A WIRELESS SOIL MOISTURE SENSING NETWORK TO AUTOMATE SITE-SPECIFIC IRRIGATION OF COTTON USING A LATERAL MOVE IRRIGATION SYSTEM

Jose Payero
Bayleah Cooper
Edisto REC/Clemson University
Blackville, SC
Rebecca Davis
Cooperative Extension/Clemson University
Bamberg, SC

Abstract

This project's overall goal was to create and field-test an affordable system to help cotton farmers increase water use efficiency by automating irrigation based on real-time soil moisture data using a wireless sensor network. The specific objectives were to: (1) develop a wireless sensor network to automate irrigation scheduling of cotton, based on real-time soil moisture using a lateral move irrigation system and, (2) field-test the irrigation automation system by evaluating the response of cotton to three irrigation trigger points. A wireless soil moisture sensor network prototype created in 2019 to automate irrigation of cotton using a subsurface drip irrigation (SDI) system was modified and adapted to a lateral move irrigation system. A field experiment was conducted at the Edisto Research and Education Center in 2020 to field-test the irrigation automation system. In this experiment, three irrigation treatments were evaluated in which irrigation was automatically applied to cotton when the weighted-average soil moisture reached either 30, 40, or 50 kPa using four replications. Soil moisture was measured using Watermark moisture sensors installed at three depths in each plot. The electronics and software for the automation system were developed and installed in the field. Limited testing during one irrigation event in mid-September showed that the system worked as expected. However, early-season delays due to COVID-19 prevented us from evaluating objective 2 during the whole growing season.

Introduction

One of our most critical global challenges is how to increase food production to feed a rapidly growing population. In South Carolina, meeting this challenge will require changing from rainfed farming systems to irrigated systems, especially for row crops like cotton. This change is already taking place, and irrigated acreage in South Carolina has been increasing in recent decades. Most of the irrigation water comes from pumping groundwater, which requires energy and comes at a considerable cost to farmers. In South Carolina, overhead sprinkler systems (mostly center pivots and a few lateral move systems) are typically used to irrigate row crops, which cover much of the state's irrigated land. In contrast, drip irrigation systems are commonly used to irrigate high-value crops (e.g., fruits and vegetables).

Although farmers in South Carolina have adopted efficient irrigation systems (i.e., center pivot and drip), managing these systems to achieve their full potential is still challenging. Current challenges include (1) high spatial variability within fields (variable soil types, uneven topographies, etc.), and (2) difficulty deciding when and how much water to apply to the field since most farmers do not use sensors to tell them when and how much to irrigate. Recently, there have been considerable advances in several technologies that could facilitate precision irrigation, such as variable rate irrigation (VRI), sensor-based irrigation scheduling, embedded electronic systems, crop modeling, and wireless communication. However, there has been little effort to integrate these technologies into an easy-to-use and affordable package to automate irrigation systems. Over the last few years, the irrigation research team at the Clemson University Edisto Research and Education Center (Edisto REC) has created and tested affordable soil moisture monitoring systems. These soil moisture monitoring systems are equipped with wireless or cell phone communication and can send the data to the Internet (Payero et al., 2017a; Payero et al., 2017b; Payero et al., 2017c).

In 2019 the Edisto REC team developed a wireless sensor network prototype to automate irrigation of a subsurface drip irrigation (SDI) system and conducted some limited testing by automating irrigation of a cotton field. This limited test allowed the research team to identify and fix some issues with the system. The overall goal of this work is to expand this prototype to be able to automate a variable-rate irrigation center pivot based on real-time soil moisture data. Since the SDI automation system worked successfully during 2019, the next step was to adapt the prototype to automate overhead irrigation machines. This adaptation would allow integrating sensor-based irrigation scheduling with variable rate irrigation (VRI) technologies for these overhead irrigation systems, which is currently expensive and challenging for farmers to apply in practice. However, the SDI prototype would have to be modified and adapted to the characteristics of the overhead systems. One crucial difference between an SDI and an overhead system is that the SDI system is stationary while the overhead system moves as it irrigates the field. The center pivot moves in a circular pattern around a central point, while the lateral move system moves in a rectangular trajectory, up and down the field.

