**MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT 62-2016 (YEAR 3)
2016 FINAL REPORT**

Title: Determine irrigation rate and timing, and water availability for optimum yield, water use efficiency and profitability of soybean in Mississippi Blackland Prairie region

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BACKGROUND AND OBJECTIVES

The desire by most producers to stabilize or enhance crop yields through irrigation has led to the overdraft of groundwater resources in many regions of Mississippi. Irrigation utilization has increased for many soybean producers, increasing the importance of optimal irrigation management practices that are site- specific in nature, since precipitation rates, soil types, and climate can vary widely between county and parcel. Thus, a comprehensive study on irrigation as it pertains to soybean production in the state of Mississippi is warranted.

Previous irrigation studies were conducted mainly in the Delta region; however, some of those observations might not be applicable on irrigated fields in northeast and east-central Mississippi due to differences in weather, soil type, and other factors. Additionally, unlike the Delta region where groundwater is a major source, producers in the Blackland Prairie region of east-central Mississippi commonly use water from rainfall and runoff that is stored in ponds. Growers in the region have steadily increased their utilization of surface water irrigation in recent years and appear eager to learn irrigation management technologies and practices for ensuring that the proper amount of water is applied at the right time and rate.

A principle focus of this project is to meet the water requirement for optimal soybean production through the use of impounded surface water. Objectives of the proposed field and simulation modeling experiments are to:

Objective 1. Determine optimal irrigation amount, rate, and timing (i.e., a triggering criteria) to maximize yield and water use efficiency (WUE) of modern soybean cultivars.

Objective 2. Determine impounded surficial water availability and sustainability for irrigation through the estimations of water dynamics and water budget in the surface impoundment structure (pond) using computer simulations in conjunction with field measurements.

Objective 3. Assess net returns to irrigation using pond water.

REPORT OF ACTIVITIES

Objective 1

Experimental design and crop management

In 2014, the project utilized a 17.4-acre, pivot-irrigated field located at the Good Farm in Noxubee County. The irrigated area, which contains Vaiden (Va), Okolona (Ok), and Demopolis (De) soil types (9.4, 5.8, and 2.3 acres, respectively; NRCS data) was divided into eight pies to accommodate three treatments in each soil type of (1) ‘Rainfed or RF’—not irrigated; (2) ‘SM’—irrigation when root zone soil moisture is 50% of total plant available water (TAW); and (3) 'ET'—75% to 80% of calculated daily crop evapotranspiration (ETc) the previous day, giving nine experimental plots. In 2015 and 2016, the project utilized a 3-acre, furrow-irrigated field located at the Mississippi State University Black Belt Branch Station in Noxubee County. The field contains a Brooksville silty clay soil and was divided into blocks from west to east. Three treatments [same as 2014 (RF, SM, and ET)] were replicated in four randomized complete blocks in 2015. In 2016, the two irrigation treatments were replicated in three randomized complete blocks. To avoid water contamination, the three ET plots were furthest away from the irrigation source (Fig. 1). A group IV cultivar, Asgrow 4632, was planted at 120,000 seeds per acre in rows spaced 38 in. apart on 8 May 2014, 19 May 2015, and 9 May 2016. Plots were mechanically harvested on 10 Sept. 2014, 15 Oct. 2015, and 22 Sept., 2016.

Sensor installation, soil and plant measurements

In each plot we installed soil matric potential sensors (Watermark, Irrometer) and soil moisture sensors TDR315 (Acclima Inc.) coupled to dataloggers (Campbell Scientific Inc.) at depths of 0-6, 6-12, 12-18, and 18-24 inches. Soil samples at the four depths using a soil probe were periodically taken to measure soil moisture by classic drying method at 105 °C. These measured soil moistures were used as standard values to calculate actual amount of irrigation applied to each plot and calibrate TDR sensors values. Percolation below the root zone was measured using a pen lysimeter (Soil Moisture, Corp) in each plot. Runoff was collected by a microflume runoff collector at the end of one furrow in each plot. The effective rainfall and canopy interception were measured using a rain guage positioned above the canopy and a complementary guage below the canopy on top of the bed. All components of water balance in the soybean field were measured on-site.

