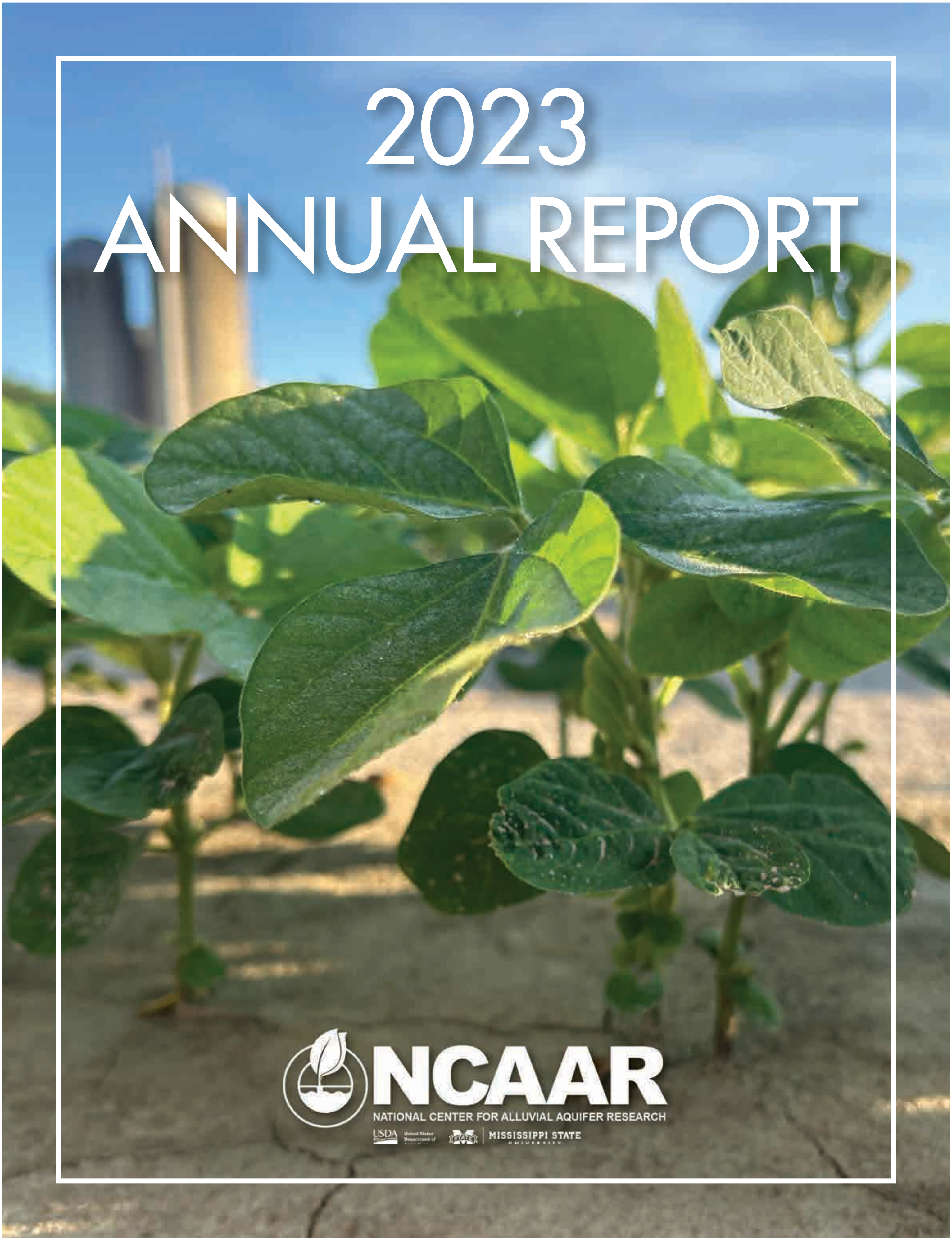

2023 ANNUAL REPORT

NCAAR
NATIONAL CENTER FOR ALLUVIAL AQUIFER RESEARCH

USDA United States Department of Agriculture | MISSISSIPPI STATE UNIVERSITY

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Research Engineer

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A letter from Chris and Drew

DREW GHOLSON
NCAAR Coordinator,
MSU Extension
Irrigation Specialist, &
MAFES Assistant Professor

CHRIS DELHOM
USDA-ARS
Research Leader &
Research Engineer

In 2023 the National Center for Alluvial Aquifer Research continued to develop research and outreach to improve water use across the Delta.

We broadened our monthly seminar series with streaming and in-person options that highlight projects from students and researchers at the center as well as others involved in water-related agricultural research across the Delta and the United States. We covered topics such as satellite-based remote sensing of cover crop performance, tailwater recovery systems, the impact of production practices and irrigation triggering on various crops, and we hope to expand the series in the coming years.

Our outreach continues to grow, and we have hosted tours for numerous groups of students, industry members, government officials, and stakeholders. The center continues to be involved in extension agent training across the Delta.

An example of our outreach includes the Mississippi Master Irrigator Course. This fall, Dillon Russell kicked off the online portion of the inaugural course with 38 participants. This course has been a long time in the making and will help producers implement water management practices on-farm.

Many significant research studies have been carried out at the center in 2023. An interesting study by Trey Freeland, a Mississippi State University graduate student, examines the potential to widen the distance between irrigation furrows in certain conditions, such as where production soil is vertisols and a high-capacity well is present. This wide spacing may lead to more efficient irrigation with less runoff and no yield loss. Read more about this important research on page 18.

Trey is among five master's students and doctoral candidates who will graduate in 2024. We are proud of the work Trey, Anna, Amilcar, Carson, and Eugene are accomplishing.

Late in 2023 we on-boarded several new permanent NCAAR staff. Dr. Andrea Simpson joined Mississippi State University as an assistant research professor in agronomy, and Dr. Zach Simpson joined ARS as a research hydrologist. NCAAR also welcomed back Dr. Chris Delhom who has returned to Stoneville as the permanent research leader for ARS and will also be serving as a research engineer.

This annual report is intended to highlight what is being accomplished at NCAAR. Together, we will lead NCAAR to an even more successful year in 2024.

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EXTERNAL FUNDING

In addition to state and federal funding from USDA-Agricultural Research Service and Mississippi Agricultural and Forestry Experiment Station, NCAAR leverages those resources for additional support from various outside organizations to expand our capabilities and those of our collaborators.

$583,466
NEW EXTERNAL FUNDING IN 2023

$1.5M
ONGOING EXTERNAL FUNDING FOR NCAAR

$3.8M
ONGOING COLLABORATIVE FUNDING

BACKGROUND

The Lower Mississippi River Basin is one of the most productive and intensively irrigated agricultural regions in the nation with 90 percent of the irrigation water pumped coming from the Mississippi River Valley Alluvial Aquifer. Overdrawing this shallow productive aquifer is negatively impacting agricultural productivity and profitability, base flows of streams, water quality, and aquatic and riparian habitats. Scientists from USDA-ARS and Mississippi State University conduct research and extension activities on water-related issues.

HISTORY

The National Center for Alluvial Aquifer Research (NCAAR) was established by Congress in 2017 as a cooperative program between USDA's Agricultural Research Service and the Mississippi Agricultural and Forestry Experiment Station at Mississippi State. NCAAR was created to address the water resources challenges in Mississippi River Alluvial Aquifer.

OUR MISSION

The mission of NCAAR is to conduct research and provide information for issues surrounding water use for agriculture and natural resources in the Lower Mississippi River Basin (LMRB).

OBJECTIVES

NCAAR aims to produce and communicate research directed at the conservation and sustainability of water resources for agriculture that include: developing water-efficient cropping systems, improving water capture, improving water distribution systems and irrigation efficiencies, use of water-saving irrigation management options, and developing economic risk assessment tools that enable producers to identify profitable, water-efficient production options.

SUPPORT

NCAAR is supported by the Agricultural Research Service, United States Department of Agriculture (USDA), under Cooperative Agreement number 58-6066-2-023 and the Mississippi Agricultural and Forestry Experiment Station.

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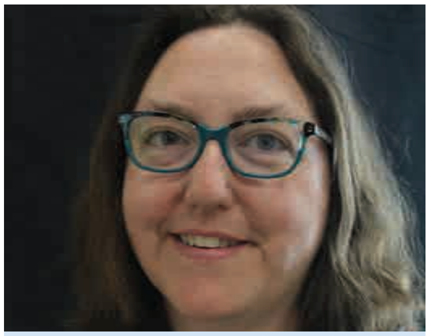

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GRADUATE STUDENT SHOWCASE

TREY FREELAND

M.S. student in Agronomy
Advised by Dr. Drew Gholson

Hometown: Leland, MS

Expected graduation date: May 2024

Describe your thesis/study and what you hope to learn from it: My thesis work was conducted to examine the difference of irrigated furrow spacing on corn grown in vertisols (shrink swell clays). The work looked at irrigated furrow spacings on every row, skip row, four row, and eight row on 40 in. beds. The main purpose was to figure out if these wider spacings will decrease the amount of water logging that is common with every row and skip row in these vertisols of the MS delta.

Tell us about any new skills, techniques, and knowledge you gained.
My new skills and knowledge gained have been immeasurable, from proper soil moisture sensor installation, some slight pivot knowledge from helping other graduate students, and how to professionally address situations and problems.

EUGENE OKU

M.S. student in Agricultural Economics
Advised by Dr. Nico Quintana

Hometown: Jamestown, Africa

Expected graduation date: Summer 2024

Describe your thesis/study and what you hope to learn from it: My thesis investigated the diffusion of water-conserving irrigation technology in the Mississippi Delta. I aimed to identify factors that influenced the timing of adoption of center pivots and computerized hole selection in this region. I found that farming experience slowed down the adoption of these practices. I learned new econometric modeling; survival analysis.

Tell us about any new skills, techniques, and knowledge you gained.
Coming from Africa and a purely economics academic background, I have learned about a new field, agriculture, and also about new data analyzing techniques using software such as SAS, R and Stata.

CARSON ROBERTS

Ph.D. student in Agronomy
Advised by Dr. Drew Gholson

Hometown: Dayton, ID

Expected graduation date: May 2024

Describe your thesis/study and what you hope to learn from it.
I studied the effects of cover crops and reduced tillage practices on soil moisture, cotton yield, irrigation water use, and profitability. We learned the importance of winter cover crops in improving infiltration and reducing irrigation water use, and we observed the economic challenges associated when implementing cover crops.

Tell us about any new skills, techniques, and knowledge you gained.
I learned how to manage large plot research, analyze data, and gained a deeper understanding of conservation agriculture.

ANNA SMYLY

Ph.D. student in Agronomy
Advised by Dr. Drew Gholson

Hometown: Stuttgart, AR
Expected graduation date: December 2024

Describe your thesis/study and what you hope to learn from it. My dissertation is determining an irrigation and nitrogen management plan in a furrow-irrigated rice (FIR) production system. FIR has become increasingly popular throughout rice growing areas in the mid-south due to the simplified crop rotations, less time spent in field preparing for the following growing season, levees are not required, and potential decrease in water usage.

Tell us about any new skills, techniques, and knowledge you gained. One of my favorite things about attending MSU is being stationed at the Delta Research and Extension Center and NCAAR. This has allowed me to be extremely hands-on with my study. I have gained so much knowledge that you can't learn from a textbook.

AMILCAR VARGAS

Ph.D. student in Agronomy
Advised by Dr. Drew Gholson

Hometown: Teculután, Zacapa, Guatemala
Expected graduation date: May 2024

Describe your thesis/study and what you hope to learn from it. My studies aimed to understand water and nutrient dynamics in irrigated corn and soybean farming within the Mississippi Delta. By experimenting with different irrigation systems, irrigation thresholds, nitrogen placement methods, and nitrogen application rates, I sought to gain insights into how these variables influence crop growth and nutrient management.

Tell us about any new skills, techniques, and knowledge you gained. I discovered that agricultural practices carried out by growers in a region come from a practical necessity. Initially, I questioned those practices, and it was not until I went through the irrigation challenges in the Mississippi Delta that all those practices made sense. This taught me the importance of fully comprehending local agricultural practices to provide meaningful assistance.

STUDY WITH NCAAR

Students at NCAAR have the unique opportunity to work not only within multiple departments at Mississippi State University but also within USDA disciplines.

NCAAR accepts master's and Ph.D. students within the following concentrations:

- agronomy
- agricultural and biological engineering
- irrigation and water
- management
- agricultural economics

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ncaar.msstate.edu

IRRIGATION & FERTILIZER MANAGEMENT

Wide-Spaced Furrow Irrigation Effects on Vertisols Under Corn Production

Trey Freeland, Drew Gholson, Himmy Lo, Gurbir Singh, Gurpreet Kaur, Erick Larson, and Joby Czarnecki

INTRODUCTION

The majority of soils in the Mississippi Delta are vertisols, whose shrink-swell behavior makes them prone to waterlogging when subjected to excessive infiltration amounts from conventional management of furrow irrigation. The goal of this investigation was to examine if corn (*Zea mays* L.) grain yield and quality can be improved in vertisols of this region by widening furrow irrigation spacing while increasing furrow inflow rate proportionally to reduce waterlogging. A research station study at the Delta Research and Extension Center and an on-farm study near Glen Allan, Mississippi, were conducted from 2021 to 2023. Furrow irrigation spacing treatments in the research station study included 3.3 ft, 6.7 ft, 13.3 ft, and 26.7 ft. The on-farm study included 10 ft, 20 ft, and "tractor track" (alternating between 10 and 30 ft furrow irrigation spacing) treatments. Wide-spaced furrow irrigation, irrigating every 8.2ft, has been shown to maintain corn grain yields and reduce the pumping costs for irrigations on fine to medium textured soils (Stone et al., 1982, 1985). Finer textured soils allow water to move as far laterally as it does downward, this feature along with wider spaced irrigated furrows allows for the soil surface to be comparatively drier (Stone et al., 1982).

Wide-spaced furrow irrigation could improve corn production in vertisols of the Mississippi Delta.

MATERIALS AND METHODS

Two study sites, on-station (DREC, Stoneville, MS) and on-farm (Glen Allan, MS), were implemented to evaluate the impacts of irrigation furrow spacings on corn production over three years. On-station, DKC 70-27 was planted on April 7, 2021, and March 31, 2023, and hybrid DKC 62-05 was planted on May 9, 2022 in 40-inch rows on 40-inch beds. Treatments are designated as 3.3 ft, 6.7 ft, 13.3 ft, and 26.7 ft. The top location begins 50 ft from the poly-tubing while the bottom location begins 400 ft from the poly-tubing; both subsections are 50 ft in length (**Figure 1**). Watermark moisture sensors (IRROMETER Company Inc., Riverside, CA, USA) were installed in the field after corn reached the V4 growth stage at depths of 6 in, 12 in, and 24 in. Irrigation was initiated when Watermark sensors weighted average reached -90 kPa. (See **Figure 1**).

On-farm, DKC 67-44 was planted on March 14, 2021, April 28, 2022, and March 28, 2023. The field was planted in 30-inch rows on 60-inch beds. Treatments are designated as 10 ft, 20 ft, and Tractor Track (TT). The TT treatment is spaced with two irrigated furrows on controlled traffic rows that are 10 ft apart with a 30 ft gap between each tractor track (**Figure 2**). Irrigation was scheduled with assistance provided by the grower's consultant (**See Figure 2**).

RESULTS AND DISCUSSION

Corn grain yields on-station showed that irrigating every 26.7 ft produced 8.5 bu/a more than all other treatments in the top location on the field (**Table 1**). The results show that there were no statistical differences between the treatments in the bottom location. Furrow irrigation inherently presents the section near the pipe (top location) with more opportunity time for water infiltration than the section of field farthest away from the pipe (bottom location). Longer opportunity times tend to lead to more water being infiltrated during irrigation

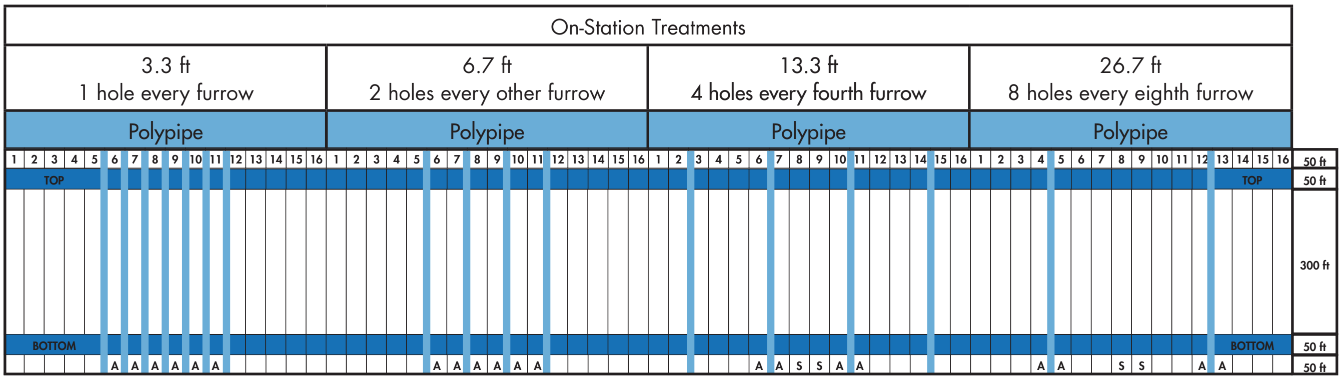

Figure 1: *Numbers 1-16 indicate corn rows, the blue vertical lines represent furrows irrigated, "A" represents section of corn row sampled for grain yield adjacent to irrigated furrows, and "S" represents section of corn row sampled for grain yield in the middle of the skip.*

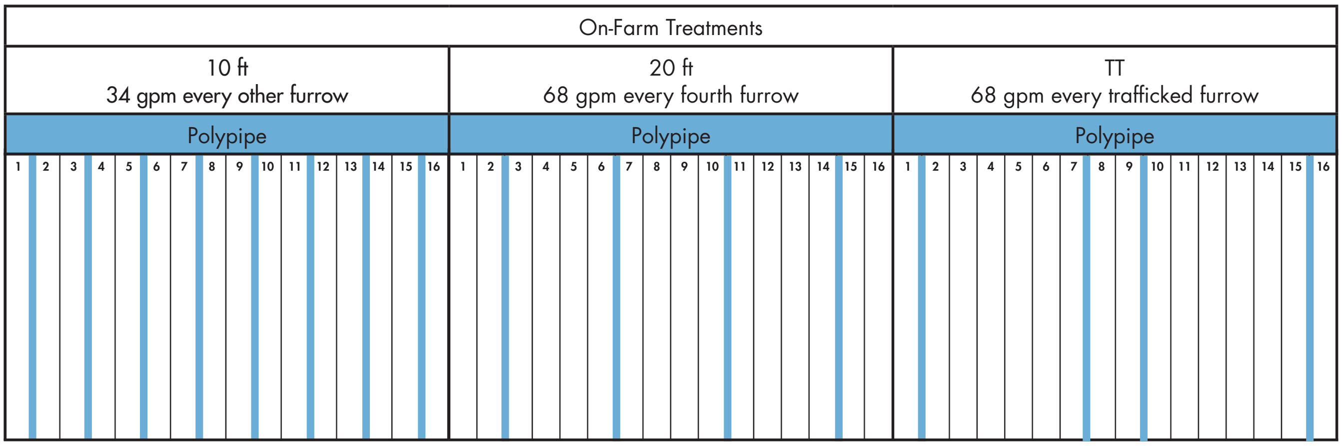

Figure 2: *Treatment designs for the 2021-2023 growing seasons; the blue vertical lines represent furrows irrigated.*

events (**See Table 1**).

Corn grain yields for on-farm showed that numerically TT had higher yield, but not statistically different (**Table 2**). This complements our finding for on-station yield that the widest spacing of 26.7 ft produced no yield loss (**See Table 2**).

CONCLUSION

These findings suggest that growers can widen irrigated furrows up to 30 ft in similar vertisols to maintain or even improve corn grain yield. While irrigating every 30 ft may not be ideal for every grower, it is important to note that a high capacity well is needed to maintain the same flow rate per length of poly-tubing. By reducing waterlogging, wide spaced furrow irrigation could improve corn production in vertisols of the Mississippi Delta and encourage growers to diversify crop rotations.

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Table 1. *On-station corn yield affected by the top and bottom location and irrigation spacing treatment for 2021-2023.*

Location	Treatment	Yield
		(bu/a)
Bottom	6.7 ft	151 a
Bottom	3.3 ft	149 a
Bottom	26.7 ft	147 ab
Bottom	13.3 ft	145 ab
Top	26.7 ft	140 b
Top	13.3 ft	131 c
Top	3.3 ft	129 c
Top	6.7 ft	126 c

**Values with the same letter are not statistically different at α=0.05.*

Table 2. *On-farm yields for 2021-2023.*

Treatment	Yield
	(bu/a)
10 ft	209
20 ft	207
TT	214

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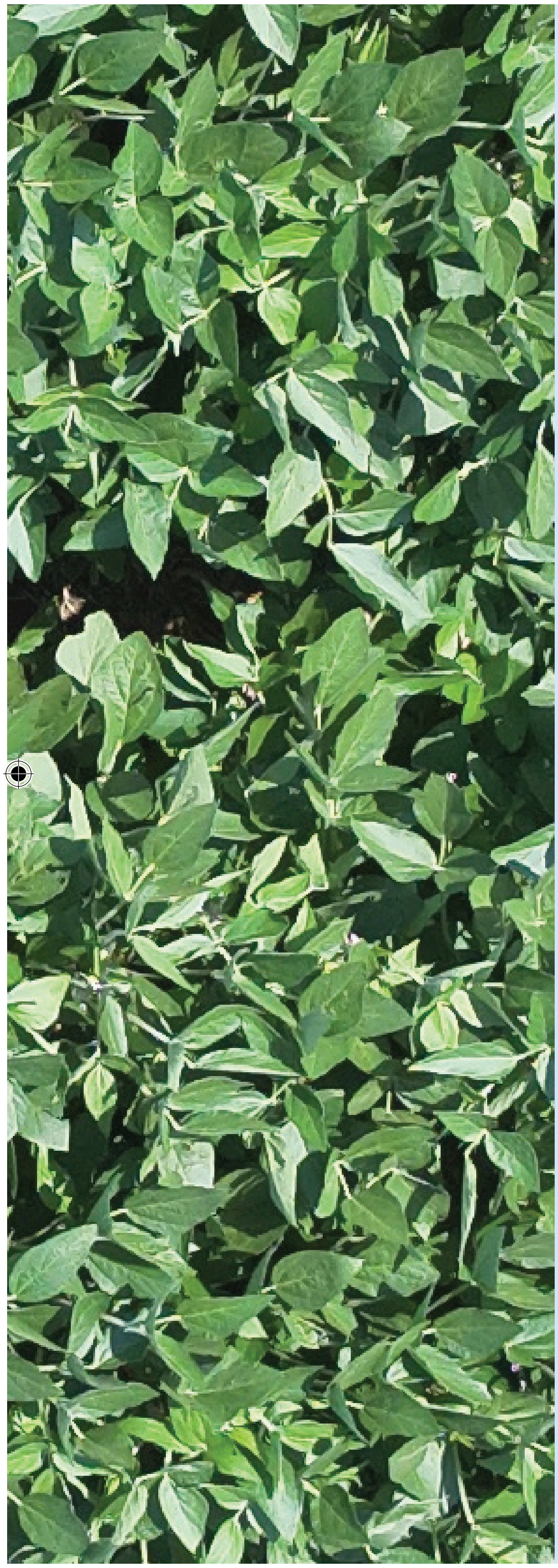

Monitoring Furrow Water Advance Using Drones

Himmy Lo, Robert Yanes, and Drew Gholson

INTRODUCTION

One way to improve furrow irrigation performance is to finetune set time (i.e., the amount of time that water is applied to an irrigation set). Optimal set times limit runoff while allowing relatively uniform infiltration of irrigation water along the furrows. The complication is that optimal set time depends on advance time (i.e., the amount of time that water takes to reach the bottom end of the field). Because the advance time of an irrigation set varies with soil moisture and furrow conditions, the optimal set time of an irrigation set may be different for each application throughout the year. If furrow water advance is monitored during each application, then set time can be finetuned on the fly based on those observations. However, monitoring furrow water advance in person can be labor-intensive, especially before advance is complete in any furrow.

Drones, particularly those with a thermal camera, might be a more efficient method for monitoring furrow water advance. A thermal camera maps the temperatures of the surfaces within its view by measuring the temperature-dependent intensity of infrared light from each surface. Thus, the cool furrow water can be distinguished from the warm plant leaves and the hot dry soil. Researchers at University of Southern Queensland have reported that

Drones, particularly those with a thermal camera, might be a more efficient method for monitoring furrow water advance.

furrow water advance can be monitored very successfully using a drone-mounted thermal camera and somewhat successfully using a drone-mounted color camera. Given these positive results from Australia, NCAAR researchers began local testing to determine the effectiveness and feasibility of this technology in the Lower Mississippi River Basin.

EXPERIMENT DESCRIPTION

An off-the-shelf drone—with both a color camera and a thermal camera built in—was flown over row-crop fields at Delta Research and Extension Center during furrow irrigation applications. With flights over the same soybean field on multiple irrigation dates, the main testing assessed the effect of canopy cover on monitoring furrow water advance using drones. Additional testing occurred over a corn field and over a cotton field. The two cameras were always pointed perpendicular to the ground, while the live video from these cameras was viewed in real time on the drone controller display with default settings.

PRELIMINARY FINDINGS

Testing confirmed that canopy cover interferes with the ability of both camera types to monitor furrow water advance. Plant leaves are not transparent, whether to the visible light sensed by color cameras or to the infrared light sensed by thermal cameras. Wherever a leaf is blocking the straight path between the furrow water and the camera, the camera is sensing the light from the leaf rather than the light from the furrow water. Consequently, monitoring furrow water advance becomes more challenging for both camera types as more leaves are above the furrow. Furrow water can be extraordinarily difficult to detect when it is flowing in a narrow trickle that is much closer to one of the two adjacent crop rows.

A major advantage of thermal cameras over color cameras seems to be a larger contrast between furrow water and shaded dry soil. Whereas both surfaces can appear similarly dark in color images (**Figure 1a**), the two surfaces can be more easily differentiated in thermal images (**Figure 1d**) because furrow water tends to be cooler than shaded dry soil. The practical benefit is that thermal cameras can monitor furrow water advance aboard higher and faster flights, so more irrigation sets can be monitored in the same amount of flight time. During testing in a soybean field with 90% canopy cover, the thermal camera monitored effectively at altitudes up to 400 feet, but the color camera monitored effectively at altitudes up to 100 feet only. This result is impressive considering that the resolution of the color camera was six times the resolution of the thermal camera. Though both camera types need low and slow flights when the crop canopy is closed, thermal cameras are generally superior for detecting water in those heavily shaded furrows (**Figures 1b and 1e**). Instead of color cameras that must catch glimpses of glistening water through dense foliage, thermal cameras highlight the water underneath unless its temperature is similar to the temperature of surrounding objects for reasons such as irrigating with warm surface water (**Figures 1c and 1f**).

In conclusion, drones can be a suitable method for monitoring furrow water advance in row-crop fields across the Lower Mississippi River Basin. Relying on the user to control the drone and to detect furrow water may be simpler for investigating a specific irrigation issue, for learning an unfamiliar furrow irrigation system, or for checking every irrigation set no more than once per application. On the other hand, automated drone flights with automated detection of furrow water may be more convenient for checking every irrigation set multiple times during every application. NCAAR researchers look forward to continuing to evaluate this and other emerging technologies for their potential to enhance farm profitability and environmental sustainability across the Lower Mississippi River Basin.