Therefore, automating the overhead system requires knowing the overhead machine's location and the relative position of each of the sprinklers in the system. It also requires keeping track of whether a specific sprinkler nozzle is inside a given irrigation zone and whether that irrigation zone needs irrigation. The location of the overhead system in the field can be obtained using input from a GPS. The automation system would also require controlling irrigation for each of the sprinkler heads, which would require installing solenoid valves in each drop hose supplying water to each sprinkler head. Therefore, the SDI prototype needed to be expanded to control a much larger number of solenoids than the SDI automation system, which could be accomplished by adding more relay modules to the SDI prototype. Therefore, this project's overall goal was to create and field-test an affordable system to help cotton farmers increase water use efficiency by automating irrigation based on real-time soil moisture data using a wireless sensor network. The specific objectives were to: (1) Develop a wireless sensor network to automate irrigation scheduling of cotton, based on real-time soil moisture using a lateral move irrigation system, and (2) field-test the irrigation automation system by evaluating the response of cotton to three irrigation trigger points.

Materials and Methods

In 2020, the Edisto REC's research team already had a lateral move system available to conduct this project. The irrigation system had already been converted to VRI technology and was instrumented with a variable frequency drive (VFD), which was needed to apply VRI technology. The VFD controlled the speed of the pump and kept the water pressure stable within a pre-set range. The electronic components for the irrigation automation systems were built using Arduino-based open-source electronics. The wireless sensor network consisted of sixteen dataloggers to collect and transmit soil moisture data (via radio) from sensors installed in the field, a rotary encoder device to determine the lateral move irrigation system's location, and a receiver/controller (Fig. 1). The receiver/controller receives the data from the sensors installed in the field and controls the irrigation valves. Before the automation system was installed in the field, the software and electronic components were first tested in the lab.

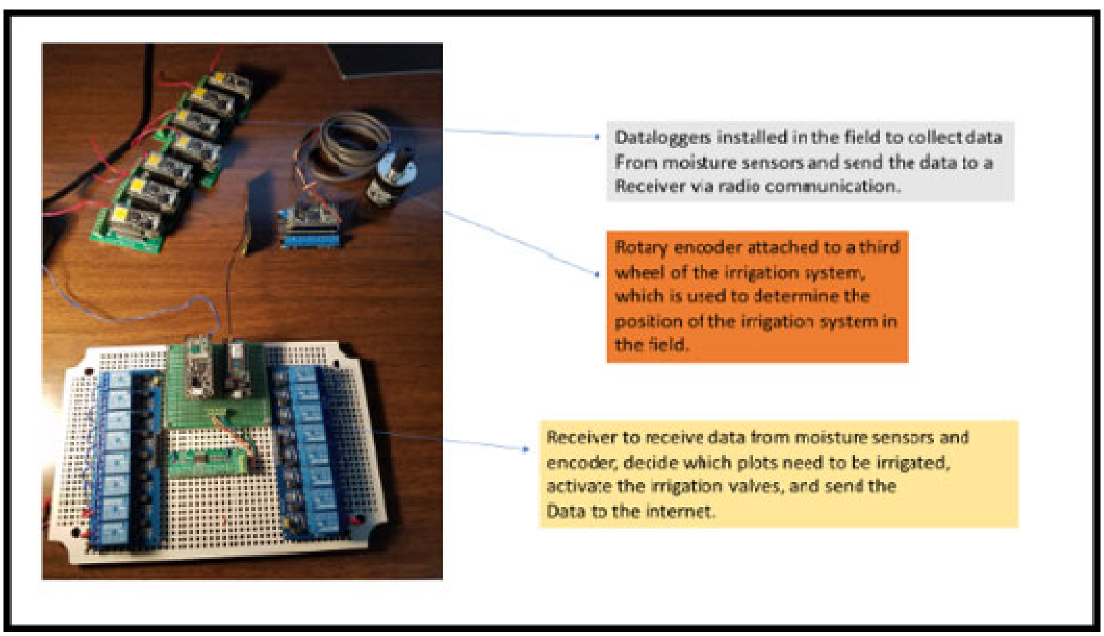

Figure 1. Electronic Components of the irrigation automation system.

