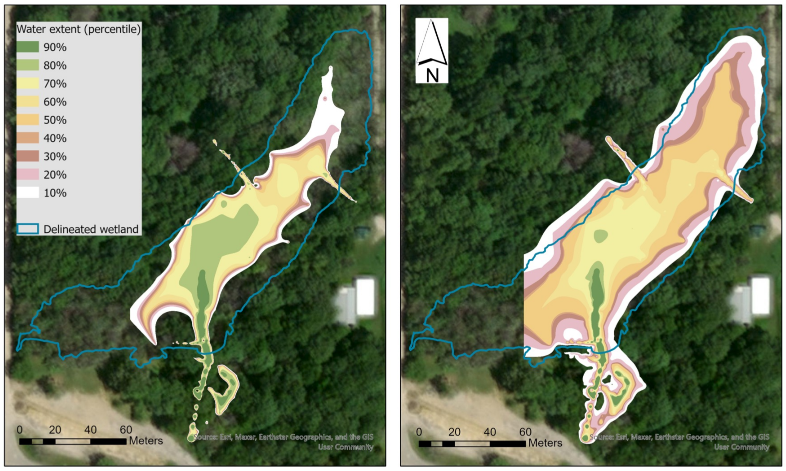
Growing Season Wetland Extent

2007-2021 2022



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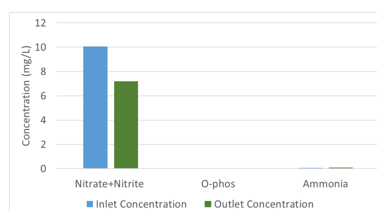
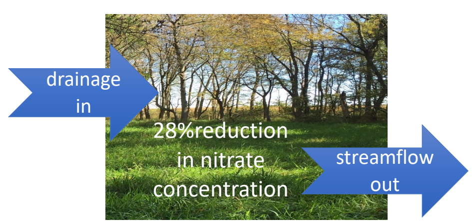
Wetland water quality impact, 2007-2021

- Existing wetland with Reed Canary Grass
  - 28% reduction in mean nitrate concentration
  - Approximate doubling of ortho-phosphate
- Nitrate reduction of about 196 kg/year or 2.8 kg/ha/yr





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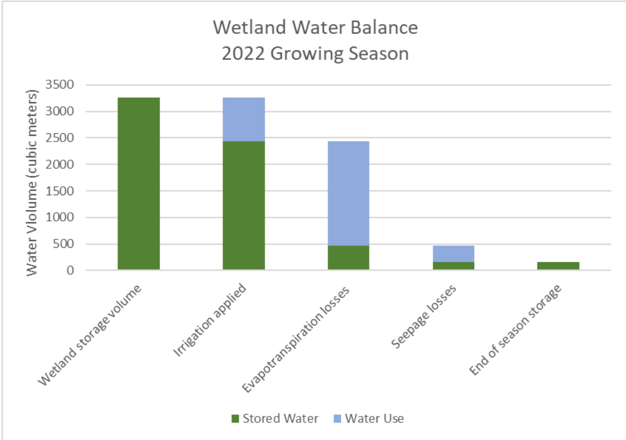
Wetland Water Balance

- Current system is limited by the storage capacity of the wetland and ET losses



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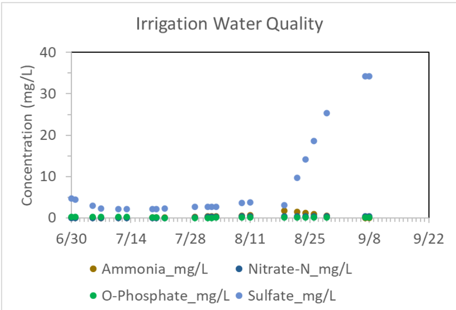
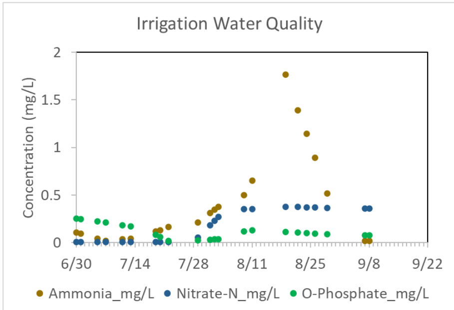
Irrigation Water Quality





