



Soil water monitoring systems: Components and costs



Rachel Schattman¹, Haley Jean¹, Joshua Faulkner², Rebecca Maden², and Bee Khim Chim³

¹The Agroecology Lab, University of Maine School of Food and Agriculture

² University of Vermont Extension

³ University of Maine Cooperative Extension

Measuring soil water availability can help improve crop yields, conserve water, and improve water-use efficiency. Soil-water information can be retrieved in several ways, either on site or from a cloud-based system. Data can be retrieved in the field using a pressure gauge attached to a tensiometer. Alternatively, you can use a portable handheld reader or a stationary data logger, both of which can be connected to granular matrix sensors (see Figure 1). Data can also be collected via cellular or wireless systems, which allow for automated, remote data access.



Figure 1: Tensiometers with gauges, a handheld meter, and a datalogger (image credits: Ele International and Irrrometer)

Tensiometer pressure gauges

Tensiometers are filled with distilled, boiled water that has been degassed. After installation in the soil, the water leaves the ceramic tip of a tensiometer but air cannot enter the reservoir. This creates suction, the force of which can be read using the attached gauge at the top of the tensiometer or by a voltage output transducer that connects to a handheld meter, a data logger, or an automated irrigation switch. Gauges report soil-water tension in centibars (cb) or kilopascals (kPa), which are equivalent measures of how much water in the soil is available to plants. Low readings indicate high soil water — i.e., wetter soils — and high readings indicate low soil water — i.e., drier soils (see Figure 2).

Handheld readers

Handheld data readers allow you to assess soil-water condition for point-in-time irrigation decisions. They are portable, and easy to keep with you on field walks or in a farm vehicle. To take a reading, attach the alligator clips to the wires at the end of a granular matrix sensor. As with tensiometer pressure gauges, the results will be shown in cb or kPa. While some handheld readers store multiple readings, you will likely need a field notebook or other method for recording data to track trends over time.

Data loggers

Data loggers are electronic devices that allow you

Banner image credit: Rachel Schattman, 2019

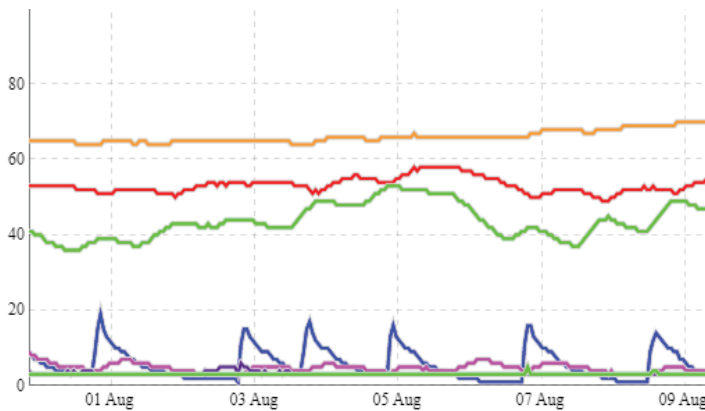


Figure 2: Example of soil water content values over time, using Irrrometer's cellular system dashboard. X axis = cB readings, with low readings indicating wetter soils and higher readings indicating drier soils; Y axis = date; Orange = temperature, all other colors = granular matrix sensors. Sharp decreases (blue lines) indicate irrigation events.

to collect data from soil-water monitoring systems over days, weeks, months, or an entire season. They store data which can be easily uploaded and analyzed on a computer. Several granular matrix sensors or other measurement tools (e.g., tipping rain gauges, wind direction and speed sensors, dew-point sensors, evapotranspiration sensors) can be attached to a single data logger. Data loggers are installed in the field, and are stored in plastic boxes to protect the equipment from the elements. The data loggers can be programmed to take readings at different intervals, for example every half hour, every hour, or once a day. These systems require battery power to operate, such as a 9-volt battery or small solar charging station. To retrieve soil-water information from a data logger, connect the logger directly to a computer using a USB cord or to a data shuttle. Alternatively, a Bluetooth connection can upload data to a phone, or a cellular modem can be installed along with the data logger, which allows you to access data remotely.

Cellular and wireless systems

Cellular and wireless systems allow you to retrieve soil-water information from the cloud. You can read the data collected through cellular or wireless systems on a smartphone, tablet, or computer. Cellular systems include a modem which is connected to a data logger. Your fields must be located in an area with good cellular coverage with a major carrier. The manufacturer of the cellular modem will specify which networks their equipment is compatible with.

Wireless systems use a signal-relay system to

transmit data to a dedicated computer or tablet, which must be connected to the internet. Granular matrix sensors or tensiometers are connected to signal relays, and must be placed within a maximum distance from the next relay (see figure 3). The manufacturers of wireless systems each have their own specifications for maximum relay distance. Most wireless and cellular systems sell optional signal extenders for an added cost.

With both cellular and wireless systems, proprietary software for reading data in a user-friendly dashboard is provided for an annual fee. The fees for these dashboards vary, ranging from a hundred to over a thousand U.S. dollars. Both cellular and wireless systems allow for frequent data collection, which can be viewed across time. Some systems also send alarm notifications to your mobile device, and can include integration with NEWA plant disease risk and insect pest models.

Cost comparison

The costs of soil-water monitoring systems vary by system and by supplier. Table 1 reports on costs of several different systems and manufacturers as of November 2022. Be advised that prices will change, and new systems may become available. The authors of this factsheet do not endorse any particular company or manufacturer.