Soybean developmental growth stage, plant height, canopy cover, and plant dry biomass were measured weekly or biweekly by taking plants from (3) 30-cm-long sections in each plot. Leaf Area Index was measured using a Decagon Inc. AccuPar LP-80.

Components of water balance

Rainfall

In the Blackland Prairie region from 1895 to 2014, the average annual rainfall was 51.2 in. The probability of occurrence of annual rainfall ≥ 44.3 inch is 75%. Annual rainfall of wet, normal, and dry category years was in the range of 57.7 to 76.0 in., 44.5 to 57.6 in., and 31.6 to 44.3 in., respectively. During the soybean season, mean rainfall was 17 in. and over 50% frequency ranged from 8.9 to 16.2 in., accounting for 30% of annual rainfall in the normal and dry years. Mean rainfall during the entire soybean season in wet, normal and dry category years was 23.5 in., 16.6 in., and 11.0 in. The range of dry category years during the soybean season was 9 to 13 in. as determined from 120 years of weather data in the region.

The annual rainfall in 2014, 2015, and 2016 was 57, 51 and 42 in., respectively; all were in a normal category year. Rainfall during the soybean season was 10.3 in. in 2014, 15.3 in. in 2015, and 11.2 in. in 2016. All were in the historical range greater than 50% frequency. Rainfall intercepted by the canopy was only 0.4 and 0.6 in. during the entire growing seasons of 2015 and 2016, respectively.

Actual Evapotranspiration (ETc)

From 1895 to 2014 in the Blackland Prairie region, average annual ETo was 48 in., and monthly ETo ranged from 4 to 6 in. between May and October. ETo was calculated by the Penman-Monteith method using 2014-2016 data from the Macon and Brooksville weather stations. During the soybean season, ETo was 25 in. for 2014 and 2015, and 27 in. for 2016.
We adopted the crop coefficient (NE Kc) published by University of Nebraska Extension, as values have not been determined for Mississippi. Average Kc values before R1, from R1 to R3, and from R3 to R6 were 0.21, 0.67, and 0.94, respectively. Crop water requirement (ETc) was obtained using ETo multipled by NE Kc. As a result, ETc in 2014-2016 was 19, 18 and 20 in. from planting to harvest, respectively, close to our mean value of 21 in. over the last ten decades.

In 2014, maximum plant height was 43 in. and ground cover was 90% or greater at R3 stage in mid-June. Approximately 15% of water was lost through evaporation, and consumptive water use by soybean was 85%. Average water use was about 0.08 in./day before R1, increased at R2 (full bloom) and continued through pod-filling stage, with an average of 0.20 and 0.16 in./day for irrigated and rainfed soybean, respectively. Peak water use occurred at pod filling stage. 70-75% of total water consumption in the entire growing season occurred during reproductive (R) stages in 2015 and 2016. Soil moisture and soil water potential sensors installed in the field indicated that soybean plants removed water down to the 36 in. soil depth in the humid US Mid-south over the three years of this study.

Rain water deficit (Rain - ETc) and irrigation demand

Rain water deficit during the entire growing season was 2.7 in. for 2015 and 8.7 in. in 2014 and 2016. Average amount of required irrigation was 7.1 in./year over 120 years and 6.4 in./year over 60 normal years. Soybean did not need irrigation for only 12 out of 120 years. Soybean required an average of 7 in./year of irrigation water across the 120-yr period from June 29 to September 7, mostly from stage R3 to R7.

Irrigation amount and timing

On-site soil moisture data measured by soil sensors and weather data at a local ARS weather station were downloaded through office modem at least weekly. Data are used to estimate available soil water in the effective rooting zone and daily ETc. Those data were used weekly to determine when root zone soil water depletion (SWD) reached irrigation trigger points of 50% of total available water (TAW) and 25% of ETc.

