METER
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CAN CANOPY MEASUREMENTS DETERMINE SOIL MOISTURE?

As a young university student, Dr. Y. Osroosh, now a researcher at Washington State University, wanted to design the most accurate soil moisture sensor. Over the years, however, he began to realize the complexity and difficulty of the task. Inspired by the work of Jackson et al. (1981) and researchers in Bushland, TX, he now believes that plants are the best soil moisture sensors. He and his team developed a new model for interpreting plant canopy signals to indirectly determine soil moisture.

HOW CAN PLANTS INDICATE WATER IN SOIL?

Osroosh and his team wanted to use plant stress instead of soil sensors to make irrigation decisions in a drip-irrigated Fuji apple tree orchard. But, the current practice of using the crop water stress index (CWSI) for detecting water stress presented some problems, Osroosh comments, “Currently, scientists use either an empirical CWSI or a theoretical one developed using equations from FAO-56, but the basis for FAO-56 equations is alfalfa or grass, which isn’t similar to apple trees.” One of the main differences between grass and apple trees is that apple tree leaves are highly linked to atmospheric conditions. They control their stomata to avoid water loss.

So Osroosh borrowed a METER SC-1 leaf porometer to measure the stomatal conductance of apple trees, and he developed his own crop water stress index, based on what he found. He explains, “We developed a new theoretical crop water stress index specifically for apple trees. It accounts for stomatal regulations in apple trees using a canopy conductance sub-model. It also estimates average actual and potential transpiration rates for the canopy area which is viewed by a thermal infrared sensor (IRT).”

SC-1 leaf porometer

WHAT DATA WAS USED?

Osroosh says they established their new "Apple Tree" CWSI based on the energy budget of a single apple leaf, so "soil heat flux" was not a component in their modeling. He and his team measured soil water deficit using a neutron probe in the top 60 cm of the profile, and they collected canopy surface temperature data using thermal infrared sensors. The team also measured microclimatic data in the orchard.

Osroosh comments, "The accuracy of this approach greatly depends on the accuracy of reference soil moisture measurement methods. To establish a relationship between CWSI and soil water, we needed to measure soil water content in the root zone precisely. We used a neutron probe, which provides enough precision and volume of influence to meet our requirements. However, it was a labor and time intensive method which did not allow for real-time measurements, posing a serious limitation."

THE RESULTS

Osroosh says they expected to see correlations, but such strong relationships were unexpected. The team found that soil water deficit was highly correlated with thermal-based water stress indices in drip-irrigated apple orchard in the mildly-stressed range. The relationships were time-sensitive, meaning that they were valid only at a specific time of day. The measurements taken between 10:00am and 11:00am (late morning, time of maximum transpiration) were highly correlated with soil water deficit, but the "coefficient of determination" decreased quickly and significantly beyond this time window (about half in just one hour, and reached zero in the afternoon hours). Osroosh says this is a very important finding because researchers still think midday is the best time to measure canopy water stress index (CWSI). He adds, "The apple trees showed an interesting behavior which was nothing like what we are used to seeing in row crops. They regulate their stomata in a way that transpiration rate is intense late in the morning (maximum) and late in the afternoon. During the hot hours of afternoon, they close their stomata to minimize water loss."

OTHER RESEARCH

Osroosh points to other efforts which have tried to correlate remotely-sensed satellite-based thermal or NIR measurements to soil water content. He says, "The closest studies to ours have been able to find good relationships between CWSI and soil water content in the root zone near the end of the season at high soil water deficits in row crops. Paul Colaizzi, a research agricultural engineer did his PhD research in part on the relationship between canopy temperature, CWSI, and soil water status in Maricopa, Arizona; also motivated by Jackson et al. (1981). Steve Evett and his team at Bushland, Texas are continuing that research as they try to develop a relationship between CWSI and soil water status that will hold up. They are using a CWSI that is integrated over the daylight hours and have found good relationships between CWSI and soil water content in the root zone near the end of the season when plots irrigated at deficits begin to develop big deficits."

WHAT'S THE FUTURE?

In the future, Osroosh hopes to study the limitations of this approach and to find a better way to monitor a large volume of soil in the root zone in real-time (as reference). He says, "We would like to see how universal these equations can be. Right now, I suspect they are crop and soil-specific, but by how much we don't know. We want to study other apple cultivars, tree species, and perhaps even row crops, under other irrigation systems and climates. We need to monitor crops for health, as well, to make sure what we are measuring is purely a water stress signal. One of our major goals is to develop a sensor-based setup which, after calibration, can be used for “precise non-contact sensing of soil water content” and “stem water potential” in real-time by measuring canopy temperature and micrometeorological parameters.”

Discover the SC-1 leaf porometer and the IRT infrared thermometer