PennState Extension

Introduction of Automatic Irrigation Systems for Tree Fruit Orchards

Soil moisture sensors have proven to be effective for assisting in irrigation scheduling for tree fruit orchards.

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Figure 1. A soil moisture sensor-based irrigation system in a peach orchard. Image: Long He, Penn State

Compared to the conventional irrigation method, precision irrigation based on soil moisture sensors can guide when and how much to irrigate. An automatic irrigation system can turn on and off water automatically or remotely as the crop needs, no longer requiring going to the specific site. In the spring of 2021, we developed an automated irrigation system with an Internet of Things (IoT) sensing system. The field test was conducted in a peach orchard at Penn State Fruit Research and Extension Center (FREC). This article will introduce the major components of the system, the field setup, the display interface, the valve control, and irrigation data interpreting. Penn State Extension is willing to assist with this system should questions arise concerning device installation and operation.

Overall System

An Internet of Things (IoT) based automatic irrigation system was developed and tested in a peach orchard. Figure 1 shows an overview of the system in the orchard. With this system, the irrigation can be operated automatically or remotely. Typically, a solenoid valve is located close to the orchard block for an irrigation zone. Conventionally, the valve is turned on or off manually when irrigation is needed. While with automatic control, this valve is expected to be turned on/off automatically or remotely. The system mainly includes three soil moisture sensors, a solenoid valve and control, and a LoRaWAN® (***Lo***ng ***Ra***nge ***W***ide ***A***rea ***N***etwork) IoT system.

The schematic design of an IoT automatic irrigation system is shown in Figure 2. The IoT irrigation system is a two-way communication system. One is to deliver the sensor data and valve status (on/off) to the end-users. The other is to control the valve by end-user command or automatically by using pre-set soil moisture threshold. Soil moisture sensors are placed in the orchard and connected to a data logger/controller. The solenoid valve is also connected to the datalogger/controller. A LoRa® (***Lo***ng ***Ra***nge) Gateway is used as a communication hub and connected to the internet in the office. You can use different IoT servers for data communication, such as the Things Network(https://www.thethingsnetwork.org/) and Allthingstalk(https://www.allthingstalk.com/) that we used.