A cotton field experiment was established in the spring of 2020 at the Edisto REC, following the plot plan in Fig. 2. The lateral move system had already been instrumented with electronic valves in each drop to allow variable rate irrigation. The lateral move system was also instrumented with a third-wheel, which was attached to a rotary encoder, to determine the irrigation system's location in the field (Fig. 3). Watermark soil moisture sensors at three depths (6, 12, and 18 in) were installed at the center of each of the sixteen plots, and the controller/receiver was installed on the lateral move irrigation system (Fig. 4).

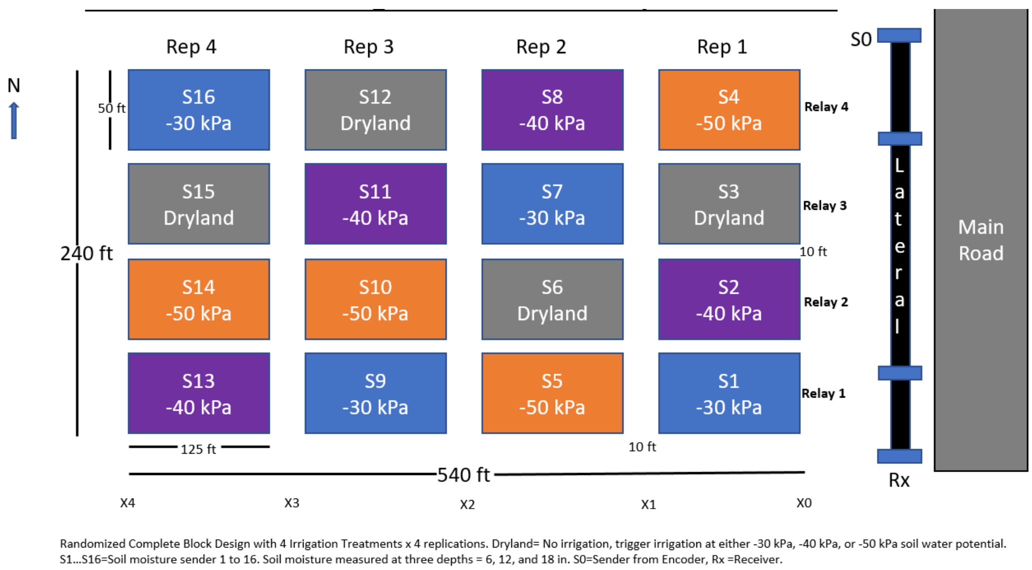

Figure 2. Plot plan for the lateral irrigation automation experiment at the Edisto REC in 2020.

Figure 3. Lateral move irrigation system with each sprinkler drop controlled by electronic valves. A third-wheel with a rotary encoder was installed to locate the irrigation system's position in the field.

Figure 4. Receiver/controller installed on the lateral mover irrigation system, and the dataloggers collecting data from moisture sensors installed at the center of each of the sixteen plots.