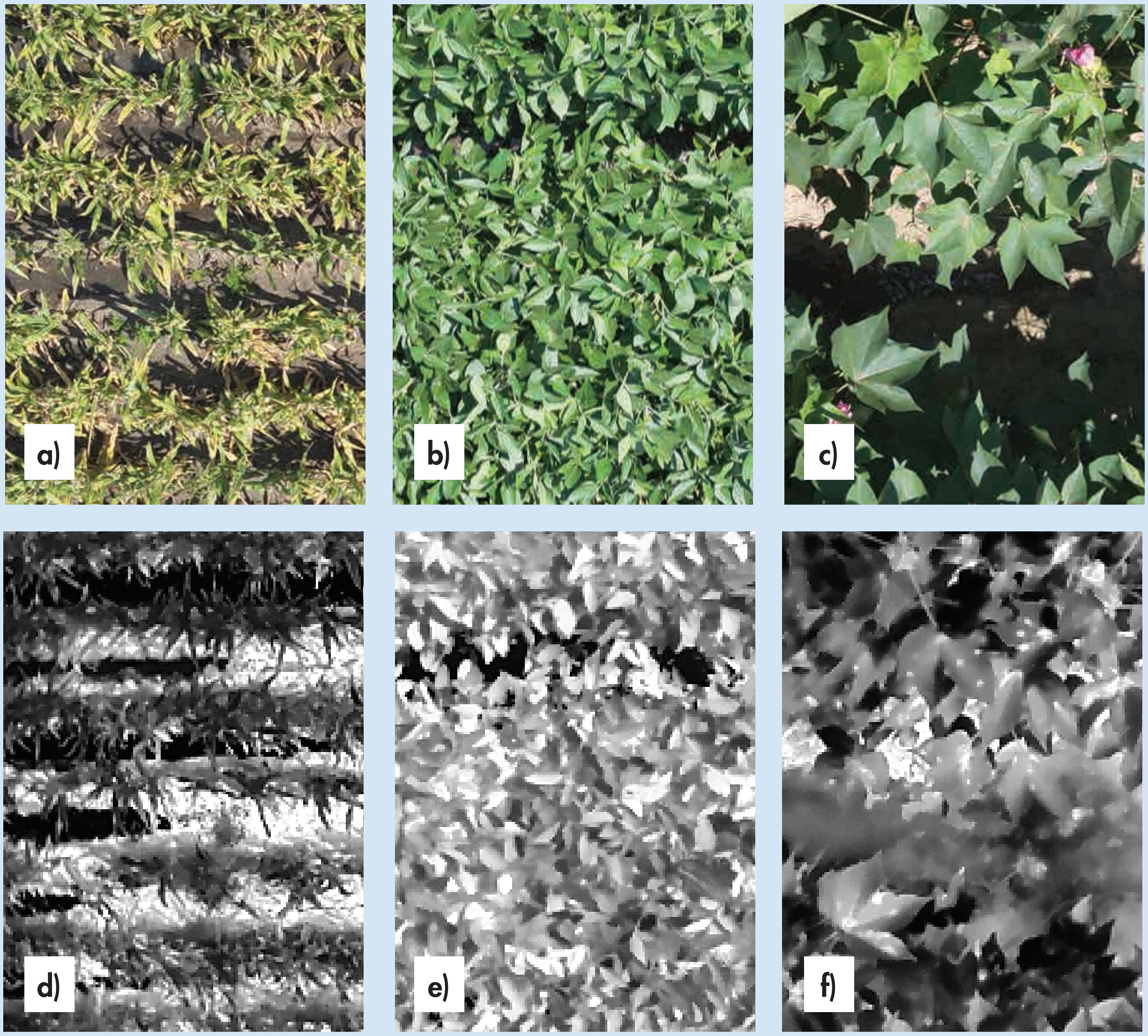

Figure 1. *The same furrow water fronts in corn (**a, d**), in soybean (**b, e**), and in cotton (**c, f**) as captured simultaneously by a color camera (**a, b, c**) and by a thermal camera (**d, e, f**); darker parts of these thermal images are cooler, whereas lighter parts of these thermal images are warmer*

The practical benefit is that thermal cameras can monitor furrow water advance aboard higher and faster flights, so more irrigation sets can be monitored in the same amount of flight time.

3-YEAR STUDY SUMMARY

Irrigation Method and Row Pattern Effects on Soybean Grain Yield and Water Use Efficiency

Amilcar Vargas, Drew Gholson, Himmy Lo, Gurbir Singh, Dave Spencer, and Jason Krutz

These results suggest that wetter irrigation thresholds are needed for sprinkler irrigated soybeans to achieve equal or greater soybean grain yields while saving water.

INTRODUCTION

The majority of soybeans in the Mississippi Delta are grown on heavy clay soils and irrigated with furrow irrigation systems. Water management practices are needed in Mississippi to improve irrigation water use efficiency (IWUE). Increasing IWUE will help to reduce the groundwater withdrawals from the Mississippi River Valley Alluvial Aquifer. The objective was to determine the effects of two irrigation methods and row patterns on soybean grain yield and IWUE in the Mississippi Delta.

MATERIALS AND METHODS

This 3-year study was conducted at the Delta Research and Extension Center on Sharkey clay soil during the growing seasons 2021, 2022, and 2023. Irrigation methods evaluated were furrow and sprinkler systems. In addition, a rainfed control was also included. Soybeans were planted in single, twin, and grain drill patterns in raised beds spaced at 40 inches. Field management operations such as tillage, weed, and pest control were conducted following Mississippi State University Extension Service recommendations. Irrigation decisions were based on the Watermark 200S soil moisture sensors, installed at 6-, 12-, and 24-inches depth in one block. In all years, the first irrigation event date occurred on the same date for both systems, following irrigation events were triggered when the weighted average of the 3 soil moisture readings was equal to -80 centibars (± 5 centibars). The weighted average was calculated following Mississippi

Table 1. *Soybean grain yield (bushels/acre) and IWUE (bushels per inch of irrigation water) averaged across 2021, 2022, and 2023 growing seasons.*

Treatments	Grain yield	IWUE
Irrigation		
Furrow	69.1 a	0.60
Sprinkler	66.5 b	0.86
Rainfed	63.2 c	not applicable
Row pattern		
Twin	68.9 a	0.69 ab
Single	67.0 b	(0.07) b
Drill	63.0 c	1.54 a

Table 2. *Total amount of water applied and the number of irrigation events in 2021, 2022, and 2023 growing seasons.*

Irrigation system	2021	2022	2023
Sprinkler			
No. irrigations	1	5	6
Total (inch)	0.9	7	6
Furrow			
No. irrigations	1	4	5
Total (mm)	4.6	13.5	12.7

State University Extension Service recommendations. Data collected included soybean grain yield and water amount applied. Irrigation water use efficiency was calculated by dividing the grain yield difference between the irrigated and rainfed plots by the total amount of irrigation water. Soybeans were harvested with a plot combine. The plot combine was equipped with an H2 grain gauge and paired with a computer for data recording, such as moisture content and weight. Soybean yield was adjusted to 13% moisture. For the statistical analysis data from 3-years was combined and analyzed using the GLIMMIX procedure in SAS. Mean separations were performed using Fisher's protected LSD at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Soybean grain yields observed in the furrow irrigated soybeans were 2.6 bu/acre greater compared to sprinkler irrigated soybeans (**Table 1**). These results agree with personal communications with soybean growers from the Mississippi Delta, especially in years with a reduced amount of rainfall. We think that using a -80 centibar threshold resulted in drier soil conditions in the sprinkler compared to the furrow system, this led to more water available in the furrow irrigated soybeans that was converted into grain yield. These results suggest that wetter irrigation thresholds are needed for sprinkler irrigated soybeans to achieve equal or greater soybean grain yields while saving water.

In terms of row patterns, the greatest IWUE was observed in the grain drill treatment producing 1.5 bu/acre per inch of irrigation water applied compared to single row soybeans, followed by the twin-row pattern with 0.69 bu/acre per inch of water. These results suggest that planting soybeans with grain drill or twin row planters can improve IWUE. The explanation for these results is that in narrow row and twin row planting configurations, plants have equal access to light, nutrients, and faster canopy cover.

Interestingly, the total amount of water applied by the sprinkler represented only 19-47% of the total amount of water applied by the furrow irrigation (**Table 2**). Our results are similar to those reported by Massey et al. (2017), who reported that furrow irrigators applied approximately 50% more water compared to sprinkler irrigation. The water conservation benefits of sprinkler irrigation could be a long-term solution to irrigate soybeans in the Mississippi Delta and reduce the groundwater withdrawals from the MRVAA.

Irrigation Thresholds, Nitrogen Rates, and Soil Texture Effects on Corn Grain Yield Under Sprinkler Irrigation

Amilcar Vargas, Drew Gholson, Himmy Lo, Gurbir Singh, Dave Spencer, and Jason Krutz

INTRODUCTION

Groundwater resource is the most exploited resource to irrigate row crops in the Mississippi Delta. The overuse and excessive pumping from agriculture and fisheries has exceeded the natural water recharge of the Mississippi River Valley Alluvial Aquifer (MRVAA). Limited research has been conducted on the use of overhead irrigation in corn production systems in the Mississippi Delta. Water and nitrogen are considered the major driving factors for corn production. Therefore, understanding the relationship between sensor-based irrigation and nitrogen rates on corn grown in sandy loam and clay under sprinkler irrigation would help to reduce the groundwater withdrawals from MRVAA.

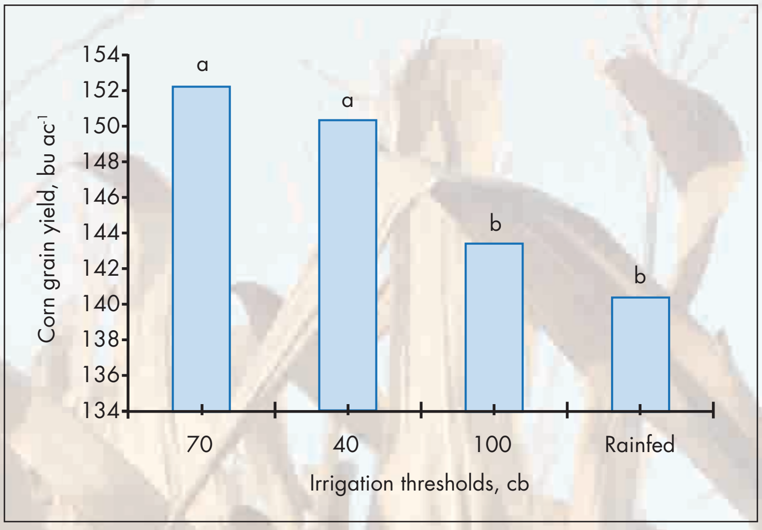

Figure 1. *Irrigation threshold (centibars) effects on corn grain yield (bu/acre). Data averaged over nitrogen rates and soil textures. Letters show significant differences at* α*=0.05.*

MATERIALS AND METHODS

This 3-year study was conducted at Delta Research and Extension Center, Mississippi State University, Stoneville, MS during 2021, 2022, and 2023. Three irrigation scheduling thresholds, based on soil water tension (-40, -70, -100 centibars, and rainfed control), four nitrogen rates (0, 100, 200, and 300 lbs N ac^{-1}), and two distinct soil textural classes (Sandy Loam and Clay) were evaluated. The nitrogen source was urea ammonium nitrate (UAN, 32%) applied in a single application at V6 growth stage. Field management operations such as tillage, weed, and pest control were conducted following Mississippi State University Extension Service recommendations. All treatments were replicated five times. The plot size for individual nitrogen rate treatment was 27 x 50 feet. In total, there were 160 plots. Soil moisture sensors were installed

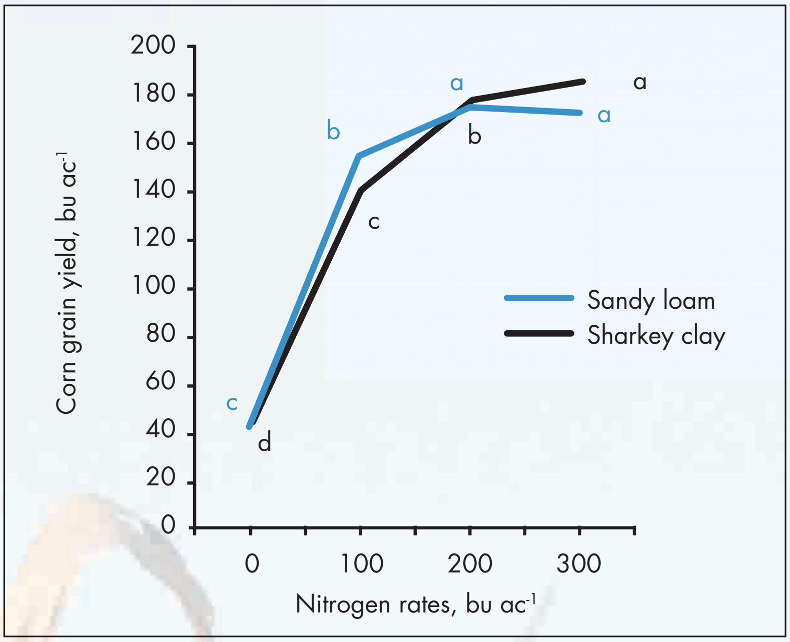

Figure 2. *Soil texture × nitrogen rates effects on corn yield. Data averaged over irrigation thresholds. Different letters within the same soil texture show significant differences at α=0.05*

at 6, 12, and 24 inches to determine soil moisture tension. Irrigation was triggered when the weighted average of the three sensors reached the irrigation threshold. Sensors at 6 and 12 inches were assigned 0.25 weight value each and 0.50 for the 24 inches depth sensor. Irrigation was terminated at R6 growth stage (black layer). The two middle row from each plot were harvested using a plot combine. Corn grain weight per each plot was recorded. Corn grain yield was adjusted to 15.5% moisture. For the statistical analysis, data from 3-years was combined and analyzed using the GLIMMIX procedure in SAS. Mean separations were performed using Fisher's protected LSD at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Corn grain yield was influenced by the irrigation thresholds (**Figure 1**) as well by the relations of soil texture and nitrogen rate applied (**Figure 2**). Corn grain yields achieved by the -40 (150.3 bu/ac) and -70 (152.3 bu/ac) irrigation thresholds were not statistically different when averaged over soil texture and nitrogen rates. Our results are similar to the irrigation initiation thresholds recommended for sprinklers by Krutz and Roach (2016). These results suggest that if the soil moisture tension is kept at -40 or -100 centibars all season long, corn yield may be reduced.

In our study, there were differences in corn yield at 200 and 300 lb nitrogen per acre on corn grown in sandy loam soil. However, in Sharkey clay soil, there was an increase of 8.2 bushel/acre from 200 to 300 lb of nitrogen per acre. These results agree with the Mississippi State University Extension Service, where corn nitrogen recommendations can be less in sandier soil compared to clay soils. Nutrient management practices that are site-specific can increase corn productivity in the Mississippi Delta.

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Water and nitrogen are considered the major driving factors in corn production systems in the Mississippi Delta.

Developing Other Methods of Scheduling Irrigation on Cracking Clay Soils

Himmy Lo and Robert Yanes

INTRODUCTION

Current recommendations on irrigation scheduling from Mississippi State University Extension Service involve the use of Irrometer Watermark 200SS soil moisture sensors. In response to stakeholder requests, NCAAR researchers have been developing recommendations on other sensor-based and non-sensor-based methods of scheduling irrigation. The goal is to expand the selection of scheduling methods that farmers in the Lower Mississippi River Basin can use to make financially and environmentally judicious decisions on irrigation timing. In 2023, an experiment at Delta Research and Extension Center advanced the development of recommendations on the use of Sentek Drill&Drop soil moisture sensors and of weather-based predictions for scheduling irrigation.

The goal is to expand the selection of scheduling methods that farmers can use to make financially and environmentally judicious decisions on irrigation timing.

EXPERIMENT DESCRIPTION

Four irrigation scheduling treatments, including a non-irrigated control, were each replicated in eight blocks of a field whose soil has been classified as Sharkey clay. The Irrometer Watermark treatment followed current recommendations from Mississippi State University Extension Service. Both the Sentek Drill&Drop treatment and the weather-based prediction treatment attempted to learn from previous years how to attain the highest yield with the least irrigation.

Soybean (Pioneer 47A64X) was planted on April 19 at 140,000 seeds per acre in 40-inch twin rows and reached full maturity on September 14. Between the R1 and R6.5 growth stages, furrow irrigation was scheduled according to treatment-specific rules (**Table 1**). No irrigation was applied during other growth stages. To minimize runoff, every irrigation application was cut off when water reached the bottom end of the field. The water volume of each irrigation application was measured by a propeller flow meter.

From an area 20 feet wide by 500 feet long in the center of each plot, the number of harvested bushels per acre was measured on September 19 using a yield monitor with load-specific calibration by a weigh wagon. The number of harvested seeds per pound was determined by weighing on a laboratory balance a sample of 1000 harvested intact seeds from each plot. The number of harvested seeds per acre was calculated from the number of harvested bushels per acre and the number of harvested seeds per pound. All three harvest variables were normalized to 13% moisture before any comparison was made.

PRELIMINARY FINDINGS

The irrigation scheduling treatments produced a statistically significant effect on seeds per acre ($p = 0.0009$), seeds per pound ($p < 0.0001$), and bushels per acre ($p < 0.0001$). Seeds per acre was the most for the Sentek Drill&Drop treatment (**Table 2**). During the seed-setting period, the lower irrigation frequency of this treatment was likely advantageous because it relieved drought stress but avoided irrigating shortly before considerable rain (which occurred twice for both the Irrometer Watermark treatment and the weather-based prediction treatment). On the other hand, seeds per pound was the fewest (i.e., seed weight was the highest) for the Irrometer Watermark treatment (**Table 2**). The higher irrigation frequency of this treatment was likely beneficial during the seed-filling period, which was characterized by sparse rainfall and by daily maximum air temperatures averaging above 95°F. In contrast, mediocre performance was achieved by the weather-based prediction treatment (**Table 2**), whose decreasing irrigation frequency with the progression of the irrigation season may have been unsuitable. The non-irrigated control treatment led to the fewest bushels per acre, the most seeds per pound (i.e., the lightest seeds), and among the fewest seeds per acre (**Table 2**).

In terms of bushels per acre, the Sentek Drill&Drop treatment was statistically indistinguishable from (and numerically higher than) the Irrometer Watermark treatment despite the former receiving two fewer irrigation applications and 2.8 inches less total irrigation. Consequently, the Sentek Drill&Drop treatment stood out from the general trend of obtaining higher yield with more irrigation. Further research is planned in preparation for releasing proven guidelines on using Drill&Drop sensors and weather-based predictions to schedule irrigation across the Lower Mississippi River Basin.

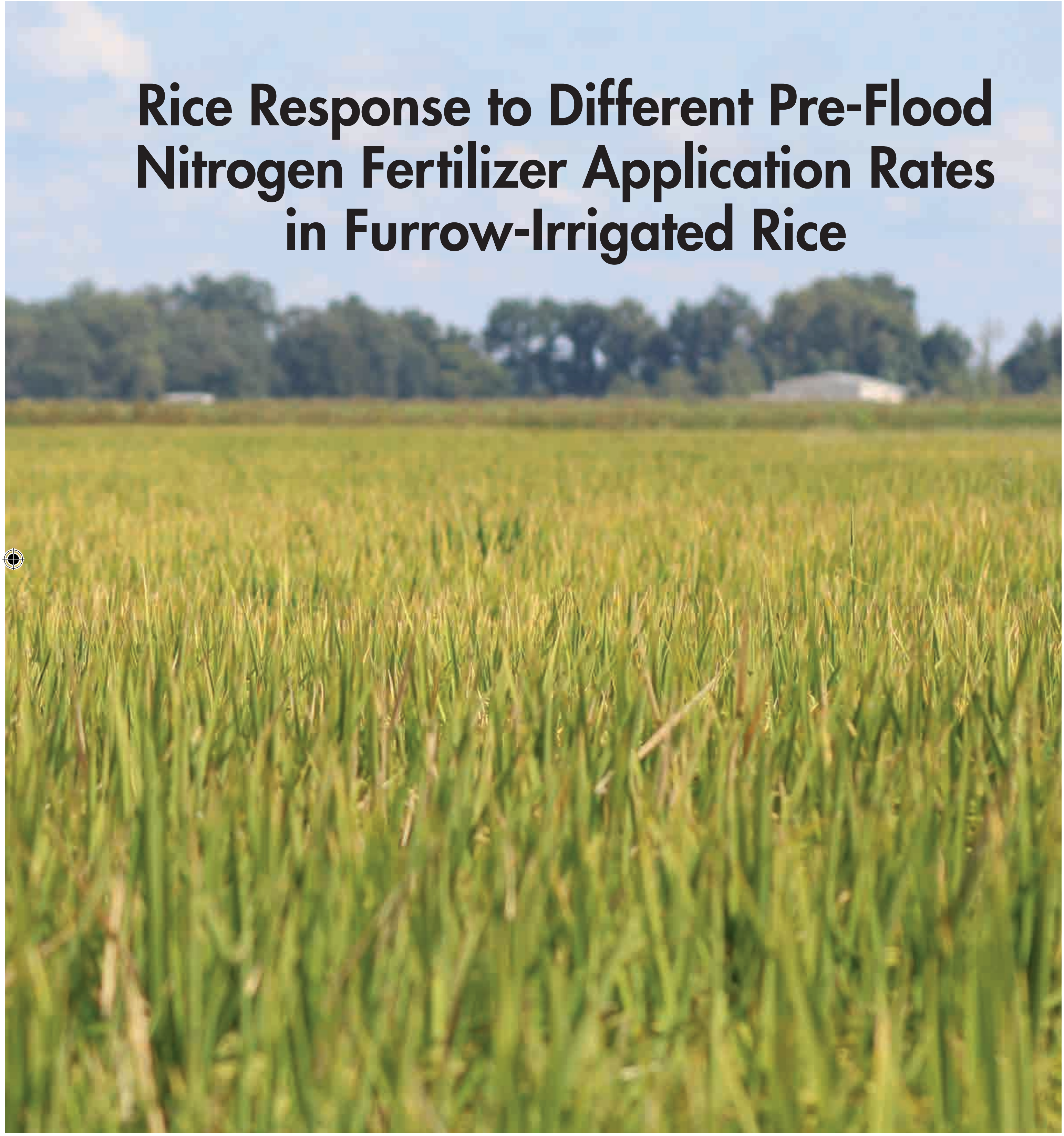
Table 1. *Irrigation scheduling rules for each of the four treatments.*

Scheduling Method	Irrigate ...
Irrometer Watermark	if Watermark soil water tension has increased to 70 centibars
Sentek Drill&Drop	if Drill&Drop relative drying rate has decreased to 80 percent
Weather-Based Prediction	if crop has experienced drought stress for two days
Non-Irrigated Control	never

Table 2. *Tentative results from the 2023 field experiment; for each harvest variable, treatments that shared a superscript letter were not statistically different in that variable according to pairwise t tests (α = 0.05).*

	Irrigation		Harvest		
Scheduling method	**Applications**	**Total Inches**	**Million Seeds Per Acre**	**Seeds Per Pound**	**Bushels Per Acre**
Irrometer Watermark	7	13.6	18.6^{B}	3363^{A}	92.4^{A}
Sentek Drill&Drop	5	10.9	19.2^{A}	3452^{B}	92.9^{A}
Weather-Based Prediction	6	13.1	18.3^{BC}	3497^{B}	87.4^{B}
Non-Irrigated Control	0	0	18.1^{C}	3894^{C}	77.6^{C}

Rice Response to Different Pre-Flood Nitrogen Fertilizer Application Rates in Furrow-Irrigated Rice

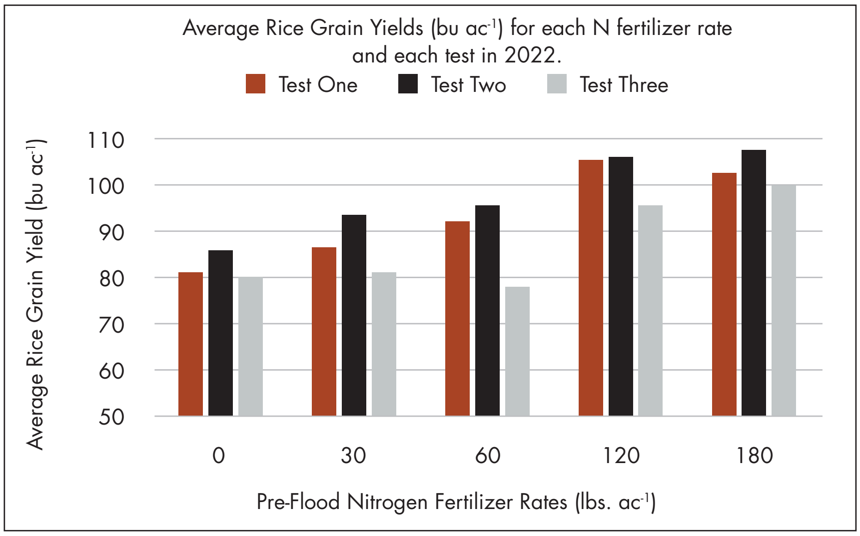


Anna Smyly and
Drew Gholson

Sponsored by Mississippi Rice Research Promotion Board

INTRODUCTION

Rice (*Oryza sativa* L.) requires large amounts of water throughout the growing season due to rice growth and development thriving under saturated, flooded conditions. Irrigation water for rice growers in the Mississippi Delta is extensively drawn from the Mississippi River Valley alluvial aquifer (MR-VAA). Aquifer depletion has become a concern for the sustainability and future use of the aquifer. Furrow-irrigated rice (FIR) has become an increasingly popular method of growing rice with less water. However, drawbacks still exist with nonuniform yields and fertility unknowns. Plant uptake of nitrogen (N) fertilizer applications tend to be more unpredictable due to the aerobic environment of FIR. The objective of this study is to evaluate the effect of different pre-flood N fertilizer rate applications in FIR.



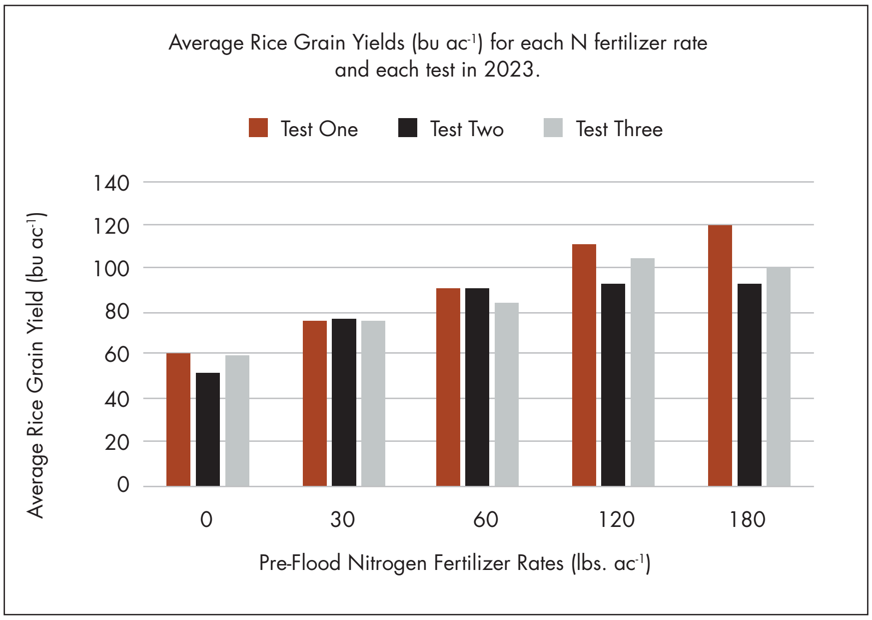


***Figure 1.** (top) Average rice grain yield (bu ac^{-1}) for each nitrogen fertilizer rate and each test in 2022. **Figure 2.** Average rice grain yield (bu ac^{-1}) for each nitrogen fertilizer rate and each test in 2023.*

MATERIALS AND METHODS

Research was conducted at the Delta Research and Extension Center in Stoneville, MS from 2021 to 2023. Five pre-flood N treatments (0, 30, 60, 120, & 180 lbs. ac^{-1}), each replicated 3 times, were arranged in randomized complete block experimental design. Rice cultivar, CLL16, was planted into 2 row plots (7 ft. x 50 ft.) on 38” row spacing. Fertility treatments were broadcast applied using a manual variable rate fertilizer spreader at the 4 – to – 5 leaf growth stage. Irrigation water delivery began after the pre-flood N fertilizer applications and continued every 3 to 5 days throughout the growing season. Plant height, whole plant nutrient analysis (mid-season & harvest), and lodging rates were collected at harvest. Rice grain yield and milling yield were collected at harvest. All data was analyzed using statistical software SAS.