2014. Both the Vaiden and Okolona soils reached SWD trigger points at about the same time on July 26 during the R5 stage (Fig. 2 & 3). A 0.7 in. rainfall on Aug. 3 replenished some depleted water, but due to remaining deficit of 0.9 in. to meet the trigger point, 1 in. was applied by center pivot to both irrigation treatments (i.e., five pivot pies) on Aug. 6.

2015. The SM treatment received 4.5 in. of irrigation and the ET treatment received 3 in. of irrigation.
Both SM and ET irrigation treatments were triggered at the same time on July 15 (R3) and July 28 (R5). Using the TAW curve, it was determined that 1.5 in. of irrigation was needed, so 1.5 in. irrigation was applied to the two treatments on July 15 and 28. On August 4, soil moisture data indicated the SM treatment needed irrigation, whereas the ET-based treatment was not forecast to receive irrigation until August 11. On August 5 (R6), approximately 1.5 in. of irrigation was applied to only the SM-based. From August 6-9, 2 in. of rainfall was recorded, pushing back all of the ET-based irrigation treatment needs. Over the next week (August 13-19), 2.5 in. of rainfall was recorded, causing all treatments to have ample water until R7 growth stage. No irrigation was needed after that time.

2016. Rain water met 56% of soybean water needs. In the vegetative growth stages, rainfall (3.2 in) fully satisfied the soybean ETc requirement of 2.3 in. All irrigation was required during the R stages. The SM treatment required six irrigations and received 9 in., whereas the ET treatment required five irrigations and received 7 in. Both SM and ET irrigation treatments were triggered at the same time on June 28 (R2), July 5 (R2), July 15 (R3), July 27 (R4), and August 4 (R5). In addition, the SM treatment was triggered earlier and one more time on June 22 (R1).

Irrigation trigger point

Because irrigation trigger point relies on the amount of TAW for a given soil, the selection or measurement of TAW is essential for sensor-based irrigation scheduling. As an example for a Demopolis soil on 15 July, on-site measured RAW (Readily Available Water, equivalent to 50% of TAW) could trigger irrigation 10 days earlier than soil texture data source and SSURGO database. The commonly used TAW is based on textural classification and is approximately 0.18 cm^3 cm^{-3} for clay loam soils. In comparison with on-site measured values, we calculated a difference of 13 days in irrigation timing and 2.6 inch in maximum root zone. The NRCS SSURGO database provides three TAW values of 0.05, 0.14 and 0.17 cm^3 cm^{-3} for Demopolis soils. Calculation revealed a difference of 18 days in irrigation timing and 2.4 in irrigation between the lowest and highest TAW values (0.05 – 0.17 cm^3 cm^{-3}). Average of the three values is 0.12 cm^3 cm^{-3} which is similar to field measurements. The average TAW value of Okolona soil is 0.20 cm^3 cm^{-3}, which is also similar to field measurements. Additionally, the TAW value of Vaiden soil is 0.13 cm^3 cm^{-3}, which is very similar to field-measured TAW.

Field capacity (FC) and wilting point water content (PWP) of Brooksville silty clay that we measured in both lab and field was 0.42 and 0.24 cm^3 cm^{-3}, respectively. Soil texture based table show FC and PWP are 0.40 and 0.28 cm^3 cm^{-3}. SSURGO database provides FC and PWP of 0.34 and 0.28 cm^3 cm^{-3}. As a result, the three data sources result in the TAW values of 0.18, 0.12 and 0.06 cm^3 cm^{-3}, respectively. However, SSURGO also provides the TAW value of 0.21 cm^3 cm^{-3} which is different from the difference between FC and PWP in the database.

Previous research suggested irrigation trigger points of 50, 60 or 80 centibars tension, which corresponds to 68 to 89% of field capacity at 33 centibar in the tested soils. Readily Available Water (RAW) is, in general, considered as approximately 50% of field capacity. Our on-site, field measured water release curves for soils common in north central Mississippi suggested the trigger point can be as high as 100 centibar.
In summary, these results and observations suggest profitable use of soil moisture sensors for irrigation scheduling will require knowledge of TAW values measured in either the field or laboratory and the subsequent use of these values should be done in combination with soil sensor readings to schedule irrigations that are accurate for a given soil and across water-critical crop growth stages.