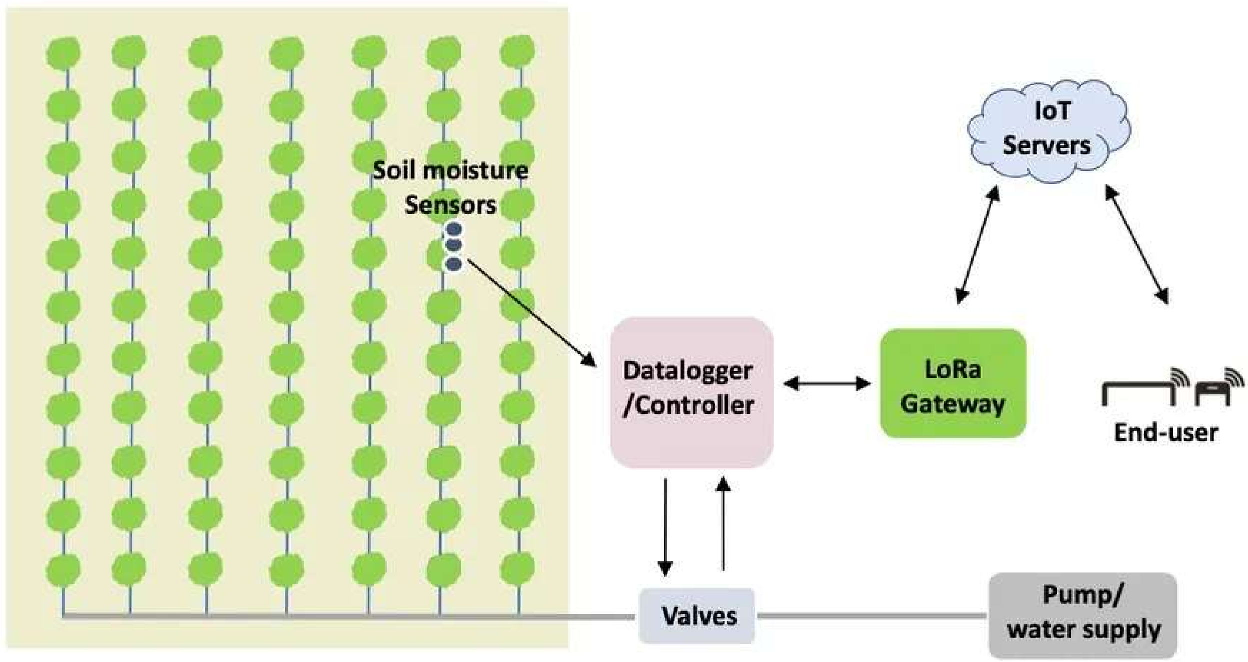

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Figure 2. Illustration of a LoRaWAN® based Internet of Things (IoT) automatic irrigation system for tree orchards. Image: Long He, Penn State

Main Components in the System

Water Supply

The water supplied to the irrigation system needs to be available without human interference (e.g., manual pump start) to apply water automatically. For most cases, we need to have an electric pump with a water pressure-based pump controller. For example, if the outlet water pressure is set at 40 psi, the pump will be turned on once the pressure goes to a lower number (typically adjustable). During irrigation, as the valve opens, the water pressure drops, which leads to the starting of the water pump to maintain the water pressure of 40 psi.

Soil Moisture Sensors

Three low-cost soil moisture sensors (Watermark 200SS-5, Irrometer Company, Inc.(https://www.irrometer.com/sensors.html)) were installed at 1, 2, and 3 ft., respectively. This type of sensor has been widely used for measuring soil moisture levels for a variety of crops. Each sensor was mounted to one end of a ½ inch PVC pipe. A hole near the dripline was dug for each sensor with corresponding depth to place the sensor. After installing the sensor, the hole needs to be filled with muddy soil to ensure close contact between the sensor and the soil. A larger number of sensor readings shows drier conditions in the soil.

Solenoid Valve

A DC latching solenoid valve was used to control irrigation by connecting and disconnecting the water supply. The valve was operated by a two-way relay with a 9-volt battery. For each irrigation zone/block, a solenoid valve is required for automatic irrigation.

Pressure Sensor

A pressure sensor added behind the solenoid valve in the pipeline indicates the irrigation status (on or off). Ideally, 0 psi indicates irrigation off, namely closure of the valve, and a positive number (e.g., 20 psi) means the irrigation is on, namely the valve is open. This indicator is critical to check any abnormal condition in the field, such as incorrect valve response or leaking. We placed the pressure sensor in a dripline in this test due to the space limitation behind the solenoid valve.

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Figure 3. shows some of the components used in the system. From left to right: pump controller, soil moisture sensors, solenoid valve, and pressure sensor. Images: Long He, Penn State

Sensor/Control Box

The soil moisture sensors, pressure sensor, and valve were connected to a control board in an enclosure box. A solar panel is also connected to provide charging power to the battery for the controller. The box was fixed on a pole in the field close to the soil moisture sensors (Figure 1). The LaRaWAN® communication protocol was used for the control box to communicate with the LoRa® gateway.

IoT System

For automatic remote access to the sensor data and control of the valve in the orchard, an Internet of Things (IoT) irrigation system was established. We used the Things Network to communicate between the hardware (datalogger/controller) and the cloud server. The Things Network is a global collaborative IoT ecosystem that creates networks, devices, and solutions using LoRaWAN®. Firstly, the wireless communication module in the datalogger/controller was configured into the Things Network(https://www.thethingsnetwork.org/). With this step, the sensors and valves are connected to the IoT system with a programmed setting (for example, data communication frequency of one soil matric potential measurement update per minute). While it is not convenient to read the sensor data and control the valve through the Things Network, it is necessary to create an interface to display the sensor data and valve control. Therefore, the IoT platform Allthingstalk(https://www.allthingstalk.com/) was used.

IoT Irrigation System Operation

Data Display and Valve Control

As we mentioned earlier, an IoT platform was used for the sensor data display and valve control. Figure 4 shows the interface of the IoT platform. This interface includes current soil moisture readings (individual sensor data and mean value), valve control (acting button and status indicator), water pressure sensor reading, battery voltage, and a chart of the mean soil moisture in a week, which you can set at different durations. When the irrigation is off, the valve status indicator shows black. When the irrigation starts, the valve status indicator turns green, the water pressure jumps to a high positive number, and the readings of soil moisture sensors start to decrease (smaller kPa (*kilopascal* see below*) values indicate wetter soil, while higher kPa values indicate drier soil). When the soil moisture reaches the setting threshold (for example, the mean value of 15 kPa), the valve will turn off, the valve status indicator turns back to black color, and the pressure drops quickly.