RESULTS AND DISCUSSION

Rice grain yield data in 2022 and 2023 shows a gradual increase in

Table 1. *Average rice grain yield (bu ac^{-1}) for each pre-flood nitrogen fertilizer rate and each of the 3 tests in 2022. Color denotes heat map of average yields with red indicating the lowest yields and green indicating highest yields.*

Nitrogen Rate (lbs. ac^{-1})				
0	30	60	120	180
Rice Grain Yield (bu ac^{-1})				
63	67	83	92	91
72	90	89	99	107
89	89	99	109	111
75	88	96	116	102
94	101	94	110	100
91	88	93	105	107

Nitrogen Rate (lbs. ac^{-1})				
0	30	60	120	180
Rice Grain Yield (bu ac^{-1})				
69	73	69	80	88
82	84	94	88	99
86	93	95	107	104
90	103	104	124	119
96	100	115	121	117
94	108	100	115	119

Nitrogen Rate (lbs. ac^{-1})				
0	30	60	120	180
Rice Grain Yield (bu ac^{-1})				
68	70	59	68	66
71	67	65	102	117
72	73	87	118	98
84	111	83	98	83
97	80	93	106	99
89	86	80	82	137

Table 2. *Average rice grain yield (bu ac^{-1}) for each pre-flood nitrogen fertilizer rate and each of the 3 tests in 2023. Color denotes heat map of average yields with red indicating the lowest yields and green indicating highest yields.*

Nitrogen Rate (lbs. ac^{-1})				
0	30	60	120	180
Rice Grain Yield (bu ac^{-1})				
19	28	44	42	60
39	58	73	82	106
65	69	100	100	106
72	95	105	128	143
88	103	106	144	150
81	102	119	169	152

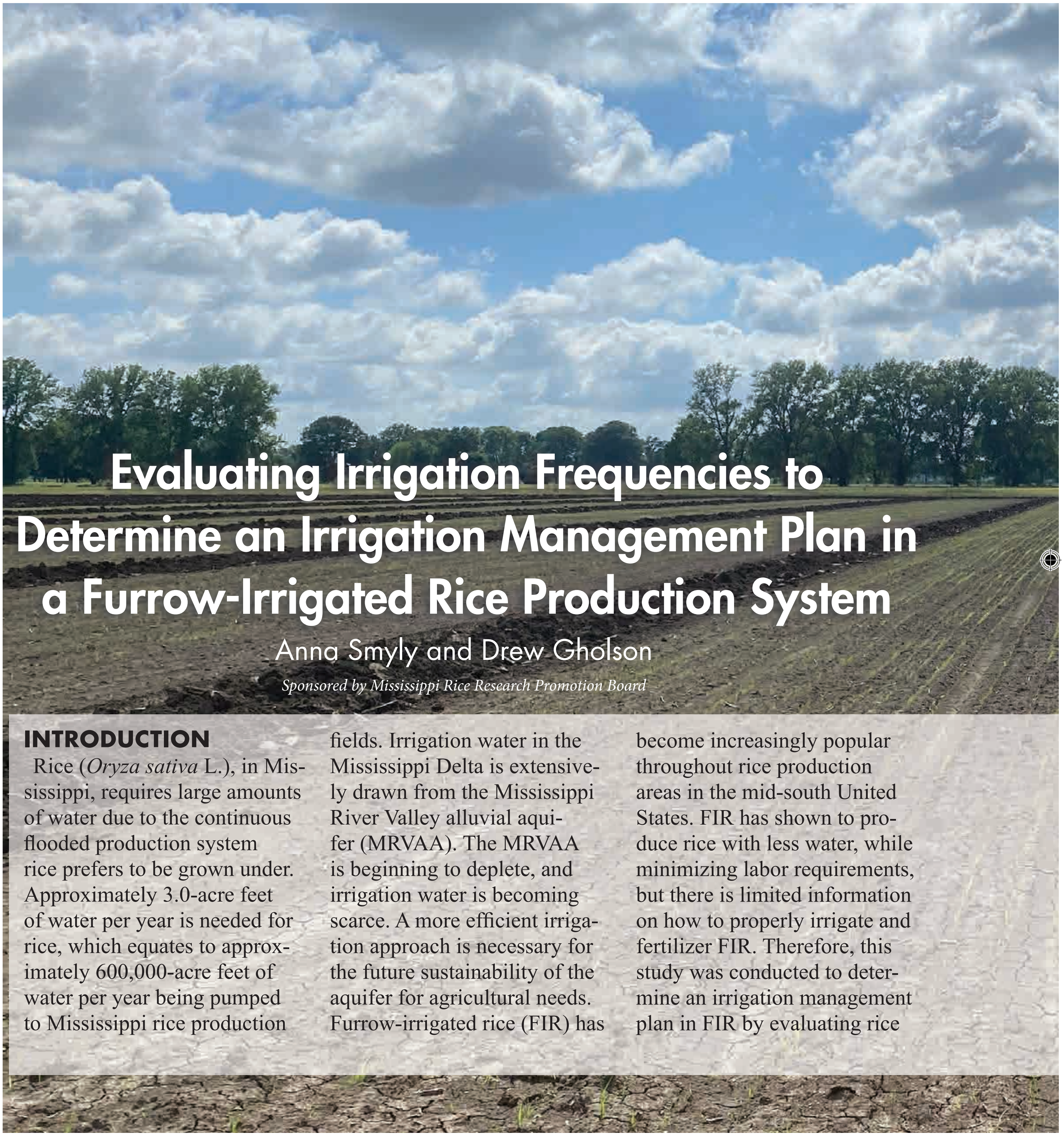
Nitrogen Rate (lbs. ac^{-1})				
0	30	60	120	180
Rice Grain Yield (bu ac^{-1})				
16	36	27	41	28
32	71	87	60	80
50	68	80	92	82
74	100	112	114	112
64	94	123	131	130
76	92	109	118	122

Nitrogen Rate (lbs. ac^{-1})				
0	30	60	120	180
Rice Grain Yield (bu ac^{-1})				
13	18	20	25	34
30	43	63	79	76
52	72	87	103	97
66	112	115	132	127
99	99	124	144	141
95	111	94	143	131

yield, numerically, from the lowest N fertilizer rate of 0 lbs ac^{-1} to the highest N fertilizer rate of 180 lbs ac^{-1} for all 3 fertility tests (**Figure 1 & 2**). **Table 1** (2022) and **Table 2** (2023) show a heat map of average rice grain yields for each fertility rate within the top, middle, and bottom zones of each test. Red indicates the lowest yields and green indicates the highest yields. Across all 3 tests in 2022 and 2023, average yield data indicated no N response in the upper zones of the treatment plots. However, the plots in the bottom zone of each treatment test tended to have greater yields than the other 2 zones of the treatment test. In 2023, average yield tended to only reach its highest point for plots that received 120 and 180 lbs. ac^{-1} in the bottom zone of the treatment test.

CONCLUSION

This study indicated regardless of the pre-flood N fertilizer rate, the plots in the top zone of each treatment test had no N response. The upper zone of FIR fields tends to dry out more quickly compared to the middle and bottom zones. This can lead to N losses and decrease plant efficiency of N fertilizer applications. The study also indicated the higher the pre-flood N fertilizer application rate, rice growth and development has greater potential to have increased yields compared to lower pre-flood N fertilizer rates. Overall, higher yields were observed in the plots in the bottom zone of the FIR field regardless of the N fertilizer application rate. More research will need to be done in order to conclude the cause of N losses and how to overcome N loss pathways in FIR to maximize FIR growth and development.



Evaluating Irrigation Frequencies to Determine an Irrigation Management Plan in a Furrow-Irrigated Rice Production System

Anna Smyly and Drew Gholson

Sponsored by Mississippi Rice Research Promotion Board

INTRODUCTION

Rice (*Oryza sativa* L.), in Mississippi, requires large amounts of water due to the continuous flooded production system rice prefers to be grown under. Approximately 3.0-acre feet of water per year is needed for rice, which equates to approximately 600,000-acre feet of water per year being pumped to Mississippi rice production fields. Irrigation water in the Mississippi Delta is extensively drawn from the Mississippi River Valley alluvial aquifer (MRVAA). The MRVAA is beginning to deplete, and irrigation water is becoming scarce. A more efficient irrigation approach is necessary for the future sustainability of the aquifer for agricultural needs. Furrow-irrigated rice (FIR) has become increasingly popular throughout rice production areas in the mid-south United States. FIR has shown to produce rice with less water, while minimizing labor requirements, but there is limited information on how to properly irrigate and fertilizer FIR. Therefore, this study was conducted to determine an irrigation management plan in FIR by evaluating rice

response to different irrigation frequencies.

MATERIALS AND METHODS

Research was conducted at the Delta Research and Extension Center in Stoneville, MS from 2021 to 2023. Four irrigation frequencies on a calendar-based schedule of irrigating every day, every 3, 5, and 7 days, each replicated 3 times, were arranged in a randomized complete block experimental design. Rice cultivar, CLL16, was planted at a seeding rate of 73 lbs. ac^{-1} in 8 row wide treatment plots. Border levees were placed on each side of each treatment plot, as well as, perpendicular to the furrows on the back end of the plots to eliminate irrigation water bleed over and hold water on the treatment plots. Soil moisture, water level depths, and water usage were recorded before and after each irrigation occurrence from the top, middle, and bottom one-thirds of each treatment plot using WaterMark® Soil Moisture Sensors®, Pani-Pipes®, Precision King AgSense Sensors®, and flowmeters. Rice grain yield and milling yield were collected across the whole plot, as well as within the different zones in each plot in order to evaluate the spatial variability among yield and treatments. Data was analyzed using statistical analysis software (SAS).

RESULTS AND DISCUSSION

Average rice grain yield (bu ac^{-1}) measurements were taken from the whole plot, as well as the 3 different zones within each treatment plot. Table 1 shows the average rice grain yields for each irrigation frequency treatment in 2021, 2022, and 2023. The study observed in 2021 and 2023, plots irrigated everyday had a higher yield (152 & 180 bu ac^{-1}) compared to the other 3 treatments. Average yield of the everyday treatment in 2022 was numerically higher, but not statistically different from the other 3 treatments. Irrigating every 7 days produced the lowest yields (140 & 144 bu ac^{-1}) in 2021 and 2023. In all 3 years, the bottom zone produced a numerically higher yield compared to the yield in the top zone of each treatment plot.

Water data was collected to calculate irrigation water usage (mm) and irrigation water use efficiency (IWUE). Figure 1 shows irrigation water usage (in) for each irrigation frequency treatment in 2022 and 2023. Figure 2 shows IWUE for each irrigation frequency treatment in 2022 and 2023. Irrigating everyday resulted in the greatest water usage and lowest IWUE, numerically, compared to the other 3 treatments. In contrast, irrigating every 7 days had the lowest water usage and highest

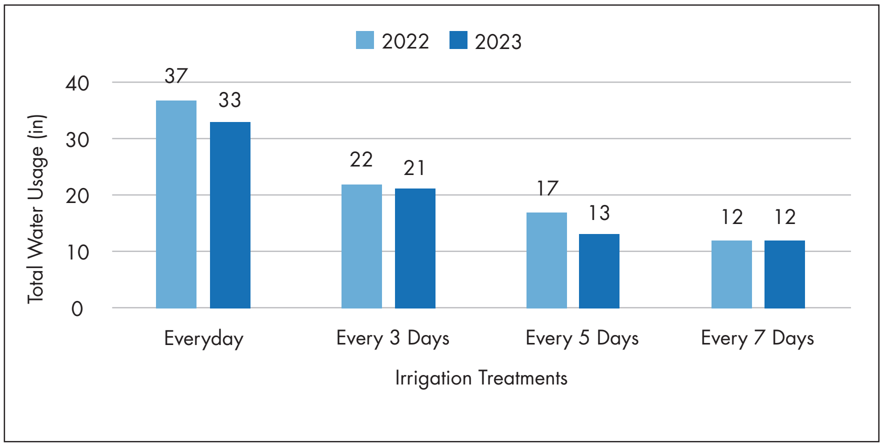


Figure 1. *Irrigation water usage (in) for each irrigation frequency treatment in 2022 and 2023.*

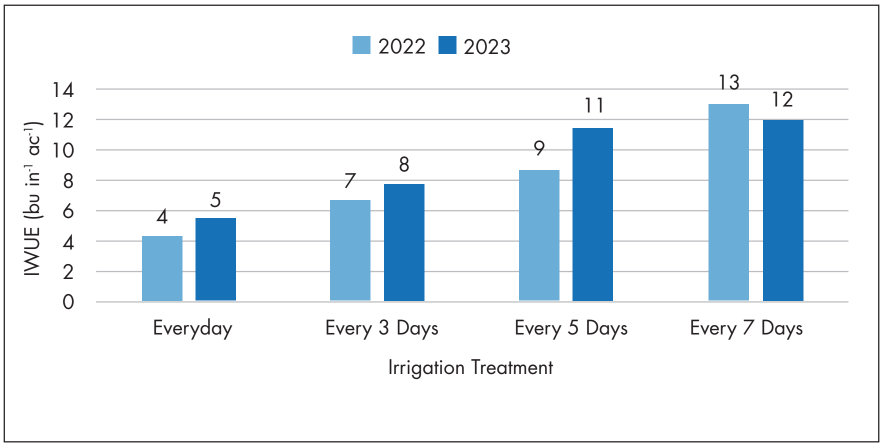


Figure 2. *Irrigation water use efficiency (IWUE) for each irrigation frequency treatment in 2022 and 2023.*

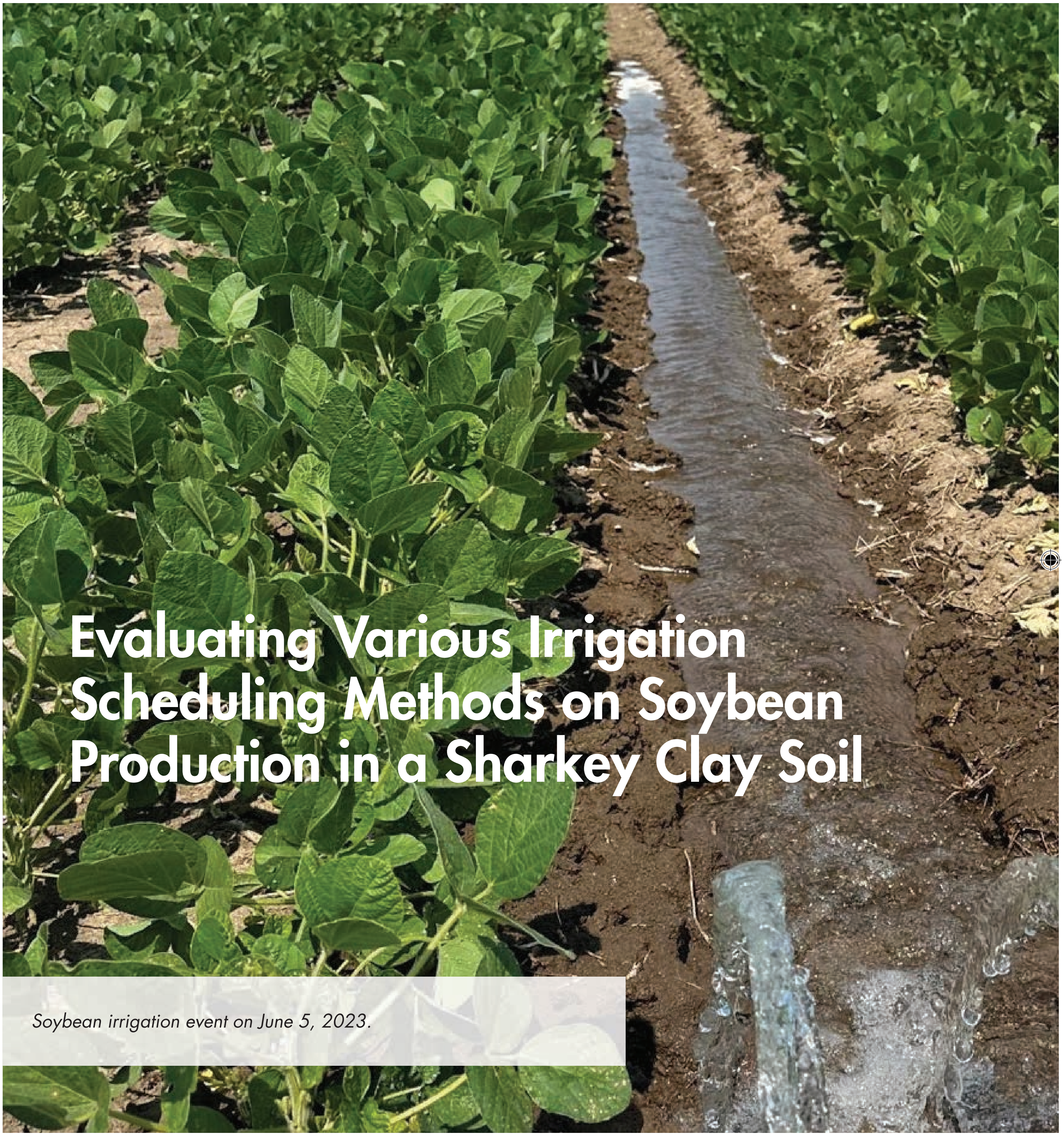
Table 1. *Average rice grain yield (bu ac^{-1}) in 2021, 2022, and 2023 for each irrigation frequency treatment. Numbers followed by the same letter are not significantly different at α = 0.05.*

Treatment	2021	2022	2023
Everyday	152 a	158 a	180 a
Every 3 Days	144 b	146 a	164 ba
Every 5 Days	143 b	147 a	149 bc
Every 7 Days	140 c	157 a	144 c

IWUE, but also resulted in the lowest average yield.

CONCLUSION

Data from 2021, 2022, and 2023 suggests irrigating FIR everyday will produce a higher yield compared to irrigating every 3, 5, or 7 days. However, irrigating everyday will have the highest water usage and lowest IWUE. Treatment plots irrigated everyday closely mimic a continuous flooded production system, which could explain why watering FIR everyday produced a higher yield, higher water usage, and lower IWUE. Irrigating everyday allows the plots to stay saturated to maximize rice growth and development. Data in 2022 contradicts the results in 2021 and 2023 by showing no significant differences in yield between any of the 4 treatments. Lodging and inconsistent irrigation water delivery down the furrows was an issue in 2022, which could have led to more similar yields. Constructing a well built-up seed bed with straight furrows is important for irrigation water delivery in FIR. FIR is becoming increasingly popular, but the efficiency and sustainability of FIR is still to be determined.



Evaluating Various Irrigation Scheduling Methods on Soybean Production in a Sharkey Clay Soil

Soybean irrigation event on June 5, 2023.

Dillon Russell

Sponsored by Mississippi Soybean Promotion Board

INTRODUCTION

Irrigation scheduling is a decision of when and how much water to apply to a field. The purpose of irrigation scheduling is to maximize irrigation efficiency by applying the exact amount of water needed to replenish the soil profile. Studies have shown that producers typically apply more water than needed to maximize crop yield, demonstrated through research using advanced technologies such as soil moisture sensors that accurately measure the amount of water in the profile. Additionally, companies have begun to focus on irrigation water management, and have developed hardware and software products that aid in making irrigation management decisions. Therefore, the objective of this study was to evaluate several different types of irrigation scheduling methods on soybeans grown in a Sharkey Clay soil.

MATERIALS AND METHODS

The study was initiated in the spring of 2023 at the Delta Research and Extension Center. The experiment was designed as a randomized complete block with three replications. Each replication included eight-row plots (each 26.67 ft x 450 ft) on 40" row spacing. The irrigation scheduling methods evaluated in this study were: Watermark 200SS soil moisture sensors triggered at a weighted average of -75 kPa, Simplot's SmartFarm Irrigation service, Goanna Ag's irrigation scheduling service, an National Center for Alluvial Aquifer (NCAAR)-developed Sentek relative depletion rate method, an NCAAR-developed soil water balance model, a soil water balance model app (SI Crop Fit) developed by the University of Georgia and Florida, a weekly calendar schedule, and a no irrigation control. The soybean variety selected for this study was Asgrow 47XF2 planted at 130,000 seeds/acre. The study was furrow-irrigated and utilized a skip-row irrigation pattern. Irrigation was delayed until the crop reached the R2 growth stage. Subsequently, irrigation events were triggered when each of the respective treatments called for irrigation. Irrigation was terminated when the crop reached the R6.5 growth stage. Data collection for this study included soybean yield and total water use.

RESULTS AND DISCUSSION

Soybean yield showed minimal differences among most of

Table 1. *Number of irrigations, total water applied (in.), and yield (bu/ac) results for each irrigation scheduling treatment during the 2023 growing season. Each irrigation scheduling treatment has a corresponding-colored raindrop that is used in* ***Figure 1****.*

Irrigation Method	# of Irrigations	Total Water Applied (in.)	Yield (bu/ac)
Watermark (-75 kPa)	5	10.90	76.5 ab
Simplot SmartFarm Irrigation	4	11.77	76.3 ab
Goanna Ag	7	12.40	74.8 bc
NCAAR Sentek Relative Depletion Rate	4	10.40	79.0 ab
NCAAR Soil Water Balance	4	9.43	79.9 a
Weekly Calendar Schedule	6	10.53	75.7 ab
SI Crop Fit (UGA/UF)	3	8.40	75.5 ab
No Irrigation Control	0	0	70.3 c

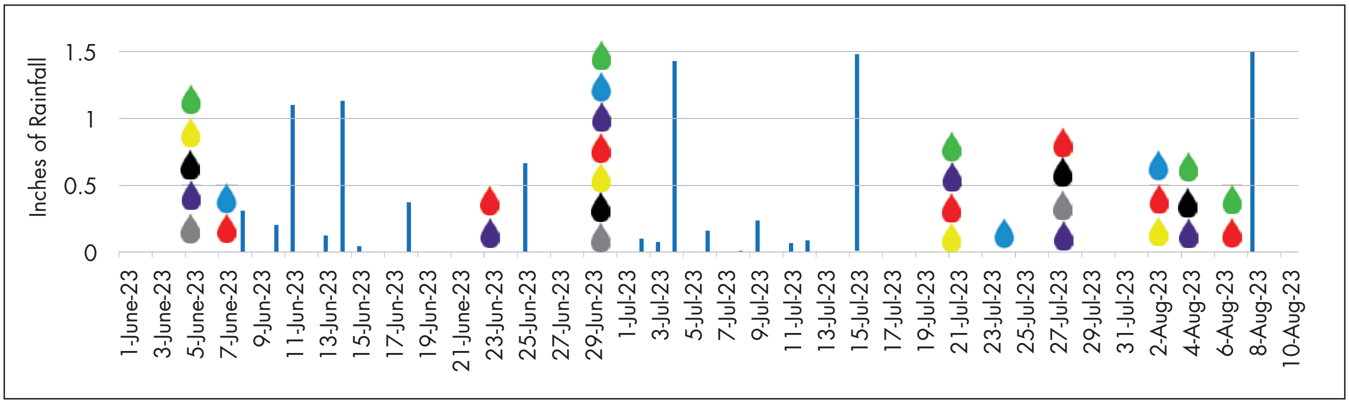


Figure 1. *Total rainfall (in.) and irrigation dates throughout the 2023 growing season. Each colored raindrop represents an irrigation event for the corresponding irrigation scheduling treatment. The color of raindrops for each treatment can be found in* ***Table 1****.*

the irrigation scheduling methods; however, the NCAAR soil water balance model was 5 bu/ac higher than Goanna Ag's irrigation scheduling service. Since soybean yield was not much different among the treatments, the total number of irrigations per treatment becomes the more important factor in this case. Among the treatments, the SI Crop Fit app was irrigated the least (3x) during the growing season and produced a 70.3 bu/ac crop. Furthermore, the NCAAR soil water balance model and the NCAAR Sentek relative depletion rate method called for irrigation four times during the growing season and produced numerically the highest yield at 79.9 and 79.0 bu/ac, respectively. The Watermark (-75kPa) method (5x), the weekly calendar method (6x), and Goanna Ag's irrigation scheduling service (7x) called for irrigation more than the aforementioned treatments with similar yield, suggesting that the additional irrigation applications were not needed to sustain yield.

CONCLUSION

In the first year of this study, most of the irrigation scheduling methods tested showed no differences in yield; however, the total number of irrigations and total water applied varied. Because of this, treatments with fewer irrigation applications would be the most profitable. This study will continue for the 2024 growing season. The irrigation scheduling methods used in this study will be repeated with the possibility of adding more methods.

Determining How Polypipe Hole Size and Field Shape Impact Cotton Water Use and Yield

Amanda M. Nelson

Programs, including the Delta Plastics Pipe Planner Program, were designed to create efficient irrigation plans under an array of field shapes using variable hole sizes in polypipe irrigation. However, little is known about how these irrigation plans impact water use efficiency and crop yield. Therefore, the objective of this study was to determine the effectiveness of this program on water use and cotton yield from regular and irregularly shaped fields. The second year of the project occurred in the 2023 growing season. The site consists of four fields located in Washington County, Mississippi (33.429777, -90.948461) at the corner of Old Leland Rd and Potter Rd (**Figure 1**) at the Delta Research and Extension Center West Farm facility. Fields were planted with Delta Pine 2115 at 40" row spacing. The big rectangle and triangle (**A and B in Figure 1**) were irrigated according to the plan determined by the Delta Plastics Pipe Planner program (referred to as CHS for computerized hole selection). The rhombus and little triangle (**C and D in Figure 1**) were irrigated under a "business as usual" plan to represent a plan that a farmer might use to irrigate similar fields in the Delta.

Each length of polypipe had its own flow meter. There was one per riser, plus one additional length using a T-pipe on the riser between the two rectangle fields. The rhombus and little triangle (**C and D in Figure 1**)

Figure 1. *The Cotton Triangle Fields include: (**A**) the big rectangle, (**B**) the big triangle, (**C**) the rhombus, and (**D**) the little triangle. Red dots indicate risers. Black dot is the well pump.*

Figure 2. *To examine the uniformity of flow post-harvest, drone images were taken (**a**, showing a subsection of the big triangle with CHS as rows were watering out), along with the recording of manual timings of individual rows watering out (**b**, big triangle with CHS).*

utilized two risers, dividing the field into two. The southern end used one size hole in the polypipe until the field starts to taper, at which point the end was tied off and the pipe from the second riser used (creating the little triangle). The pipe from the second riser used two sizes of holes; 3/8" for 135 rows, 7/16" for the remaining rows until the field started to taper again (~280 rows), then back to 3/8" for the remainder.

The big rectangle (**A in Figure 1**) used two hole sizes, per the CHS output; 1/2" for 165 rows and 9/16" for the remaining ~230 rows. The triangle (**B in Figure 1**) used the CHS plan in **Table 1**.

Water was applied as recommended by the Goanna Ag GoField sensoring system (Queensland, Australia), until the longest rows were wet. The Goanna GoField comprehensive system integrates field sensor data, satellite imagery, and integrated algorithms that provide critical information for making field specific, precise irrigation scheduling decisions, thereby reducing water use and increasing water use efficiency.

Preliminary results show that CHS used an average of 26% less water on the triangular fields in 2022 and 19% in 2023.

These fields are also being used for a post-harvest project to monitor irrigation uniformity with the above CHS plans via drone imagery and geospatial statistics (**Figure 2**). Drone flights recorded the water movement down the furrows using multi-spec imagery over time, while researchers took note of the time it took to water out the rows of varying lengths.

Table 1. *CHS plan for the polypipe for the big triangle field (**B in Figure 1**).*

Hole Size	Furrow Count
5/16"	18
3/8"	8
7/16"	9
1/2"	10
9/16"	11
5/8"	11
11/16"	13
3/4"	47
11/16"	46
5/8"	37
9/16"	33
1/2"	28
7/16"	25
3/8"	21
5/16"	41

Water Use Efficiency for Sweetpotato in North Carolina

Amanda M. Nelson

INTRODUCTION

Mississippi is a leading state in sweetpotato (*Ipomea batatas*) production in the United States, with a total of 30,000 planted acres in 2022 (USDA-NASS 2023). Sweetpotato is rapidly becoming an important crop with the state's production outperforming the reported growth at the national level. With the recent recorded growth, sweetpotato currently ranks 7th among crop commodities in MS with a statewide production value of $91.5 million in 2022 (MSU Extension Service and NASS, 2023), highlighting the economic importance of sweetpotato production in the state.

The role of water in sweetpotato's growth and yield is vital. Climate change is leading to increased extremes in both frequency and intensity of droughts and floods. Water deficits reduce leaf water potential and total water use, and subsequently reduce total plant mass and storage root yield. The uncertainty in water supply makes it necessary to understand the role water has in sweetpotato cultivation, including water use (WU) and water use efficiency (WUE). Little research has been done on WU and WUE in sweetpotato and field studies are rare, especially within the United States.

MATERIALS AND METHODS

As a preliminary step to address this research need and calculate regional values, WU and WUE were measured and calculated for the 27 cultivar trials being conducted by ARS and NC State in North Carolina in two locations over three years.

