A WIRELESS SENSOR NETWORK FOR SENSOR-BASED IRRIGATION AUTOMATION OF COTTON

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Abstract

Water is a critical input in agricultural production. However, making the most efficient use of irrigation water resources is challenging for farmers since they have to make daily irrigation decisions to adapt to constantly changing weather and crop conditions. In addition, farmers mostly have to rely on experience and local rules of thumb to make important daily decisions regarding if, when, and where to apply irrigation. With current available technology, such as electronic sensors, microcontrollers, and wireless communication, it is possible to develop an affordable system to automate irrigation with minimum input from the farmer. Therefore, the objectives of this study were to: (1) build a cost-effective and reliable sensor-based irrigation automation system using open-source electronics, and (2) field-test the system by automating irrigation of cotton using a subsurface drip irrigation (SDI) system. In 2019, an irrigation automation prototype was developed at the Clemson University Edisto Research and Education Center in South Carolina. The system consisted of a wireless sensor network with nine sensor nodes (End Nodes) that collected data from Watermark soil water sensors and transmitted the data to a receiver (Coordinator). The Coordinator used the data to activate a series of relays to control irrigation of an SDI system. The Coordinator also connected to the Internet and sent the data to a Cloud server. The automation system was constructed using low-cost open-source electronics (Arduino compatible devices). The system was successfully used in 2019 to automate irrigation of nine cotton research plots.

Introduction

Producing more crop with less water is an important challenge, which will need to be met to be able to sustain a growing world population. This is especially true in many arid and semi-arid regions where water resources are already limited. Effective and affordable technologies are needed to help farmers make more efficient use of irrigation water. A first step towards improving irrigation efficiency in the United States has been the adoption of a variety of efficient pressurized irrigation systems (i.e. sprinkler and drip) as alternatives to less efficient surface irrigation systems. To further improve the irrigation efficiency of these pressurized irrigation systems, additional development and adoption of site-specific irrigation scheduling technologies will be needed.

Sensor-based irrigation scheduling technologies are of especial interest, since it is very difficult to manage what you do not measure. Over the years, a large variety of soil moisture sensors to help farmers schedule irrigation have been developed and commercialized. However, for many reasons, the adoption of sensor-based irrigation in commercial farms has been low, although its potential for lowering water waste in agriculture has been documented (Irmak et al, 2012). Recent research has shown that electronic soil moisture sensors can be integrated with open-source electronics and Internet-Of-Thing (IoT) technologies to create wireless sensor networks (Payero et al, 2017a and Payero et al, 2017b). These internet-connected sensor networks could be a transformative technology for facilitating adoption of sensor-based irrigation in agriculture. The next logical step in the development of these technologies would be to use wireless sensor networks to automate irrigation based on site-specific real time soil moisture data. Therefore, the objectives of this study were to: (1) build a cost-effective and reliable sensor-based irrigation automation system using open-source electronics, and (2) field-test the system by automating irrigation of cotton using a subsurface drip irrigation (SDI) system.

Materials and Methods

An irrigation automation prototype was developed at the Clemson University Edisto Research and Education Center in South Carolina in 2019 (Fig. 1). The system consisted of a wireless sensor network with nine sensor nodes (End Nodes) that collected data from Watermark soil water sensors (Irrometer, Inc.) and transmitted the data to a receiver (Coordinator). The Coordinator used the data to activate a series of relays to control irrigation of an SDI system. The Coordinator also connected to the Internet and sent the data to a Cloud server (Thingspeak.com). The automation system was constructed using low-cost open-source electronics, based on Arduino microcontrollers and compatible electronic components. The basic component for building the End Nodes was a Feather M0 RFM95 LoRa Radio (900MHz) (Adafruit.com), which integrated an Arduino-compatible MO microcontroller with a Long Range (LoRa) packet radio transceiver. A printed circuit board was fabricated to be able to read four Watermark moisture sensors with a Feather MO device. Power for each End Node was provided by a LiPo battery, which was charged by a small (6V) solar panel. The basic components for the Coordinator included a Feather Mo LoRa and, a Feather MO WiFi (Adafruit.com), and 12 relays. A Verizon hotspot was used to provide the WiFi signal.

