PennState Extension

Updates on Soil Moisture-Based Irrigation for Orchards

Now is the time to consider the use of soil moisture sensors in orchards to provide guidance for irrigation scheduling.

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Photo: Mingsen Huang, Penn State

Installation and monitoring of the data produced are simple procedures and can provide excellent benefits in the form of reduced water usage and improved crop quality. In 2019, there were periods of dry conditions in Pennsylvania, especially from July through August. Should similar conditions occur this year, planning now will provide ample time to install the technology and become familiar with its operation prior to times of need. This article provides updates from Penn State's commercial field trials conducted in 2019, and recommendations for a low-cost soil moisture system will be introduced for consideration. Penn State Extension is willing to provide assistance should questions arise concerning device installation and operation.

Updates of Trials at Commercial Orchards

In the 2019 season, four field trials were established at commercial orchards in Adams County. Collaborating with Penn State were Hollabaugh Bros., Inc., Twin Springs Fruit Farm, El Vista Orchards, and Mt. Ridge Farms. One set of sensor systems was installed at each orchard. Figure 1 illustrates the basic system configuration in the orchard, including all of the major components and necessary services: the irrigation system itself, the soil moisture sensors, a datalogger for measuring signals from the sensors and reporting the data, cellular communication services between the datalogger and the remote cloud system for uploading the sensor records, and the data monitoring/analysis software to provide intelligible information to support operational decision-making.
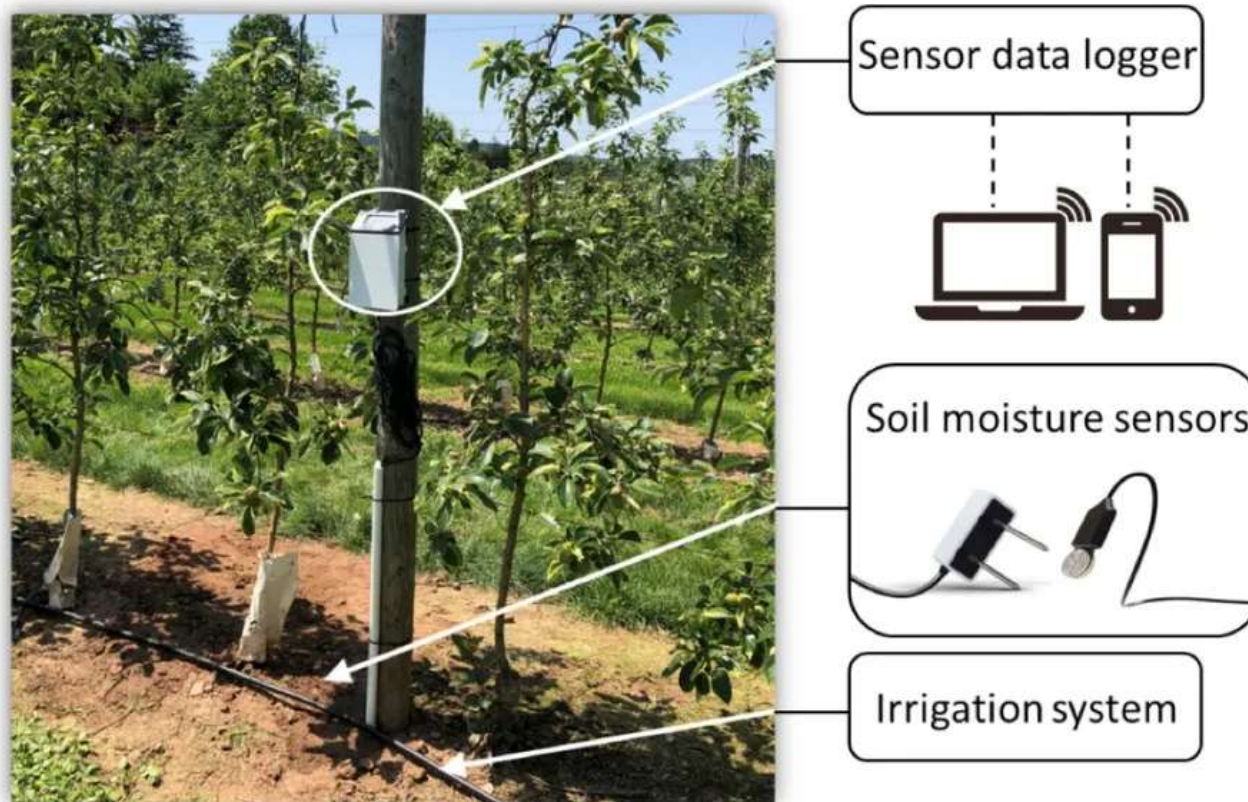
(https://extension.psu.edu/media/wysiwyg//extensions/catalog_product/6725a7ea4ff1479d87de366b198dbaf1/f/i/figure_1-jpg.jpg)

Figure 1. Illustration of soil moisture sensor-based irrigation system in a tree fruit orchard. Image: Long He, Penn State

The soil moisture sensors are buried and not visible in the photo. Cabling from the sensors is threaded through the white protective PVC tubing attached to the post and enters the base of the datalogger. The datalogger is powered by an array of AA batteries, which are recharged by a small solar array visible on the top of the housing. Data is uploaded to a cloud service on the internet via cellular service, thus there is no cabling leaving the datalogger.