Water use (WU) for each treatment was calculated as the residual of a soil water balance:

$WU = P + I - D - R - \Delta SWC$ (1)

where: WU = water use, P = precipitation (in), I = irrigation (in), D = drainage (in), R = runoff (in), and ΔSWC = changes in soil water content (in). Runoff (R) and drainage (D) were not quantified during the trials.

And WUE was calculated as:

WUE = Total yield (lbs ac-1)/WU (in)

As these sites had no irrigation, WU was equal to precipitation. All trials had an average rainfall of 18.7 in (17.8 at one site, 19.8 at the other) during the growing period, which was an average 116 days (114 at one site, 119 at the other). The world average WU for sweetpotato is estimated to be 19.7 in (Afzal et al. 2021), putting North Carolina around that level even without irrigation added.

RESULTS

Total lbs of sweetpotato yield per acre, per in ranged from 166.8 to 3449.8, with an average of 902.3, which is at the upper end of previous world-wide estimates of sweetpotato WUE. WUE varied widely for the different cultivars (Figure 1). For the two most common varieties in North Carolina, Beauregard and Covington, WUE were comparable (Figure 2). It was interesting to note the decrease in WUE between the two generations (G2 and G3) of each variety, most likely due to a decreased yield from disease pressure.

As the goal for this project is to determine regional WU and WUE values, more data will be added to this study. Data from Mississippi, South Carolina, and another set from North Carolina have been acquired for analysis.

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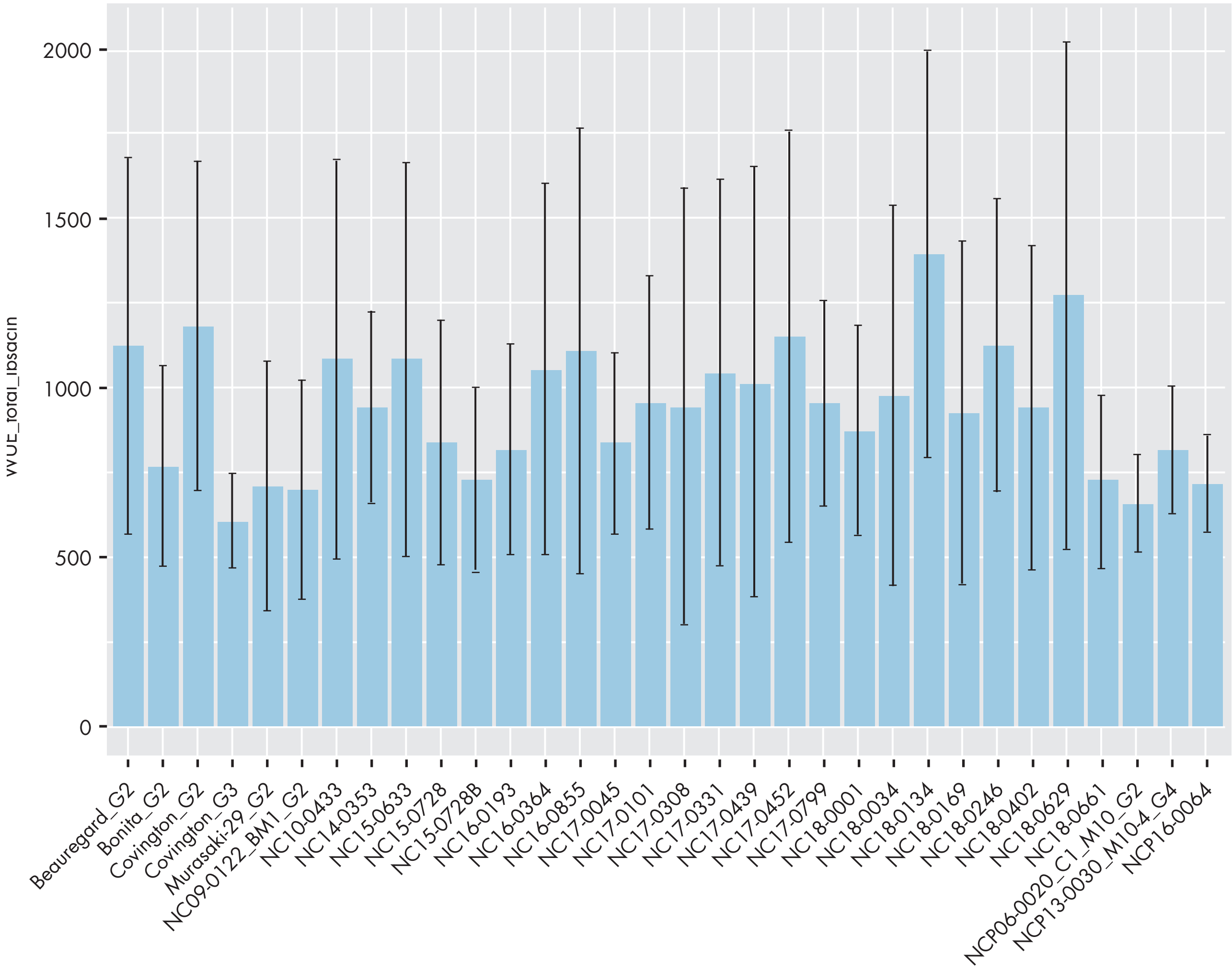
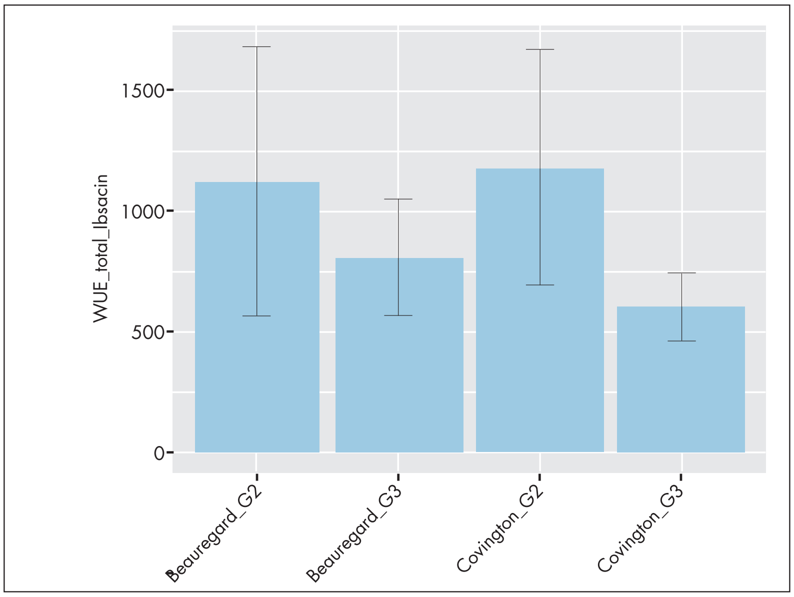


Figure 1. *Mean water use efficiency for select cultivars in North Carolina trials (2020-2023). Cultivar names deliberately obscured for proprietary reasons.*
Figure 2*. Mean water use efficiency for Beauregard and Covington varieties within the North Carolina trials (2020-2023).*



Legacy Phosphorus in Agricultural Soils and Sediments of the United States: Unique Context of the Mississippi Delta

Zach Simpson, Joshua Mott, Pete Kleinman, Lisa Duriancik, Lindsey Witthaus, Ethan Pawlowski, and Martin Locke

INTRODUCTION

Phosphorus (P) is a key nutrient for crop production but it is also the fuel for eutrophication of our waterways. An extreme yet nearby example of this issue is the Gulf of Mexico, where a major hypoxic zone (where oxygen is depleted, severely impacting the ecosystem) persists year after year due to high nitrogen and P loads in the Mississippi River. While we know many good practices to tackle P pollution today, we struggle with the 'legacy' of historical P inputs. Simply, P sticks around for decades or longer and continues to pollute waters.

The USDA Legacy P project is a national scale research effort to advance the science on legacy P. We focus on 7 watersheds in the Conservation Effects Assessment Project (CEAP), one of which is the Beasley Lake watershed near Indianola, MS. In this phase of the project, we study in-depth the P characteristics of a wide variety of soils and sediments with an eye towards generalized relationships describing P availability in the environment. Here we highlight some of the unique challenges for legacy P in some soils of the Delta.

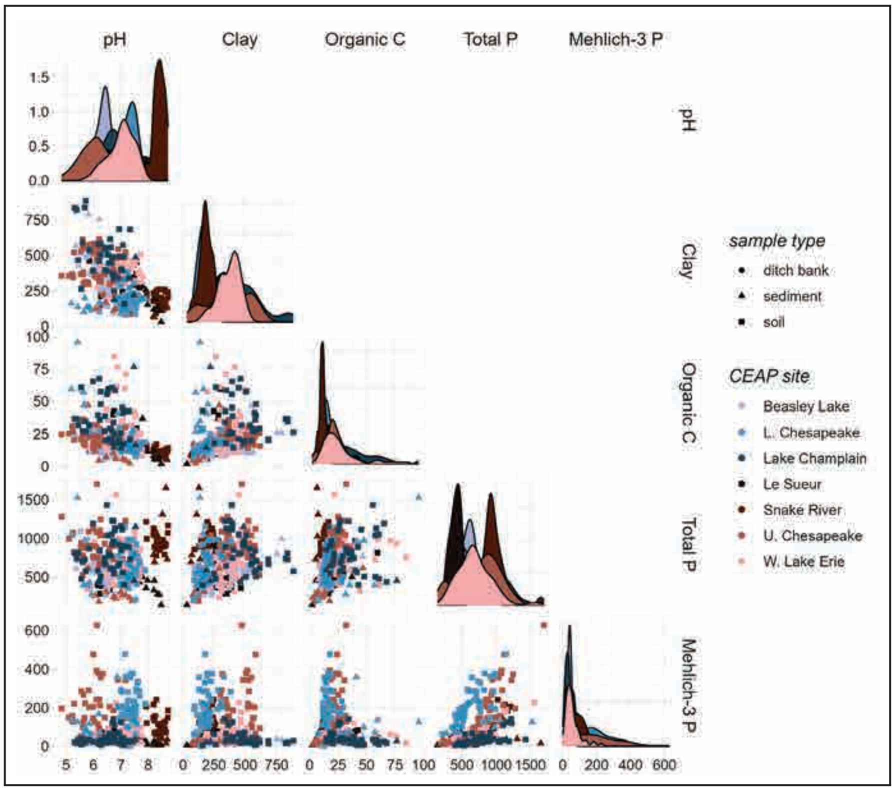


Figure 1. Correlation matrix of general properties for topsoils and sediments in the Legacy P project.

MATERIALS AND METHODS

More than 600 soils and sediments were collected across 7 CEAP watersheds with a pronounced P history: Beasley Lake (MS), Le Sueur River (MN), Snake River (ID), Western Lake Erie Basin (IN), the Upper (PA) and Lower (MD) Chesapeake Bay watershed, and the Lake Champlain basin (VT). Using a common laboratory, we analyzed the samples for a battery of physical and chemical properties including some with particular focus on P. These involved, for example, the chemical nature of P (pools of redox-sensitive P, various soil test P), P buffering strengths, and P sorption properties.

The data here can improve watershed models, guide further process understanding around P chemistry, and ultimately benefit P stewardship.

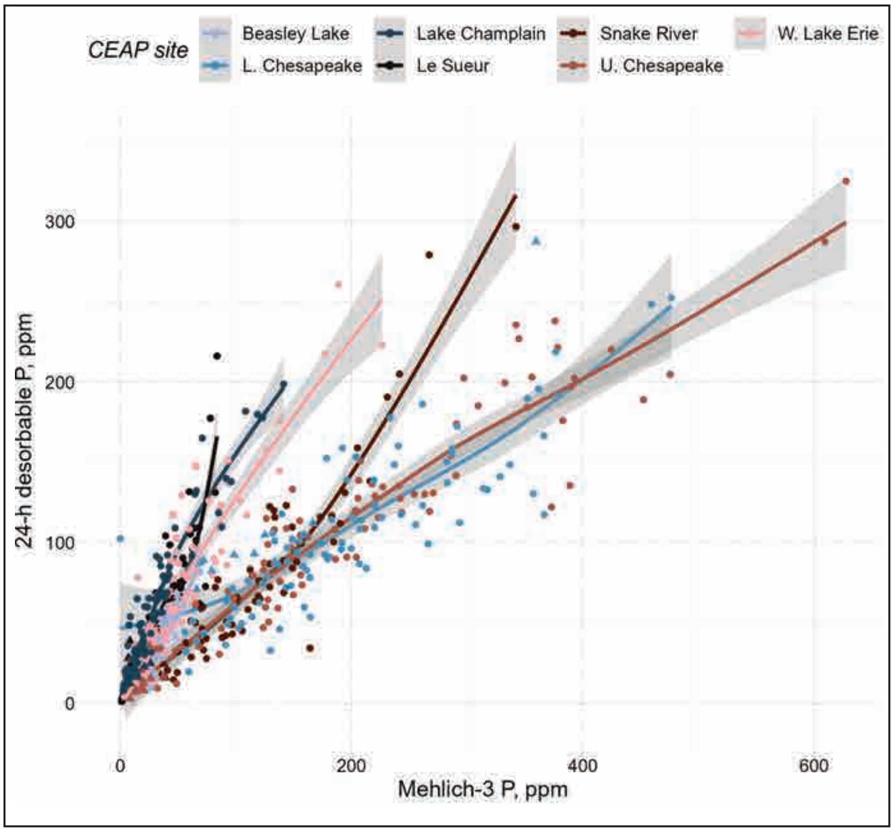


Figure 2. *Site-specific relationships between the maximum amount of P desorption in 24-hour period (a measure of the P loss potential) and soil test P.*

RESULTS

Soils, and sediments derived from them, across the project spanned a diverse range of soil types, pH, clay contents, organic matter, and P concentrations (**Figure 1**). Typical agronomic optimum values for soil test P are usually ~20 to 50 ppm P (for Mehlich-3); the averages for the soils here ranged far above the optimum (37 to 219 ppm depending on site), with maximum Mehlich-3 ranging from 70 to 630 ppm P. Further evidence of the history of P inputs at these sites is the stratification ratio: soil test P in the top 2 in. of soil was on average 8% (Snake River) to 140% (W. Lake Erie) greater than that in the 2-6 in. depth.

The soils and sediments here displayed a weak capacity to buffer more P inputs. The average equilibrium P concentrations at net zero sorption (a measure of the P concentration that soil/sediment buffers water P concentrations towards) were 0.057 (Beasley Lake) to 1.25 (Upper Chesapeake) ppm P. Taking Beasley Lake as an example, soils and sediments here will buffer P concentrations in runoff towards 0.057 ppm P, yet the concentrations needed to trigger eutrophication in lakes and streams can often be as low as 0.002 to 0.030 ppm P (~2-30 fold lower).

The data also shows that soils/sediments impacted by legacy P can release more P into solution than expected. Many watershed models predict similar field-scale P losses given a soil test P value, but **Figure 2** suggests that this relationship is highly site-specific. Soils/sediments from sites such as Beasley Lake can even lose more P to water than what soil tests estimate, this surprising result speaks to the large store of legacy P built up in these soils and sediments.

CONCLUSIONS

Legacy P is a grand challenge for nutrient pollution management. The data here can improve watershed models, guide further process understanding around P chemistry, and ultimately benefit P stewardship. The impacts of legacy P will be highly site-specific, but there is potential for identifying relationships that generalize across settings. Soils in the Delta may behave much like those at Beasley Lake: even for apparently modest soil test P, the potential for P loss to waters looms large.

Soil Redox Dynamics Under Furrow Irrigation and the Effect on Phosphorus Mobility

Zach Simpson, Lindsey Witthaus, Trey Freeland, Drew Gholson, Amanda Nelson, Andrea Simpson, Ethan Pawlowski, Martin Locke, and Matt Moore

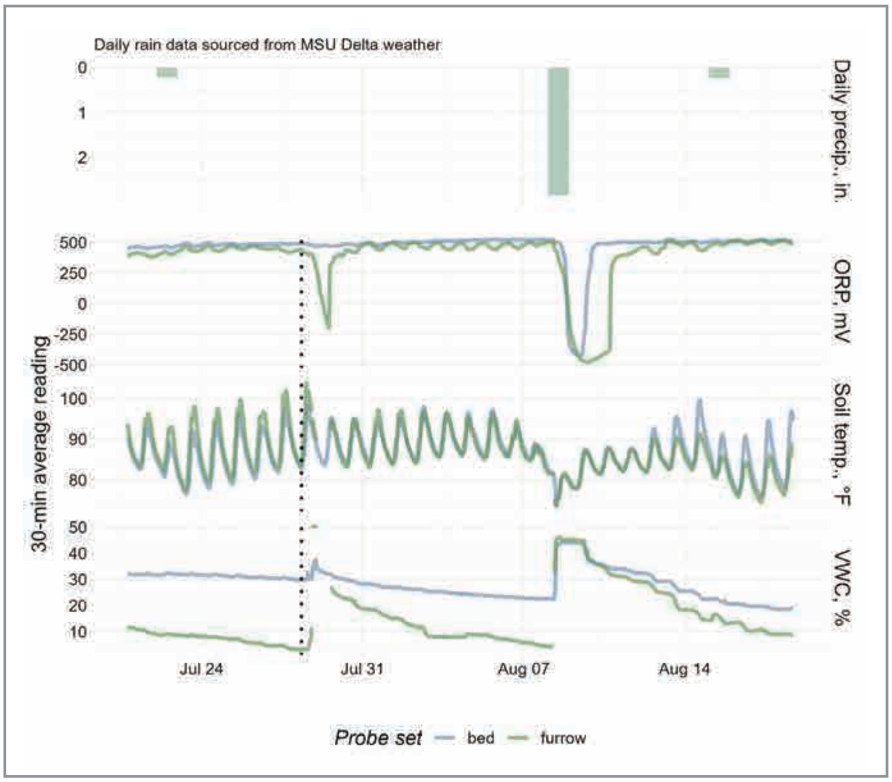


Figure 1. *For the corn experiment during the 2023 season, timeseries of soil moisture (as volumetric water content; VWC), temperature, and soil oxidation-reduction potential (ORP) as well as daily precipitation at a nearby weather monitoring station. The dotted line indicates an irrigation event. Two probe sets were deployed within 6 ft of each other to a depth of 2 in., one within a bed and the other in a nearby furrow. The irrigation event was approximately 13h in duration.*

The groundwater source for irrigation in the Mississippi Delta is particularly high in dissolved iron, as anyone will note when looking at rust-stained irrigation pipes and pumps. This is a result of the aquifer's reduced status: due to microbially driven processes within the aquifer, such as respiration, oxygen is depleted and iron is reduced from Fe(III) to Fe(II). Once this water is pumped to the surface, the dissolved iron is exposed to atmospheric oxygen and can then oxidize back to Fe(III). However, iron in soils may also reduce and mobilize following rain or irrigation events due to water-logging.

This cycling of iron is complex but may be important to how phosphorus (P) – a key plant nutrient but also a harmful pollutant – moves through furrow-irrigated fields. We hypothesize two important implications for the region: (1) Iron-bound P may be unavailable to plants during key growth stages due to the increased presence of iron oxides; and (2) large rain events or even runoff as a result of irrigation may mobilize large amounts of P to our waterways if the soil redox conditions are right.

MATERIALS AND METHODS

We studied two fields, both located at the Delta Research and Extension Center (DREC), during the 2023 growing season: corn under different skip-row irrigation treatments and cotton on irregularly-shaped fields. Soils at the two fields are Dowling clay (corn) and Bosket very fine sandy loam (cotton). Soils were collected (0-2 in.) across the full length of the fields and for 3-4 field replicate plots. Soils were sampled 1 day before and several days (~5-10 days) after irrigation events to measure the impact of irrigation on soil iron and phosphorus contents and their chemistry. Water samples were collected at the polypipe and within furrows during irrigation events to measure how iron chemistry and P concentrations progressed across the field and over time. Samples were filtered in the field, with an additional acidified subsample collected to measure iron speciation.

We deployed sets of soil probes within the fields for the following measurements: volumetric water content, soil temperature, electrical conductivity, and oxidation-reduction potential (ORP). Probes were located within crop beds and furrows.

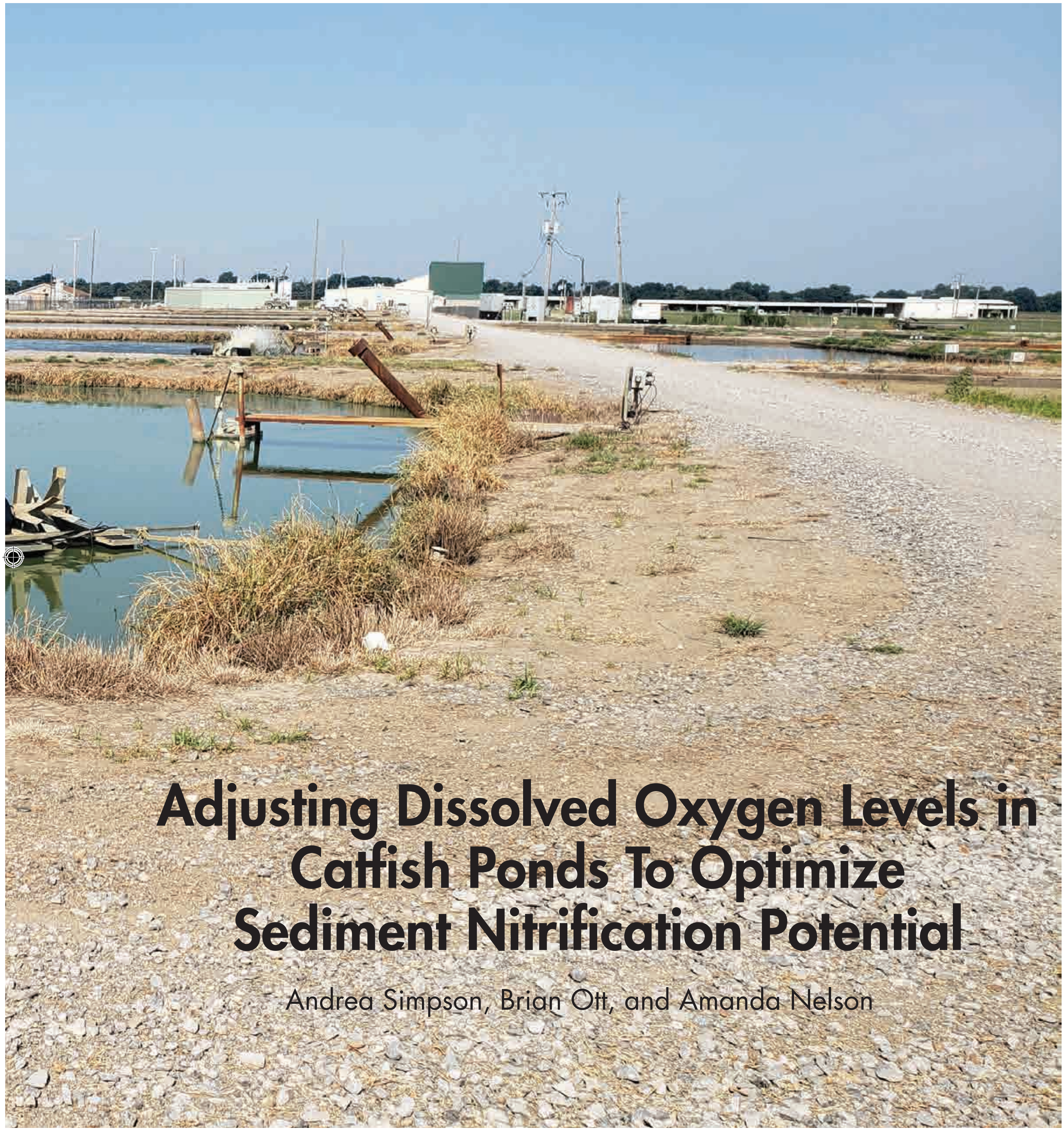
Figure 2. *(**Top left**) one of the soil data logging stations within the corn field; (**top right**) a soil redox probe freshly installed in the cotton field; (**middle**) irrigation water advancing down a furrow in the cotton field, note the hydrophobic nature of the soil and the iron oxide deposits; (**bottom**) water sample filters from an irrigation event on the cotton field, arranged from up-field to down-field.*

PRELIMINARY FINDINGS AND NEXT STEPS

Soil redox status was highly sensitive to rain events and, depending on location within the field, to irrigation events (**Figure 1**). Redox measurements within furrows were sensitive to both precipitation and irrigation events; ORP usually plummeted from an oxidized status (~400 mV) to a reduced status (~-100 to -500 mV). For the same relative soil depth but in a crop bed, soil redox status was less variable unless large events occurred (e.g., a 2.85 in. rain on August 8th). Reduced status also persisted longer for furrow soil.

We observed in the field that iron oxides developed on the soil surface within furrows, particularly for the silt-loam planted in cotton. Water samples during irrigation events developed a stronger rust color as irrigation progressed, particularly for samples collected near the bottom of the field. These visual cues point to the strong presence of iron oxides, which will be investigated further once water and soil samples are processed in the laboratory. Laboratory analyses should be completed during 2024. Additionally, we observed during soil sampling that the cotton field (silty loam soil) developed a soil crust following irrigation events which was notably absent in the rainfed sections of the field. Further experiments are being planned to investigate how iron cycling may impact soil-water processes such as infiltration.

Figure 1. *Catfish ponds at the Delta Research and Extension Center in Stoneville, MS.*



Adjusting Dissolved Oxygen Levels in Catfish Ponds To Optimize Sediment Nitrification Potential

Andrea Simpson, Brian Ott, and Amanda Nelson

Figure 2. *Catfish pond with active automatic aerator.*

INTRODUCTION

In aquaculture systems, efficient nitrification of ammonia-nitrogen is a crucially important process for maintaining high production (Kuhn et al., 2010). Ammonia originates from animal and feed waste and is toxic to fish in relatively low concentrations. In contrast, nitrate, which is the end-product of nitrification, can be tolerated by fish at relatively high concentrations. Although it is well known that efficient nitrification is important for fish health, growth, and survival rates, it remains unclear why nitrification rates in some large, commercial catfish ponds are below the optimum, leading to an accumulation of ammonia that may compromise fish production. Nitrification is an aerobic process, and so an insufficient supply of oxygen may reduce nitrification rates.

The "shaken-slurry" method is commonly used for measuring potential nitrification rates in soils (Belser & Mays, 1980). Although this method has been used for sediment samples, it is still uncommon and mostly confined to samples from estuaries (Sanders & Laanbroek, 2018). Considering that catfish ponds are a very different ecosystem with much higher nutrient loads than estuaries, it was unknown whether the shaken-slurry method could be

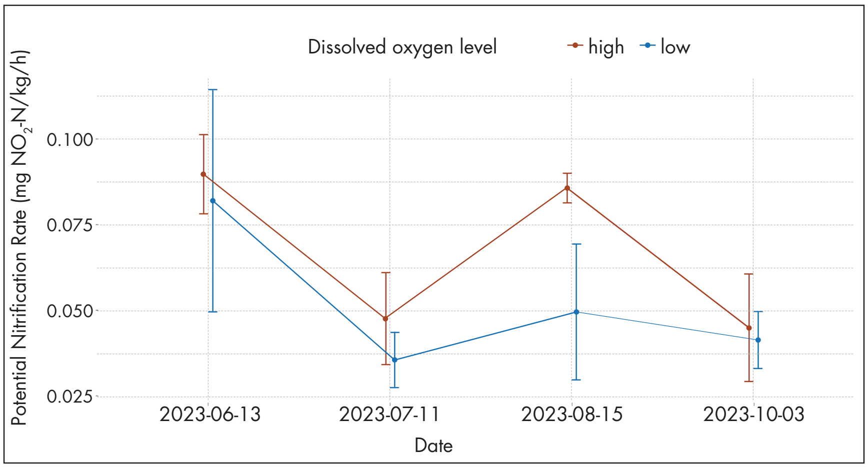


Figure 3. *Potential nitrification rates for the sediments from catfish ponds with low and high dissolved oxygen levels. Points are mean potential nitrification rates; error bars are standard errors of the mean.*

used for measuring potential nitrification rates in sediments from catfish ponds. Our study objectives were (1) to test the shaken-slurry method for measuring potential nitrification rates on catfish pond sediment samples, and (2) to test the effect of dissolved oxygen concentration on catfish pond water and sediment nitrification potential.