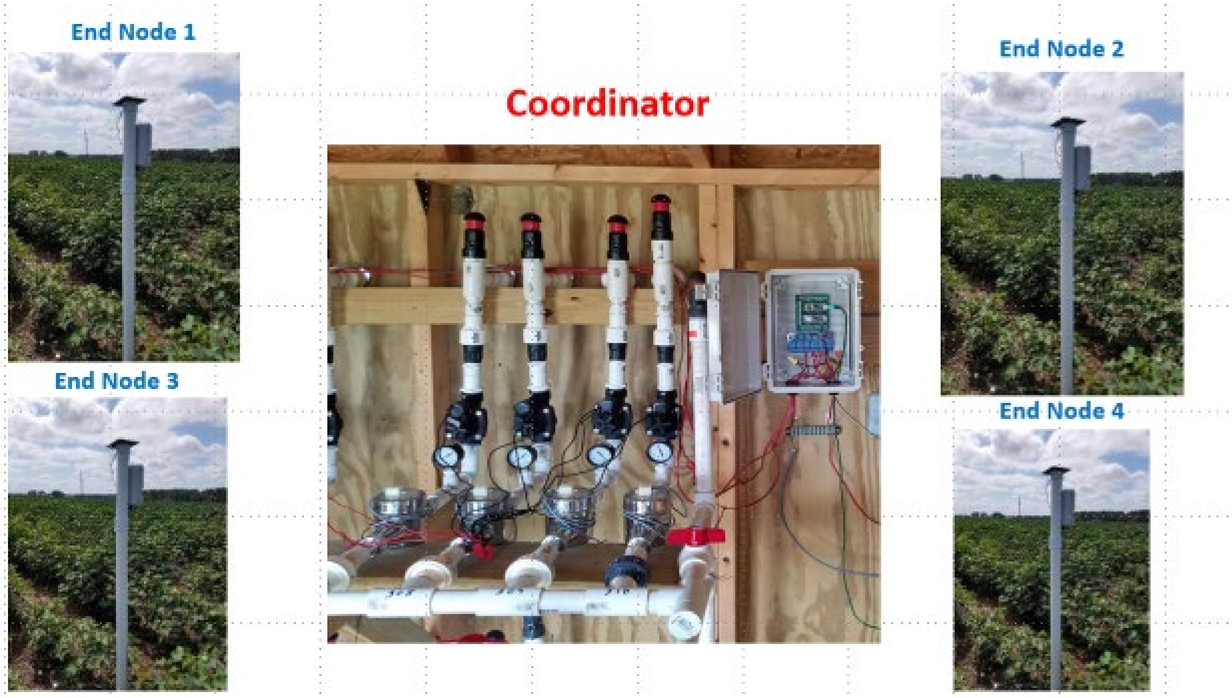

Figure 1. Irrigation automation system.

The automation system was field-tested by conducting a field experiment in which irrigation was automatically applied to nine cotton plots. Each plot (eight cotton rows x 50 ft long) represented an experimental unit in an experiment with three irrigation treatments and three replications. Four Watermark sensors were installed in each plot at depths of 6, 12, 18, and 24 inches. The irrigation automation was aimed at keeping the soil moisture (weighed average of the 4 sensors) in each plot within a specified upper limit (UL) and a lower limit (LL). The UL and LL for each irrigation treatment are shown in Table 1.

Table 1. Soil moisture limits (Upper Limit and Lower Limit) for each irrigation treatment.

Irrigation Treatment	Soil Water (kPa)	
	Upper Limit	Lower Limit
T1	-20	-25
T2	-25	-35
T3	-30	-40

Results and Discussion

Most of the 2019 crop growing season was used to build and troubleshoot the electronics and the software needed to automate irrigation of the SDI system. The cotton crop was planted in mid-May (May 15th) and the first automation prototype was installed in mid-July (July 13th). The first prototype worked as expected, except that in rare occasions data connection to the Internet failed and the microcontroller needed to be manually reset to reestablish connection to WiFi. This issue was traced back to a problem with the WiFi hotspot, which was replaced by a new one and the problem was corrected. As an example of the performance of the automation system, Fig. 2 shows soil moisture data from four sensors installed in one of the cotton plots (plot #6) as plotted in the Thingspeak.com web server. The sudden drop in the soil moisture at the very end of the season was data collected after the sensors had already been taken out of the ground. Fig. 3 (left) shows the weighted average soil moisture (AvgSM) and cumulative irrigation time in minutes (IrrigTimeMin) for each irrigation event for that same plot. Fig. 2 and Fig. 3 indicate that during the last month of the growing season, there was not data gap and the system always operated as expected. The AvgSM graph also shows that the soil moisture in the plot was maintained relatively constant within the specified Upper and Lower Limits for the T3 treatment.

Figure 2. Soil moisture from four sensors installed in one of the cotton plots (plot #6).

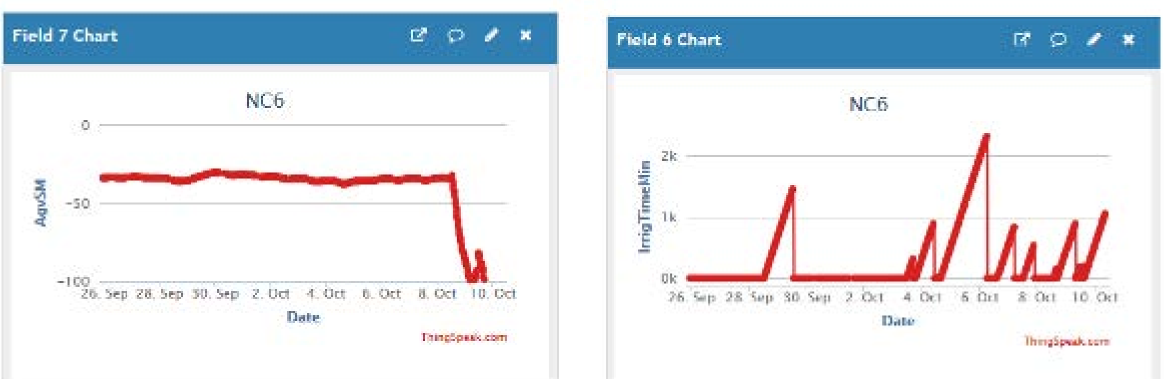

Figure 3. Weighted average soil moisture (AvgSM) and cumulative irrigation time in minutes (IrrigTimeMin) for each irrigation event for one of the cotton plots (plot #6).

Summary

In this study, a system to automate irrigation of a subsurface drip irrigation system was developed. The system used a wireless sensor network constructed using very affordable open-source electronics. The system sends data from moisture sensors installed in the field to the Internet where it is available to the farmer in real time. The system uses the real time sensor data to automatically trigger irrigation to maintain the soil moisture content in the crop root zone within a specified range. The irrigation automation system was successfully tested by automating irrigation of nine cotton plots in 2019 at the Clemson University Edisto Research and Education Center.

Acknowledgements

The author would like to acknowledge the financial support provided by the South Carolina Cotton Board, Cotton Incorporated, Clemson University, and USDA-NIFA (Hatch Project No. SC-1700540).

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