WIRELESS SENSOR NETWORK FOR "ON FARM" SOIL MOISTURE DATA ACQUISITION AND IRRIGATION SCHEDULING

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Introduction

Currently, irrigation scheduling decisions are made based on a combination of three tools: 1) ground truth where field conditions are scouted manually, 2) evapotranspiration calculations, where a "checkbook method" is used to estimate the amount of water required and is subsequently added, and 3) the use of soil moisture monitoring sensors. Irrigation scheduling is a key component of efficient water use (Shock et al. 2013b). When properly installed, soil moisture sensors provide a valuable resource for determining what is happening in the field. When soil water tension (SWT) for a crop has been estimated for a soil type, soil sensors provide excellent data to base scheduling decisions on (Shock and Wang 2011, Shock et al. 2013a). Granular matrix sensors have been used as a reliable moisture sensing tool (Shock 2003, Shock and Wang 2011). One of the primary drawbacks to the use of soil sensors is the need to manually download or review the data onsite at the collection manifold. In recent years, work has been done to provide soil moisture sensor data on a remote platform. This would enable sensors to be placed on a strategic basis rather than bound by the logistics of physical access. Proper representation of field conditions can be even more critical when irrigating during drought conditions with very scarce water or when irrigating crops that are very sensitive to over- or under-irrigation (Shock et al. 2013a).

The collection of SWT data can then be used in conjunction with crop-specific guidelines for proper irrigation. By using previously determined parameters for the soil moisture, SWT will provide an objective dataset on which to base decisions. Figure 1 provides an example of onion irrigation with a SWT criterion of 25 kPa.

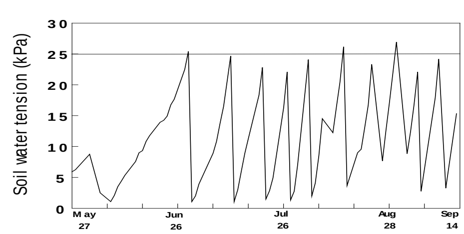

Figure 1. Soil water tension (SWT) at 20-cm depth for furrow-irrigated onion at a criterion of 25 kPa. A SWT of 0 is saturated soil. Note the wide fluctuations in SWT and the frequent instances of saturated soil (Shock et al. 2010).

Having soil moisture data remotely accessible would enable managers to make decisions by accessing the data on their laptop, tablet, or cell phone. This report discusses a remote monitoring platform that was deployed at the Oregon State University Malheur Experiment Station near Ontario, Oregon in 2014. This cloud-based platform is the IRROmesh™ system using the SensMit Web™ radio platform. This system was installed in several different fields across the Malheur Experiment Station to determine its monitoring ability. Similar remote monitoring platforms have been developed by other companies with varying radio frequencies and strengths with some using cell phone technology. Many are solar powered while others are battery powered. A very similar system is the ClimateMinder™ by RainBird that uses a series of nodes that report across a network and have collected soil moisture data posted to a website. The Connect™ platform by McCrometer and the WagNet™ system by AgSense are also available products that provide data collection that is reported to a website for remote access and archived.

Materials and Methods

The IRROmesh system (Irrometer Co. Inc., Riverside, CA) was composed of an array of nodes that communicated with each other in a relay fashion using a radio communication vehicle called the Fresnel Zone. The radio waves in the Fresnel Zone bounced from one node to another, transmitting the data to a node referred to as the base station. The base station was near a personal computer (PC) link that is the first node in the mesh. The PC link was wired into the computer hosting the data reporting and logging of the mesh. All data collected at the computer was compiled and archived to a website. Data could then be accessed via the internet in real-time or could be exported to a Microsoft Excel file on any internet enabled device. To access the reported data, a subscription and account was created. Nodes were solar powered and were placed on the top of poles about 9 ft above the ground. This was to facilitate the football-shaped radio waves that comprise the node communication in the Fresnel Zone.
The software was programmed to report every 30 min. Three Watermark soil moisture sensors (Irrometer Co. Inc.) and one soil temperature sensor were connected to each node. There was also a temperature sensor inside each node to provide "ambient" temperature. The temperature sensor was not a representative data point, however, because it was inside the clear plastic housing that protects the node. Some nodes were designated as "relay" nodes and some were "end" nodes. End nodes had only the hardware for collecting soil data and sending out signals while relay nodes were built to report their own data and receive messages from other nodes, then relay the data on across the mesh to the base station.