The Soil Moisture Sensor System

Each complete sensor station consists of the following components depicted in Figure 1:

- Three Soil Water Content Sensors (Meter Group, Inc., TEROS 10)
- One Soil Water Potential Sensor (Meter Group, Inc., TEROS 21)
- One Sensor Datalogger (Meter Group, Inc., ZL6)
- Cloud-based Cellular Data Service (Zentra Cloud)

System Installation and Setup

Prior to installation, it is important to assess the quality of cellular service in the area where the sensors are to be deployed. The ZL6 datalogger supports AT&T and T-Mobile networks. If neither of these services are available in the area, or if the signal strength is insufficient to maintain a satisfactory connection for brief, but hourly intervals, the datalogger will be unable to report the data to the online monitoring software. Access to the data will be limited to a physical connection to the device via a USB cable, eliminating the advantage of this system.

Once it is established that the datalogger can communicate with the cloud-based server from where it is to be deployed, installation is a simple matter. In brief, the installation process involves the following steps:

- Dig a hole 3' deep and 6" in diameter mid-way between two irrigation emitters.
- Place the three water content sensors at depths of 3', 2', and 1' and one water potential sensor at 2'. The sensors' probes must be in firm contact with the soil to produce accurate readings.
- Connect the sensor cables to the datalogger. It is recommended that the cables be clearly labeled with the type of sensor and the depth at which it is placed since the sensor itself is buried.
- Mount the datalogger on a post or other stand. Choose a position on the post that provides a southern exposure to ensure that the solar panels receive the maximum amount of sunlight throughout the day and the season.
- Create an account at ZentraCloud and confirm that data is being uploaded. If a Windows-based laptop is available, the datalogger can be connected to it temporarily via a USB cable. This is useful for diagnosing problems with the datalogger in the field should data uploads fail or if sensors are suspected of being faulty.

Additional details about how to install sensors and how to access the data can be found in the Penn State Extension article Monitoring Soil Moisture Level for Precision Irrigation in Apple Orchards (https://extension.psu.edu/monitoring-soil-moisture-level-for-precision-irrigation-in-apple-orchards).

Results and Discussion of the Meter Group Sensor Technology

Figure 2 shows the soil moisture levels (in this case an average of the soil water content at all depths and soil water potential) plotted with irrigation events throughout the season in a Crimson Crisp apple block at Twin Springs Fruit Farm. The time period covered by this chart is from late June until the end of September. Initially, the irrigation scheduling plan was based on a pre-set timer, namely six hours every Tuesday, Thursday, and Saturday, represented by the vertical orange bars.

In the early season (June and July), the average water content was measured to be above 32% and the water potential was nearly -10 kPa. This indicates very wet conditions in terms of water abundance (high water content) and availability (little energy required to extract the water from the soil by the tree roots).

Beginning in August, the irrigation frequency was reduced, and eventually, in September, the duration of water applications per irrigation event was reduced to four hours. The water content dropped to a range of 27%-30%, and the water potential had significant variation in the range of -10 to -45 kPa that clearly reflected the application of water from the drip irrigation system.

