STAMP Decision Tool for Agronomic Crops in Louisiana

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Abstract. In Louisiana, irrigation efficiency can be improved by determining irrigation events based on plant water requirements. The objective of this project was to develop a decision tool to determine when to trigger irrigation based on plant water requirements for agronomic crops. The decision tool relies on a soil water balance to keep track of water movement in the root zone. This simplistic tool was developed using a spreadsheet for ease of access and availability without internet. Calibration of the tool was conducted by using irrigation data collected from research plots in 2015 and 2016 that included soil moisture measurements to determine actual water movement in the soil. In addition to the benefit of knowing when an irrigation event should occur, this spreadsheet can also act as a descriptive record that keeps track of water application and calculates irrigation efficiency for each irrigation event.

Keywords. Cotton, irrigation, scheduling, sensors, soil moisture, soybean

Introduction

In Louisiana, furrow irrigation is the most common method of water application to row crops. Generally, there is very little control in the applied volume per event. 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 tools to determine when to apply irrigation can delay an application, eventually skipping an irrigation event, or increase irrigation during critical growth stages that can lead to increased yield. The objective of this project was to develop a decision tool to determine when to trigger irrigation based on plant water requirements for agronomic crops.

Materials and Methods

The Smart Technologies for Agricultural Management and Production (STAMP) Irrigation Scheduling Tool was developed as a first step to scientific irrigation scheduling in Louisiana. This excel-based tool uses the soil water balance to estimate when irrigation should be applied. Since it was designed to be used by row crop farmers, it was pre-populated with agronomic information that best fit the available data. However, there's very little agronomic information related to irrigation available regionally, so each site-specific selection can be customized. The tool is currently in the testing phase and has not been released to the public at this time. This paper presents the testing results to date. It is anticipated that the tool will develop into a more sophisticated product as producers become aware of its usefulness through education and demonstration.

A field study was designed to measure irrigation application and soil moisture in cotton and soybean 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. None of the field plots were irrigated ideally during any crop season due to logistical restrictions; however, this resulted in a wide range of moisture conditions and crop responses for testing the STAMP tool.

The GS-1 (Decagon Devices, Pullman, WA) and the Watermark (The Irrometer Company, Riverside, CA) were chosen as the volumetric water content and soil water potential sensors, respectively. Translation of soil water potential measurements to volumetric water content for the Watermark sensors required soil sampling and long-term analysis that is in process and will not be finished until next year. As a result, only the plots with GS-1 sensors were evaluated here. The GS-1 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 up to 30 inches.

The study was conducted in 2015 and 2016 at Louisiana Agricultural Experiment Stations across northern Louisiana to test the treatments on three distinct soil types. The Red River Research Station (Bossier City, LA) was 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) was predominantly silt loam representing the Macon Ridge soils. The final location, at the Northeast Research Station (St. Joseph, LA), had cracking clay soils that 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 and removed prior to harvest.

Results and Discussion

As reported last year, the most accurate data in the study for the GS-1 sensors occurred in the sandy clay loam soil where cotton was grown. Cotton was also a beneficial crop for this evaluation because it is the only agronomic row crop with published local crop coefficients (Kumar et al. 2015). Using the 2015 data, the STAMP irrigation scheduling tool provided a fairly acceptable estimation of volumetric water content considering the known limitations to the methodology (Figure 1). The comparison between predicted and observed daily soil moisture values across all timesteps between 7/17 and 9/20 resulted in a Nash-Sutcliffe coefficient of efficiency (C_N) of 0.33 and a root mean square error (RMSE) of 0.028 m^3/m^3 (Table 1). All six combinations of soil types and years produced similar model results where decreased model performance was attributed to uncaptured hydrological processes and data quality.

There were two irrigation events, occurring on 7/21 and 8/11,that caused an increase in soil moisture estimations in the STAMP tool, but were not measured within the soil. Removing the data for these two events increased the C_N to 0.77 and decreased the RMSE to 0.015 m^3/m^3.

This indicated that there were physical processes not captured in the STAMP Tool. It is hypothesized that adding consideration for infiltration rates and compaction would increase the model's performance.