MATERIALS AND METHODS

We used eight catfish ponds (0.25 ac each) at the Delta Research and Extension Center in Stoneville, MS (**Figure 1**). Four of the eight ponds were automatically aerated (**Figure 2**) when the dissolved oxygen concentration fell below 3.0 mg/L (high DO), while the remaining four ponds were automatically aerated when the dissolved oxygen concentration fell below 1.5 mg/L (low DO). We collected pond sediment samples to a depth of 2 inches in mid-June, -July, -August, and early October 2023, and estimated the potential nitrification rate by the shaken-slurry method (Belser & Mays, 1980). We incubated the sediment samples in an ammonium-rich reagent solution on a shaker and measured the increase in nitrite over a 20-hour period. To increase the sensitivity of the assay, we added sodium chlorate to the reagent solution which inhibits the oxidation of nitrite to nitrate.

RESULTS AND DISCUSSION

We consistently obtained sufficient and increasing nitrite concentrations over the incubation period for all our sediment samples. This suggests that the shaken-slurry method is effective for estimating potential nitrification rates for pond sediments.

The average potential nitrification rate in the sediments in the high and low DO catfish ponds were 0.068 and 0.047 mg N/kg/h, respectively. That means that in the low DO catfish ponds, the potential nitrification rate was on average 0.021 mg N/kg/h lower than in the high DO catfish ponds. Over the duration of a 24-hour period, this is a difference of 0.5 mg N/kg. This difference was higher during warmer months and especially pronounced in the samples that we collected in August (**Figure 3**). If we assumed that the potential nitrification rate was uniform across the area of the pond and that the bulk density of the sediment was 1.5 g/m^3, we would obtain an average mass of nitrate-nitrogen that was converted from ammonia of 7.5 lbs (3.4 kg) and 5.2 lbs (2.35 kg) daily for the low DO and high DO catfish ponds, respectively. Our results suggest that a dissolved oxygen concentration of 3.0 mg/L increases the efficiency of sediment nitrification in catfish aquaculture.

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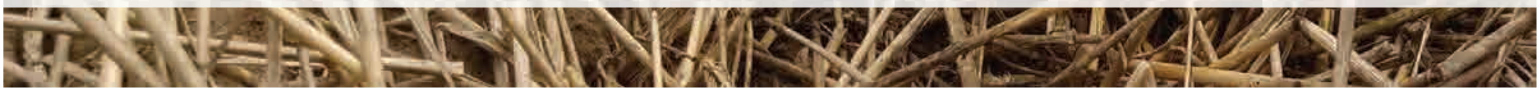
COVER CROPS, TILLAGE, & SOIL CONSERVATION



Irrigation Expenses and Economic Returns of Conservation Tillage and Cover Crop Cropping Systems

Carson Roberts, Drew Gholson,
Nicolas Quintana-Ashwell, Martin Locke,
Dave Spencer, Whitney Crow, and Brian Pieralisi

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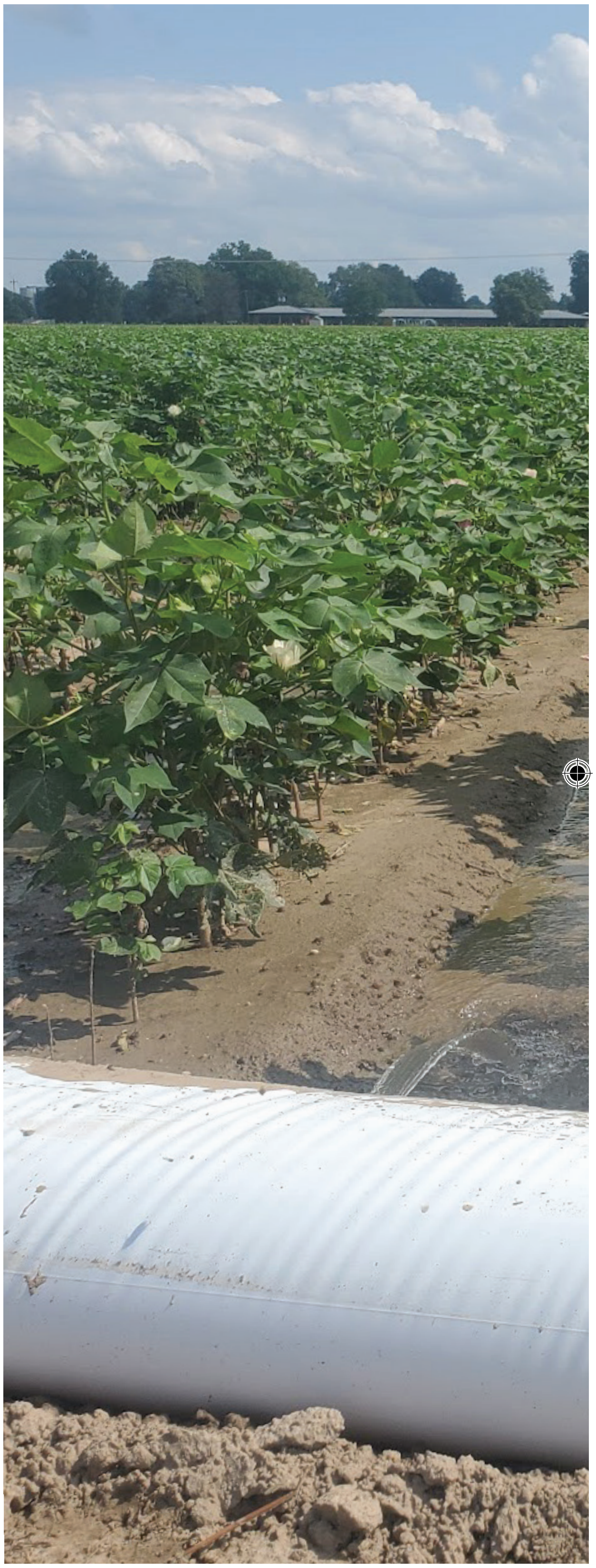


INTRODUCTION

Profitability is a substantial concern when considering a new cropping system or practice. Over the years cover cropping and no-tillage have not been adopted mainly for economic reasons. This occurs despite the advantages that cover crops bring: erosion control, improved infiltration, weed suppression, among others. Traditionally, savings in irrigation costs have not been considered when deciding whether cover crops will work on an operation. The purpose of this study is to identify the cropping system that best conserves water without reducing profitability.

MATERIALS AND METHODS

This study was conducted at Delta Research Extension Center (DREC) in Stoneville, MS, from 2021 to 2023 on a Dubbs silt loam. Study treatments included: disk tillage, subsoil, winter fallow (grower standard); strip tillage with winter fallow (ST-WF); strip tillage with cover crop (ST-CC); strip tillage with subsoil and cover crop (ST-SS-CC); no seedbed tillage with winter fallow (NT-WF); no seedbed tillage with cover crop (NT-CC); minimal surface disturbance subsoil with cover crop (MSS-CC).

Fall-established cover crops of a 50/50% blend of hairy vetch and cereal rye planted at 60 lbs/acre and were terminated at least two weeks prior to planting. The variety Deltapine® 2012 BX3 was planted, routine fertility, pesticide, and PGR applications were made. Watermark® soil moisture sensors were installed, and irrigation was triggered at -80 kPa. Costs of all practices were estimated using Mississippi State University Extension Service's planning budgets for each of the three years.

RESULTS AND DISCUSSION

Labor, fuel equipment, irrigation, gin & haul (G&H), and seed costs all varied by treatment (**Figure 2**).

Figure 1. *Furrow irrigating conventional cotton.*

The system that best reduces irrigation water use and maintains profitability is the no seedbed tillage with winter fallow system.

Expenses were highest where cover crops were grown. Seed costs for cover crops increased expenses by $87 per acre. The NT-WF treatment expenses were $59 per acre lower than the grower standard. The treatments with a cover crop had more soil moisture and did not require as much irrigation as the grower standard, so irrigation expenses were reduced by $7.40 per acre (**Figure 3**). The cover crop systems also saved $2.86 per acre in irrigation costs compared to ST- and NT-WF systems.

Profitability and risk depended on the treatment (**Figure 4**). The ST- and NT-WF systems had a higher risk-reward benefit than the grower standard, and the grower standard was similar in risk to the cover cropped systems. The ST-WF system was lower in risk than the NT-WF system, but they are very similar in relation to the risk-return line. However, cover crop systems reduced profitability av-

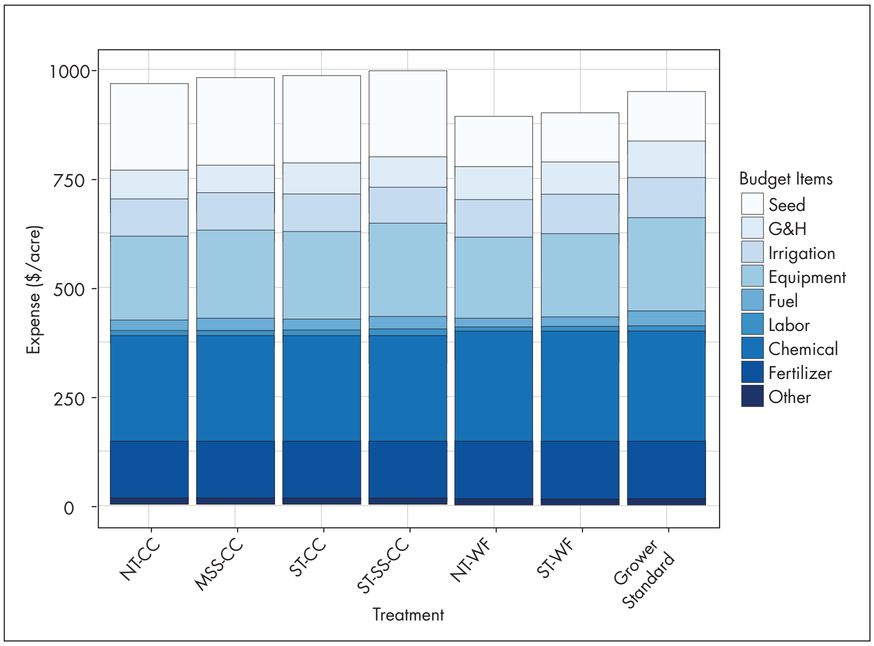


Figure 2. *Expense items including gin and haul (G&H) associated with seven tillage and cover crop treatments at the Delta Research and Extension Center in Stoneville, MS from 2021-2023 including: NT - no seedbed tillage; CC - cover crop; MSS - minimal surface disturbance subsoil; ST - strip tillage; SS - subsoil tillage; WF - winter fallow; Grower Standard - a combination of subsoil, disk tillage, and winter fallow.*

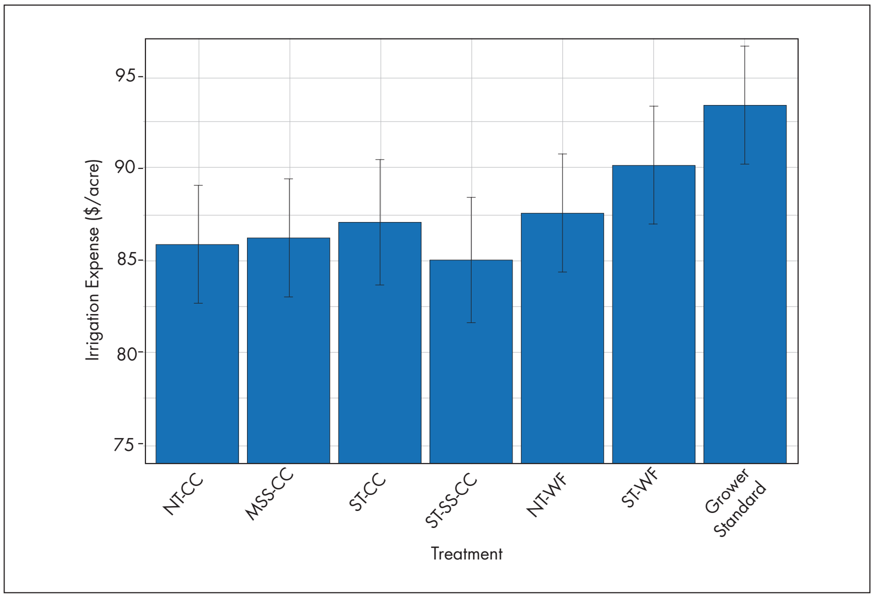


Figure 3. *Average irrigation expenses with a 95% confidence interval of seven tillage and cover crop treatments at the Delta Research and Extension Center in Stoneville, MS from 2021-2023 including NT-no seedbed tillage; CC-cover crop; MSS-minimal surface disturbance subsoil; ST-strip tillage; SS - subsoil tillage; WF - winter fallow; Control - a combination of subsoil, disk tillage, and winter fallow.*

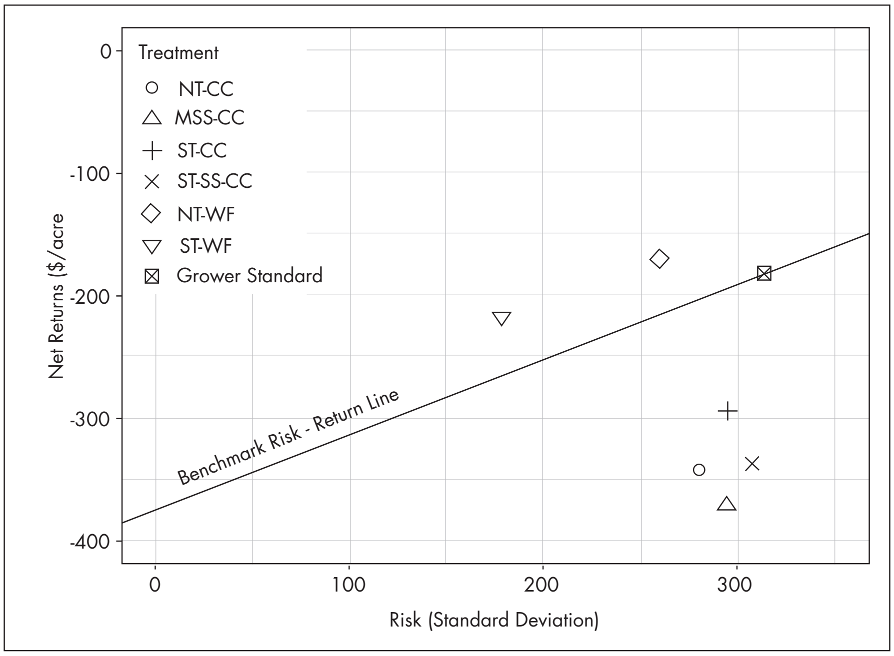


Figure 4. *Net returns and variability across tillage and cover crop cropping systems during 2021-2023. The benchmark risk-return line indicates a baseline where values above the line represent better risk-return than values below the line. Since the net returns here are negative, the line originates at the lowest net return value (y = -374) for NT - no seedbed tillage; CC - cover crop; MSS - minimal surface disturbance subsoil; ST - strip tillage; SS - subsoil tillage; WF - winter fallow; Grower Standard - a combination of subsoil, disk tillage, and winter fallow.*

eraged across all three years by $170 per acre. This reduction in profitability is a product of both higher expenses and low lint yields in 2023.

CONCLUSION

The system that best reduces irrigation water use and maintains profitability is the NT-WF system. Irrigation costs were reduced by cover crop systems but not enough to offset the cost of growing a cover crop. Risk is higher with both where cover crops were sown and the grower standard. There was no advantage to using strip-tillage practices over no-tillage. Both improved yield and reduced costs are needed for cover crops to be competitive with a conventional system.

Combating Poor Infiltration in Silty Loam Soils

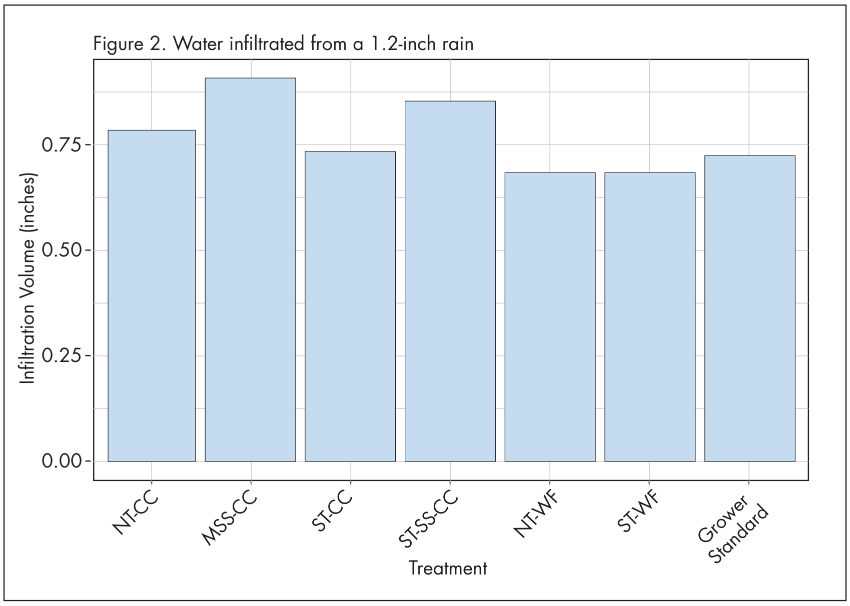
Carson Roberts, Drew Gholson, Martin Locke, Dave Spencer, Whitney Crow, Brian Pieralisi, and Nicolas Quintana-Ashwell

Partially funded by Cotton Incorporated under project 21-863

INTRODUCTION

Many soil textures, excluding sandy soils and cracking clays, can have low or poor infiltration. This is detrimental to field crop production in both irrigated and non-irrigated fields. Poor infiltration leads to an array of problems like increased water runoff, pollution, erosion, ineffective irrigation, and loss of valuable moisture. Poor infiltration can develop when rainfall droplets collide with the soil surface, jarring soil particles loose and transporting them across the soil surface. This soil particle movement clogs soil pores and causes the development of platy soil structures as seen in **Figure 1**. The platelike structures further discourage the downward movement of water, and the cycle of rainfall, soil movement, and platy structure development continues. Soils with high fractions of silt are particularly vulnerable to this cycle that leads to poor infiltration. This study aims to find ways to improve infiltration and ultimately soil moisture by testing various conservation cropping practices that stabilize and aggregate the soil.

Figure 1 (left). *Soil from a conventionally tilled field.*
Figure 2 (below). *Estimated infiltration volume of a 1.2-inch rainfall event during the 2021-2023 growing seasons at the Mississippi State University Delta Research and Extension Center near Stoneville, MS. Treatments included NT-no seedbed tillage; CC-cover crop; MSS-minimal surface disturbance subsoil; ST-strip tillage; SS-subsoil tillage; WF-winter fallow; Grower Standard, a combination of subsoil, disk tillage, and winter fallow.*



MATERIALS AND METHODS

A study was conducted at the Delta Research and Extension Center in Stoneville, MS, from 2021 to 2023 on a Dubbs silt loam. Study treatments included: disk tillage, subsoil, winter fallow (grower standard); strip tillage with winter fallow (ST-WF); strip tillage with cover crop

Figure 3. *Soil from a field with a fall-seeded cover crop.*

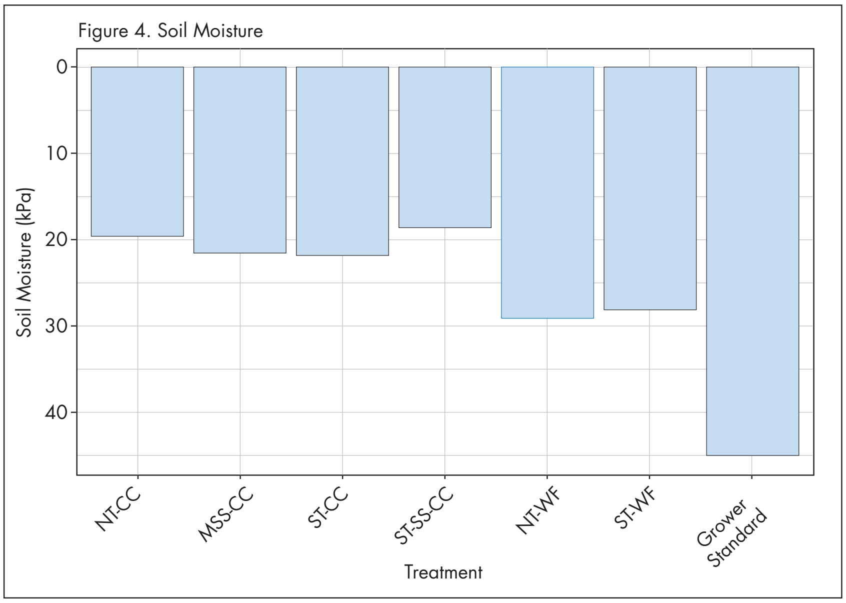


Figure 4. *Average in-season soil tension at the Mississippi State University Delta Research and Extension Center near Stoneville, MS from 2021-2023. Treatments included NT-no seedbed tillage, CC-cover crop; MSS-minimal surface disturbance subsoil; ST-strip tillage; SS-subsoil tillage, WF-winter fallow; Grower Standard, a combination of subsoil, disk tillage, and winter fallow.*

(ST-CC); strip tillage with subsoil and cover crop(ST-SS-CC); no seedbed tillage with winter fallow (NT-WF); no seedbed tillage with cover crop (NT-CC); minimal surface disturbance subsoil with cover crop (MSS-CC).

Fall-established cover crops were a 50/50% blend of hairy vetch and cereal rye planted at 60 lbs/acre and were terminated at least two weeks prior to planting. The variety Deltapine® 2012 B3XF was planted, routine fertility, pesticide, and PGR applications were made. Watermark® soil moisture sensors were installed, and irrigation was triggered at -80 kPa, and were also used to collect soil moisture data.

RESULTS AND DISCUSSION

Both cover crops and subsoiling improved infiltration throughout the growing season. All cover crop treatments increased the volume of rainfall infiltrated by 13%, on average (**See Figure 2, 3**). Using no-tillage practices in combination with cover crops further increased infiltration by 20% compared to treatments where no cover crops were sown. Subsoiling combined with cover crops improved water infiltration by 16% compared to cover crops alone. The grower standard had poor infiltration despite being subsoiled each year. It has been found in this and other studies that following subsoiling with disking diminishes the effectiveness of the subsoil.

Improved infiltration among the cover crop treatments improved soil moisture content throughout the growing season. Soil tension in the grower standard was at least 16 kPa higher than all other treatments across all years (**See Figure 4**). Soil moisture was higher with soil tension being improved by 29% in treatments where cover crops were grown compared to the NT-WF and ST-WF treatments.

CONCLUSION

Cover crops improved both soil moisture and infiltration in this study. These findings suggest that wise cover cropping practices can improve infiltration and soil water capacity which could save irrigation water or increase yield in non-irrigated cotton. Considerations including the economics of these practices should be made before adoption.

A WHEAT-CORN PILOT STUDY

Rainfed Double-Cropping for Aquifer Conservation

Himmy Lo, Jim Nichols, and Hayden Burford

INTRODUCTION

Narrowing the profitability gap between irrigated and rainfed cropping can help incentivize reductions in groundwater withdrawal from the Mississippi River Valley Alluvial Aquifer. One strategy to achieve this goal may be to produce multiple rainfed crops per year. While wheat-soybean double-cropping is already familiar to farmers and scientists alike in the Lower Mississippi River Basin, a pilot study was designed to better understand the prospects of rainfed wheat-corn double-cropping in this region.

EXPERIMENT DESCRIPTION

The experiment was conducted from November 2022 to October 2023 at the Delta Research and Extension Center's West Farm. The field had been under rainfed soybean single-cropping for multiple years, and its soil has been classified as Bosket very fine sandy loam. Wheat (variety Pembroke) was drilled in 7.5-inch rows at 100 pounds per acre across the entire field on November 4, 2022, which was followed by corn (product Pioneer 1870R) planted in 40-inch rows at 36,000 seeds per acre in 2023. Two treatments differing in the management of these wheat and corn crops were imposed in six blocks of the field.

The "cover crop treatment" managed the wheat as a cover crop and managed the corn as a cash crop. The wheat received 20 pounds of nitrogen (N) per acre from one fertilizer application and was terminated using glyphosate on March 16, 2023. The corn received 250 pounds of N per acre in total from two fertilizer applications. Corn planting, emergence, silking, maturity, and harvest occurred on March 30, April 6, June 4, August 1, and August 23, respectively.

The "double-crop treatment" managed both the wheat and the corn as cash crops. The wheat received 110 pounds of N per acre in total from three fertilizer applications and was harvested on June 5 (**Figure 1**). The corn received 250 pounds of N per acre from one fertilizer application. Corn planting, emergence, silking, maturity, and harvest occurred on June 5, June 13, July 26, September 21, and October 10, respectively.

PRELIMINARY FINDINGS

The wheat season started mild, but then plants were injured by a rapid decline in air temperature from a high of 48°F on December 22 to a low of 9°F on the next day. During the reproductive stages, wheat leaves displayed mild disease symptoms, which may have been promoted by rainy weather between late March and early April.

Weather in the corn season was more favorable for the cover crop treatment than for the double-crop treatment. The cover crop treatment enjoyed timely rainfall except during a 26-day drought that ended in the middle of corn pollination. In this drought, rainfall totaled 0.3 inches, and daily maximum air temperature averaged 88°F. On the other hand, the double-crop treatment suffered a 23-day drought that centered on the corn pollination period. In this drought, rainfall totaled 0.4 inches, and daily maximum air temperature

Figure 1. *Wheat of the "double-crop treatment" next to corn of the "cover crop treatment" on June 5, 2023*

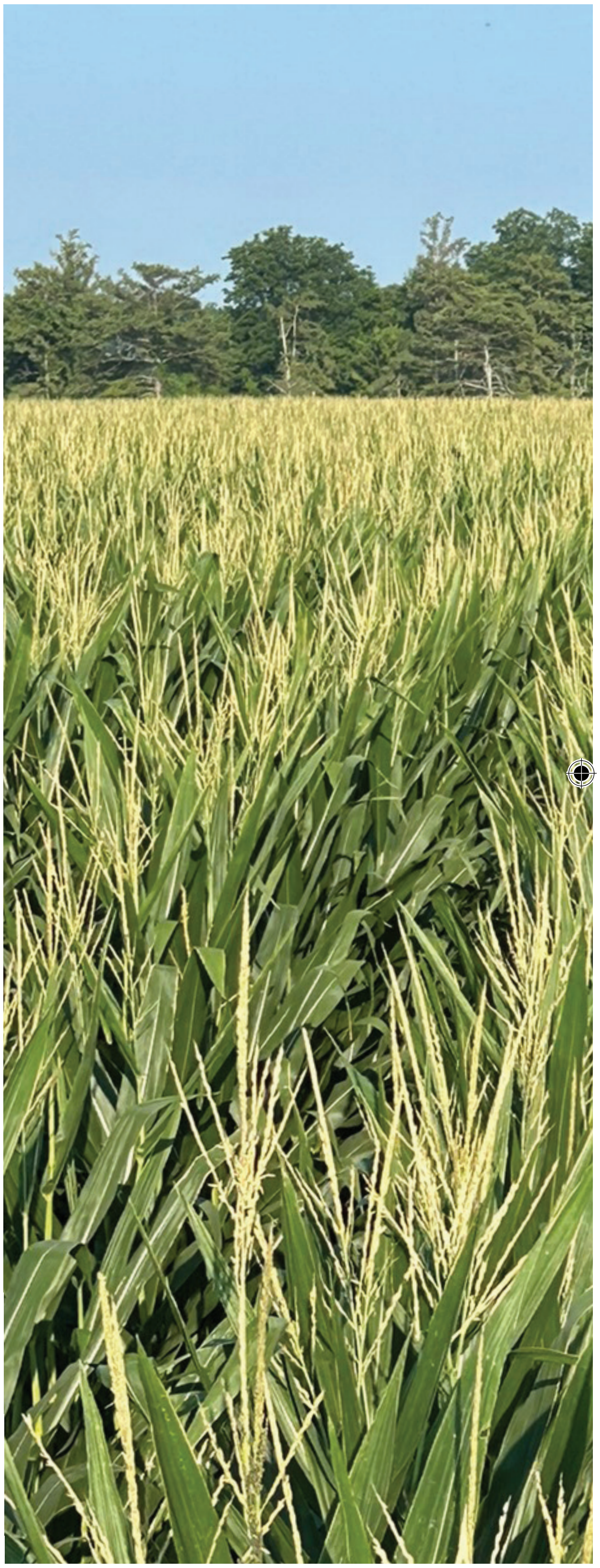
averaged 97°F. Then in the 43 days preceding maturity of the double-crop corn, only 1.2 inches of total rain was received. Insect and disease pressure was also clearly higher in the double-crop corn.