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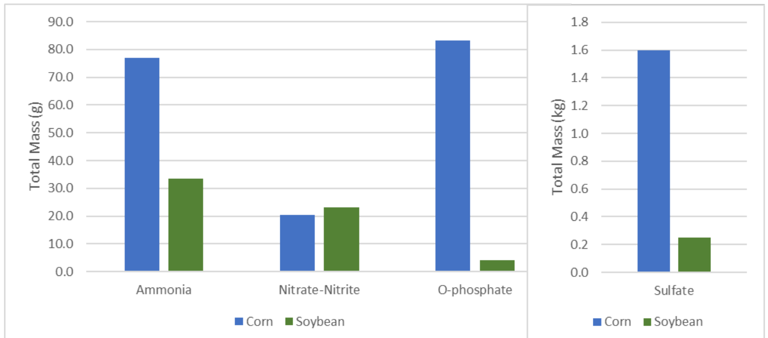
Wetland Nutrient Balance



- Represents the direct reduction in load downstream (Nitrate 50 g/yr vs 196 kg/yr)
- Increased ET and seepage may have contributed to indirect reduction or delay of nutrient load

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In-Field Nutrient Loss

- Quantified using plant nutrient samples and suction cup lysimeters to quantify differences in leaching
  - Only sporadic lysimeter samples collected during the growing season,
  - Monitoring will continue over the winter
  - Plant nutrient content samples also expected to reveal an increased rate of nutrient utilization

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Corn and Soybean Intensive Management with Drip Irrigation and Fertigation

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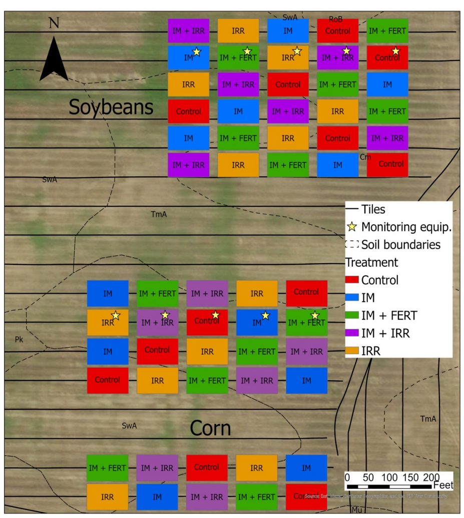
Experimental Design



- Randomized complete block design with 6 replicates
- 2 rainfed treatments
  - Traditional
  - Intensive Management
- 3 irrigated treatments
  - Traditional
  - Intensive Management
  - Fertigation
- Plot locations based on drainage tile lines and soil types

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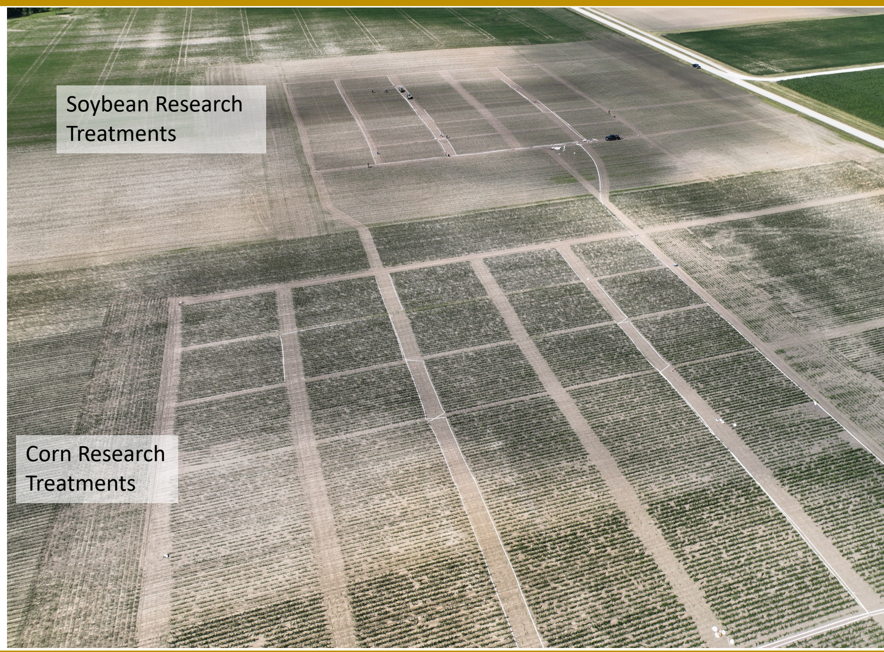