Runoff and leaching

No runoff was measured in any collector during the growing season of any year. However, 1.4-4.5 liter of water percolated to the 36 in. depth from June 12 to Aug.11, 2014. More water percolated below 36 in. in the Vaiden soil than in the Okolona and Demopolis soils. In 2016, leachate waters ranging from 13 to 1000 ml were measured at the 36 in. depth from July 1 to Aug. 27 during the R1-R7 period. Variation in leaching was due to the different soil physical and chemical characteristics at varying depth of soil above a shallow chalk layer.

Production

*2014. S*oybean irrigated at R5 stage on Aug. 6 had mean grain yield (n=6) of 5589 lb/acre (93 bu/acre, based on hand harvest of 12-in. length of row) and a harvest index of 50%. Irrigation increased grain yield, aboveground biomass, thousand grain weight, and harvest index by 10, 8, 7, and 3%, respectively (Table 1). Yield and yield components did not differ significantly between irrigation treatments or soil types. Rainfall after irrigation was twice that of long-term average rainfall, so pod filling was not significantly affected, and thousand grain weight averaged 0.33 and 0.31 lb for irrigated and rainfed treatments, respectively, which could explain the small difference in grain yield. Approximately 40% of growing-season rainfall occurred after irrigation, and the site received 8.7 in. of rainfall during the vegetative and early reproductive stages, so soybean was not stressed. The two irrigation treatments had similar water use efficiency (317 lb/acre/in.) and biomass water use efficiency (635 lb/acre/in.).

2015. Soybean was irrigated three times at the R3 (7/15/15), R5 (7/28/15,) and R6 (8/5/15) stages, and produced mean grain yield (n=4) of 2881 lb/acre (48 bu/acre, based on combine harvest) and a harvest index of 61%. Soybean irrigated two times at the R3 and R5 stages had mean grain yield (n=4) of 2667 lb/acre (45 bu/acre) and a harvest index of 66% (Table 2). Irrigation three times and two times increased grain yield by 18% and 9%, aboveground biomass by 23% and 44%, thousand grain weight by 34%, and harvest index by 40%. Pod filling was not significantly affected, and thousand grain weight averaged 0.31 and 0.28 lb for irrigated and rainfed treatments, respectively. Table 2 indicates that the two irrigation treatments had similar water consumption (21 in.) and grain water use efficiency (134 lb/acre/in.).

2016. Soybean irrigated six times on June 22 (R1), June 28 (R2), July 5 (R2), July 15 (R3), July 27 (R4), and August 4 (R5) had mean grain yield (n=3) of 2747 lb/acre (46 bu per acre, based on combine harvest) and harvest index of 32%. Soybean irrigated five times at R2, R3, R4 and R5 had mean grain yield (n=3) of 2663 lb/acre (44 bu/acre) and harvest index of 32% (Table 3). Irrigation six times and five times significantly increased grain yield by 41% and 40% and total aboveground biomass by 46% and 38%, respectively. Additionally, irrigation increased harvest index by approximately 10%. Irrigation did not affect pod filling, as thousand grain weight averaged 0.33 lb. in the two irrigated treatments and 0.35 lb in the rainfed treatment. Irrigation increased the number of pods by 100%, a difference that contributed to grain yield increase over the rainfed treatment. Table 3 indicates the irrigation and rainfed treatments had grain water use efficiency of 144 lb/acre/in. and 119 lb/acre/in., respectively. Though the sensor-based method triggered one more time of irrigation, it only increased grain yield by 3%.