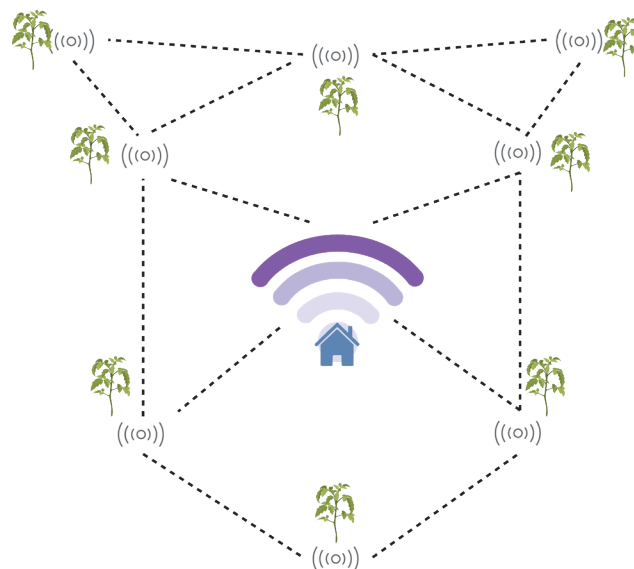


Figure 3: Schematic of a wifi relay network, showing paths of data transmission across a network of sensors. Created with Biorender.com

Table 1: Soil-water-monitoring systems - example components, manufacturers, and estimated costs in US dollars (2022)

Component	2022 price (USD)	Manufacturers	Additional information
Sensors			
Granular matrix sensors (Watermark)	\$35 - \$45	Irrrometer	Choice of lead wire length: 5-15', can add wire for additional length.
Tensiometers	\$80 - \$240	Irrrometer, Meter Group, Renke, Blumat, Jet Fill, Ele International	Choose ceramic tip type based on your soil. Standard models come with gauges or voltage output wires. Choose body length at time of purchase (6-48").
Handheld readers			
Watermark Handheld Meter	\$230 - \$250	Irrrometer	Alligator clips are compatible with voltage output wires on granular matrix sensors.
Data loggers			
Data loggers	\$550 - \$756	Irrrometer, HOBO, Spectrum Technologies (WatchDog), Davis Instruments	Proprietary data loggers can be used with data shuttles, PCs or Apple products (manufacturers may vary), cellular systems or wireless systems.
Data shuttles	\$280 - \$360	Irrrometer, HOBO, Spectrum Technologies (WatchDog)	Connects to proprietary data loggers, allows for download onto PC computers.
Cellular systems			
IRROcloud	\$580	Irrrometer	Compatible with granular matrix sensors or tensiometers for soil moisture. Other sensors can be added. Can be used with wireless systems as well.
DataScout modem - cell option	\$565 - \$795	Spectrum Technologies	Connects to WatchDog Retrievers.
Wireless systems			
WatchDog Retriever & Pups sensor network	\$1,985 for base components	Spectrum Technologies	Multiple components required.
DataScout modem - WiFi option	\$565 - \$795	Spectrum Technologies	Connects to WatchDog Retrievers.
HOBOnet Wireless sensor network	\$1,700 for base components	HOBO	Total system costs depend on the number of sensors and accessories. Includes mobile alerts, integrated with NEWA pest and disease models. Use with HOBO brand sensors.

Acknowledgements

This factsheet was created with support from The National Institute of Food and Agriculture, U.S. Department of Agriculture, through the Northeast Sustainable Agriculture Research and Education program under subaward number LNE19-391R, and the Maine Agricultural and Forest Experiment Station Hatch Project number ME0-1022424. This project was also supported by the USDA Northeast Climate Hub, through 20-JV-11242306-087. Special thanks to Dr. Stephanie Burnett for her content review, and Karrah Kwasnik for design consultation.



United States Department of Agriculture
Northeast Climate Hub



The Agroecology Lab



In complying with the letter and spirit of applicable laws and pursuing its own goals of diversity, the University of Maine System does not discriminate on the grounds of race, color, religion, sex, sexual orientation, transgender status, gender, gender identity or expression, ethnicity, national origin, citizenship status, familial status, ancestry, age, disability physical or mental, genetic information, or veterans or military status in employment, education, and all other programs and activities. The University provides reasonable accommodations to qualified individuals with disabilities upon request. The following person has been designated to handle inquiries regarding non-discrimination policies: Director of Equal Opportunity, 101 Boudreau Hall, University of Maine, Orono, ME 04469-5754, 207.581.1226, TTY 711 (Maine Relay System).

The University of Vermont and State Agricultural College is committed to a policy of equal educational opportunity. The university therefore prohibits discrimination on the basis of unlawful criteria such as race, color, religion, national or ethnic origin, age, sex, sexual orientation, marital status, disability, or gender identity or expression, as those terms are defined under applicable law, in admitting students to its programs and facilities and in administering its admissions policies, educational policies, scholarship and loan programs, athletic programs, and other institutionally administered programs or activities made available to students at the university. The university also prohibits harassment, as defined in the Vermont Statutes at Title 16, section 11(a)(26). Unlawful harassment is a form of discrimination and is therefore prohibited. Sources: Title VI of the Civil Rights Act of 1964; Title IX of the Education Amendments of 1972; the Age Discrimination Act of 1975; Section 504 of the Rehabilitation Act of 1973; the Americans with Disabilities Act of 1990; the Vermont Public Accommodations Act; and such other federal, state, and local non-discrimination laws as may apply.