Averaging across the six blocks, the cover crop treatment produced no wheat and 204 bushels of corn per acre, whereas the double-crop treatment produced 80 bushels of wheat per acre and 128 bushels of corn per acre. In other words, rainfed wheat-corn double-cropping increased annual grain dry matter production by 6% relative to rainfed corn single-cropping. The productivity advantage of double-cropping was even larger in terms of non-grain dry matter production (**Figure 2**), which might enhance soil health and provide additional income streams (e.g., carbon credits, bioenergy feedstocks) in the future. Under the environmental and economic conditions of this experiment, the double-crop treatment was not as profitable as the cover crop treatment. However, rainfed multiple-cropping systems deserve further investigation as potential adaptations for a more sustainable Mississippi River Valley Alluvial Aquifer.

Figure 2. *Corn of the "double-crop treatment" on July 3, 2023; the wheat residue remained present even after corn harvest.*

Corn and Soybean Yield Response to Tillage Intensity, Subsoiling, and Cereal Rye Cover Crop

Andrea Simpson and Himmy Lo



INTRODUCTION

Agricultural soils in the Mississippi Delta are typically tilled on a regular basis to incorporate crop residue, prepare raised beds for planting and irrigating, control weeds and diseases, and relieve soil compaction. However, many conventional tillage practices accelerate soil carbon loss and destroy soil aggregates and structure, contributing to reduced water holding capacity and surface sealing/crusting, which can reduce water infiltration and seedling emergence. Reduced and no-tillage practices are being promoted as they minimize soil disturbance, preserve soil structure, and improve water retention (Sheehy et al., 2015; Blanco-Canqui and Ruis, 2018). Although some reduced and no-tillage practices have been associated with reduced yield, their yield impact often varies by crop, soil type, and climate (Pittelkow et al., 2015). The objective of this study was to test reduced and no-tillage practices on corn and soybean yield grown on a loamy soil.

MATERIALS AND METHODS

We tested seven tillage practices (**Table 1**) in a rainfed field experiment at the Delta Research and Extension Center in Stoneville, MS. The treatment plots were laid out in a randomized complete block design with eight replications, four of which were planted in corn while the other four replications were planted in soybean. Previously, the entire field had been under corn production since the 2017 growing season. The tillage practices are presented in **Table 1**. The prevalent soil types are Commerce very fine sandy loam and Commerce silt loam.

Dekalb 70-27 corn was planted on March 23 and harvested on August 31st, while Asgrow 47XF2 soybean was planted on April 18 and harvested on October 11.

PRELIMINARY FINDINGS AND NEXT STEPS

The effect of tillage practices was found to be statistically significant on corn yield ($p = 0.0004$) and soybean yield ($p = 0.0004$) (**Table 2**). For a given tillage intensity, the addition of subsoiling or a cereal rye cover crop did not cause statistically significant differences in corn yield or soybean yield. For both corn and soybean, conventional

Table 1: Tillage practices investigated.

Tillage practice	Description	Start Date
Conventional tillage	Fall disking + pan-hipping; spring do-all + furrow-plowing	Fall 2016
Conventional tillage + in-row subsoiling	Fall low-till parabolic subsoiling + disking + pan-hipping; spring do-all + furrow-plowing	Fall 2018
Conventional tillage + cover crop	Fall disking + pan-hipping + do-all + cereal rye drilling at 60 lbs/ac; spring furrow-plowing	Fall 2016
Reduced tillage	Winter bedder-rolling	Fall 2022
Reduced tillage + furrow subsoiling	Winter bedder-rolling; spring Ecolo-Til inline-ripping	Fall 2022
No tillage	No tillage	Fall 2016
No tillage + cover crop	Fall cereal rye drilling at 60 lbs/ac	Fall 2022

Table 2: Grain yield for corn and soybean under the different tillage practices.

Tillage practice	Grain Yield (bushels per acre)*	
	Corn	*Soybean*
Conventional tillage	211 ^{AB}	78 ^{A}
Conventional tillage + in-row subsoiling	221 ^{A}	74 ^{AB}
Conventional tillage + cover crop	195 ^{BC}	74 ^{A}
Reduced tillage	199 ^{BC}	77 ^{A}
Reduced tillage + furrow subsoiling	199 ^{ABC}	78 ^{A}
No tillage	162 ^{D}	67 ^{BC}
No tillage + cover crop	181 ^{CD}	64 ^{C}

** For each crop, the tillage practices that shared a superscript letter were not statistically different in grain yield for that crop according to pairwise t tests (α = 0.05).*

tillage yielded numerically higher than reduced tillage and no tillage, but the difference between conventional tillage and reduced tillage was not statistically significant. Purely in terms of yield, this experiment does not support the adoption of no tillage (with or without a cereal rye cover crop) for corn and soybean on loamy soils of the Delta; this finding is consistent with corn results from previous years at the same site (Rix et al., 2023). For soybean production under similar conditions, reduced tillage may deserve further evaluation. Bedder-rolling on February 21, 2023, was its only tillage operation after corn harvest and stalk chopping in 2022 and before corn/soybean planting in 2023. Future research can validate whether this practice can consistently provide sufficient improvement to seedbed conditions and surface drainage while avoiding the financial cost and soil degradation of conventional tillage.

Since some tillage treatments were kept unchanged for five to seven years, we will collect soil samples in 2024

and will investigate how the multi-year tillage systems have affected a selection of soil physical properties. We will also examine how soil fertility parameters have changed since the beginning of the experiment. The results are expected to demonstrate the effectiveness of multi-year tillage systems on soil health parameters.

Figure 1 (top) *Photo of the reduced tillage treatment one month after bedder-rolling. (**Above):** Photo of the reduced tillage + furrow subsoiling treatment immediately after inline-ripping.*

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THE INITIATION OF WEST 18

A Long-Term Study on the Effects of Field Practices on Runoff Water Quality

Amanda M. Nelson

The site for a new, long-term field study at the Delta Research and Extension Center's West Farm, Stoneville, MS began construction in 2023. This project, known as West 18, is set to examine the effects of field practices (cover crops, minimal and adaptive tillage processes) on runoff water quantity and quality from soybeans cultivation. The impact of cover crops on bed shape retention and soil quality parameters will also be examined.

The experimental area (~22.2 acres) has been arranged in a randomized complete block design with three blocks. The site consists of 18 plots located in Washington County, Mississippi (33.420165, -90.954244) at the corner of Old Leland Rd. and Potter Rd, on the south side, south of the railroad tracks (**Figure 1**). Fields will be planted with soy at 40 in row spacing in the spring.

Each of the 18 experimental plots is 750 ft long by 53 ft wide (~0.9 acre) and will be equipped with automated

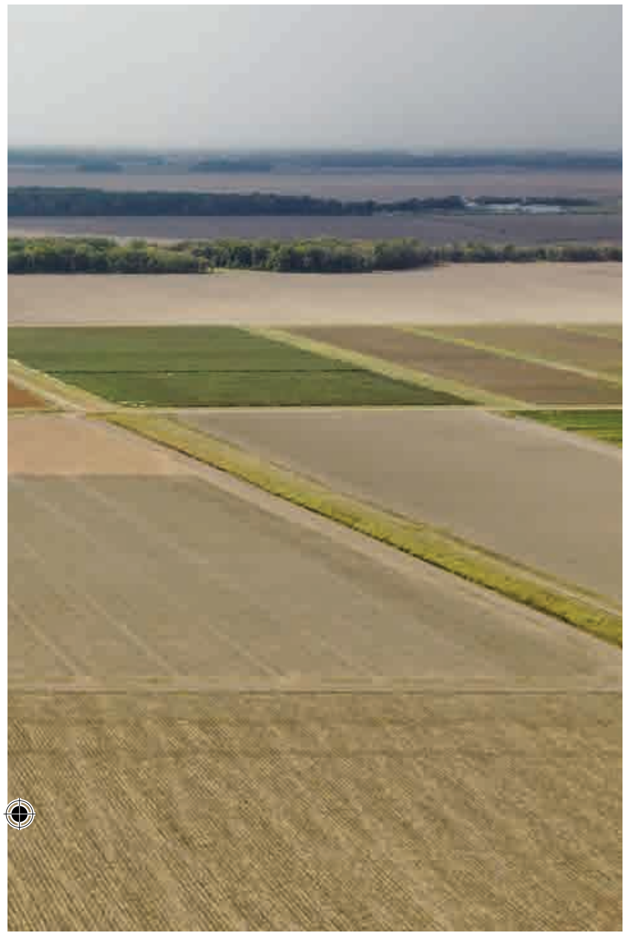


Figure 1. *(left) An aerial view of West 18 after the side levees were built.*
Figure 2. *(above) The building of the levees between the plots, necessary to guide the water to the samplers and to prevent flow between plots.*

surface runoff sampling equipment. Each plot has 16 rows with berms around each plot (6 ft wide, flat top). Runoff samples will be collected during runoff events to determine sediment and nutrient (N and P) losses.

There are six cover crop treatments in this study. They include:

No cover - clean - These plots will have no cover crops and will be kept clean with herbicides, as is common in the Delta.

No cover - natural - These plots will have no cover crops and will not be kept clean with herbicides. Weeds will be allowed to grow as "natural cover" during the non-growing season.

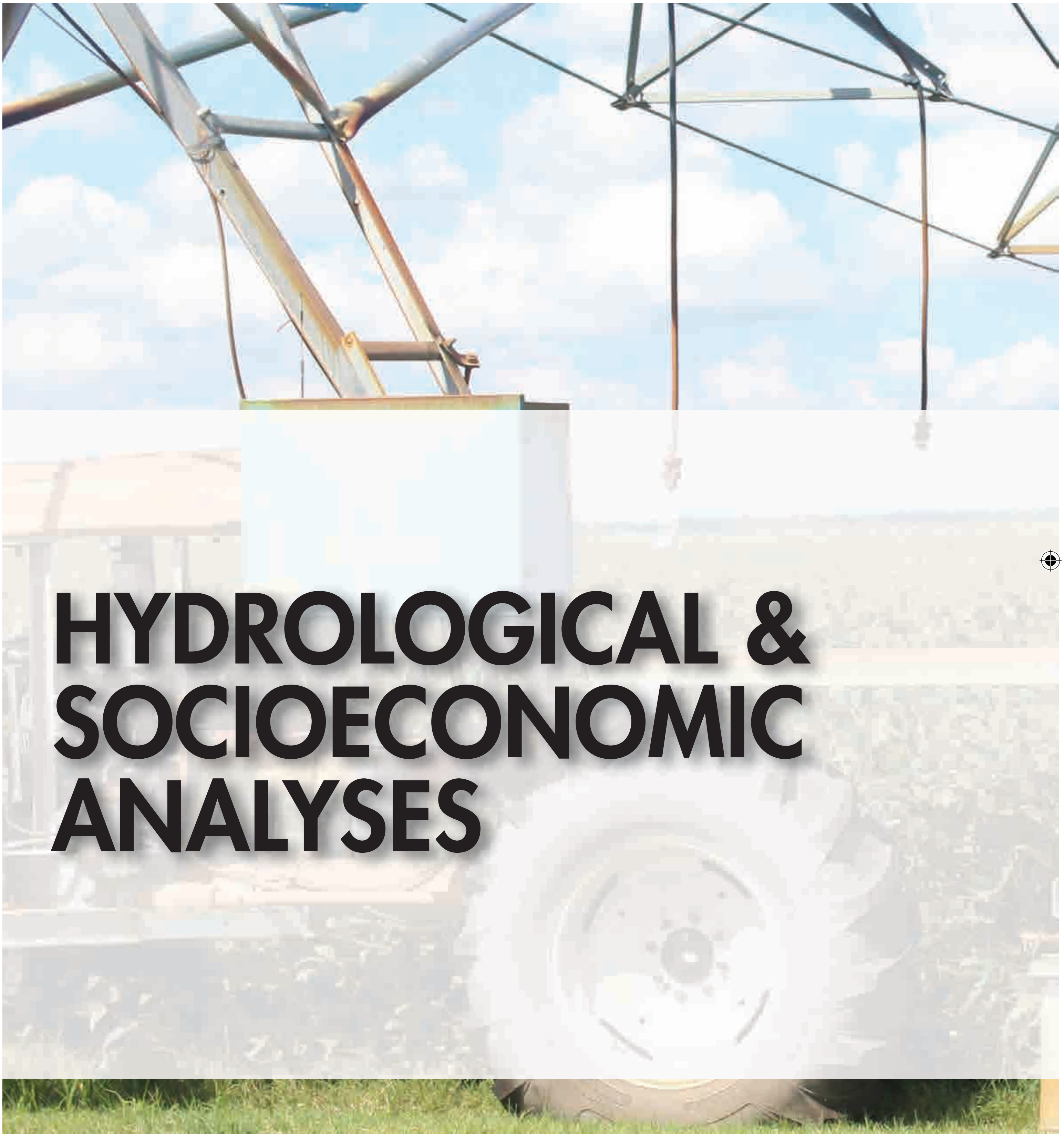
Cereal Rye

Rackstar cover crop blend - Wheat; oats; Austrian winter peas; winter rape; clover

Pollinator mix - A custom MS pollinator blend including several coreopsis species, echinacea, liantris, and sunflowers

Soil health mix - Black oats; tillage radish; hairy vetch. "This blend will give the grower good erosion control, weed suppression, reduced compaction, more organic matter, nutrient sequestration, nitrogen fixation as well as nematode and disease suppression."

In addition to the research on runoff water quantity and quality, bed shape retention, and soil quality, this site will have the potential for many future research projects conducted by permanent National Center for Alluvial Aquifer Research employees, as well as future post-doctoral researchers and graduate students. This site will be used for demonstrations and outreach education opportunities as part of an ongoing effort.



HYDROLOGICAL & SOCIOECONOMIC ANALYSES

INSIGHTS FROM REGRESSION ANALYSES OF REPORTED GROUNDWATER PUMPING AND GIS DATASETS

What To Expect From Improved Irrigation Water Use Efficiency With Regards to Groundwater Use

Nicolas E. Quintana Ashwell, Amer Al-Sudani,
and Drew M. Gholson

The demand for groundwater as an input for irrigation describes, in essence, how the benefit obtained in terms of crop yields achieved at different levels of water applied in irrigation relate to the cost of applying that water. This framework allows us to understand what can be expected when irrigation water use efficiency is improved on the field.

How is the demand curve formed? The demand curve captures the benefits from applying an input at different quantities. Those benefits can come from increased crop yields (up to a point). This is exemplified by the top diagram of Figure 1 showing a crop yield response curve (yield, Y, and amount of water, w, axes) and the resulting irrigation water demand curve below it (cost per inch applied, Pw, and amount of water, w, axes). At some point, there is no longer a yield response to added water, which is where the demand curve intercepts the horizontal axis.

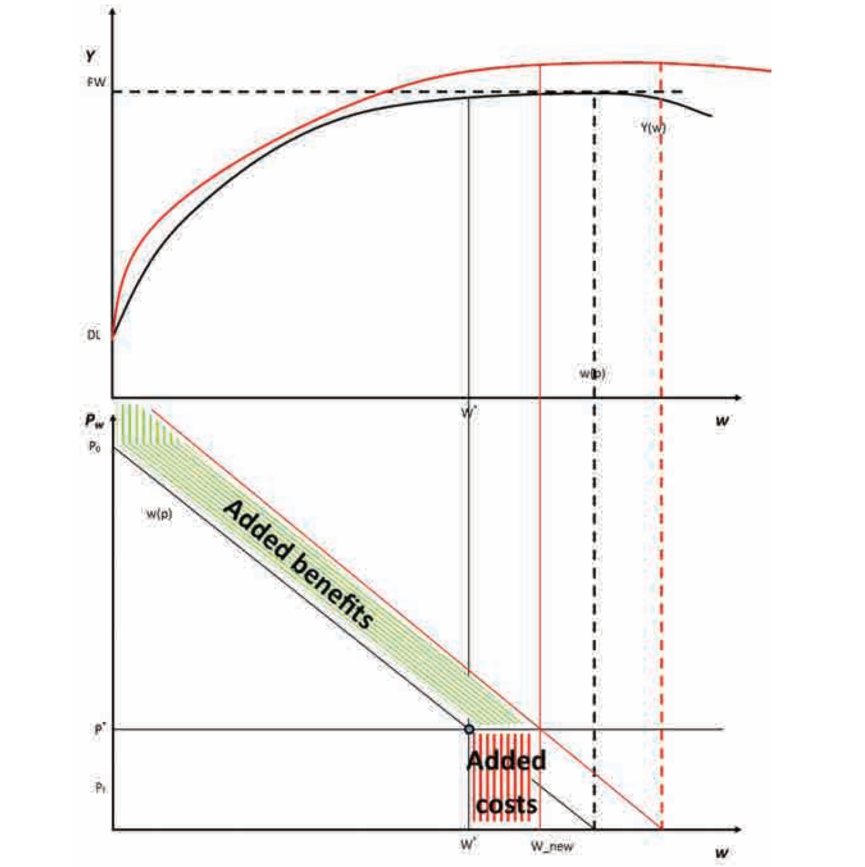


Figure 1, Case 1. Graphical representation of the benefits from improved irrigation efficiency in the form of more crop per drop with higher maximum yield and the resulting demand curve for irrigation groundwater. More crop per drop innovations could be expected to result in higher total water use all else equal.

What happens to the demand curve when irrigation water use

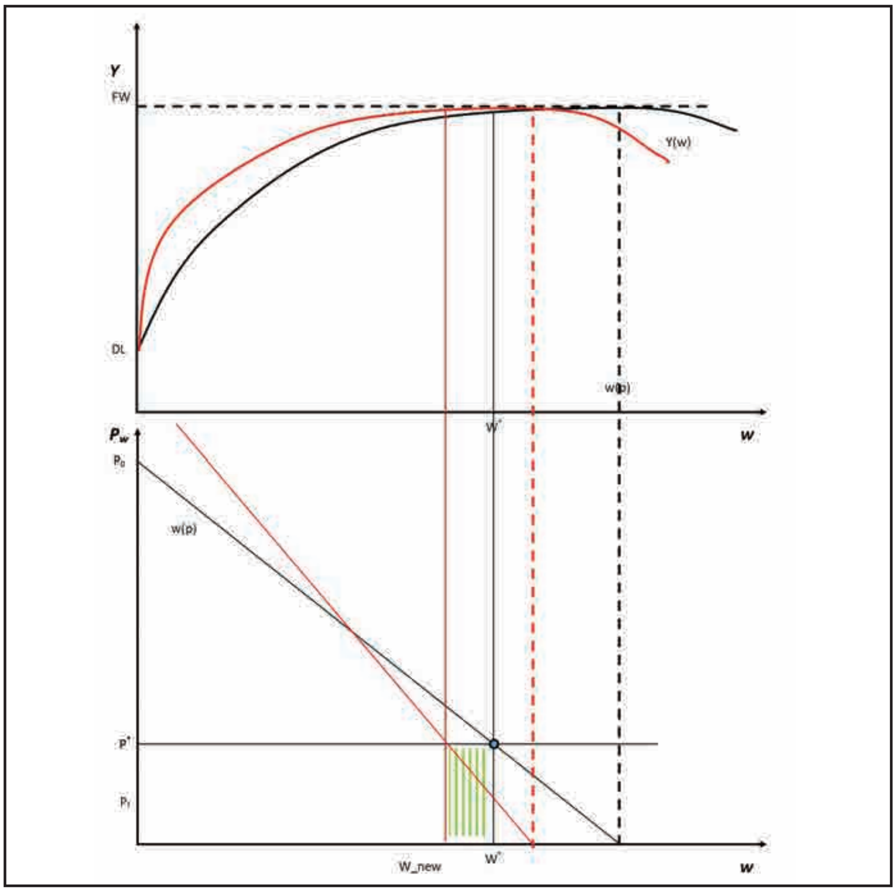


Figure 2, Case 2: *Graphical representation of the benefits from improved irrigation efficiency without higher maximum yield and the resulting demand curve for irrigation groundwater. More efficiency without higher output could be expected to result in lower total water use all else equal.*

The message here is that more crop per drop, by itself should not lead us to expect reductions in water use.

efficiency improves? It depends on what is meant by efficiency. In most agronomy articles, it is meant as a measure of productivity, more crop per drop, or higher crop yields at every level of input application (Case 1). Another possibility is that it results in higher yield at every level of water applied but not higher total yield (Case 2).

Case 1: more crop per drop with higher maximum yield. This is represented by the solid red curve in the top diagram in Figure 1; which is consistently higher than the previous response curve (in black). Notice that the higher crop-per-drop curve achieves a higher maximum yield. The marginal benefits translate to the demand curves below it. In essence, the more crop per drop is an outward shift of the demand curve for irrigation water. If the cost of irrigation does not change, the new equilibrium quantity would be to the right of the previous one, indicating that more water applied than before would be optimal.

So, does more crop per drop mean more water use? Not necessarily. Efficiency improving measures can cause the cost of irrigation to increase in which case the line P* could shift upwards (or downwards) and result in more or less total water applied. The message here is that more crop per drop, by itself, should not lead us to expect reductions in water use; only more benefits from using it.

Case 2: higher efficiency but same maximum yield. In this case the yield response to irrigation is more acute but flattens out quicker than before (red curve in top diagram of Figure 2, in red). This results in a demand curve that starts above the previous case but intersects the horizontal axis before the older one. In this case the equilibrium point given irrigation costs is to the left of the previous one and water use savings are achieved.

Which type should we expect? A case 1 would be most beneficial to farmers but risks accelerating the rate of depletion of the MRVAA. Should the Delta aim for a future of higher agricultural productivity (with higher profits per acre for farmers), then a sustainable aquifer would require the use of surface water sources to some degree. Given the amount of off-season precipitation, the solution would involve the capture, storage, and reuse of pluvial and irrigation runoff.

INSIGHTS FROM REGRESSION ANALYSES OF REPORTED GROUNDWATER PUMPING AND GIS DATASETS

Managing Crop Heat Stress With Irrigation Does Not Prevent Yield Penalties and Is Costly

Nicolas E. Quintana Ashwell, Amer Al-Sudani, and Drew M. Gholson

Employing powerful two-way fixed effect regression analysis, we made two surprising discoveries: (i) in-season precipitation and evapotranspiration do not determine (in the statistical sense) the amount of groundwater pumped for irrigation; and (ii) the occurrence and persistence of elevated temperatures is a highly significant determinant of the amount of groundwater pumped for irrigation. The problem is that additional moisture does not prevent penalty yields from high temperatures and pumping is costly.

What may be driving the excess pumping? The most likely explanation is that producers want to avoid the yield penalties that occur from crop heat or water stress. Our review of the literature indicates that heat-related yield losses occur mainly because of high nighttime temperatures induces accelerated rates of phenological development (i.e., crops "aging" faster than they "grow"), with daytime heat having no negative impact in yield and even positive in some cases; additional application of irrigation because of daytime conditions is virtually wasteful; especially if soil moisture conditions are adequate. Heat penalties are a real thing. Studies at various scales across the nation quantify the yield and profit losses associated with elevated temperatures; and irrigated crops show lower losses in those studies. But the likely explanation is that the data being captured for rainfed crops is a combination of heat and water stress penalty losses.

Table 1. *Estimated cost of mismanaging crop heat stress with irrigation in the Delta.*

Acre-feet per acre reduction per degree day above 32C	0.015 AF	
Average DD>90F	19.5 degree days	
Average irrigated acreage by well	106.4 acres	
Total groundwater over-pumped per well (AF)		**31.2 AF**
Number of permitted wells (units)	20,806	
Total acre-feet over-applied due to visual crop cues		**649,270 AF**
MSU budget pumping cost $/acre-feet	$49.89/AF	
Cost of excess pumping per year		**$33.3 M**
NRCS implied conservation cost $/acre-feet	$29.64/AF	
Conservation value of extra water		**$19.2 M**
Total value of excess pumping per year		**$51.6 M**

Figure 1. *Leaf flipping in soybean (**left**) and curling in corn (**right**) with adequate soil moisture as evidenced by sensors.*

So, does a farmer just irrigate when it's hot? We don't think so. Our hypothesis is that some farmers trigger irrigation events based on crop conditions or appearance. We found extension bulletins, mostly across the mid-west, that indicate that crop leaf curling or flipping is a symptom of water stress. This is not quite correct, particularly in irrigated agriculture. **Figure 1** shows leaf flipping (soybean) and curling (corn) with adequate soil moisture as evidenced by sensors. Consequently, we think this is the most likely trigger for unnecessary irrigation events.

How to know if it's time to irrigate? Soil moisture sensors are the best objective indicator of soil moisture conditions. For producers who have not acquired or sufficiently covered their fields with soil moisture sensors, the other objective indicator from the literature is from air and canopy temperature differentials. Water-related stress starts after the canopy temperature surpasses the air temperature. Farmers could employ infrared thermometers and compare air to canopy temperatures in leaf-flipped or curled fields to verify that time to irrigate may be closed.

What to do with heat stress? Because the mechanism that induces yield losses is acceleration of phenological development, a more suitable strategy for seasons expected to present extreme temperatures is to plant slower maturing varieties. But we have not been able to test this solution for the Delta just yet. For now, our recommendation is to avoid triggering irrigation events based exclusively on heat-related indicators (particularly visual). The savings from groundwater pumping go straight to farmers' bottom-line and yield benefits from avoiding over-watering may also arise.

How costly is it? We estimate the cost to Delta farmers at over $30 million per year and a total conservation value of over $50 million per year.

INSIGHTS FROM REGRESSION ANALYSES OF REPORTED GROUNDWATER PUMPING AND GIS DATASETS

Implications of Overestimated Benefits From or Underestimated Costs of Irrigation

Nicolas E. Quintana Ashwell, Amer Al-Sudani, and Drew M. Gholson

Our analyses of data from the voluntary groundwater pumping reporting program reveals that, on average, irrigators in the Delta (i) over-estimate the benefits they obtain from irrigation at the margin (i.e., benefits from the last irrigation event); or (ii) underestimate the costs of irrigating at the margin. These are the underlying issues inducing some farmers to irrigate to minimize yield losses from extreme heat. The problem can be illustrated and characterized with a demand curve—see **Figure 1**.

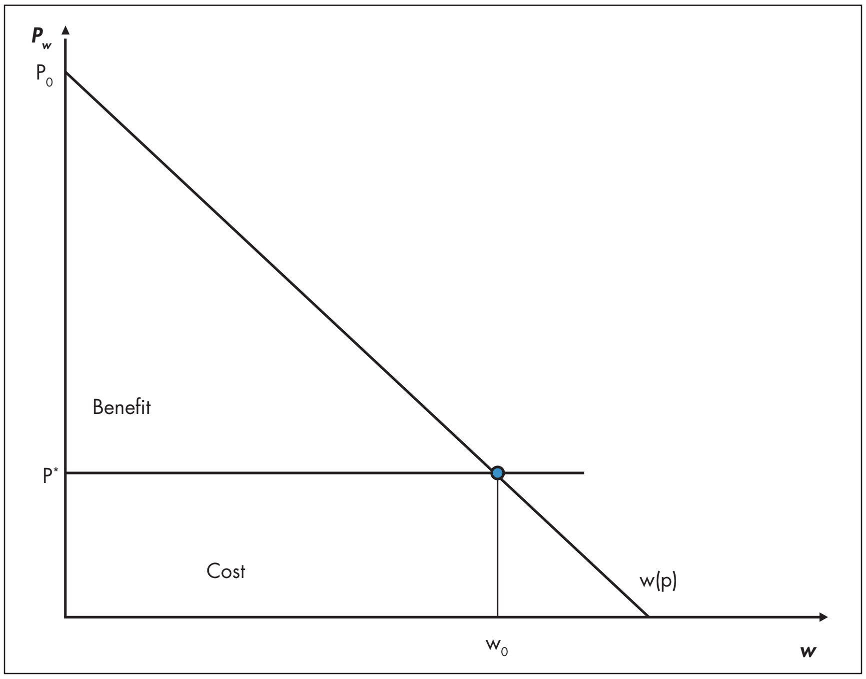


Figure 1. Graphical representation of the demand for irrigation groundwater. The area under the demand curve is the magnitude of the benefits from applying groundwater for irrigation, the rectangle formed by the intersecting lines through w_0 and P represent the total cost of applying that amount of groundwater. The difference is the profits represented by the area of the triangle above the costs and below the demand curve.*

Demand curve for groundwater. There is a price (or cost) level at which it is not worth it to apply any irrigation. This is called the "choke price" and is represented by price level P0. There's also an amount of water at which additional moisture is detrimental and no benefits can be extracted even if it is costless to apply more water (this is where the curve crosses the horizontal axis).