<u>Simulation study</u>

The Agricultural Policy/Environmental eXtender (APEX) agro-ecosystem model was calibrated, validated, and then applied to simulate rainfed and irrigated soybean grain yield (GY) for nine major soils in the Blackland Prairie during 14 years (2002–2015). The simulation study revealed that:

- The average rainfed grain yield for wet, normal and dry category years was 73, 67 and 55 bu ac^{-1}, respectively.
- Rainfed soybean yield ranged broadly from 40 to 86 bu ac^{-1}, and rain use efficiency varied from 4.2 to 13.0 bu/acre/in. on seven soil types, all silty clay. Available water volumetric content (difference between field capacity and wilting point water content) differed from 0.07 to 0.19 in.
- Under rainfed conditions and averaged across 13 years, Vaiden, Leeper and Catalpa soils produced 91 bu/acre. Brooksville, Okolona and Kipling soils produced 86 bu/acre, and Demopolis, Sumter and Griffith soils produced 71 bu/acre.
- Supplemental irrigation was primarily applied at R2 to R7 stages, with relatively high water stress, overall, occurring during the R4, R5, and R6 stages of plant development.
- Simulated yield potential of soybean without water stress for nine soil types from 2002 to 2014 ranged from 67 to 97 bu/acre.
- Yield increase by irrigation (yield gap, Yg) ranged from 3 to 50 bu/acre. The nine soils had a large average Yg variance from 5 to 24 bu/acre.

Objective 2

The objective states: “Determine impounded surface water availability and sustainability for irrigation through the estimations of water dynamics and water budget in the surface impoundment structure (pond) using computer simulations in conjunction with field measurements.”
Computer simulation in conjunction with field measurements in Objective 1 will be used to estimate the irrigation pond water budget based on water dynamics. A net water budget (storage in the pond) that will depend on the pond size and water holding capacity is used to determine the availability and sustainability of water for supplemental irrigation within a growing season.

This project: (1) developed a STELLA (Structural Thinking, Experiential Learning Laboratory with Animation) pond model to characterize pond water balance and hydrological processes such as rain water collection, runoff water gathering, surface water evaporation, irrigation water use, pond discharge pipe release, pond spillway release, and soil seepage and drainage losses; (2) developed a STELLA soil water balance model to predict soil hydrological processes such as surface water runoff, percolation, soil water storage, and deficit of soybean water requirement; and (3) coupled the two models to a pond and irrigation model (PIM) which is capable of estimating soybean irrigation timing and amount on various soil types under different weather conditions. Therefore, the PIM can predict pond water availability for supplemental irrigation over time during the soybean growing season, soybean irrigation demand, and irrigation timing. The PIM triggered irrigation based on either percentage of crop evapotranspiration or management allowable depletion root zone soil water content. The model can calculate optimal ratios of farm pond size to cropland with sufficient pond water available for soybean irrigation. The model was calibrated and validated, and the decision support tool is available for growers to design and construct their on-farm ponds, estimate pond water availability for irrigation, and schedule soybean irrigation for the right amount at the proper time. The tool helped determine a reasonable ratio of pond size to irrigated soybean land as 1:18 if the irrigation rate was 1 inch/day and the low limit of the pond water level was near zero (3.2 inch). Under the ratio of 1:18, a 1-acre pond with an average depth of 6.6 ft could irrigate 18 acres of soybean.

Objective 3

The APEX model was employed to simulate soybean yields on nine major soil types in the Blackland Prairie region under both rainfed and non-water stress/irrigation conditions for 13 years. Results indicated the average net return to irrigated soybean can be increased by approximately $38/acre among nine soil types from 2002 to 2014, as compared to rainfed conditions. Irrigation can increase net return regardless of dry, normal, or wet years. The average net return of each acreage increased by $79, $24, and $28 for dry, normal, and wet years, respectively. Vaiden clay, Catalpa silty clay, and Leeper silty clay had the relatively lower increase in average net return, ranging from $5 to $16/acre. In comparison, Griffith silty clay, Sumter silty clay, and Demopolis clay loam had relatively higher increases in average net return with irrigation, ranging from $70 to $87 per acre.