Implementation

The IRROmesh monitoring started on 28 May 2014 and continued through the growing season. Watermark sensors and soil temperature sensors were installed at predetermined sites in 12 fields with 7 different crops (Table 1). The sensors were installed at 20-cm depth using techniques described previously (Shock et al. 2013a) then the sensors were wired to the nodes. The array of nodes installed at the Malheur Experiment Station was representative of a layout that could be implemented by growers wanting to monitor several different crops around a base station (Fig. 2). The GPS locations of the nodes were entered manually into the IRROmesh software on the

PC, providing the overview of the mesh in Figure 2. A grower also might want to have multiple nodes installed within the same field to help capture soil differences, irrigation dynamic differences, etc.

Table 1. Soil water tension monitored in seven crops with an IRROmesh™ system at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2014.

Crop	Scientific name	Number of fields monitored	Irrigation method
Onion	*Allium cepa*	3	Drip
Sugar beet	*Beta vulgaris*	1	Furrow
Potato	*Solanum tuberosum*	2	1-Drip, 1-Sprinkled
Stevia	*Stevia rebaudiana*	1	Drip
Fernleaf biscuitroot	*Lomatium dissectum*	2	Drip
Canby's lovage	*Ligusticum canbyi*	2	Drip
Quinoa	*Chenopodium quinoa*	1	Furrow

Figure 2.The layout of an IRROmesh™ system at the Malheur Experiment Station, Oregon State University, Ontario, OR in 2014.The white triangle was the location of the base station and the receiving computer. The black triangles were the locations of the nodes with soil moisture sensors. The black bar represents a distance of 730 m along Onion Avenue.

Discussion

After the mesh was installed and reporting and the subscription was created, users navigated to a login page where they entered their own ID and password to access their account. When logged in, users navigated the site to a map of the nodes as deployed. Once the archived data was accessed, customized graphs immediately appeared on a smart phone or PC (Fig. 3). In this example, SWT in an onion field was shown for 2 weeks. The time interval of data displayed, the scale of the graph (cb = kPa), or the crop field being examined could easily be adjusted. Figure 3 shows a drying trend starting about 17 July and continuing above the 20 kPa irrigation threshold for drip-irrigated onion until 21 July. Accessed in real-time, growers could use data to increase irrigation duration or frequency to meet plant needs. In addition to seeing a spike of dryness as it is unfolding, there could be a chance to have a post-mortem evaluation at the end of the season. This format enables the grower to see when a field may have become too dry during the growing season. This may help explain quality or yield issues and enable the grower to avoid such circumstance in future years.

