STEPHEN AUSMUS (D2810-1)

Two Approaches for Optimizing Water Productivity

Above: Agricultural engineer Susan O'Shaughnessy views an irrigation prescription map constructed from data collected by an ARS wireless sensor system. The map shows variable crop water needs. Next to her, agricultural engineer Joaquin Casanova tests his prototype TDR (time domain reflectometry) probe.

Right: A variable-rate center-pivot irrigation system at Bushland, Texas. Technician Luke Britten (left) and Susan O'Shaughnessy (right) adjust wireless infrared thermometers in the field while technician Brice Ruthardt (center) uses a neutron gauge for soil water measurements.

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Agricultural Research Service researchers in Bushland, Texas, are helping farmers make the most of their water supplies in a region where they depend on the Ogallala Aquifer, a massive underground reservoir under constant threat of overuse.

Steve Evett, Susan O'Shaughnessy, and their colleagues at the Conservation and Production Research Laboratory are developing and testing soil-water and plant-stress sensors and automated irrigation systems that will irrigate fields only as necessary. Automated systems are considered key to sustainable use of the aquifer and to helping growers reduce water and labor costs.

"As water becomes more precious and the costs to pump it continue to rise, we need to tap the potential of every drop used in agriculture. To do that, we need to develop the best systems possible for accurately scheduling and controlling irrigation," Evett says. The researchers are developing automated irrigation and sensor systems based on two approaches that complement each other, O'Shaughnessy says. One system applies water based on levels of crop water stress detected by wireless sensors mounted on aboveground moving pipelines of commercial irrigation systems.

In the other system, the researchers are adapting sensor technology designed for urban sites so that it will work in agriculture. It triggers irrigation based on soil water content detected by sensors in fixed locations in the soil.

"Each system has advantages and disadvantages. But the combination of these two networked systems in a single field would be ideal, providing the temporal frequency and spatial coverage needed for monitoring crop water stress and robust control of irrigation," O'Shaughnessy says.

Sensing Water Needs From Above

Evett, O'Shaughnessy, and their colleagues have filed for a patent on the automated irrigation system. They verified its effectiveness in numerous field studies that compared it with manual irrigation control based on soil water monitoring with a neutron probe. The probe is a research standard for irrigation scheduling, but growers avoid it due to expense and regulatory burdens.

In one study, the researchers cultivated early- and late-maturing sorghum for 2 years. They used 16 prototype wireless sensors on a center-pivot irrigation system to monitor crop canopy temperatures. They chose sorghum because of its importance as a cash crop in the Southern High Plains and because it withstands water stress. Even so, irrigation plays a significant role in sorghum production in the region, tripling its yields.

Crop canopy temperature was monitored during the growing season as the pivot system moved across the field. Other instruments recorded weather data. The information was processed daily by a computer at the pivot point, which automatically scheduled and delivered irrigations when and where necessary.

"The sensor network was mounted on a six-span center pivot, but the technology could be adapted to other types of moving or static irrigation systems," O'Shaughnessy says.

An earlier system used to trigger irrigation manually was the Crop Water Stress Index. It calculated water stress based on canopy temperatures and weather factors measured at midday. Because cloud cover and other weather changes could make once-a-day measurements irrelevant to daily water use, the researchers developed a system using continuous measurements over the course of a day and calculated an Integrated Crop Water Stress Index (iCWSI). Irrigations were delivered automatically when and where iCWSI values exceeded a threshold established from previous data.

In a sorghum field, ARS technician Jourdan Bell (left) collects soil water content data from TDR (time-domain reflectometry) probes that measure crop water use. In the background, soil scientist Robert Schwartz observes grain fill in plants grown under deficit irrigation.


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Besides comparing crop yields and water-use efficiency between automatic and manual control methods, the study also evaluated yields at "deficit irrigation" levels. This was important since growers in the region sometimes increase profits by irrigating less, which saves on water and pumping costs.

The study results, published in 2012 in *Agricultural Water Management,* showed that the automated method of irrigation scheduling was just as effective as the manual method at both the full and deficit irrigation levels, producing similar grain yields and water-use efficiency levels.

Through a cooperative research and development agreement (CRADA), Evett and his colleagues are modifying Nebraska-based Valmont Industries' commercial irrigation systems in ways that will make them more useful to growers. The research team is integrating the ARS-developed sensor networks and irrigation-control system with the company's variable-rate and center-pivot irrigation systems.

ARS researchers in Florence, South Carolina; Maricopa, Arizona; Portageville, Missouri; and Stoneville, Mississippi are working with Evett and Valmont on the CRADA as part of an ARS multi-location research plan. The scientists are also developing sensor technology that will allow irrigation levels to be set based on site-specific data, which can be updated based on changing weather conditions.

Sensing Water Status Below the Soil Surface

For the automated irrigation system using underground sensors, Evett and his colleagues established a CRADA with Acclima, Inc., of Meridian, Idaho, to create a soil-water sensor designed to measure deeply and accurately. Evett and Bushland researchers Robert Schwartz and Joaquin Casanova are coinventors of the system.

Acclima makes sensor-based irrigation control systems with probes that use time-domain transmission technology, which measures the time required for an electromagnetic pulse to travel along an electrode embedded in the soil. Water slows the signal's travel, and the recorded speed is an accurate representation of the amount of water in the soil. A computer automatically activates water pumps and/or valves at predetermined soil water content levels.

Because Acclima's sensors are designed to control irrigation on tracts of grass, shrubs, and ornamentals, they only need to monitor water content to depths of about 4 to 6 inches. For use in agriculture, the probes need to be installed at depths of 50 inches or more and take readings at multiple depths.

Evett and his Acclima partners are developing new technology that uses time-domain reflectometry. They are using hollow, nonconductive, plastic tubes that can be drilled deeper into the soil. The tubes are divided into segments that attach to each other so they can be drilled down to any desired depth.

Prototype designs tested in water and test fluids, in clay and loam soils, and in the field have shown the feasibility of the approach, Evett says. ARS and Acclima have filed for a patent on the technology, which also includes the ability to assess soil salinity.

A new generation of relatively inexpensive wireless sensors is likely to make sensor network systems affordable in the near future, O'Shaughnessy says. Combining these sensor systems and improving and testing control algorithms based on years of data will increase the robustness and effectiveness of the irrigation automation solution.

Says Evett, "This is the future of irrigation, getting water where it is needed when it is needed, and limiting water use to the exact amount that is needed."—By **Dennis O'Brien,** ARS.

This research is part of Water Availability and Watershed Management, an ARS national program (#211) described at www.nps.ars.usda.gov.

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