PROJECT SUMMARY

1. Three years of field study measured rainfed and irrigated soybean yields of 27 and 48 bu/acre for Brooksville silty clay and 84 and 97 bu/acre for other soils.
2. During the entire soybean season, reference evapotranspiration was 25.4, 25, and 26.2 in.; crop evapotranspiration was 17, 18, and 20 in.; and rainfall was 14, 15 and 11 in. in 2014, 215, and 2016, respectively.
3. Average water use before R1 was 0.08 in./day and increased up through R5 to R5.5 to 0.16 - 0.20 in./day, with peak usage at pod filling stage.
4. No irrigation was required before R stage; irrigations were triggered from R2 to R6 stages.
5. Irrigation trigger points of Watermark™ sensor readings can be as high as 90 centibar.
6. Soybean uptake of water was from as deep as 36 in.
7. Suction-cup lysimeters at the 36-in. soil depth showed great percolation, which was greater in Vaiden than the other soils. No runoff was measured and rain intercepted by the canopy was only 0.4-0.6 in. during the entire season each year from 2014-2016.
8. Knowledge of site specific as well as soil type specific water holding capacity can improve accuracy of irrigation trigger points and amount.
9. It is critical to measure site specific and soil type specific field capacity and wilting point water content to improve accuracy of irrigation trigger points (irrigation timing) and amount of water to apply.
10. Soils vary considerably in topography, depth, physical properties, and texture. This complicates the soil moisture sensor-based irrigation approach. This study suggested that both the sensor-based and ET-based methods can be used for scheduling soybean irrigation in this region.
11. A farm pond water irrigation management tool (PIM) for soybean production is being developed. The tool has been applied in the Blackland Prairie to find that
    a) over 120 historical years, 80% of annual rainfall was over 43 in., with a mean value of 52 in. Average rainfall during the growing season is 17 in., with a deficit soybean water requirement of 4.6 in.
    b) Soybean average water requirement over ten decades was estimated at 21 in., with an irrigation demand of 6.3 in. Irrigation was required in all but 12 out of 120 yrs.
    c) every 1-acre of pond with an average depth of 6.6 feet can irrigate 18 acres of soybean land. The best ratio of pond size to irrigated soybean land is 1:18 in Mississippi.

d) PIM is a useful tool to estimate pond water availability and water budget, soil water dynamic, soybean irrigation demand, and timing.

12. The average irrigation net return from each acre increased by $79, $24, and $28 for dry, normal and wet years.

IMPACTS AND BENEFITS TO MISSISSIPPI SOYBEAN PRODUCERS

The project determined field capacity and total available water content for six dominant soils in the Blackland Prairie region, which are essential values that irrigation managers should use to set an irrigation trigger point for a specific soil and/or an installed Watermark™ soil moisture sensor. The findings of our 3-years' field study, which involved one late-season irrigation with center pivot in 2014, two or three surface irrigations in 2015, and five or six surface irrigations in 2016, suggested that the scheduling of irrigations for soybean is similar for the ET-based and the sensor-based methods on the six soils. Interestingly, these different soils in the region appear to have high variability of depth and soil physical properties which affect soil water storage and availability to plants.

The project also determined a reasonable ratio of pond size to irrigated soybeans land is 1:18. The ratio will be beneficial to growers for building ponds and scheduling irrigation. A decision support tool developed by project scientists will enable growers to irrigate their soybeans with the right amount at the proper time. Identifying ways to use water more efficiently will benefit 0.2 million acres of soybean production in the Blackland Prairie region of Mississippi.