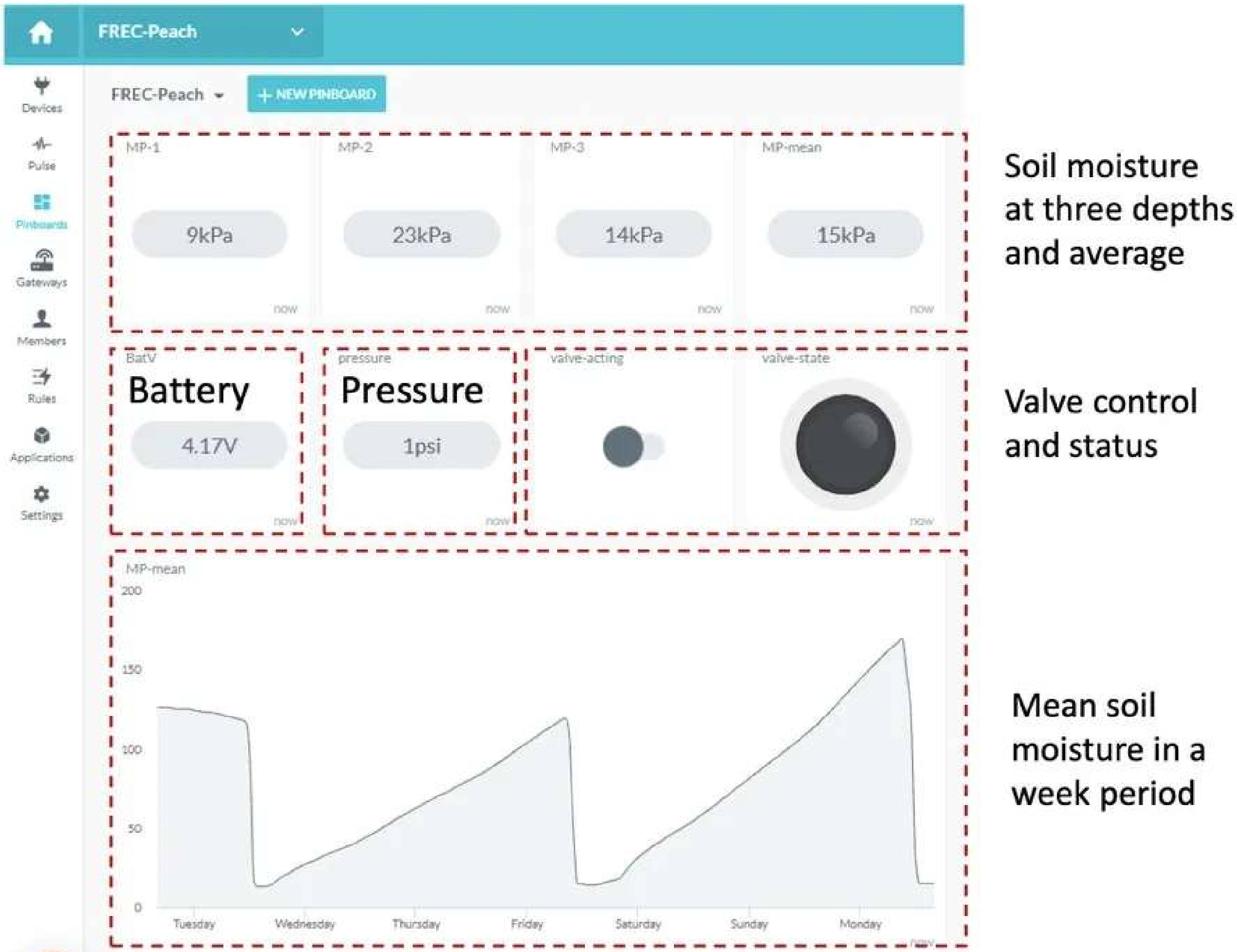

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Figure 4. The illustration of IoT platform interface used in the study

Irrigation Scheduling

In this study, we did not run the irrigation in full automation. Instead, the irrigation was turned on and off remotely with the interface shown in Figure 4. We closely monitored the soil moisture readings, and once the average soil moisture reached the set threshold (100 kPa as the initial setting), the valve turned on to open for irrigation. Since we did not run in full automation, the irrigation may have sometimes been delayed. On very dry, hot days, the soil moisture level can change significantly, even within one day. Fully automatic irrigation will be tested in our next study.

