METER
ENVIRONMENT

STEM WATER CONTENT CHANGES OUR UNDERSTANDING OF TREE WATER USE

We highlight two current research projects using METER soil moisture sensors to measure volumetric water content (VWC) in tree stems and share why this previously difficult-to-obtain measurement will change how we look at tree water usage.

STUDY #1: SOIL MOISTURE SENSORS IN A TREE?

In a recent research project, Ph.D. candidate Ashley Matheny of the University of Michigan used soil moisture sensors to measure volumetric water content in the stems of two species of hardwood trees in a northern Michigan forest: mature red oak and red maple. Though both tree types are classified as deciduous, they have different strategies for how they use water. Oak is anisohydric, meaning the species doesn't control their stomata to reduce transpiration, even in drought conditions. Isohydric maples are more conservative. If the soil starts to dry out, maple trees will maintain their leaf water potential by closing their stomata to conserve water. Ashley and her research team wanted to understand the different ways these two types of trees use stem water in various soil moisture scenarios.

Historically, tree water storage has been measured using dendrometers and sap flow data, but Ashley's team wanted to explore the feasibility of inserting a capacitance-type soil sensor in the tree stems as a real-time measurement. They hoped for a practical way to make this measurement to provide more accurate estimations of transpiration for use in global models.

Ashley and her team used meteorological, sap flux, and stem water content measurements to test the effectiveness of capacitance sensors for measuring tree water storage and water use dynamics in one red maple and one red oak tree of similar size, height, canopy position and proximity to one another (Matheny et al. 2015). They installed both long and short soil moisture probes in the top and the bottom of the maple and oak tree stems, taking continuous measurements for two months. They calibrated the sensors to the density of the maple and oak woods and then inserted the sensors into drilled pilot holes. They also measured soil moisture

and temperature for reference, eventually converting soil moisture measurements to water potential values.

RESULTS VARIED ACCORDING TO SPECIES

The research team found that the VWC measurements in the stems described tree storage dynamics which correlated well with average sap flux dynamics. They observed exactly what they assumed would be the anisohydric and isohydric characteristics in both trees. When soil water decreased, they saw that red oak used up everything that was stored in the stem, even though there wasn't much available soil moisture. Whereas in maple, the water in the stem was more closely tied to the amount of soil water. After precipitation, maple trees used the water stored in their stem and replaced it with more soil water. But, when soil moisture declined, they held onto that water and used it at a slower rate.

TREES USE DIFFERENT STRATEGIES AT THE SPECIES LEVEL

The ability to make a stem water content measurement was important to these researchers because much of their work deals with global models representing forests in the broadest sense possible. They want to figure out the appropriate level of detail for tree water-use strategy in a global model. Both oak and the maple are classified as broadleaf deciduous, and in a global model, they're lumped into the same category. But this study illustrates that if you're interested in hydrodynamics (the way that trees use water), deciduous trees use different strategies at the species level. Thus, there is a need to treat them differently to produce accurate models.

Read the full study in Ecosphere.

Reference: Matheny, A. M., G. Bohrer, S. R. Garrity, T. H. Morin, C. J. Howard, and C. S. Vogel. 2015. Observations of stem water storage in trees of opposing hydraulic strategies. Ecosphere 6(9):165. http://dx.doi.org/10.1890/ES15-00170.1

TEROS 12 soil moisture sensor

STUDY # 2: DETERMINING TREE STEM WATER CONTENT IN DROUGHT-TOLERANT SPECIES

Tadaomi Saito and his research team were interested in using METER dielectric soil moisture sensors to measure the tree stem volumetric water content of mesquite trees and tamarisk, two invasive species dominant in Sudan and arid parts of the United States. Mesquite is a species that can access deep groundwater sources using their taproots which is how they compete with native species. Tamarisk, on the other hand, uses shallow, saline groundwater to survive. The team wanted to see if dielectric probes were useful for real-time measurement of plant water stress in these drought-tolerant species and if these measurements could illuminate differing tree water-use patterns. These sensors could then potentially be used for precision irrigation strategies to assist in agricultural water management.

TEMPERATURE CALIBRATION WAS ESSENTIAL

After calibrating the soil moisture sensors to the wood types in a lab, the team inserted probes into the stems of both trees. They also monitored groundwater and soil moisture content to try and infer whether or not the trees were plugged into a deep source of water. Interestingly, Saito found that, unlike soil, where temperature fluctuation is buffered, tree stems are subject to large variations in temperature throughout the course of the day. This temperature fluctuation interfered with the soil moisture probes' ability to accurately measure VWC. The team came up with a simple method for accounting for temperature variability and were then able to obtain accurate VWC measurements.

WATER USE DEPENDED ON LANDSCAPE POSITION

Saito's results were similar to Ashley Matheny's study in that they found a lot of different patterns, even in trees of the same species. Water-use depended on where the trees were on the landscape. Some of them were tapped into groundwater, and the stem water storage didn't change no matter how dry the soil became. Whereas others, depending on their position in the landscape, were very dependent on soil moisture conditions.

You can read the full study details here.

IMPLICATIONS

Saito's study illustrates that we see everything about a tree that's above ground, but we may have no sense of what's going on below ground. We can put a soil moisture sensor in the ground and decide there's plenty of moisture available. Or if conditions are dry, we may decide the tree is under drought stress, but we don't know if that tree is tapped into a more permanent source of groundwater.

Other researchers have put soil moisture sensors in orchards looking at stem water storage from a practical standpoint for irrigation management. Their data didn't work out so well because of cable sensitivity where water on the cable created false readings. However, the data they were able to obtain showed that some of the trees were plugged into water sources that were independent of the soil. Those trees were able to withstand drought and needed less irrigation, whereas other trees were much more sensitive to soil moisture.

If we had an inexpensive, easy to deploy measurement device plugged into every tree in an orchard, we could irrigate tree by tree, give them precisely what they needed, and account for their unique situation.

WHAT DOES IT ALL MEAN?

The interesting thing about using soil moisture sensors in a tree is that stem water content is a difficult-to-obtain piece of information that has now been made easier. Historically, we've focused on measuring sap flow, but that's just how much water is flowing past the sensor. We've measured what's in the soil: a pool of moisture that's available to the tree. But some trees are huge in size, such as ones along the coast of California. They're able to store vast amounts of water above-ground in their tissue. Understanding how a tree can use that water to buffer or get through periods of drought is a unique research topic that has had very little attention. With these kinds of sensors, we can start to investigate those questions.

Reference: Saito T., H. Yasuda, M. Sakurai, K. Acharya, S. Sueki, K. Inosako, K. Yoda, H. Fujimaki, M. Abd Elbasit, A. Eldoma and H. Nawata , Monitoring of stem water content of native/invasive trees in arid environments using GS3 soil moisture sensor, Vadose Zone Journal , vol.15 (0) (p.1 – 9) , 2016.03