END PRODUCTS

Presentations

1. Feng, G., J. Read, Y. Ouyang, D. Reginelli, A. Adeli, and J. Jenkins. 2014. Development of irrigation management practices for optimum yield and water use efficiency of soybean in east central mississippi. Agronomy Abstract. Soil Science Society of America Annual Meeting, Long Beach, CA. Nov.2-5, 2014.
2. Feng, G. 2015. Analysis and prediction of water deficit for soybean, corn and cotton in the state of Mississippi. The Annual Mississippi Water Resources Conference, Jackson, MS. April 7-8, 2015.
3. Feng, G. 2015. Irrigation of soybean in Prairie soils. Mississippi Chapter-American Society of Agronomy, Summer Agronomy Tour in Noxubee County, On-site presentation in the field day. June 24, 2015.
4. Feng, G., Y. Ouyang, J. Read, A. Adeli, D. Reginelli, and J. Jenkins. 2015. A farm pond water irrigation management system in Mid-South United States. American Society of Agricultural and Biological Engineers Annual International Meeting, New Orleans, Louisiana. July 26-29, 2015.
5. Feng, G., J. Read, Y. Ouyang, A. Adeli, D. Reginelli, and J. Jenkins. 2015. Soil water sensor-based and evapotranspiration-based irrigation scheduling for soybean production on a Blackland Prairie soil in humid climate. American Society of Agronomy Annual Meeting, Minneapolis, MN. Nov. 15-18, 2015.
6. Feng, G., R. Sui, Y. Ouyang, J. Read, A. Adeli, D. Reginelli, and J. Jenkins. 2015. Irrigation scheduling as affected by field capacity and wilting point water content from different data sources. Soil Science Society of America Annual Meeting, Minneapolis, MN. Nov. 15-18, 2015.
7. Zhang, B., G. Feng, X. Kong, Y. Ouyang, J. Read, A. Adeli, D. Reginelli, and J. Jenkins. 2015. Soybean productivity under various rainfed conditions and irrigation levels determined by WinAPEX Model in Blackland Prairie of East Central Mississippi State. Soil Science Society of America Annual Meeting, Minneapolis, MN. Nov. 15-18, 2015.
8. Feng, G., Y. Ouyang, D. Reginelli, and J. Jenkins. Prediction of future agricultural water needs in Mississippi Delta and Blackland Prairie under pond/ditch surface water supply and groundwater pumping scenarios. The Annual Mississippi Water Resources Conference, Jackson, MS. April 5-6, 2016.
9. Tang, Q., G. Feng, Y. Ouyang and J. Jenkins. Crop water requirement, rainfall deficit and irrigation demand of major row crops in Mississippi Delta. The Annual Mississippi Water Resources Conference, Jackson, MS. April 5-6, 2016.
10. Ouyang, Y., J.O. Paz, G. Feng, J. Read, A. Adeli, and J. Jenkins. 2016. A model to estimate hydrological processes and water budget from on-farm ponds in Mississippi. Institute of Biological Engineering Annual Conference, Greenville, SC, April 7-9, 2016.

11. Feng, G. May 19. 2016. Development and application of irrigation scheduling technologies for sustainable agriculture. China Agricultural University, Beijing, China. (in-kind paid).
12. Tang, Q., and G. Feng. Relations between pan evaporation and reference evapotranspiration in Mississippi Delta**. *T*he 2016** Southeast Regional **Soil-1048 Meeting. Oxford, MS. June 2, 2016.**
13. Ouyang, Y., G. Feng, J. Read, T. Leiniger, and J. Jenkins. 2016. Estimating the ratio of pond size to irrigated soybeans land in Mississippi: A case study. American Society of Agricultural and Biological Engineers Annual International Meeting. New Orlando, FL. July 17-20, 2016.
14. Feng, G. and Y. Ouyang 2016. Crop model application to soybean irrigation management in a humid region. Invited oral presentation, American Society of Agricultural and Biological Engineers Annual International Meeting. New Orlando, FL. July 17-20, 2016.
15. Feng, G., L. Ma, Y. Ouyang, and J. Jenkins. Conjunctive use of groundwater and surface water for sustaining irrigated agriculture in a humid region. Ninth international conference on irrigation and drainage, Fort Collins, Oct. 11-14, 2016.
16. *Feng, G., and R*. Sui. Evaluation of capacitance and TDR soil moisture sensors in undisturbed soils across the state of Mississippi. Soil Science Society of America Annual Meeting, Phoenix, AZ. Nov. 6-9, 2016.
17. Feng, G., J. Read, Y. Ouyang, A. Adeli, D. Reginelli, and J. Jenkins. Assessment of irrigation scheduling approaches in a soybean field located in a humid region. Agronomy Abstract. Soil Science Society of America Annual Meeting, Phoenix, AZ. Nov. 6-9, 2016.
18. Feng, G. Jan. 3. 2017. Soybean field experiment and modeling of water management in agroecosystems. China Agricultural University, Beijing, China.
19. Ouyang, Y, and G. Feng. 2017. Estimate 120 years vadose zone water dynamic, crop irrigation demand, and groundwater conservation in an agricultural land in Mississippi. Seventh Unsaturated Zone Interest Group Workshop & Information Exchange. University of Florida, Gainesville, April 4-6, 2017.
20. Feng, G., Y. Ouyang, D. Reginelli, and J. Jenkins. 2017. Water consumption and yield variability of nonirrigated and irrigated soybeans in Mississippi dominant soils across years. The Annual Mississippi Water Resources Conference, Jackson, MS. April 11-12, 2017.