Results and Discussion

Calibration of the third wheel/rotary encoder system was conducted in the field to evaluate its accuracy for determining the position of the lateral move system (Fig. 5). The calibration resulted in an excellent correlation between the encoder reading and the lateral move system's measured travel distance in the field (r^2=0.9999). Also, the wireless data communication system performed as expected when installed in the field. Data were collected and sent to the Internet from the soil moisture sensors, every 20 minutes, and the rotary encoder, every 2 minutes. Figure 6 shows the soil moisture data collected from one of the sixteen plots shown in the Internet Cloud Service (Thingspeak.com) website. It also shows the data from the rotary encoder indicating the irrigation system's location in the field during an irrigation event. Project delays due to COVID-19 prevented irrigation early in the growing season. Therefore, irrigation was applied on Sept 10, 2020, to test the whole system's performance. During this time, some of the plots needed irrigation, and others did not. Irrigation to the different plots worked as expected (Fig. 7). Although the automation system worked as expected during this test, sufficient rain in September and October prevented additional irrigations needed to fully accomplish objective 2 of the project. Therefore, the field experiment to further test and fine-tune the automation system and evaluate objective 2 will be conducted in 2021.

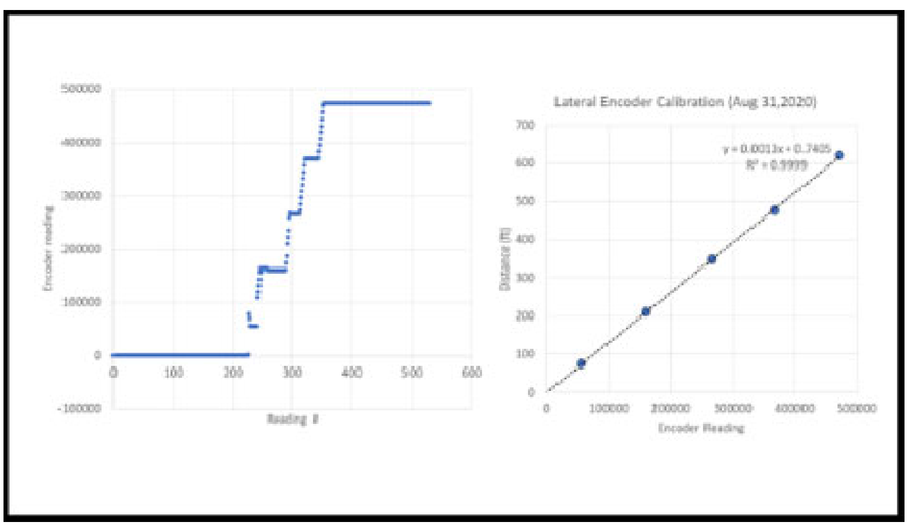

Figure 5. Results of calibration of the rotary encoder.

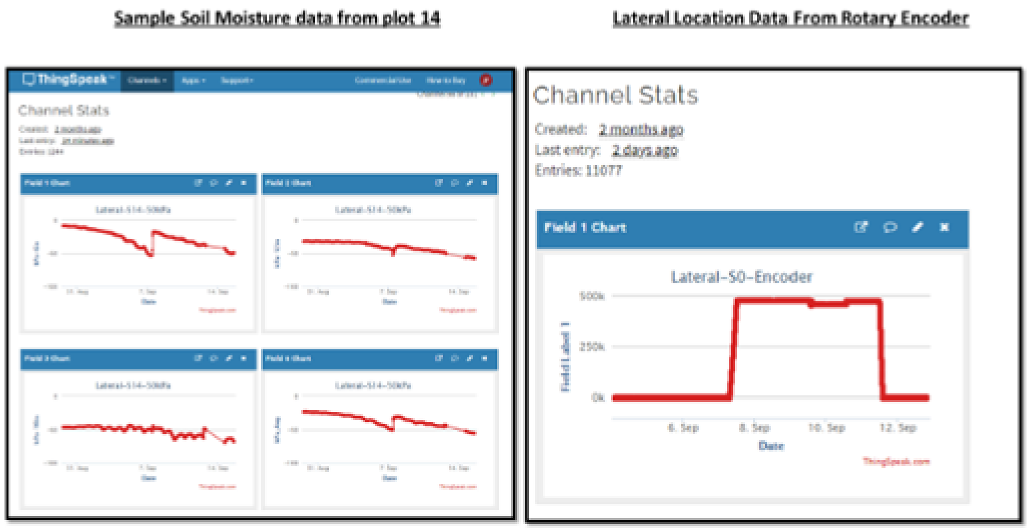

Figure 6. Data sent to the Internet from the soil moisture sensors and the rotary encoder.