Shape of the curve. This is almost impossible to know but the simplest form is a straight line. The line can be built if the interception points are known, which is never the case; or if the average quantity and prices are known in combination with the demand elasticity at that point, From the voluntary metering program, we have an estimate of average overall water use; and from engineering formulas and estimates of depth to water we have estimates of the average marginal costs of pumping

The MITOOL app helps you estimate the cost to irrigate. It is available online at www.ncaar.msstate.edu/outreach/mitool.php. Step-by-step instructions for using the app can be found on page 88.

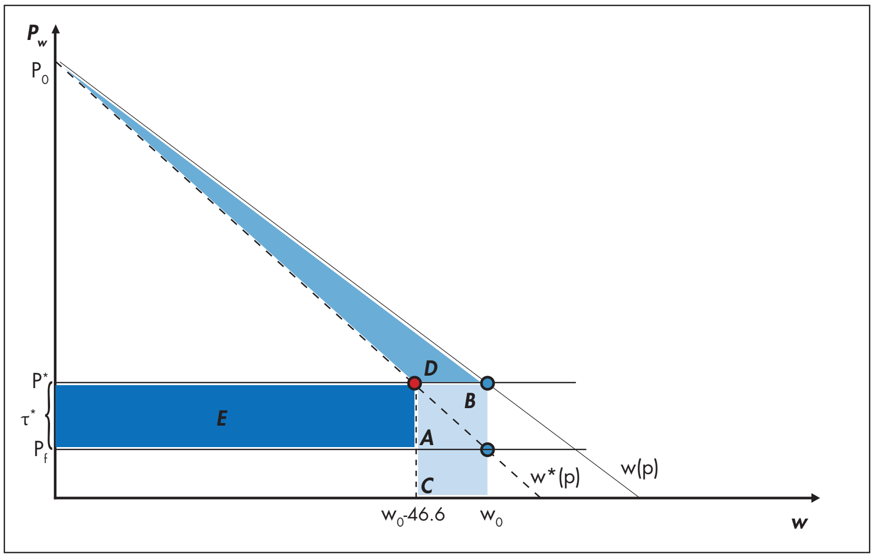


Figure 2. *Graphical representation of the distorted demand for irrigation groundwater. The dashed line is the perceived or distorted demand curve. It shows that benefits from irrigation are overestimated (area D) and the costs underestimated by magnitude A+B+E. Correcting the distortions would result in profit increases of areas A+B+C.*

groundwater. With this point and the elasticity estimates a demand curve can be construed for analysis. If the observed water quantity is w_0 and we estimate the marginal cost at P*, the total cost of pumping is w_0 x P* (square "cost" in **Figure 1**). The total benefit is the area under the demand curve, w(p), up to the amount of pumping observed and the net benefit from irrigation is the triangle above the total cost and under the demand curve.

What happens when irrigation cost is underestimated? It means that the quantity is still as observed but the perceived cost is lower so that the perceived irrigation benefit curve is no longer w(p) but w*(p)—see **Figure 2**. This introduces two distortions into the economic management of irrigation. First, it over-estimates the benefits from irrigation, represented by the area labeled D in Figure 2. Second, it underestimates the cost of the irrigation event by areas A+B+E.

What is the gain from understanding and managing the irrigation costs? Farmers who understand and possess a good estimate of their irrigation cost can increase their net profits by areas A+B+C. The actual amount of the gain will depend on how large the two distortions are in each farmer's perceptions. But, because these amounts go straight to the bottom-line, the profitability outcomes could be more noticeable than any improvements in crop yields, for example.

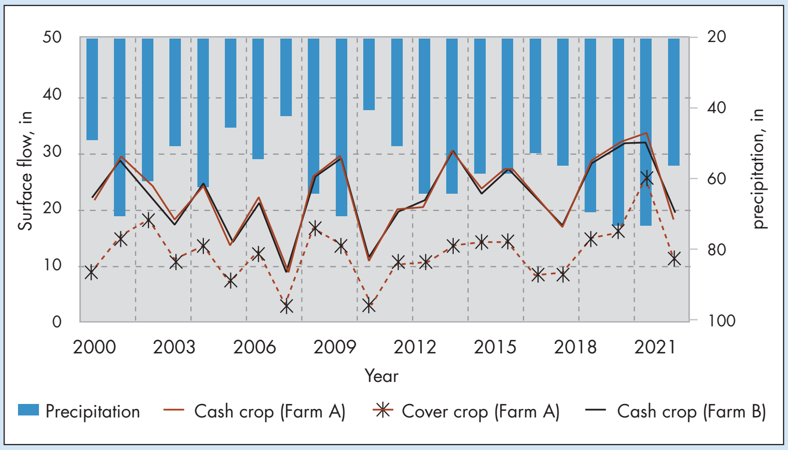
How can the distortions be reduced or eliminated? NCAAR developed the Mississippi Irrigation Termination Optimization On Line app (MiTOOL) to help farmers estimate their irrigation costs as precisely as possible and help them make the determination of whether the expected gains from the irrigation event are sufficient to compensate for the additional cost. See Page 86 or visit https://www.ncaar.msstate.edu/outreach/mitool.php.

Improving Agro-Hydrological Modeling Tasks To Provide Suitable Fieldscale Conservation Practices in the Lower Mississippi River Basin

Mahesh L. Maskey, Amanda M. Nelson, Christopher D. Delhom, and Drew M. Gholson

The Lower Mississippi River Basin (LMRB) is facing challenges with inefficient agricultural management practices, including excessive tillage operation and ineffective irrigation schedules, that lead to non-point source pollution. To improve the effectiveness of irrigation scheduling and minimize tillage operations, combinations of best management practices, like cover crops and irrigation water management (IWM) tools, are beneficial for sustainable farming systems. In order to demonstrate how these integrated management practices effectively improve water quality and quantity in the LMRB, an agro-hydrological computer model called APEX (Agricultural Policy Environmental Extender) was used.

APEX is a watershed simulation model used to assess the impact of agricultural management practices on water flow, sediment, and nutrients that incorporates regional or



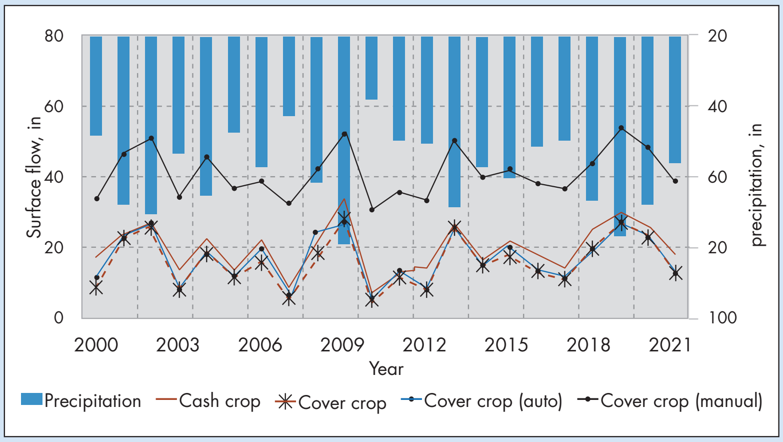


***Figure 1. (top)** annual time series of surface runoff; and **Figure 2 (above)** annual time series of surface runoff.*

national Digital Elevation Models, soils, and crop databases in order to provide default model input values for a given study area. These base models are combined with on-farm management data to help simulate water quality and quantity outputs.

For our initial investigation, we selected only a few fields: Farm A (21.68 ac) and Farm B (22.35 ac), in Humphreys County, where cotton was grown followed by cover crop mixes of oats, radish, and crimson clovers only in Farm A, and in Sunflower County, Grower West (38.25 acres) cultivated soybeans with triticale as a cover crop with automated vs. manual irrigation schedules. Farm A and Farm B were used to study the runoff response to cover crop mixes. In Grower West, automated irrigation was scheduled every seven days from April 30 to August 31 to compare the scenarios with manual irrigation maintained for ten days in winter and seven days in summer to ensure equal amounts of irrigation.

With the first-year management information, we simulated field-scale watersheds in the fields from 2000 to 2021. Farm A, simulated with and without cover crops, showed decreased surface flow, while Farm A and B had comparable surface flow without cover crops (**Figure 1**). Cover crops increased subsurface flow and deep percolation (**Table 1**) and decreased nitrogen and phosphorus losses with a notable increase in cotton yield with cover crops in Farm A. Grower West Farm experienced decreased surface flow with cover crops, regardless of automatic or no automatic irrigation. However, with manual irrigation, we observed increased water yield, surface and subsurface flow, deep percolation, nitrogen loss, phosphorus losses and sediment (**Figure 2, Table 1**.)

With one year of field observation, we succeeded in demonstrating the environmental and agronomic impact of cover crops with automated and manual irrigation strategies in farm-scale watersheds. While we are still in the preliminary stage, the results are promising and offer valuable insights into coupled irrigation water management tools. However, further study is necessary to draw concrete conclusions about the effectiveness of this research. To that end, we will continue refining our models using the APEX model while calibrating and validating these models.

Table 1. *Annual results of major indicators of water quantity and quality per acre after simulating the farm-scale watersheds via the Nutrient Tracking Tool interface over 22 years (2000-2021), together with planting dates.*

Response Variables	Humphreys County			Sunflower County			
	Cash crop (cotton)	Cover crop	Cash crop (cotton)	Cash Crop (soybean)	Cover Crop	Cover Crop (Auto)	Cover Crop (Manual)
Date of planting	5/2/2022	10/15/2021	5/2/2022	4/20/2022	10/15/2022		
Water yield, (in)	18.08	7.66	18.43	12.95	9.9	11.3	35.77
Surface flow (in)	22.38	11.77	22.16	19.81	16.04	17.16	41.29
Subsurface flow (in)	1.87	8.13	1.72	9.31	8.85	8.96	33.84
Deep percolation (in)	1.25	5.42	1.15	6.21	5.9	5.97	22.56
Nitrogen losses (lb)	47.58	7.37	45.79	18.52	16.18	16.67	21.62
Phosphorus losses (lb)	9.09	0.96	8.2	5.6	0.88	0.93	2.96
Total sediment (t)	5.14	0.05	5.13	0.15	0.04	0.06	0.15
Crop Yield (lb or bu)[1]	1020	4120	1117	62	62	62	64

[1]*Crop yield unit is measured in lb for cotton while soybean in bushel (bu)*

Potential Analytical Framework in Integrating the Surface and Subsurface Hydrological Models With the Economic Model for the Sunflower River Basin

Mahesh L. Maskey, Amer Al-Sudani, Amanda M. Nelson, and Nicolas Quintana-Ashwell

The Mississippi Delta, a region of the Lower Mississippi River Basin formed between the Mississippi and Yazoo Rivers in western Mississippi, is a vital water resource hub in the United States, producing crops such as cotton, soybeans, corn, rice, and catfish, which contribute around $6.8 billion in annual agriculture revenue. Since the Delta receives most annual precipitation outside the growing season, groundwater-dependent agricultural management practices substantially increased the number of permitted wells up to more than 20,000 in 22 years, leading to groundwater depletion in the Mississippi River Valley Alluvial Aquifer (MRVAA). Therefore, we conceptualized a framework that integrates surface and subsurface hydrological models with economic information to study hydrologic and economic dynamics behavior in depleted aquifers like the Delta.

We implemented the proposed framework for the Big Sunflower River Basin, a tributary of the Yazoo River (**Figure 1a**). The area with a nearly flat

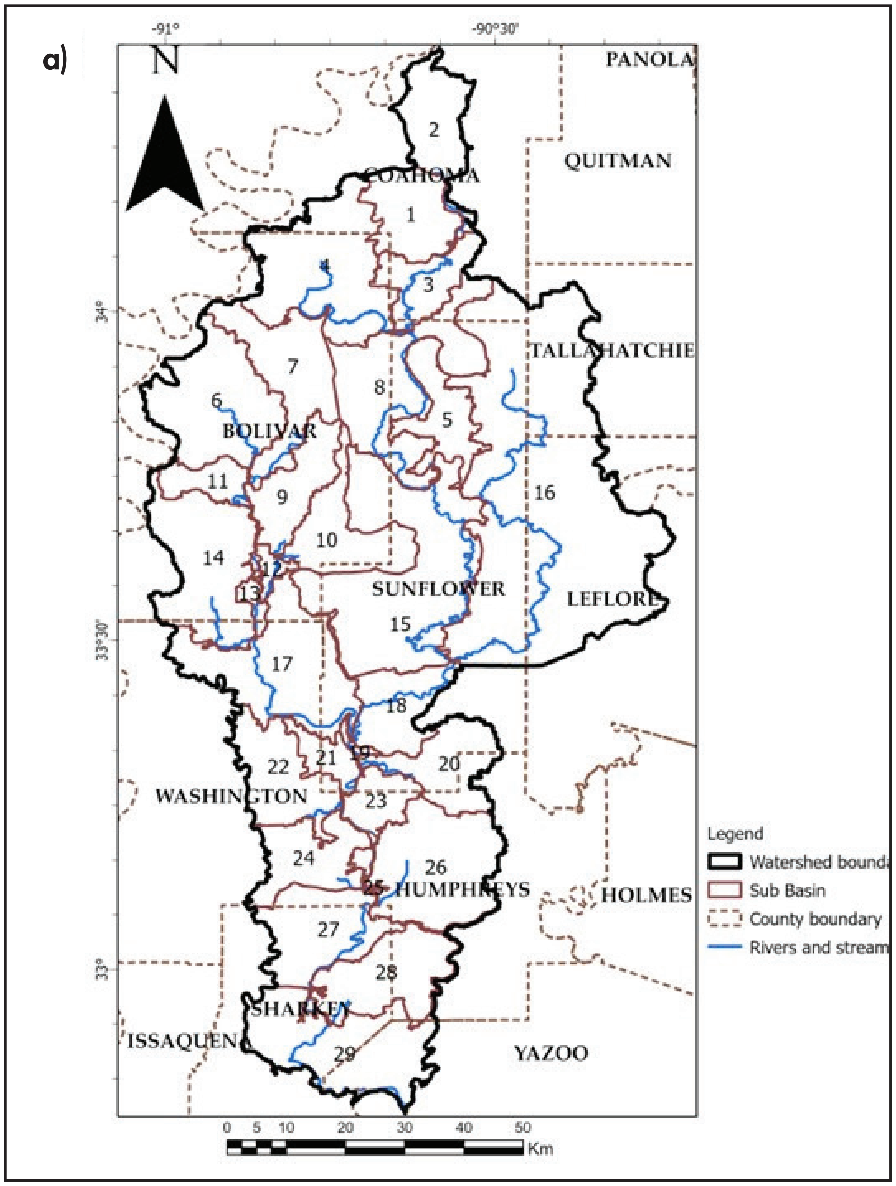


Figure 1. a) *The Big Sunflower River Basin encompassing ten Mississippi counties.*

topography is mostly soybean-dominated land, followed by corn and cotton.

In this study, we used ArcAPEX, a GIS-based Agricultural Policy Environmental Extender (APEX), to develop an agro-hydrological model for the basin with 10-m digital elevation model (DEM), land-use, and meteorological station network-generated weather data. The model simulated deep percolation and evapotranspiration for the groundwater model and crop yield for economic analysis for twenty years (2000-2019). These results were then input to the modular three-dimensional finite-difference groundwater flow model, MODFLOW, resulting in 500-meter grids generated groundwater tables and pumping lifts. Scenarios were run with no pumping and pumping for randomly chosen 131 wells among 15,000 wells spread across the basin assuming uniform groundwater extraction – an average of four-year pumping data (2014-2017) acquired from Yazoo Mississippi Delta Joint Wa-

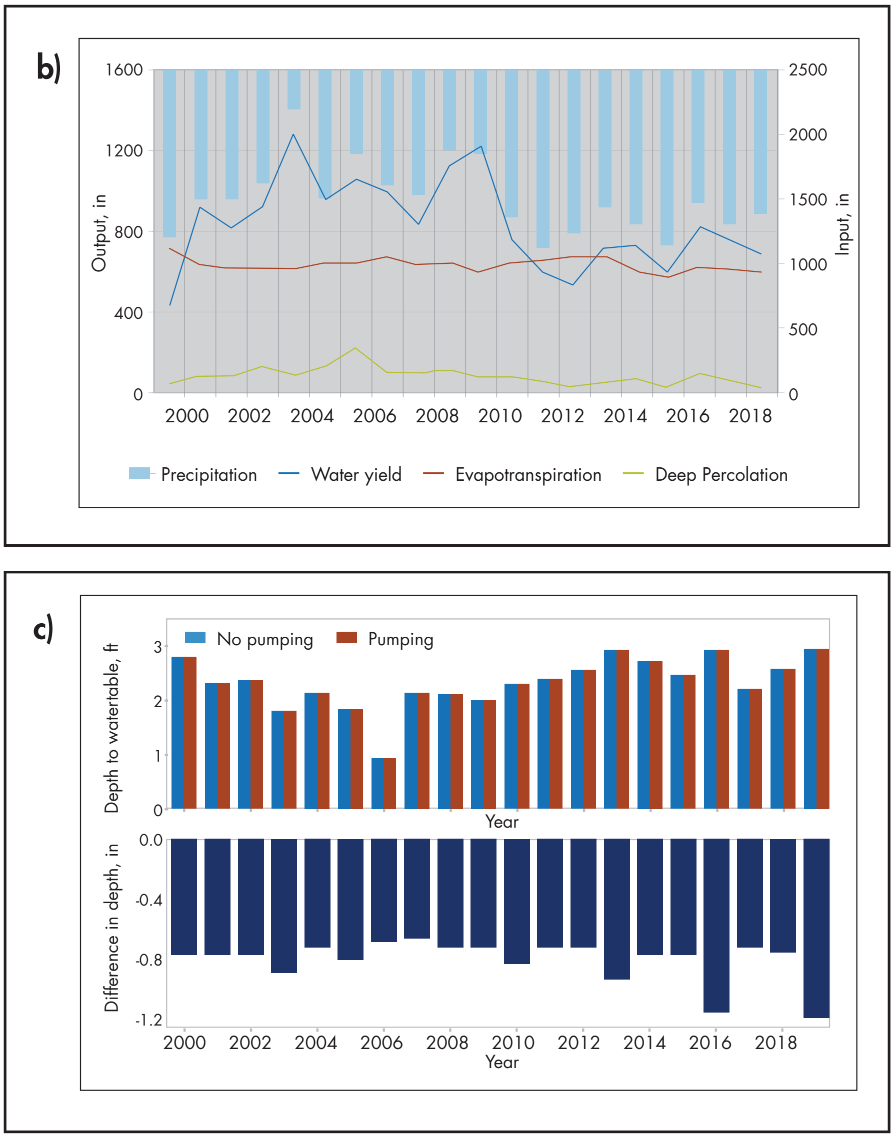


Figure 1. b) *Water balance over 20 years; and* ***c)*** *Groundwater depths implied by two scenarios (top) and their differences (bottom) over time.*

Table 1. *Optimized water use, lift, profit, and marginal cost over 20 years for different base years (mean ± standard deviation).*

Base years	Water use, thousand ac-ft	Lift, ft	Profit, $million	Marginal cost, $/ac
2000	542.89 ± 0.73	39.09 ± 4.26	228.88 ± 0.82	1.19 ± 0.11
2014	543.1 ± 0.86	36.4 ± 5.03	229.1 ± 0.96	1.12 ± 0.14
2015	544.19 ± 1.53	24.37 ± 9.00	230.29 ± 1.73	0.79 ± 0.24
2016	541.93 ± 0.13	48.07 ± 0.74	227.82 ± 0.14	1.43 ± 0.02
2017	429.69 ± 2.96	10.23 ± 14.5	207.26 ± 2.89	0.41 ± 0.39
2019	541.88 ± 0.1	48.93 ± 0.58	227.77 ± 0.11	1.45 ± 0.02

ter Management District for simplicity. Finally, we employed the Positive Mathematical Programming method for economic analysis based on simulated yield, lifts, and prevailing economic parameters from the literature (Quintana-Ashwell et al., 2021).

Water yield was the highest component, followed by evapotranspiration and deep percolation as per the simulated water balance from 2000 to 2019 (**Figure 1b**). The simulated soybean yield ranged from 10.4 to 31.2 bu/ac, while the reported yield varied from 28.8 to 71.4 bu/ac at the county level. Slighter groundwater depletion, in fact, reflects the inclusion of fewer wells in the domain, causing a maximum difference of 1.2 inches in groundwater depth (**Figure 1c**).

Table 1 presents the variability of the economic indicators useful for the local farmers in the county relying on hydrological information implied by selected base years. As expected, economic behavior is not consistent for different years. For instance, the base year 2015 implied maximum water usage and maximum profit, while the base year 2017 revealed lower values across all four indicators with a high correlation between optimized crop acreage and net revenue (not shown).

We conceptualized the integrated hydroeconomic model for the Big Sunflower River Basin. Integration of surface and subsurface hydrological and economic models provides valuable insights into the impact of depleted aquifers on agricultural revenue. Such an interdisciplinary notion offers several avenues for generating plausible historical and future scenarios to inform decision-makers when groundwater depletion is more of a concern elsewhere.

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Devising Protocols for Sensitivity and Uncertainty Analyses of Calibrated Agro-Hydrological Model for Runoff From Farm-Scale Watersheds Under Grazing Operations

Mahesh L. Maskey, Amanda M. Nelson, and Nicolas Quintana-Ashwell

Advancements in modern computational technologies have led to the proposal of simple to complex watershed models to improve water quality and quantity in agriculture. Likewise, scientists have been investigating sensitive parameters and intrinsic uncertainties in such models. However, accurately measuring calibration parameters has remained a challenge, and existing methods often rely unreasonably on their probability distribution. Therefore, we were motivated to refine a framework and improve hydrological modeling tasks: calibration, sensitivity, and uncertainty analyses. In companion to preliminary results from calibration, this project focused on the development of sensitivity and uncertainty analyses.

Nelson et al. (2023) calibrated the recently upgraded Agricultural Policy Environmental Extender (APEX) as an agro-hydrological model with an enhanced grazing database called APEX-graze to study watershed response to grazing operations in two small-scale watersheds with native prairie and cropland-maintained in the Water Resources and Erosion watersheds of the USDA-ARS Oklahoma & Central Plains Research Center near El Reno, Oklahoma. This study tested the refined protocols for sensitivity and uncertainty analyses of runoff quality and quantity parameters of the calibrated APEX-graze (Figure 1a) based on published data between 1977-2000.

Figure 1a presents frameworks for sensitivity and uncertainty analyses of runoff-related parameters from the calibrated APEXgraze model that satisfy the Moriasi Criteria (Moriasi et al., 2007, 2015), which helps discover a best-fit model from the thousands of simulations. The calibrated parameter set was then adjusted from -5% to +5%, resulting in 4,200 additional models for sensitivity analysis. Maskey et al. (2023) evaluated the objective function values for these and derived four types of sensitivity indices, listed in Table 1. In the uncertainty analysis, the mean (μ) and standard deviation (σ) of each parameter were calculated and tweaked within $\mu \pm 3\sigma$ with a 0.001 increment for 6,000 models.

Figure 1b illustrates how the percent change in individual parameters changes objective function value, in percent, for native prairie under grazing operations. For example, parameter PARAM [18] with dark purple cell appears to be the most sensitive because of higher changes in objective function value while tweaking the calibrated parameter by 2.79-2.94% (Table 1). Table 1 reports the most sensitive parameters, implied by four sensitivity indices for both watersheds and scenarios. Note it is challenging to obtain consistent sensitive parameters across different indices.

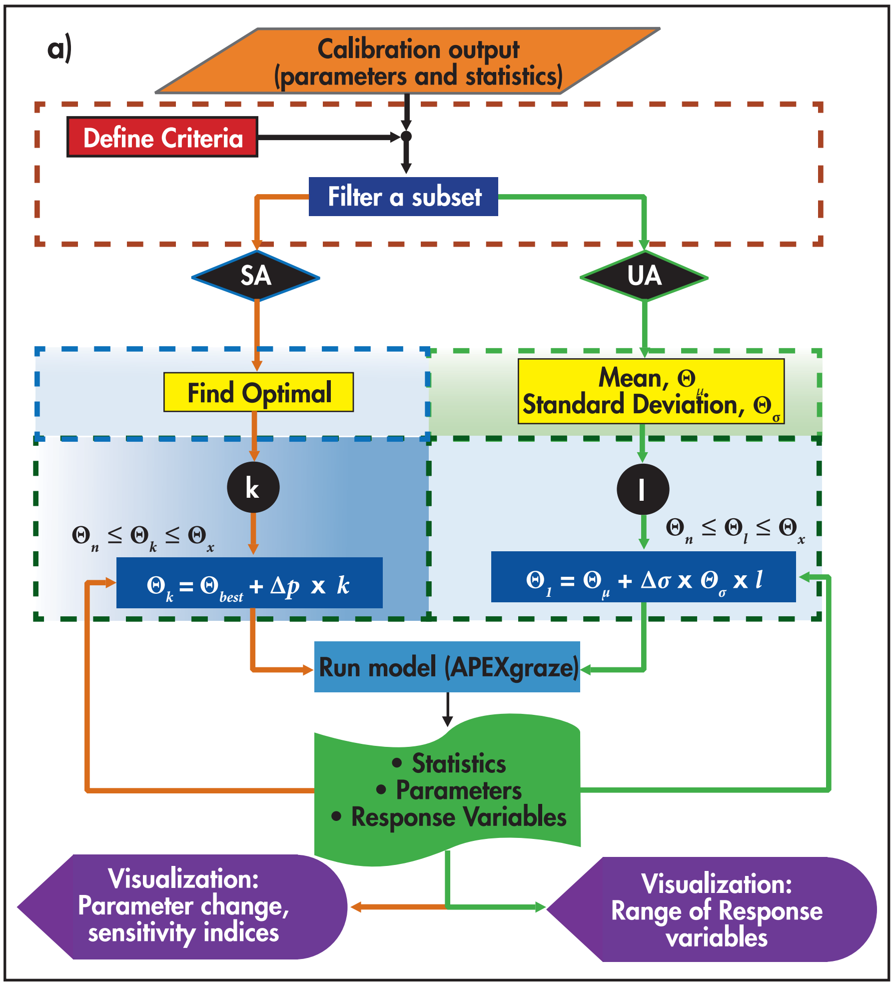

Figure 1. a) *Generalized frameworks for sensitivity and uncertainty analysis of parameters from calibrated APEX-graze model.*

Figure 1c exemplifies the monthly runoff at a cropland watershed outlet with grazing operations. As expected, the tweaked parameters resulted in observation and the best solution within the $\mu \pm \sigma$ that satisfies the Moriasi criteria.

The proposed sensitivity analysis framework revealed that the complex nature of watershed processes in any management system leads to inconsistent trends among sensitivity indices. Therefore, modelers should make subjective judgments while selecting suitable sensitivity indices for real-world problems. Likewise, refined technique uncertainty analysis is adequately able to capture the internal dynamics of hydrological processes within a statistically significant range of parameters, resulting in a small band of water balance in magnitude. The proposed protocols offer a chance to identify redundant parameters associated with sensitivity and uncertainty analyses. To further enhance this protocol, specific user interfaces will be developed for NCAAR-related projects and the scientific community.

