Spatial and Temporal Dynamics of Hillslope-Scale Soil Moisture Patterns

Soil moisture is the central variable in the hydrological cycle, and the vadose zone, where the soil water resides is the subsurface layer that plays a central role in supporting plant roots and filtering water. The vadose zone is the pathway for recharge to the water table. Soil moisture varies at very fine spatial scales, and any large-scale network for in-situ measurements needs to account for scaling and expense. On 29 Jan. 2015, NASA launched a satellite mission to map soil moisture—SMAP (Soil Moisture Active and Passive Mission). However, in-situ measurements are still required to provide validation for satellite-derived soil moisture and to represent the small spatial-scale variability that is not possible using satellite data. Issues of scaling remote-sensing measurements and ground-based validation points transcend nearly all the sciences dealing with earth observations.

In the April 2015 issue of Vadose Zone Journal, Martini et al. set up an experiment to monitor in-situ soil moisture on a hillslope using wireless technology. Their goal was to monitor the spatial and temporal patterns of wetting and drying and to combine these and other geophysical measurements with soil and hydrological data and processes. The properties of soil and their spatial variability play a central role in these physical processes.

The authors carried out this work at the Schäfertal experimental site—a hillslope in a small headwater catchment (250 by 80 m) in central Germany—that has been intensively instrumented to measure groundwater, meteorological data, and discharge. The soil patterns were mapped using electromagnetic induction (EMI) and gamma ray spectrometry measurements. There were 40 soil moisture-monitoring locations, and the soil profile was characterized to a depth of 60 cm. The study site was characterized using four Soil-Topographical Units (STUs), each of which exhibited unique hydrologic responses.

Two states were defined for the Schäfertal site—a wet state, in which precipitation exceeded evapotranspiration and lateral flow dominated vertical fluxes; and a dry state, in which evapotranspiration exceeded precipitation and the vertical fluxes dominated lateral fluxes. The central aim of this experiment was to ascertain the switch between these two states using observations and statistical analyses. The authors used a mean relative differencing approach to estimate persistence of the spatial organization of soil moisture between two dates and then tested the persistence using the Spearman Rank correlation coefficient.

This study showed (a) similar soil moisture organization for both wet and dry states, (b) a decrease in variability of spatial organization with depth (soil moisture status became homogeneous), and (c) indications for preferential flow that was determined by soil properties and that dominated the distribution of soil moisture in the wet state. Transitions to both the wet and the dry states proceed from the surface to the subsurface. The authors illustrated the dominant role of soil processes in the broader expressions of hydrologic function at this watershed and the value in intensively monitoring soil water status.

Studies of this nature are important for local spatial analysis for determining the soil wetting and drying processes on soil properties. Soil hydraulic properties remain one of the least known variables in all of hydrology.


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The Schäfertal hillslope observed from south toward north: Black dotted lines represent the boundaries of the four Soil-Topographical Units.