Sensor Strategies for Scheduling Irrigation in Louisiana

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Abstract. The objective of this study was to evaluate multiple types of soil moisture sensors to determine their applicability for producers in Louisiana agriculture. Irrigation treatments were determined using: A) soil matric potential sensor system, B) volumetric water content sensor system, or C) weekly irrigation depending on rainfall. Overall, both soil moisture sensor systems were capable of limiting irrigation events compared to weekly irrigation during dry periods with 70% water savings without yield reduction occurring at one location. Though accuracy in sensor readings declined over time, they were still helpful in determining trends in soil moisture. However, using a static threshold to trigger irrigation events was not advisable for either sensor system due to their inaccuracy. Proper implementation requires that the producer has the knowledge to interpret the soil moisture data in reference to the physical system for best management practices.

Keywords. Crops, irrigation, scheduling, sensors, soil moisture

Introduction

The competition for agricultural water supplies continues to increase in Louisiana due to many factors including short-term and long-term drought, increasing irrigated acreage, and demand from other sectors like industry, power generation, public supply, and aquaculture. One approach to addressing agricultural water challenges is to improve irrigation efficiency of functioning irrigation systems.

The primary method of agricultural irrigation in Louisiana, estimated as 80% of the irrigated acreage, is furrow irrigation. Using this irrigation method, efficiency can be improved by either addressing infiltration as the water moves across the field or by using tools to determine when irrigation is necessary. Various tools exist to provide feedback to the grower concerning field conditions. Soil moisture sensors are one such tool that can be cost effective; however, there are several brands of sensors on the market, which differ in accuracy, capabilities, and price. The overall objective of this study was to evaluate multiple types of soil moisture sensors to determine their applicability for producers in Louisiana agriculture.

Materials and Methods

In Louisiana, typical existing agricultural irrigation infrastructure includes a groundwater well with an electric, diesel, or propane fueled pump and an underground pipe network with periodic access via aboveground risers. Irrigation is distributed to each furrow using temporary thin walled lay-flat tubing with manually punched holes resulting in overland flow from the edge of the field having the highest elevation toward the tail end (Fig. 1).


Figure 1. Example of surface irrigation using lay-flat tubing in soybeans.

Generally, there is very little control in the applied volume per event when it comes to furrow irrigation. Irrigation volumes depend on pump efficiency, available head pressure, pipe-riser system design, hole size selection in the lay-flat tubing, and infiltration characteristics of the soil. Most of these dependencies require considerable investment and effort to change, which is only likely to occur by producers when required (such as replacing an end-of-life pump) and not just for improving irrigation efficiency. However, using soil moisture to determine when to apply irrigation can delay an application by a few days from the typical producer schedule of once per week, eventually skipping an irrigation event. Measurements of soil moisture can also aid a producer in determining if rain or irrigation infiltrated the soil surface and will be effective for the crop.

Soil moisture sensors generally fall into one of two categories depending on the type of produced data. The soil matric potential sensors, also commonly referred to as granular matrix sensors, estimate the tension or suction required by the plant material to remove the water from the soil. These sensors report soil moisture in centibars where 0 cb represents saturation, -10 to -30 cb represents field capacity, and -1,500 cb represents permanent wilting point. Volumetric water content sensors estimate soil moisture as the volume of water per volume of soil column and is typically reported as a percentage. Thresholds for saturation, field capacity, and permanent wilting point are dependent on the soil type and must be determined prior to application in the field.

A study was designed to measure irrigation application based on the following treatments: A) soil matric potential sensor system, B) volumetric water content sensor system, and C) weekly irrigated treatment. Each treatment was replicated three times with at least six rows on 40 inch spacing and a minimum row length of 300 ft. Irrigation application was measured using volumetric flow meters (McCrometer, Inc., Hemet, CA) assuming equal application across treatments when more than one treatment received irrigation. Yield was used as the primary response variable to determine whether differences in irrigation application resulted in negative impacts to the crop. Yield was harvested from the two middle rows of each plot in a 100 ft portion of the row. Ideally, irrigation was triggered for the sensors at either 80 cb or around 30% (based on soil conditions) depending on measurement type.

