New soil moisture sensor tracks drought conditions in Arizona, Mexico

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72-foot meteorological flux tower in the west Phoenix neighborhood of Maryvale with COSMOS sensor installed at the base of the tower. Credit: Adam Schreiner-McGraw

Soil moisture measurements are needed to improve our understanding of water availability in rural and urban areas. Adam Schreiner-McGraw, an Arizona State University graduate student studying hydrology, has installed a new type of soil moisture sensor in four different ecosystems in the southwestern U.S. and northwest Mexico. Currently in the second year of measurements, these probes have tracked remarkably well the moderate drought conditions in Arizona and the aid provided by the wetter-than-average conditions during last summer's monsoon.

Many parts of the hydrologic cycle are difficult to measure (such as groundwater movement or evapotranspiration), so mathematical models are used to help estimate these fluxes and understand how the hydrologic cycle might be changing. Schreiner-McGraw hopes that the data obtained by these soil moisture sensors can be used to improve watershed hydrology models used commonly for assessing impacts of land cover or climate change.

About the size of a person and shaped like a space shuttle, these novel probes are called cosmic-ray soil moisture sensors. They are affiliated with the COSMOS (cosmic-ray soil moisture observing system) project, a National Science Foundation-supported project to measure soil moisture based upon cosmic-ray neutrons. An off-the-shelf device, these solar-powered sensors have remote data capture and can be installed in two days with a single field calibration.

The technology uses "fast neutrons" generated when cosmic-rays hit the atmosphere, cascade onto the land surface and are captured by hydrogen atoms. Intermediate scale measurements are possible, meaning that soil moisture is averaged over several hundred square meters. This allows observations that are in between traditional soil sensors and satellite estimates, the two most common ways to measure soil moisture. The sensor itself measures the density of fast neutrons above the soil surface. This density is inversely proportional to the amount of hydrogen bound in water within and above the soil surface. The higher number of neutrons measured by the sensor, the drier the soil is, providing a means to track water availability in rural or urban areas.

Adam Schreiner-McGraw downloads data from a COSMOS sensor to quantify water availability in a low-density residential area. Credit: Courtesy Adam Schreiner-McGraw

"We are currently obtaining real-time soil moisture data at three rural sites – southern Arizona, southern New Mexico and Sonora, Mexico – that have each been affected by human-induced land cover change," explains Schreiner-McGraw, who is pursuing a doctorate in ecohydrology within the School of Earth and Space Exploration under the supervision of ASU associate professor Enrique R. Vivoni.

The two rural sites in the United States are undergoing woody plant encroachment, a process in which woody shrubs have occupied historical desert grasslands, while the site in Mexico had woody trees cleared away for the establishment of a pasture for cattle grazing. Both of these land cover changes are widespread throughout the world in arid and semiarid regions. Schreiner-McGraw is investigating the effects of these land cover changes on the water cycle, and the implications on ecosystem functioning, runoff generation and soil erosion.

"Recently, I installed another sensor in west Phoenix within the Maryvale community. To my knowledge, this is the first time one of these sensors has been installed in an urban setting. It is difficult to obtain an accurate measurement for soil moisture in urban settings because these sensors measure all sources of water in the footprint, so if somebody fills up their bathtub, it will likely affect the measurement," says Schreiner-McGraw. "What we have found so far is that the neutron count rate in an urban setting is much lower and more stable than in the various rural areas that we are sampling. This indicates that soil moisture is likely higher and less variable in our urban setting, probably due to the large amount of urban irrigation occurring in Phoenix."

According to Schreiner-McGraw, these sensors are useful because they provide a single value for soil moisture over a large region that is being sampled, thus averaging the amount of water available at scales relevant for management purposes. A network of such sensors in a metropolitan area, such as Phoenix, could aid in quantifying outdoor water use at an intermediate scale, a highly elusive measurement due to the large variations among individual homeowners.

"Hopefully, integrating this type of soil moisture data into hydrologic models of rural and urban areas will improve our ability to predict the changing hydrologic cycle," says Schreiner-McGraw, who after graduation would like to continue doing research, perhaps with the U.S. Geological Survey, the U.S. Department of Agriculture or at a university as a professor.

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