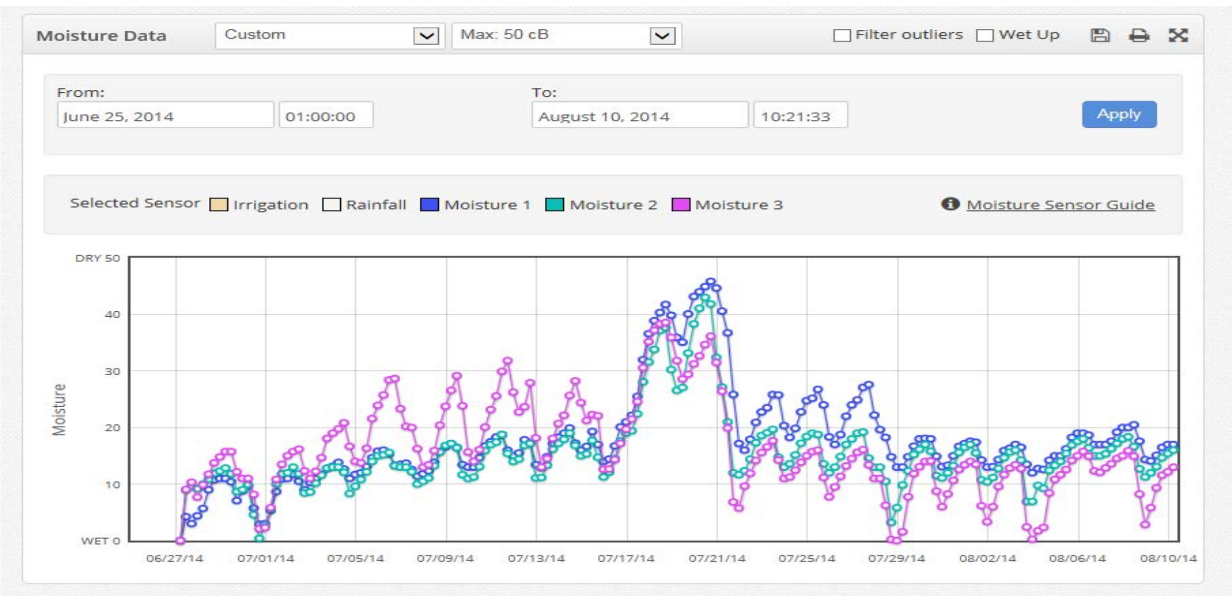

Figure 3. An example of soil water tension records for three Watermark soil moisture sensors at 20-cm depth in a drip-irrigated onion field for a selected timeframe at the Malheur Experiment Station, Oregon State University, Ontario, OR in 2014.

The internal temperature (the temperature inside the node) became very hot, often rising above the actual ambient air temperature (Fig. 4). The external soil sensor measures soil temperature and can be used to correct soil moisture sensor readings for temperature effects. This figure also depicts the ability of the user to use the pop-down menu and date selection to examine specific information by date.

The software also allowed easy download for the SWT history for any field at any date.