The soil matric potential sensor chosen for the study was the Watermark (Irrometer Company, Riverside, CA). It is the most popular soil matric potential sensor on the market due to a comparatively low price point and simplicity (Spaans and Baker 1992, Thompson et al. 2006).

The sensors were coupled with Aqua Trac (AgSense, Huron, SD) telemetry units for logging and transmitting the soil moisture data. Each Aqua Trac unit was capable of managing four sensors; sensors were installed at 6 inches, 12 inches, 18 inches and 24 inches. Each replication received a sensor system.

The GS-1 (Decagon Devices, Pullman, WA) was chosen as the volumetric water content sensor. It was new to the market and meant for agricultural situations. It was chosen primarily due to its comparability to the Watermark based on size and installation style. Decagon RM50G telemetry loggers were used to access the soil moisture data. Each logger can support five sensors thus these sensors were installed every 6 inches, similar to the Watermarks, with one additional sensor at the 30-inch depth.

The study was conducted in 2015 and 2016 at three Louisiana Agricultural Experiment Stations across northern Louisiana to test the treatments on three distinct soil types. The field at the Red River Research Station (Bossier City, LA) is located on sandy clay loam, part of the Red River Alluvial soils inherent to the region. The field at the Macon Ridge Research Station (Winnsboro, LA) is predominantly silt loam representing the soils of the Macon Ridge. The final location, at the Northeast Research Station (St. Joseph, LA), has cracking clay soils that are known to dominate the Mississippi Delta region. Soybeans were grown at the Macon Ridge and Northeast Research Stations whereas cotton was grown at the Red River Research Station. All sensors were installed after planting (and fertilization for cotton) and removed prior to harvest.

Results and Discussion

Due to many uncontrollable circumstances, the goal of determining irrigation application based on yield differences was not successfully completed each year at all research locations. However, soil moisture was collected at all locations and was instrumental in identifying secondary objective information such as deficit conditions, infiltration of various irrigation and rainfall events, and identifying sensor performance. The most informative results are presented here.

2015 Results

The GS-1 sensors provided the most accurate data in the sandy clay loam soil. Due to the perceived accuracy, the changes in soil moisture across all sensors within the measurement area were quantified as crop evapotranspiration (ET_C). The ET_C was used to calculate the ratio of ET_C to reference evapotranspiration (ET_O), also known as crop coefficients (Fig. 2). These estimations were compared to crop coefficients developed for cotton in Louisiana using weighing lysimeters (Kumar et al. 2015). The dips in crop coefficient correspond with two missed irrigation events indicating that a stress coefficient was introduced during the growing season.