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Corn Treatments

- **Plot Size**
  - 60 ft wide x 75 ft long (24 rows wide)
- **Control Treatment**
  - 32,000 seeds per acre
  - 200 lbs N per acre (starter + V5 sidedress)
- **Intensive Management (IM)**
  - 38,000 seeds per acre
  - 200 lbs N per acre (starter + V5 + V10 sidedress)
  - 15 lbs S per acre (V5 sidedress)
  - Foliar Fungicide (R1 application)
- **Fertigation Management (FERT)**
  - Intensive management practices +
  - 20 lbs N per acre (V12, R1, and R2 applications)
  - 2 lbs S per acre (V12, R1, and R2 applications)

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Soybean Treatments

- **Plot Size**
  - 55 ft wide x 75 ft long (44 rows wide)
- **Control Treatment**
  - 140,000 seeds per acre
- **Intensive Management (IM)**
  - 140,000 seeds per acre
  - 20 lbs S per acre (pre-emergence application)
  - Foliar Fungicide and Insecticide (R4 application)
- **Fertigation Management (FERT)**
  - Intensive management practices +
  - 12 lbs N per acre (R4, R5, and R6 applications)
  - 6 lbs S per acre (R4, R5, and R6 applications)
  - 9 lbs K per acre (R4, R5, and R6 applications)

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Irrigation Applied

		Corn		Soybean	
Month	Precipitation	IRR	# events	IRR	# events
	mm	*mm*		*mm*	
Jun	30	9	1	0	0
Jul	44	49	9	0	0
Aug	114	8	3	33	8
Sept	46	5	1	9	2
Total	**234**	**71**	**12**	**42**	**9**

Corn Irrigation – Began at Growth Stage V10
Soybean Irrigation – Began at Growth Stage R3

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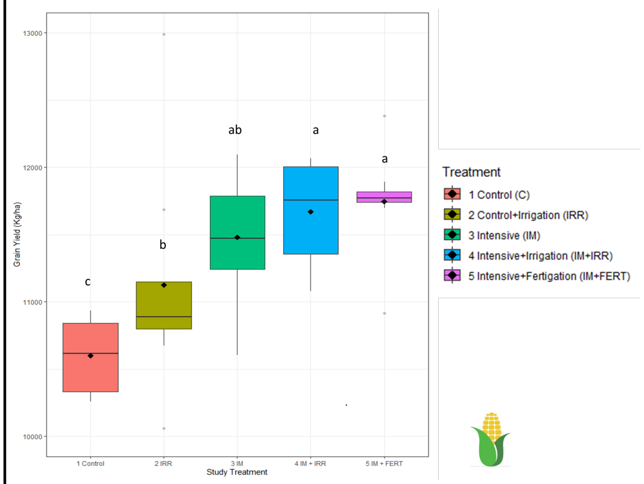

Note: TRT means were separated at α=0.1 using the "LSD.test" function of the package "agricolae" in R. TRT was designated as a fixed factor and REP was designated as a random factor .Different letters above the box plots indicate a statistical difference between treatments at P<0.1.