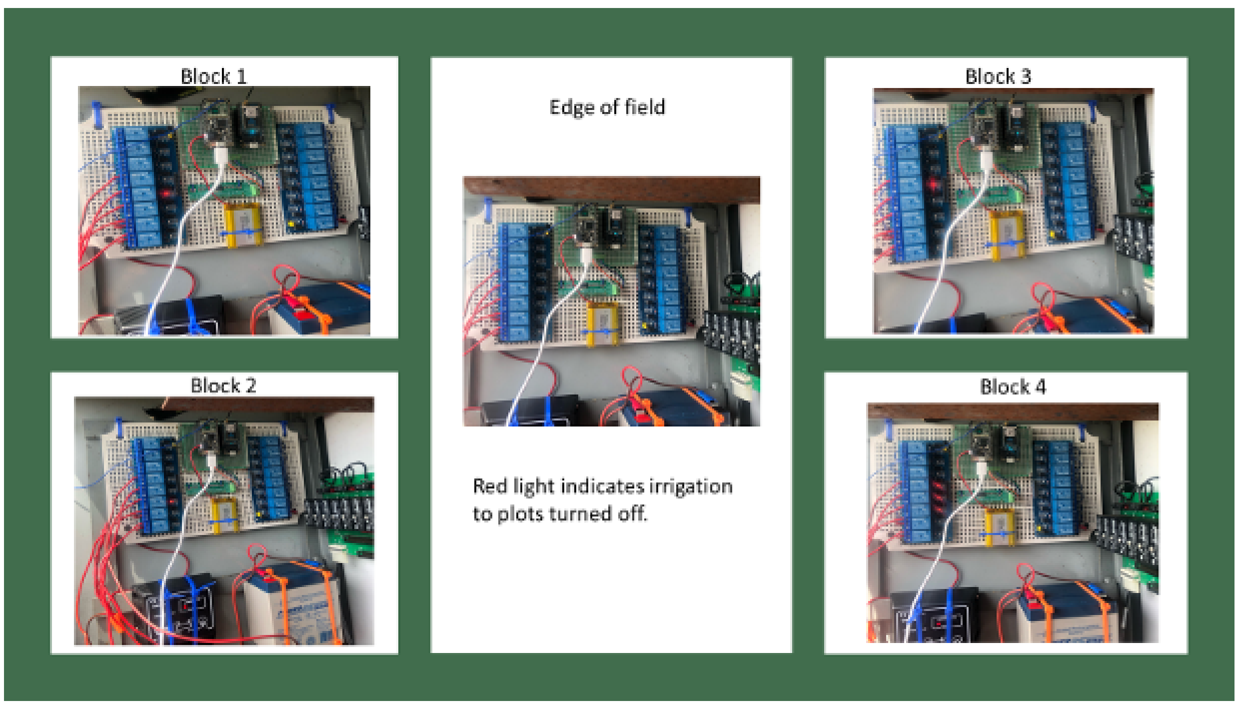

Figure 7. Irrigation applied on Sept 10, 2020.

Summary

In this study, a prototype wireless sensor network was developed to automate irrigation using a lateral move irrigation system. A field experiment was conducted at the Clemson University Edisto Research and Education Center in 2020 to field-test the irrigation automation system. In this experiment, three irrigation treatments were evaluated in which irrigation was automatically applied to cotton when the weighted-average soil moisture reached either 30, 40, or 50 kPa using four replications. Soil moisture was measured using Watermark moisture sensors installed at three depths in each plot. The electronics and software for the automation system were developed and installed in the field. Limited testing during one irrigation event in mid-September showed that the system worked as expected. However, early-season delays due to COVID-19 and sufficient rain late in the season prevented the full evaluation of objective 2 during the whole growing season. The field experiment will be repeated in 2021.

Acknowledgments

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