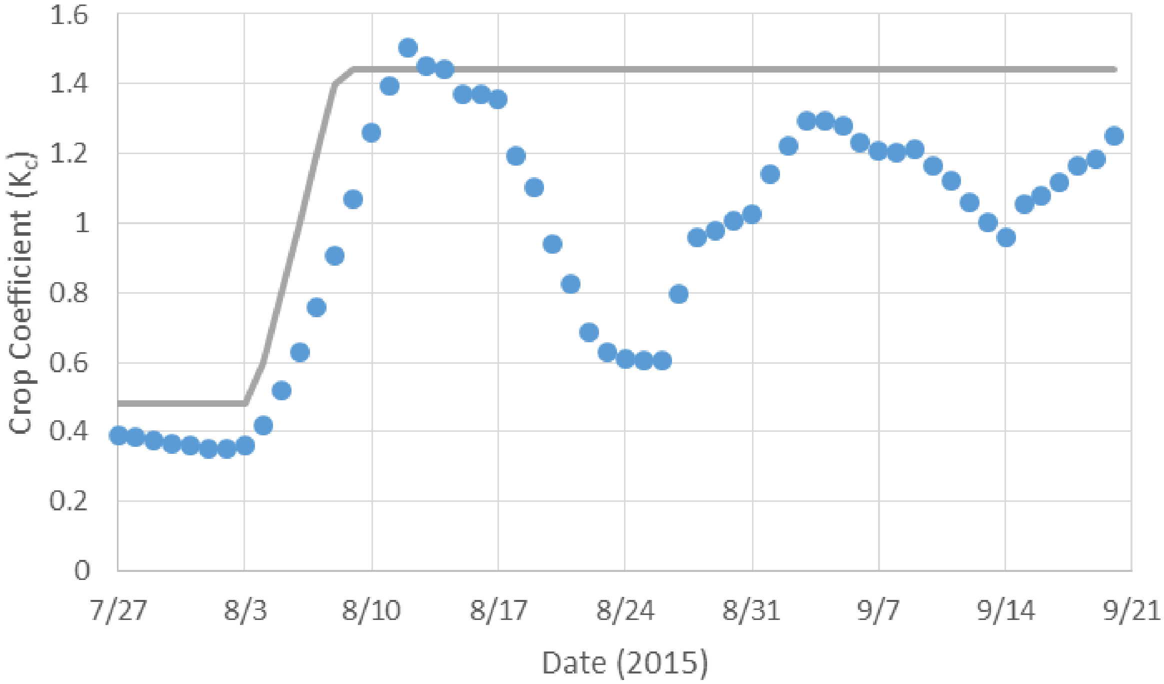

Figure 2. Rolling average crop coefficients (blue dots) were determined using soil moisture sensors for cotton in 2015. Calculated coefficients were compared to published coefficients for Louisiana determined using weighing lysimeters (gray line).

The Watermark sensors did not respond to changes in soil moisture in the sandy clay loam. Though it is possible that infiltration was an issue in these plots, it's unlikely considering that the plots with GS-1 sensors were irrigated at the same time and had distinct and immediate responses. This was the lightest textured soil of the three locations, further strengthening the previous research suggesting that these sensors do not perform well in coarse soils, such as those with significant sand content (Varble and Chavez 2011, Cepuder et al. 2008).

The opposite result occurred of the cracking clay location, having the heaviest soil in the study. The Watermark sensors showed immediate response to irrigation with significant drawdown between events. However, the GS-1 sensors showed very little change in soil moisture over the season and only if they were able to provide data at all. Both sensor types rely on good contact between the sensor and soil for accuracy. It is hypothesized that the cracking soil pulled away from the metal rods of the GS-1 sensors, resulting in inaccurate soil moisture estimations, whereas the mesh construction of the Watermarks provided continued contact with the soil despite cracking.

In general, there were good responses to soil moisture changes in the silt loam soil by both sensor types. However, the GS-1 sensors did not have enough accuracy to utilize the method for determining crop coefficients using the sensor data. The Watermarks did not always respond to irrigation at all sensor depths, indicating that accuracy was questionable as well.

2016 Results

In most locations, equipment for both sensor types were reused from the previous year. As a result, sensor data was much less accurate than expected in the second year. Indications of inaccuracy were obvious with the GS-1 sensors where soil moisture data began to oscillate to below permanent wilting point and above saturation. In some instances, the readings dropped from an acceptable soil moisture to below permanent wilting point suddenly and without reason. The Watermarks were not as obvious, but showed a distinct decline in the range of soil moisture within the wet portion of the drying curve, resulting in inappropriately delayed irrigation. It is hypothesized that the manual labor required to install and remove these sensors under extreme weather conditions during Louisiana summers reduced the amount of care in handling the sensors.

The location with the most complete results occurred at the Northeast Research Station on cracking clay soil. This location received 19.7 inches of rainfall from May through September (Table 1). Irrigation for the weekly treatment occurred during weeks where rainfall was not abundant, resulting in five irrigation events, totaling 29.8 inches of irrigation, that occurred during reproductive growth in the dry period of the growing season. Only two irrigation events were scheduled for the sensor treatments resulting in 8.8 inches of irrigation. Despite the difference in irrigation application, there were no differences in yield between the three treatments, averaging 65.4 bushels per acre. Thus, 70% water savings were achieved by using the sensors despite the previously mentioned inaccuracies. The production soybeans surrounding the plots were unirrigated and of the same variety. Randomly sampled for comparison, the unirrigated soybeans had lower average yield of 40.8 bushels per acre compared to the irrigated soybeans, indicating that irrigation was beneficial in 2016.

Table 1. Summary of irrigation and yield results of soybean for the cracking clay research site located at the Northeast Research Station.