The STAMP Irrigation Scheduling Tool was easily converted to an irrigation prediction model by introducing irrigation events when maximum allowable depletion was reached. Irrigation was restricted to the period of growth between the developmental phase and late growth that represented the end of reproduction and never exceeded field capacity. The STAMP irrigation schedule represents the ideal irrigation schedule when the model limitations previously discussed were not a factor. These limitations were consistent between the two model outputs thus inconsequential in this analysis. Also, it was already known that irrigation wasn't adequate during most of these scenarios, thus variation between the calculated soil moisture and the predicted STAMP irrigation schedule was expected.

In the 2015 cotton scenario previously discussed, irrigation initiation should have been delayed by three days (Figure 2) and one additional irrigation was necessary for the season, totaling six events instead of five. The delay in initiation was carried through the season with early irrigations occurring for the first four events. The fifth event occurred at the predicted time and the sixth event was predicted for the end of the season, about two weeks after the final event.

The STAMP irrigation schedule predicted the same or more irrigation events than what was applied during the study at all locations (Table 2). Also in most locations, the amount of irrigation required per event was less than what was applied. The lack of efficient application inherent in furrow irrigation situations can negate the benefits to applying less irrigation and ultimately result in more irrigation over the season. For example, irrigation applications of 8.53 inches of water occurred due to failing to turn the water off at the appropriate time and wasn't related to need. Unfortunately, this is a common occurrence in the mid-South.

Table 1. Summary of model statistics from all three locations and both years.

Year of Crop Season	Location	Crop	Soil Type	Nash-Sutcliffe Coefficient of Efficiency[1]	Root Mean Square Error (m^3/m^3)[2]
2015	Bossier City	Cotton	Sandy Clay Loam	0.33	0.028
2016	Bossier City	Cotton	Sandy Clay Loam	0.30	0.022
2015	Winnsboro	Soybean	Silt Loam	0.39	0.034
2016	Winnsboro	Soybean	Silt Loam	-1.9	0.074
2015	St. Joseph	Soybean	Cracking Clay	-0.02	0.028
2016	St. Joseph	Soybean	Cracking Clay	0.20	0.019

[1]This term ranges from -∞ to 1 where 0 to 1 indicates that the model predicted the mean as well or better than the observed mean.
[2]This term ranges from 0 to ∞ where 0 indicates that the model predicted the regression line of best fit perfectly.

Table 2. Summary of irrigation application by location based on what was actually applied and what was predicted by the STAMP tool.

Year of Crop Season	Location	Soil Type	Number of Irrigation Events by Treatment	Predicted Number of Irrigation Events	Average Depth per Event by Treatment (in)	Predicted Average Depth per Event[1] (in)
2015	Bossier City	Sandy Clay Loam	5	6	3.54	3.36
2016	Bossier City	Sandy Clay Loam	2	2	2.27	3.46
2015	Winnsboro	Silt Loam	3	5	3.06	2.90
2016	Winnsboro	Silt Loam	3	3	8.52	2.56
2015	St. Joseph	Cracking Clay	3	5	4.98	2.59
2016	St. Joseph	Cracking Clay	2	5	4.39	2.40

[1]These values were increased by an efficiency factor of 0.7 to directly compare to the gross irrigation estimates measured in the field.