- IRR, FERT and IM significantly **increased corn yield** as compared to the control.
- IRR & FERT **didn't increase corn yield beyond the addition of IM practices** alone
- Recycled drainage water has the greatest potential to increase corn yield in a "low-input" management system

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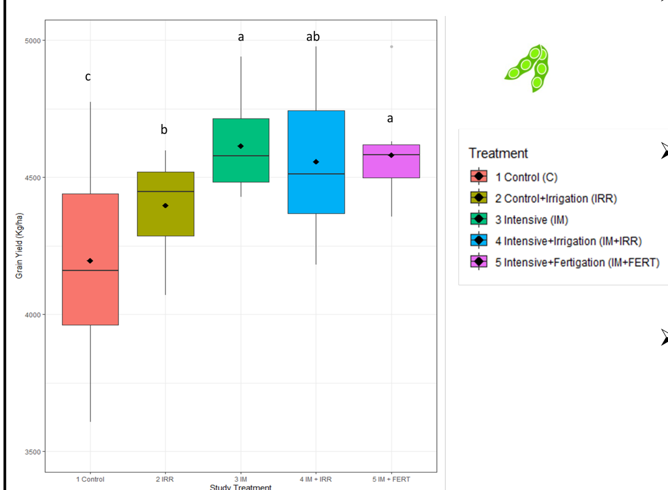

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- Simliar to corn, IRR, IM, and FERT **increased soybean yield** compared to the control
- IRR & FERT **didn't increase corn yield beyond the addition of IM practices** alone
- Greater pod damage due to bean leaf beetle and stink bugs observed in control and IRR treatments
- Visual sulfur response observed

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Summary of Preliminary Results

- Corn and soybean intensive management practices combined with multiple in-season fertigation applications produced the highest grain yield for both crops.
- Drip irrigation utilizing recycled drainage water provided the greatest yield increases in "low-input" management systems.
- Additional data still required to assess plant nutrient uptake and use efficiency differences

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Next Steps

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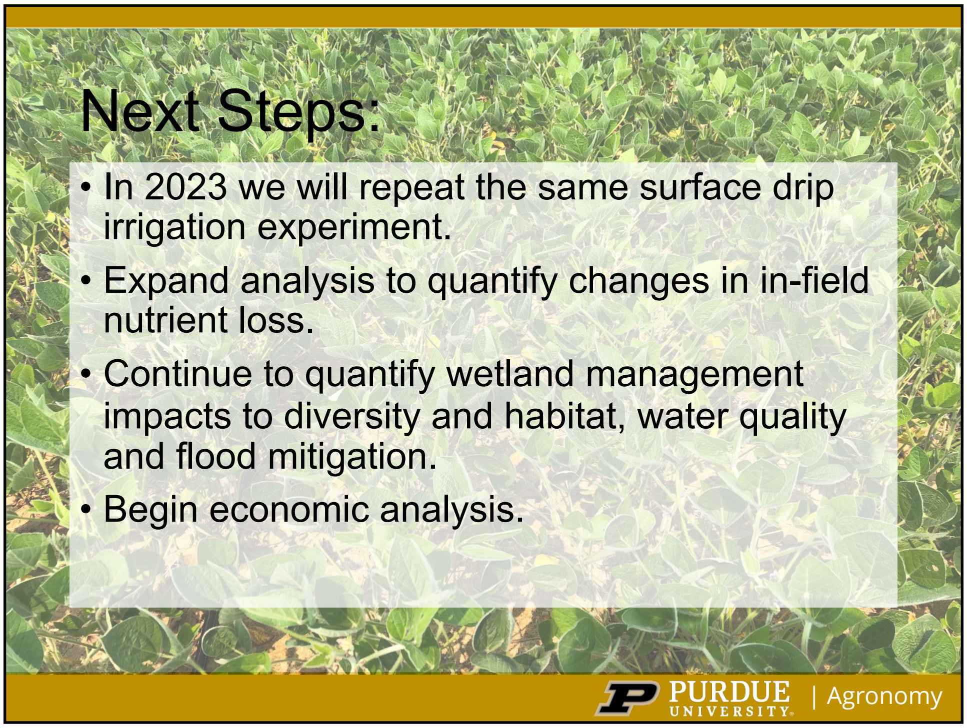

Next Steps:
• In 2023 we will repeat the same surface drip irrigation experiment.
• Expand analysis to quantify changes in in-field nutrient loss.
• Continue to quantify wetland management impacts to diversity and habitat, water quality and flood mitigation.
• Begin economic analysis.
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Questions?
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