Peer Reviewed Journal Articles

1. Zhang, B., G. Feng, J. Read, X. Kong, Y. Ouyang, A. Adeli and J. Jenkins. 2016. Simulating soybean productivity under rainfed conditions for major soil types using APEX model in East Central Mississippi. *Agricultural Water Management*. 177: 379-391.
2. Feng, G., S. Cobb, Z. Abdo, D.K. Fisher, Y. Ouyang, A. Adeli, and J. Jenkins. 2016. Trend analysis and forecast of precipitation, reference evapotranspiration and rainfall deficit in the Blackland Prairie of Eastern Mississippi. *J. of Applied Meteorology and Climatology* 55: 1425-1439. DOI: 10.1175/JAMC-D-15-0265.1
3. Zhang, B., G. Feng, X. Kong, L. Rattan, Y. Ouyang, A. Adeli and J. Jenkins. 2016. Simulated yield potential by irrigation and yield gap of rainfed soybean using APEX model in a humid region. *Agricultural Water Management*. 177: 440-453.
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5. Ouyang, Y., J.O. Paz, G. Feng, J. J. Read, A. Adeli, and J. N. Jenkins. 2017. A Model to Estimate Hydrological Processes and Water Budget in an Irrigation Farm Pond. *Water Resources Management* 31(7): 2225-2241. DOI 10.1007/s11269-017-1639-0.
6. Ouyang, Y., G. Feng, J. J. Read, T.D. Leininger, and J.N. Jenkins. 2016. Estimating the ratio of pond size to irrigated soybean land in Mississippi: A case study. *Water Science and Technology: Water Supply,* 16: 1639-1647.

Table 1. Yield components, harvest index (HI), total aboveground dry biomass (TDM), and soybean water consumption of soybeans growing on different soils and treatments in 2014.

Soil type	Treatment	Grain yield (bu/acre)	TDM (ib/acre)	HI	Thousand grain weight (ib)	Seeds per plant	Pods per plant	Water consumption (in)
Vaiden	SM	94	12111	0.46	0.30	132	56	18
	ET	88	9347	0.57	0.35	107	62	16
	RF	91	9810	0.56	0.31	123	45	16
Okolona	SM	87	9437	0.55	0.33	111	44	18
	ET	88	10925	0.49	0.33	113	50	18
	RF	83	10561	0.47	0.29	120	54	15
Demopolis	SM	110	13832	0.48	0.34	136	44	18
	ET	92	11424	0.48	0.36	109	49	16
	RF	78	10620	0.44	0.33	100	39	16

Table 2. Yield components, harvest index (HI), total aboveground dry biomass (TDM), and soybean water consumption of different soils and treatments in 2015.

Treatment	Grain Yield (bu/acre)	TDM (ib/acre)	HI	Seeds per plant	Pods per plant	Thousand grain weight (ib)	Water consumption (in)
SM	48a	37672	0.61	113	41	0.34	21
ET	45ab	51570	0.66	118	45	0.29	20
RF	41b	29003	0.40	58	21	0.28	16

Table 3. Yield components, harvest index (HI), total aboveground dry biomass (TDM), and soybean water consumption of different soils and treatments in 2016.

Treatment	Grain yield (bu/acre)	TDM (ib/acre)	HI	Seeds per pod	Pods per plant	Thousand grain weight (ib)	Water consumption (in)
SM	46a	9445a	0.32a	3	41a	0.32a	20a
ET	44a	8283a	0.32a	3	40a	0.33a	18b
RF	27b	5138b	0.29a	3	21b	0.35a	14c