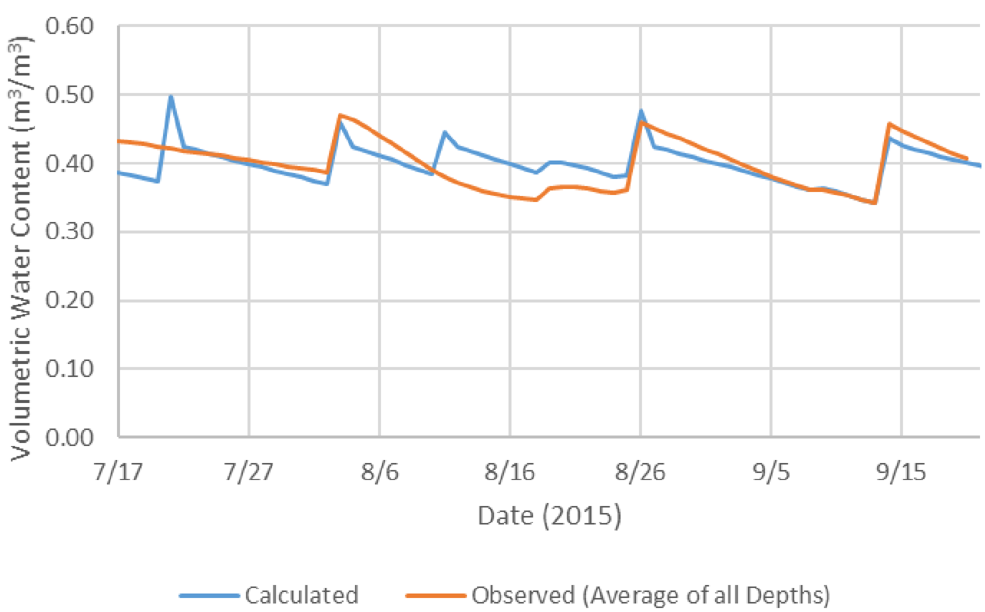

Figure 1. Comparison of soil moisture calculated from the STAMP Irrigation Scheduling Tool and observed from the GS-1 soil moisture data. Irrigation events on 7/21 and 8/11 resulted in a large response in soil moisture using the STAMP Tool, but little to no response was measured in the field.

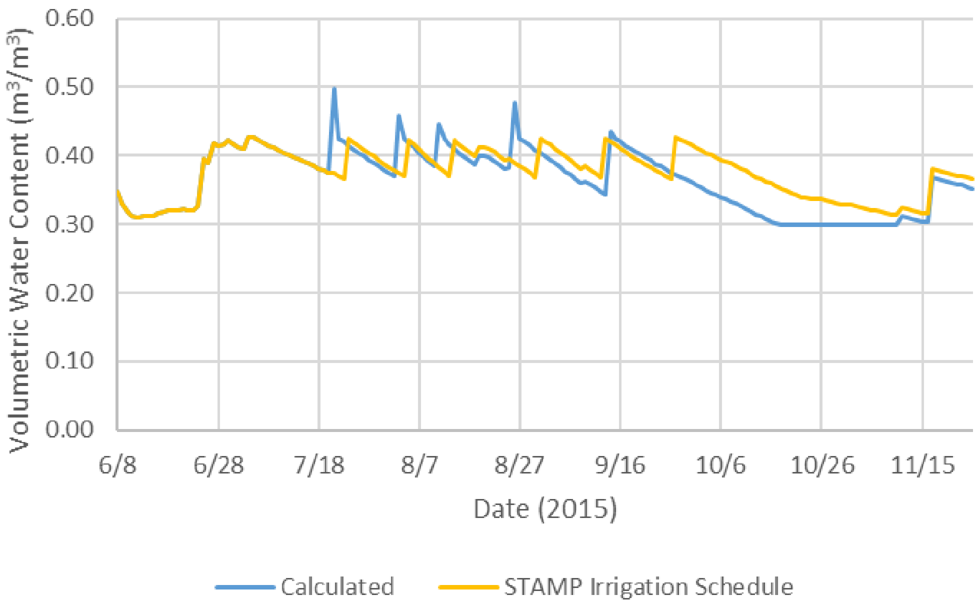

Figure 2. Full season comparison of the soil moisture estimated using the STAMP Irrigation Scheduling Tool. The calculated soil moisture was based on actual irrigation events that occurred whereas the STAMP irrigation schedule was estimated by assuming irrigation occurred when at the predicted times.

Conclusion

Generally good performance was experienced during the first step to evaluating the STAMP irrigation scheduling tool. Volumetric water content values were related when close in time. Thus, one irrigation event that was measured but produced runoff without infiltrating can not only create an outlier for the day of irrigation, but also for some time after the outlier occurred. Future work will include expanding the data available for analysis, fully calibrating the current model, and exploring more physical processes that can improve the model.

References

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