Irrigation Data Interpreting

Data Overview

We started to monitor the soil moisture in this orchard block on June 11, 2021, and finished monitoring on July 27, 2021. Figure 5 shows the daily average of soil moisture and the irrigation events applied during this period. Typically, four hours of irrigation is long enough to bring the soil moisture to a sufficient level. If we wait too long to irrigate—which means the soil is drier than the set threshold—four hours is not enough. For example, on July 19, 2021, the average metric potential was over 130 kPa. We had two irrigations on two consecutive days (around 4 hours each day) to bring the numbers down. There were also a few rainfall events during the period, which helped reduce irrigation schedules (for example, July 10 to July 18).

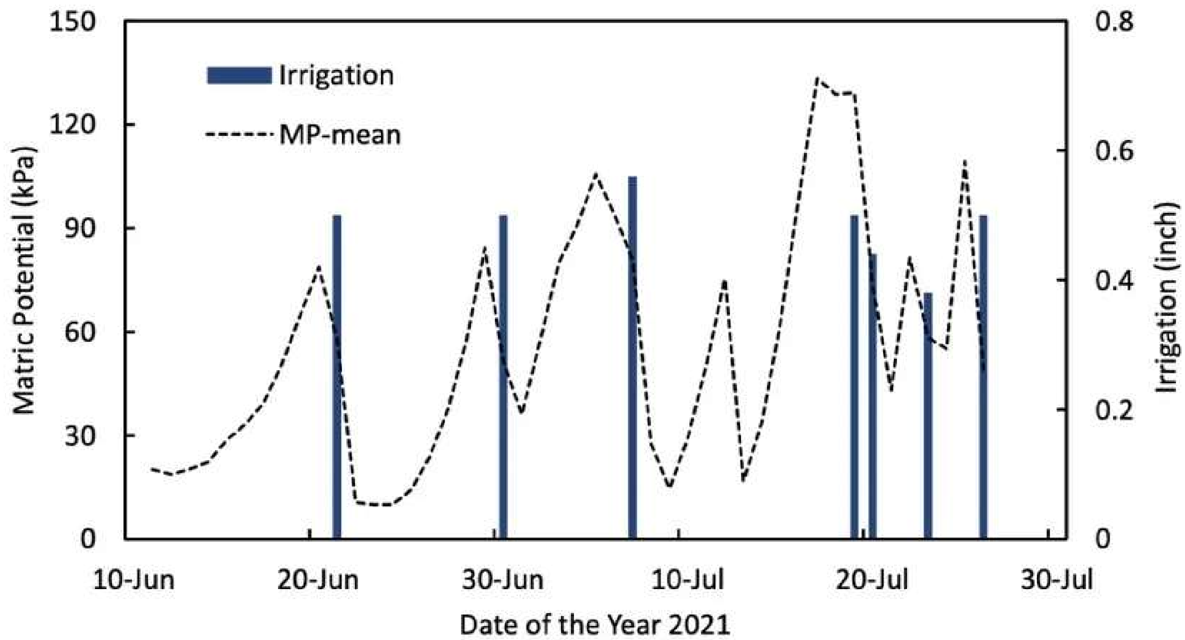

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Figure 5. The daily average soil moisture (matric potential) and the irrigation events during the period of June 11 to July 27, 2021.

An Irrigation Event

Figure 6 shows an example of an irrigation event. The initial readings for the three sensors were 122, 96, and 61 kPa, which was averaged at 93 kPa. Four hours of irrigation brought all the readings to around 10 kPa, indicating that the water got down to the 3 ft depth, and the monitored root zone received sufficient water. Since the top portion of the soil was pretty dry, it took about 2.5 hours to get a response from the first sensor at one-foot depth, followed by the changes of the second and third sensors. We can also see that the matric potential rapidly changed during an irrigation event.