Even during the driest conditions in late August and mid-September, the orchard was not water-stressed and there remained a sufficient abundance of available water in the soil for the trees. By monitoring this data, it was possible to reduce the irrigation frequency and duration with no negative impact on water availability. The measured data also indicated that the water potential sensor is more sensitive compared to the water content sensors, especially during dry conditions when water stress began to occur.
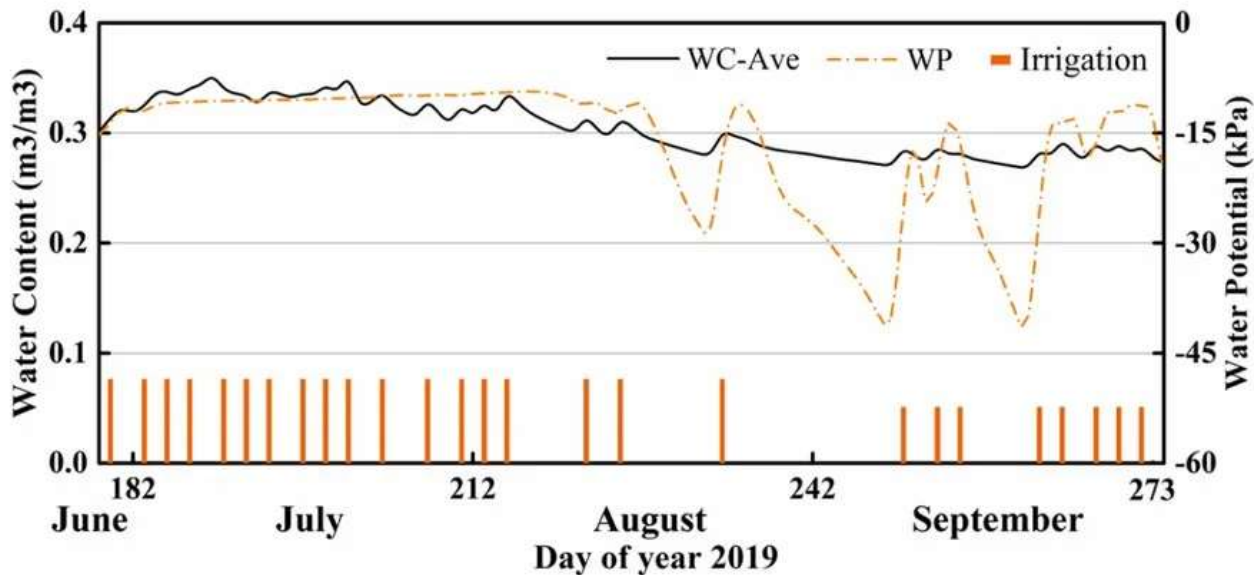
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Figure 2. Irrigation frequency and duration, daily soil water content, and soil water potential values throughout the season in an apple block. Image: Long He, Penn State

In this study, three water content sensors and one water potential sensor were used in order to compare them side by side. This arrangement could be used in the future, or the installation could be restricted to use only water content sensors or only a water potential sensor. Since the water potential sensor produced more sensitive results, it may be possible to only use the water potential sensors without jeopardizing the integrity of the data reported.

The thresholds for determining when to start and stop irrigation need to be identified for each individual orchard and depends heavily on soil types. Here, only the results from one orchard are discussed. The results from the other orchards participating in this research project are similar, but also produced differences due to the soil type. For instance, the soil water status changed more slowly at one orchard due to the soil containing more clay which has a higher water-holding capacity, as expected.

In 2019, this research mainly focused on monitoring the soil moisture levels and providing some initial feedback and suggestion to the participating growers. It did not use the sensor readings to precisely apply irrigation water based on the soil moisture data. During the 2020 season, this project will continue to collaborate with the growers to identify optimal irrigation frequencies and durations based on real-time data from the sensors.

Another Low-Cost Sensor System

The WATERMARK soil moisture sensor from IRROMETER® is a simple, low-cost, widely used system for measuring soil moisture levels for a variety of crops.

Figure 3 shows the process of installing and reading the sensors in the field. Prior to the sensor installation, the pre-conditioning of the sensors is necessary. The pre-conditioning process includes slowly wetting the sensors by partially submerging them (no more than halfway) in water for 30 minutes in the morning, letting them dry until evening, wetting for another 30 minutes, letting them dry overnight, wetting once again for 30 minutes the following morning, and letting it dry again until evening. Then soak the sensor over the next night and install it while still wet. It is important that these sensors be installed wet. This pre-conditioning process ensures a quick response to changing soil moisture conditions.

(https://extension.psu.edu/media/wysiwyg//extensions/catalog_product/0aaba0a983ed4a02935efc1a92d32326/f/i/figure_3-jpg.jpg)

Figure 3. A low-cost soil moisture sensor system (a WATERMARK soil moisture sensor) for orchard irrigation. From left to right: preparing the pre-conditioned sensor with a PVC pipe, boring a hole with a soil probe, placing the sensor by inserting it into the borehole, and reading the sensor with a hand-held digital meter. Image: Long He, Penn State

In Figure 3, the sensor is read using a hand-held meter. This is not a requirement; the sensor could be connected to a datalogger – similar to the ZL6 described above – to display and store the data. In development as part of this research is an automated irrigation system utilizing an Internet of Things (IoT) platform. This platform will allow remote sensor data monitoring and can control irrigation valves automatically.

This experiment will be conducted at the Fruit Research and Extension Center in Biglerville, Pennsylvania. Results are expected at the end of the 2020 growing season. While this type of system may require additional initial labor to configure, it is expected to provide a lower-cost irrigation system for growers with the capabilities of remote or automatic irrigation control.

Acknowledgments

Authors

Long He, Ph.D.

Assistant Professor of Agricultural and Biological Engineering

Expertise
- Mechanization and Automation for Specialty Crops
- Robotic Solutions for Agricultural Applications

- Precision Agriculture
- Electro-Hydraulic Control System

Daniel Weber, Ph.D.

Extension Educator, Horticulture, Commercial Tree Fruit Team

Expertise

- Horticulture, Commercial Tree Fruit Production, Genetics & Breeding, Computer Science