Treatment	Number of Irrigation Events	Cumulative Irrigation (in)	Cumulative Rainfall (in)	Yield Weight (bu/ac)*
Watermark	2	8.8	19.7	63.2 a
Decagon	2	8.8	19.7	64.8 a
Weekly	5	29.8	19.7	68.2 a
Unirrigated	0	0	19.7	40.8 b

*Treatments with significant differences ($\alpha = 0.05$) were represented with different lowercase letters.

Treatment implementation and data collection was inconsistent for the silt loam soil at the Macon Ridge Research Station. As a result, there were no differences in irrigation application across treatments at this location (Table 2). Additionally, most of the plots were accidentally harvested as production; harvest occurred for one plot each of the Watermark, Decagon, and unirrigated treatments. As a result, yield could not be statistically evaluated.

Despite these issues, there was one important outcome observed using the soil moisture sensors. Neither sensor type consistently responded to irrigation after an event. Though it would be plausible that sensor inaccuracies were at play, the anecdotal yield data indicated that there was no difference between irrigated and unirrigated soybeans at this location. Considering the relatively acceptable sensor performance last year, it is likely that irrigation water failed to infiltrate while moving across the field. It is hypothesized that the velocity of the water across the soil surface combined with unideal soil conditions prohibited infiltration into the root zone. This hypothesis was supported by individuals in the agricultural industry that work in this region and on this soil type.

Table 2. Summary of irrigation and yield results of soybean for the silt loam research site located at the Macon Ridge Research Station.

Treatment	Number of Irrigation Events	Cumulative Irrigation (in)	Cumulative Rainfall (in)	Yield Weight (bu/ac)*
Watermark	3	9.0	15.2	46.0
Decagon	3	9.0	15.2	43.8
Weekly	3	9.0	15.2	--
Unirrigated	0	0	15.2	43.7

*Treatments with significant differences (α = 0.05) were represented with different lowercase letters.

There were no differences in yield for the cotton grown on the sandy clay loam (Table 3). Irrigation occurred four times during the dry period for the weekly and Watermark treatments, but only two irrigation events occurred for the Decagon treatment. There were difficulties in maintaining pressure within the lay-flat tubing as the season progressed, so irrigation events were not always typical. Also, replications were significant in the model indicating that growing conditions were variable across the plots. This variation has been an issue at all three research locations.

Table 3. Summary of irrigation and yield results of cotton for the sandy clay loam research site located at the Red River Research Station.

Treatment	Number of Irrigation Events	Cumulative Irrigation (in)	Cumulative Rainfall (in)	Yield Weight (bale/ac)*
Watermark	4	8.8	20.2	2.5 a
Decagon	2	5.3	20.2	2.6 a
Weekly	4	8.8	20.2	2.3 a

*Harvest data was not available at the time of publication.

Conclusion

Overall, both soil moisture sensor systems were capable of limiting irrigation events compared to weekly irrigation during dry periods. There were quantifiable water savings at locations where infiltration occurred. At one location, there was no reduction in yield despite 70% water savings. Though accuracy in sensor readings declined over time, they were still helpful in determining trends in soil moisture. However, using a static threshold to trigger irrigation events was not advisable for either sensor system due to their inaccuracy. Also, it's likely that repeated installation and removal increased the opportunity for sensor failure.

The combination of inefficiencies in irrigation conveyance, lack of trained labor, and aging infrastructure across research stations have led to inconsistencies in conducting irrigation-specific research across the state. Future work in this area will be localized in a more controlled setting to improve irrigation application, data collection, and overall management of the project. Sensors will be checked for quality prior to installation in 2017 and failures will be noted to determine life expectancy of the equipment.

Though the level of measurement inaccuracy is important to know when using a soil moisture sensor, this issue can be overcome when considering that they are just one tool that can provide the producer with information about management. There are many other considerations; for example, a soil moisture sensor tends to provide point measurements used to represent conditions over a large acreage that may have variability in soil type, plant type, or irrigation requirements based on evapotranspiration. As in any technology, the provided information requires knowledge of the physical system for interpretation. Proper implementation requires that the producer understands the data and can make an educated decision based on the provided information and on-site observations.

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