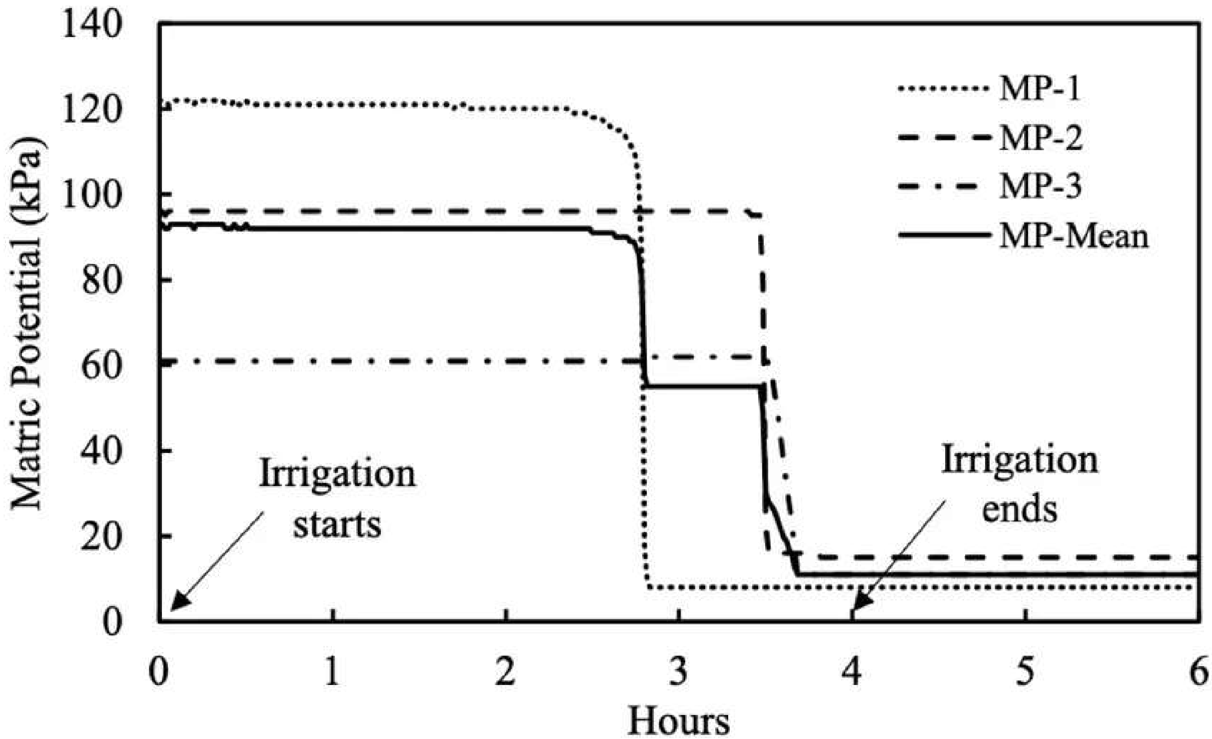

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Figure 6. The soil moisture change (matric potential) at different depths in a four-hour irrigation event. The naming convention adopted was 'MP-X' where 'MP' refers to matric potential sensor returning measurements in terms of kilopascals (kPa) followed by the depth of the sensor in feet. Therefore, 'MP-3' refers to the sensor placed at a depth of three feet in the soil.

Overall, the developed IoT irrigation system worked functionally during the test period. We monitored soil moisture levels at different soil depths with the average readings used for the irrigation. The irrigation events were applied remotely when the soil was dry. This study provided guidance on developing a fully automatic irrigation system.

* **Kilopascal (or kPa) Definition:** Kilopascals (kPa) are metric units of pressure. For those used to working with PSI, 100 PSI is almost 689.5 kPa. The soil matric potential is essentially a measurement of how much pressure would be required to move a certain volume of water off of the area of the soil particles' surfaces. As soil dries out, it requires more pressure to extract that volume of water (to make that water available for roots) because the water will cling tightly to the surface of the particles. Squeezing water out of a sponge is an analogy that is not quite correct, but suitable for illustrating matric potential. It takes less hand pressure to squeeze a cup of water out of a large, fully saturated sponge fresh from a bucket than from one that has been allowed to drain on a table, and far less hand pressure than what would be required to get water out of a sponge that has dried in the sun for an hour.

Acknowledgments

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