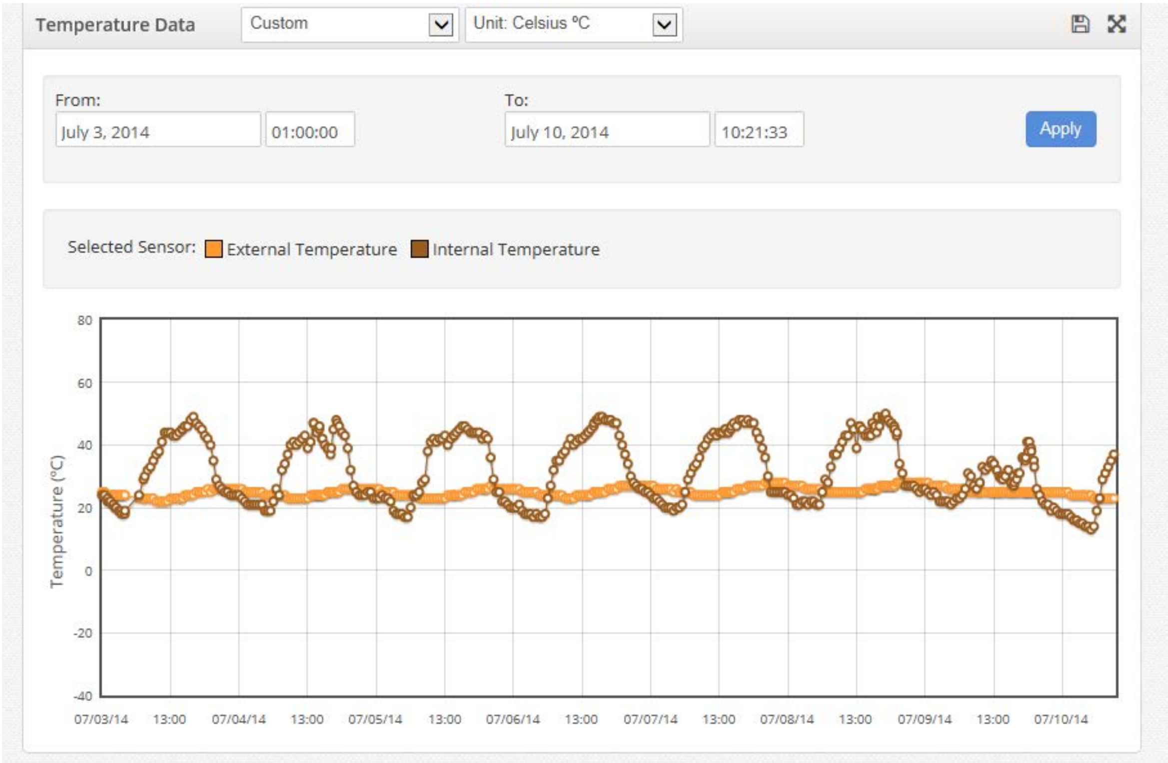

Figure 4. An example of a soil and air temperature record using the IRROmesh™ at the Malheur Experiment Station, Oregon State University, Ontario, OR in 2014.

When accessing the data, current data were available but the users could also create a custom data request. Table 2 provides an example of data exported to an Excel file at the request of a user. Data were summarized to meet the specific requirements of the viewer.

Table 2. An example of a soil moisture record exported to an Excel file for a furrow-irrigated quinoa field for a selected timeframe at the Malheur Experiment Station, Oregon State University, Ontario, OR in 2014.

		Moisture sensors (cb)			Temperature (°C)	
Node	Local time	MO1	MO2	MO3	Node	Soil
Quinoa	7/5/2014 16:59	20	27	26	43.5	21.5
Quinoa	7/5/2014 17:29	20	28	26	43.5	21.5
Quinoa	7/5/2014 17:59	20	28	26	43.5	21.5
Quinoa	7/5/2014 18:29	20	29	26	43.0	21.5
Quinoa	7/5/2014 18:59	20	29	26	44.5	21.5
Quinoa	7/5/2014 19:29	20	29	27	41.5	21.5
Quinoa	7/5/2014 19:59	20	29	27	34.0	21.5
Quinoa	7/5/2014 20:29	20	30	27	27.0	21.5

Under the conditions of the present trial, the mesh was able to communicate at least 300 m between nodes. For producers who are managing many crops and fields, remote sensor technology can help ensure that farm employees are following irrigation management guidelines. A manager can review many different fields at once and have a significant grasp of conditions in the field. As management attention to soil moisture conditions becomes apparent to farm employees, this remote oversight could enhance their attention to proper irrigation and related duties.

One of the issues incurred with the nodes was occasional intermittent lapsing in reporting. Despite the nodes indicating they were at full charge, some nodes would stop reporting during the night only to start again near mid-morning the following day. Another issue was the prescribed height of the nodes. If 9 ft height above the field is necessary for transmission, nodes could be hit by sprinkler systems and spraying equipment. Elevated nodes could also create a personnel hazard for aerial applicators with poles that are difficult to see, in addition to the potential damage that could be done to the nodes and the soil moisture sensing equipment. Further testing could assess if this height could be lowered to a more manageable height.

Summary

There are several attributes that remote moisture sensors can provide for growers. Rapid access to soil moisture data is a great aid for efficient irrigation scheduling. While an attractive irrigation scheduling tool, it should not be considered a total replacement for spending time in the field assessing conditions in person. The ability to access data real-time and review the archive at the end of the season will provide quality insight into irrigation scheduling.

Acknowledgements

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Disclaimer

The intent of this report is to share the findings of the Oregon State University Malheur Experiment Station in regards to the use of a sensor web to efficiently manage irrigation to maintain critical soil moisture for crop production. Its intent is neither to endorse the IRROmesh™ system with its SensMit Web™ radio platform and Watermark soil moisture sensors nor criticize any competing systems or products.