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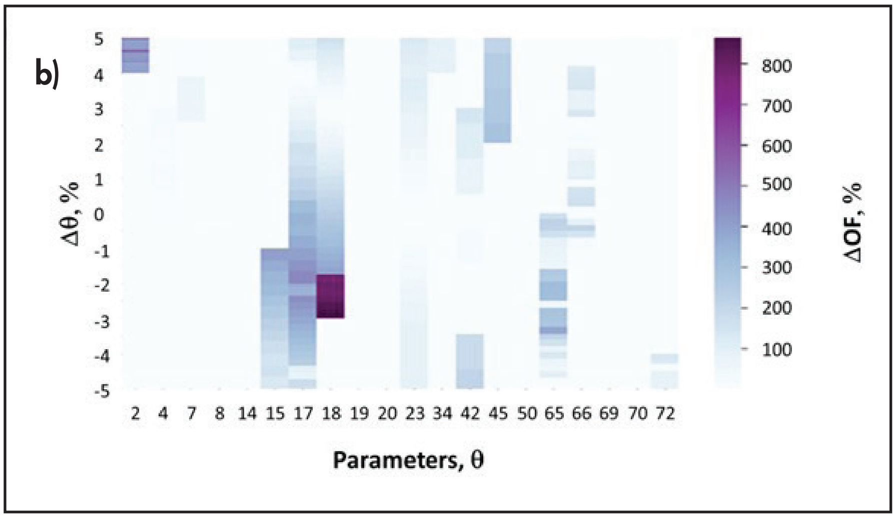

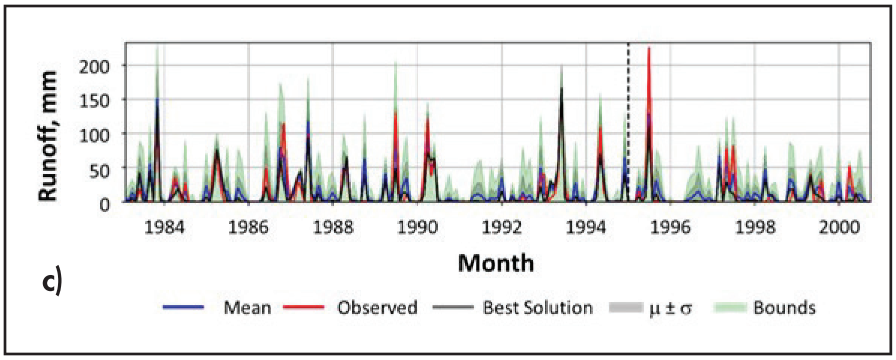

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Figure 1: b) *Heatmap of percent change in objective function values percent change in individual parameters with respective to calibrated values by ±5% with increment (decrement) of 0.05% for native prairie with grazing operations; and* ***c)*** *The range of monthly surface runoff at the outlet of cropland, implied by the uncertainty range of parameters within μ±σ and μ±3σ.*

Table 1. *Most sensitive runoff parameters for both watersheds without (left) and with grazing (right) operations with respect to the objective function values and derived sensitivity indices, each with first-order and total effects: one-to-one relationship index, variance-based SOBOL, Fourier amplitude sensitivity test (FAST), and Standardized Regression Coefficients (SRC). The one-to-one relationship indices do not have both orders, as they are derived from all simulations.*

Farms Watersheds		Without grazing		With grazing	
	Indices	First-order (value)	Total-effect (value)	First-order (value)	Total-effect (value)
Grassland (native prairie)	One-to-one	PARAM [2] (-4%, 1342.31)		PARAM [18] (2.79-2.94%, 862.70)	
	SOBOL	PARAM [20] (0.43)	PARAM [72] (0.48)	PARAM [34] (0.42)	PARAM [70] (0.51)
	FAST	PARAM [66] (0.03)	PARAM [2] (8.45E-03)	PARAM [66] (0.77)	PARAM [66] (0.98)
	SRC	PARAM [8] (-0.80)	PARAM [15] (-1.00)	PARAM [8] (5.27)	PARAM [20] (-3.86)
Cropland (wheat & oats)	One-to-one	PARAM [2] (-4.5%, 36.89)		PARAM [2] (-4.65%, 36.998)	
	SOBOL	PARAM [72] (0.25)	PARAM [72] (0.25)	PARAM [72] (0.35)	PARAM [72] (0.35)
	FAST	PARAM [70] (2.91E-03)	PARAM [8 & 45] (0.33)	PARAM [34] (2.12E-03)	PARAM [8 & 45] (1.00)
	SRC	PARAM [15] (-1.00)	PARAM [66] (-7.85)	PARAM [8] (2.69)	PARAM [8] (1.63)

DECISION TOOLS, EXTENSION RESOURCES, & EDUCATION

Calculating Pumping Costs Using MITOOL

Follow These 14 Steps to Calculate Your Irrigation Costs and Break-Even Yield

Being informed of the cost to irrigate can enable you to save time and money as you make irrigation termination decisions.
Our Mississippi Irrigation Termination Optimization On-Line (MITOOL) app helps you estimate the cost to irrigate. It can be accessed at: www.ncaar.msstate.edu/outreach/mitool.php.

1 Select Irrigation Type

Select the irrigation type. This aids the calculator in determining the dynamic head.

2 Enter Acreage

Enter the acreage of the field where irrigation is being considered

.

3 Enter Flow and Irrigation Depth or Hours per Irrigation

Pump flow, irrigation depth, and hours per irrigation are dependent on each other. Start by entering flow in gallons per minute. Then, either enter the quantity of water desired in inches in the "Irrigation Depth" parameter or enter the desired duration of the irrigation event in the "Hours per Irrigation" parameter (changing one field will adjust the other). Learn how to measure flow at https://www.ncaar.msstate. edu/outreach/fmcalc.php.

4 Select Pump Fuel Type

Select fuel type and then adjust the energy price depending on current fuel prices. Gasoline and diesel costs are in dollars per gallon, and electricity price is in dollars per kilowatt-hour (kWh).

5 Determine Pumping Lift

Use the dropdown menu to select a county to obtain the average depth (in feet) to water for that county or enter the depth to water of your well if known. If surface water is used, enter the elevation change from the water source to the riser.

6 Adjust Discharge Pressure

Discharge pressure has been pre-estimated based on irrigation type (40 pounds per square inch [PSI] for sprinklers and 5 PSI for others). You can also manually enter the numbers yourself.

7 Enter Pump Efficiency

This parameter is prepopulated to 65% but can be manually entered if known. Pump efficiency ranges from 50% to 80%, depending on pump impeller age; older impellers will have more wear and be less efficient. Write percentages as whole numbers.

8 Enter Gear Head Efficiency

This parameter is prepopulated depending on your selected pump type. Gear head efficiency ranges from 90% to 100% depending on pump drive type. Fuel-based engines with direct shaft drive are approximately 95%, belt-driven pumps are usually around 90%, and electric pumps are 100%. Enter manually if known, and write percentages as whole numbers.

9 Enter Management Time

Management time includes coordinating labor to accomplish the irrigating task. The default is 15 minutes, but time can be manually entered.

10 Enter Labor Time

This parameter is prepopulated based on given acreage. Studies suggest that it takes 1.53 minutes for each acre irrigated. This tool uses acreage to estimate labor costs but can be manually entered if known.
Labor costs regarding irrigation are often underestimated. Labor time varies depending on type of irrigation, infrastructure, distance to the field, pump maintenance, number of sets per event, progress monitoring, and other factors.

11 Enter Hourly Wages

Management and labor hourly wages are default for Mississippi median hourly wage but can be manually entered if known.

12 Pump Ownership Costs

Cost of repair, maintenance, and financing of the pumping station are measured in dollars per acre-inch. The default is $0.40 per acre-inch, but values can be manually entered if known.

13 Enter Crop Values

Individual market price of corn, cotton, and soybeans can be entered to determine yield needed to break even.

14 Click "Calculate"

Click "Calculate." If the calculator does not generate results, check that every field is filled, follow the prompts, and try again.

Irrigation Parameter

○ Furrow ○ Sprinkler ○ Other Non-Pressured

Total Acres	1
Irrigation Depth	4
Hours per Irrigation	
Pump Flow	

Pumping Costs

○ Electric ○ Gasoline ○ Diesel

Energy Price	
County	
Pumping Lift	
Discharge Pressure	5
Water Horsepower	

Pumping Efficiency

Pump Efficiency	65
Gear Head Efficiency	95

Labor Cost

Management Minutes	15
Labor Minutes	345.78
Management Hourly Wage	27
Labor Hourly Wage	13
Repair, Maintenance and Finance cost	0.40

Crop Parameters

Corn Price in $/bushel	5
Cotton Price in $/lb of lint	1
Soybean Price in $/bushel	9

Calculate

Results

Cost	$/Acre	Total
Pumping	$9.89	$395.68
Labor	$0.50	$20.01
Capital	$1.20	$48.00
Total Irrigation Event	$11.59	$463.69

Compare the cost of another irrigation with the expected benefits of additional irrigation; you can expect to profitably irrigate if the next irrigation event will reslt inthe following yield gains:

Commodity	Yield
Corn	2.32 bu/acre
Cotton	11.59 lbs/acre
Soybean	1.29 bu/acre

Understanding MITOOL Calculator Output

Pumping Cost

Pumping costs consider the pump's workload, fuel type, runtime, efficiency ratings, and energy prices.

Labor Cost

Labor costs are calculated by time spent and the cost of labor.

Capital Cost

This is the cost of repair, maintenance, and financing of the pumping station for the proposed irrigation event.

Total Irrigation Event Cost

This is the sum of pumping, labor, and capital costs.

Costs not estimated in this calculator, such as vehicle mileage, and additional equipment, should also be considered.

Commodity Break-Even Yields:

This is the needed yield benefit from irrigation to breakeven. If the expected yield gains from an additional irrigation exceeds the breakeven yield point, applying irrigation water will be profitable.

Other factors can affect the need to irrigate. Consider the precipitation and temperature forecast, current soil moisture conditions, and expected crop water use. Crops usually require less water during later growth stages.

Mississippi Master Irrigator

Dillon Russell and Drew Gholson

MOTIVATION

Currently, about 50% of Mississippi's agricultural land is irrigated, and approximately 40,000 to 50,000 new irrigated acres are added each year (Coblentz, 2023). With the steady addition of irrigated acres, it becomes extremely important that irrigation water is used more efficiently to reduce groundwater withdrawals. There are tons of water conservation and irrigation water management tools and practices that are available for producers, but adoption of these tools and practices is difficult when the producers either do not know about the tools and practices or they do not have enough information to successfully implement the tools and practices. Because of this, the Mississippi Master Irrigator program was developed to inform and educate irrigators across the state on irrigation water management tools and practices that can be used to reduce groundwater withdrawals, increase irrigation efficiency, and maintain or improve profitability.

PROGRAM

The Mississippi Master Irrigator program is an in-depth, educational course designed to address all facets of agricultural irrigation. The idea of the program is not new. Our program is being modeled after the original Master Irrigator course offered by the North Plains Groundwater Conservation District. Since the inception of the original Master Irrigator, numerous states around the country have developed similar programs. To become a Master Irrigator, it is required that all participants receive at least 24 hours of educational content. All other Master Irrigator programs around the country satisfy this requirement by offering three, 8-hour, in-person training sessions. Our program differs from the others in that our program utilizes a combination of online and in-person training. First, participants complete 8 hours of self-paced, educational content through our online course. Next, all qualifying participants who complete the online course meet in Stoneville for two, 8-hour, in-person training sessions. Some of the topics covered in our program include irrigation water management practices (IWM), soil health, water agronomics, irrigation scheduling, irrigation systems and equipment maintenance, the economics of irrigated agriculture, and policy and management. The online training material and in-person training sessions are taught by MSU Extension Specialists, as well as other individuals/entities with specialized experience in each discussion topic.

CURRENT PROGRAM UPDATE

The first Mississippi Master Irrigator certifying class is ongoing, and 50+ participants have registered and are currently completing the online portion of the course. Participants registered for the course include producers, consultants, industry professionals, research scientists, extension agents, and college students. The in-person training sessions are set to kick off in mid-February. We have also developed an extensive, in-depth

TAKE NOTE

2023 MASTER IRRIGATOR

38

PARTICIPANTS CERTIFIED

Participants include growers, farm managers, and researchers in the Mississippi and Arkansas Deltas.

24

HOURS OF CONTENT

Participants complete 8 hours of course work online and 2 8-hour in-person sessions of hands-on training.

14

IRRIGATION PROFESSIONALS

Specialists from across the MidSouth provide demonstrations and updates on the latest in irrigation regulations, practices, and technology.

$16K

SPONSORSHIPS, VOUCHERS, & GIVEAWAYS

Sponsors of the first Mississippi Master Irrigator course donate prizes and rebates and contribute to a first-class event.

irrigation manual that encompasses all the course content and more. This manual will be given to each program participant that completes the course. At the conclusion of the in-person trainings, participants will be granted a certificate titling them a "Mississippi Master Irrigator," which we expect will grant them funding and/or priority ranking from NRCS programs and discounts on soil moisture monitoring equipment.

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RESEARCH + OUTREACH

WATER IN AGRICULTURE SEMINAR SERIES

NCAAR researchers have had the opportunity to share their research and the NCAAR mission with other researchers and our local stakeholders through a continuing seminar series. This series combines ARS and Mississippi State University employees, as well as invited speakers from other water-related research centers across the country, and serves as an outlet in which NCAAR scientists and staff can get their research out to a wider audience.

PRESENTATION TOPICS:

- Satellite remote sensing of cover crops
- Analysis of tailwater recovery systems
- Cost of mismanaging crop heat stress
- Advancing environmental sustainability in the Mississippi Delta

DELIVERED BY:

- 4 NCAAR scientists
- 2 post-doctoral fellows
- 3 graduate students
- 2 invited speakers

Seminars are held monthly through the MSU school year. The seminars average 25 attendees in person and virtually.

Use your phone's camera to watch the 2023 seminar series.

NCAAR
NATIONAL CENTER FOR ALLUVIAL AQUIFER RESEARCH
USDA United States Department of Agriculture
MISSISSIPPI STATE UNIVERSITY

Increasing Mississippi Youth Interest in and Entry to Sustainable Agriculture Practices and Careers

Tinuola Osho, Peyton Johnson, Himmy Lo, Drew Gholson, Leslie Burger, Beth Baker, Mary Love Tagert, Manola Erby, Carolyn Banks, Jacqueline McComb, Sonia Eley, Karla Turner-Bailey, and Steele Robbins

Sponsored by USDA-NRCS under award NR204423XXXXC116

OVERVIEW

Mississippi agriculture is becoming increasingly technical, and the industry faces intensifying economic pressures and environmental concerns. Our state must develop a skilled and motivated workforce capable of overcoming these challenges to secure the future of our agricultural industry and the rural communities that depend on it. This project seeks to grow youth interest and participation in agriculture through a collaboration among Mississippi State University (MSU), Alcorn State University, Hinds Community College, and Mississippi Delta Community College.

The project focuses on three goals. First, we educate high school students about the scientific principles and societal importance of soil and water conservation and sustainable agriculture. Second, we introduce high school students to the breadth of educational and employment opportunities in the fields of agriculture and natural resources. Third, we offer disadvantaged students hands-on learning experiences in agriculture and natural resources.

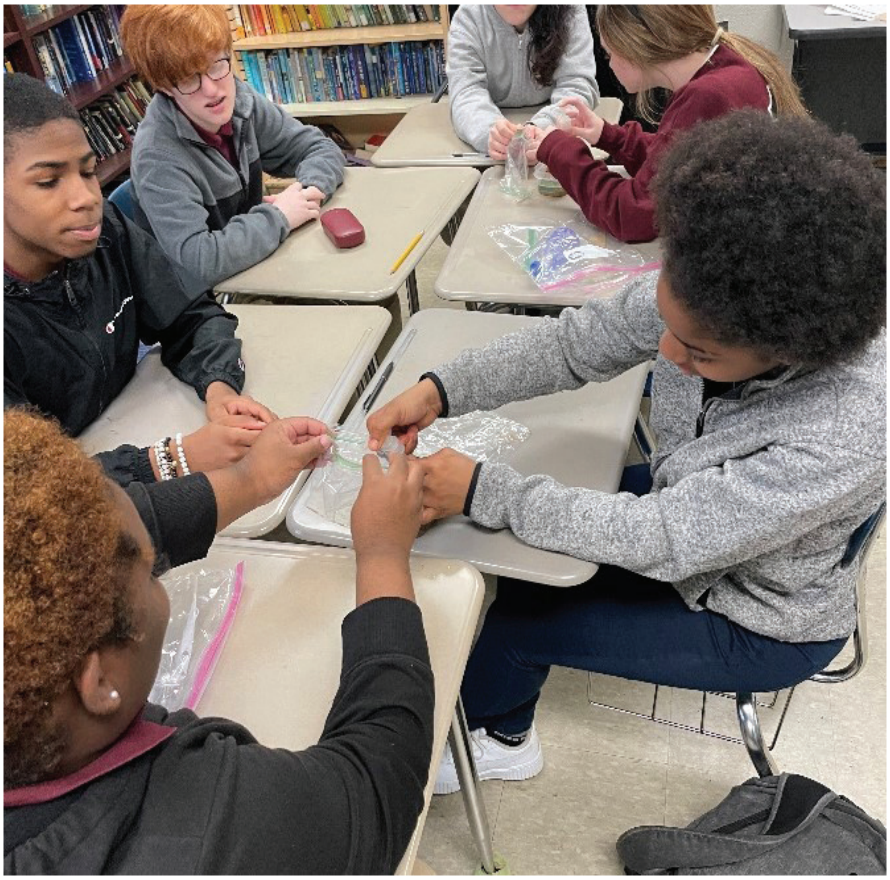


Figure 1. *Mississippi high school students engaging in an interactive classroom activity where they are learning about groundwater aquifers and their agricultural importance.*

The project has been ongoing in the Mississippi Delta. In the summer of 2023, the project expanded its geographical scope to include Central Mississippi with the addition of Ms. Peyton Johnson coordinating efforts there.

Figure 2. *Mississippi elementary students learned about honey bees from faculty and staff of the National Center for Pollinator Health.*

CLASSROOM PROGRAM

During 2023, the project reached approximately 2000 Mississippi high school students through the classroom program. The classroom program consists of two interactive lesson modules. The first module focuses on sustainable agriculture, soil and water conservation, and food science. The second module focuses on career pathways and introduces students to educational requirements and jobs in agriculture and natural resources. As indicated by questionnaire responses from participating students, the classroom program nearly doubled the percentage of students interested in agriculture and its careers while also increasing students' awareness of diverse job options in agriculture.

FIELD TRIPS

On May 18, 2023, the project hosted 35 students from local high schools at Delta Research and Extension Center (DREC). Following a career fair format, students interacted with professionals from DREC and from the United States Department of Agriculture (Natural Resources Conservation Service, Agricultural Research Service, and Forest Service) to discuss careers in agriculture and natural resources. Students also toured plant pathology and catfish pathology laboratories, a cotton-ginning research facility, and live demonstrations of irrigation, precision planting, soil moisture sensing, and catfish feeding.

On two separate summer days, the project collaborated with the DREC Apiculture Lab and the Indianola Library System to host honeybee field trips for almost 100 students. Students learned about honey extraction, insect biology, tree planting, waggle dancing, and candle making.

AGRICULTURAL INTERNSHIPS

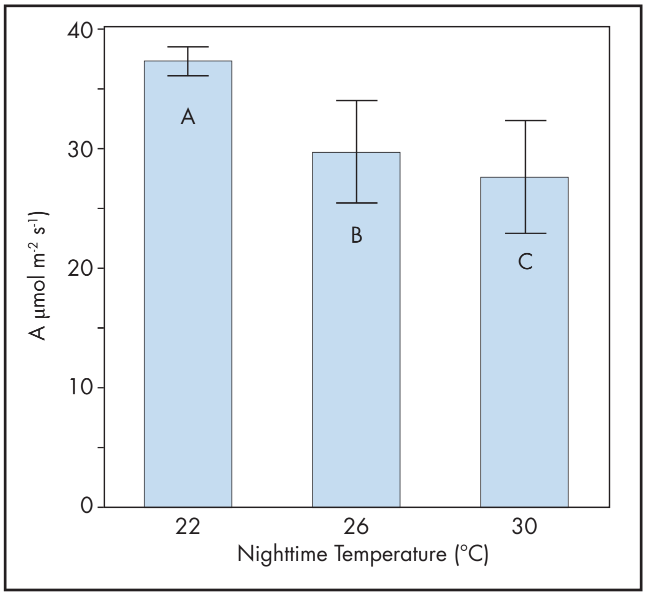
In 2023, the project launched a paid internship program. Nine student-interns were hired to work with agricultural professionals at DREC and the MSU Starkville campus. These student-interns were recruited through public schools where the classroom program had been presented and through a collaboration with Minorities in Agriculture, Natural Resources, and Related Sciences (MANNRS).

SUMMER PROGRAMS

During the summer of 2023, project co-investigator Dr. Leslie Burger organized a three-day Science Scholars Camp on the MSU Starkville campus targeting women and minorities. Ms. Tinuola Osho assisted and gave the classroom program to 24 participants. During the 2023 State 4-H Congress, Ms. Tinuola Osho spoke to 25 high school students about careers in agriculture and natural resources.

MINORITY ROLE MODELS IN AGRICULTURE

The project has been creating a series of interview videos featuring Black/African American professionals in agriculture and natural resources. Five videos were completed in 2023, and more are anticipated in the coming years. Once released on YouTube and on social media platforms, these videos are expected to serve as an informational and motivational resource for minority students in Mississippi and beyond.



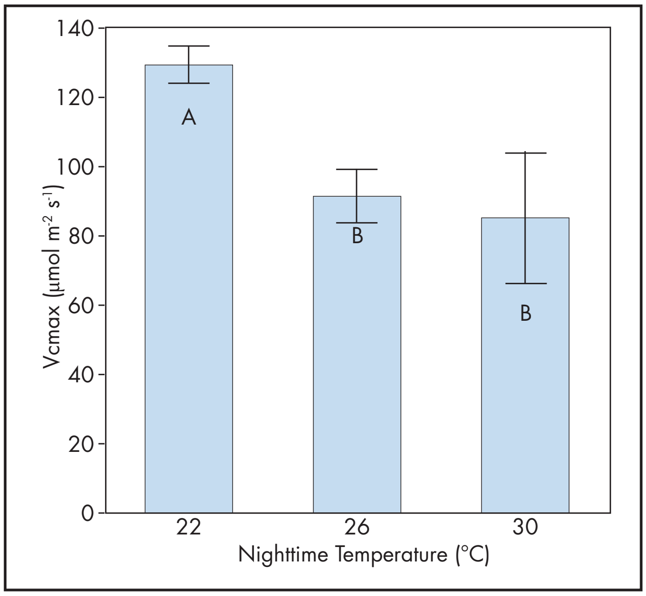


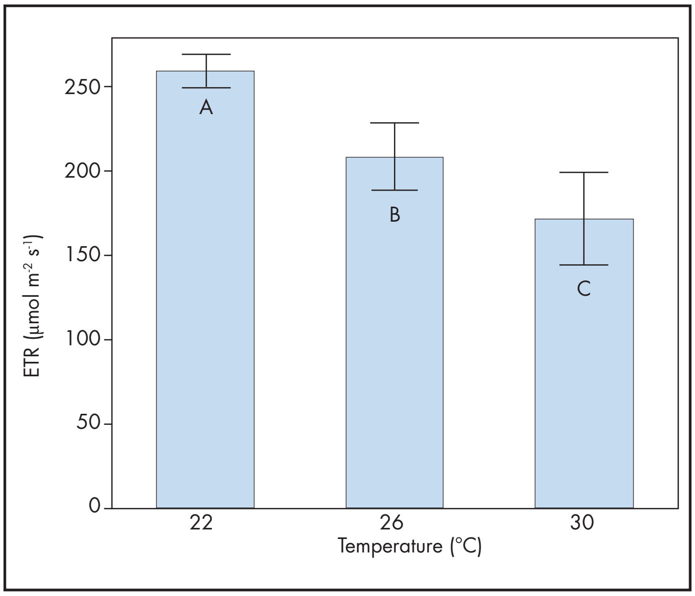
Figure 1 (left). *Net photosynthesis (A) by nighttime temperature. Data are means ± SE (n=6).* ***Figure 2.*** *Maximum rate of carboxylation (Vcmax) by nighttime temperature. Data are means ± SE (n=6).*

The Effect of Nighttime Temperature on Midday Photosynthetic Parameters

Daryl Chastain

In recent years, the southeastern United States has experienced a concerning trend of increasing nighttime temperatures. This shift is attributed to a combination of factors, including urbanization, changes in land use, and broader climate patterns. Moreover, alterations in land use, such as deforestation and agricultural practices, may disrupt natural cooling processes. Climate change exacerbates these effects, with rising overall temperatures impacting the region. The consequences of warmer nights pose specific challenges for agriculture in the region. Warmer nights can disrupt physiological mechanisms for crops, affecting their growth and development. Crops, especially those sensitive to temperature fluctuations during specific growth stages, may experience altered yields and reduced quality. Additionally, the increased heat stress on plants can elevate water demand, putting additional pressure on irrigation systems and irrigation sources such as surface and groundwater (Sadok and Jagadish, 2020). Farmers may need to adapt by implementing new agricultural practices, selecting heat-tolerant crop varieties, and optimizing irrigation strategies.

Rising nighttime temperatures can significantly impact cotton growth, yield, and physiology. Cotton is particularly sensitive to temperature stress (Zahid et al., 2016). High nighttime temperature has been shown in other crops to increase nighttime respiration while decreasing midday photosynthesis. This results in increased energy expenditure without corresponding photosynthetic gains; however, this is not well documented in cotton. This can lead to reduced overall growth and yield. Additionally, extended periods of warm nights may disturb the plant's reproductive development, affecting flower and boll formation/retention. Cotton is also sensitive to water stress, and higher nighttime temperatures can exacerbate this by increasing nighttime evapotranspiration rates, requiring more water to maintain optimal growth. This places additional pressure on irrigation



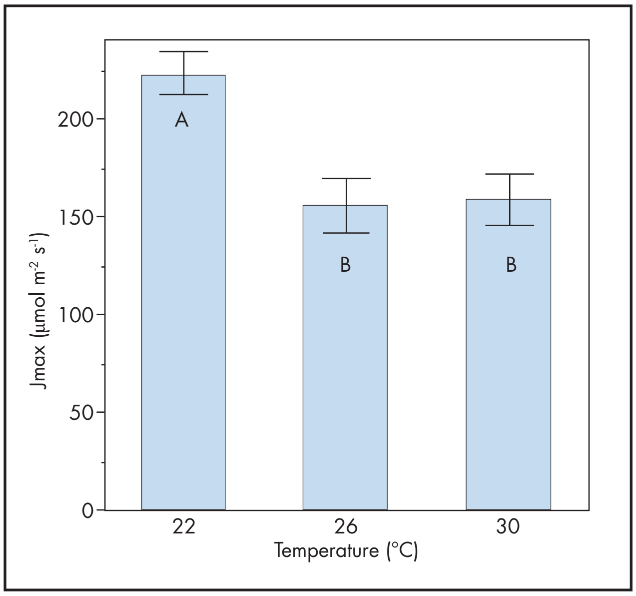


Figure 3 (left). *Electron transport rate (ETR) by nighttime temperature. Data are means ± SE (n=6).* ***Figure 4.*** *Maximum electron transport (Jmax) by nighttime temperature. Data are means ± SE (n=6).*

systems, impacting water management.

In order to fill knowledge gaps and to gain a better understanding of the physiological processes that are most sensitive to nighttime heat stress, we designed an experiment to investigate the effect of elevated nighttime temperature on midday photosynthesis. For this short report, we will focus on photosynthesis and a few associated parameters. Briefly, cotton plants were grown under an 86/72°F, day/night temperatures until flowering in controlled environments. Then, two treatments were subjected to either a 79 or 86°F nighttime temperature for 40 days. After which, the uppermost fully expanded leaf was measured for photosynthesis, chlorophyll fluorescence and CO_2 response.

Figure 1 shows that despite optimal conditions during the day, elevated nighttime temperature resulted in a significant decrease in midday photosynthetic rate. Interestingly, Vcmax (**Figure 2**), a parameter that indicates the maximum rate of photosynthesis, was also affected. This indicated that the enzymes relevant to storing carbon as sugars is somehow inhibited. **Figure 3** describes the actual rate of electron transport (an important indicator of the plants ability to capture energy to be used to store carbon). Under elevated temperature treatments, ETR was shown to be negatively affected. This is reflected in Jmax, a parameter indicative of the maximum rate of energy storage and transfer to the carbon storage reactions, was also negatively affected.

Typically, when cotton is grown under stressful temperature regimes, the main solution is to irrigate to provide adequate moisture for evaporative cooling. Under elevated nighttime temperature, this is not an option since transpiration during the night rates are often very low and result in little cooling of the crop, contributing negatively to the overall crop water budget. Transpiration rates during the day appear to be unaffected (data not shown) by this temperature stress; however, decreased photosynthetic rates during the day are depressed which results in a decrease in crop water use efficiency (data not shown). One potential solution to this problem could be timely planting to push the flowering stage into more favorable conditions. Additionally, breeding efforts where selection is based on the parameters described in this paper could produce varieties more suitable to future climate scenarios.

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PUBLICATIONS

NCAAR faculty shares their research in academic communities through publication submissions to agricultural and scientific journals. What follows is a listing of the work our faculty contributed to journals in 2023.

Anapalli, S.S., Pinnamaneni, S.R., Reddy, K.N., Wagle, P., Ashworth, A.J. 2023. Eddy covariance assessment of alternate wetting and drying floodwater management on rice methane emissions. Heliyon. 9(4): e14696. https://doi.org/10.1016/j.heliyon.2023.e14696

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