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A semi-wireless network to monitor soil moisture over disparate spatial and temporal scales.

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It is important to know how soil moisture content varies at different spatial and temporal scales. This information is necessary to design efficient networks to monitor soil moisture content in specific circumstances (e.g. at the field scale as an input to a catchment-scale hydrological model or at finer scales where variations in water content might influence the risk of landslides) and to integrate the output from soil moisture sensors with other larger-scale sources of information such as satellite images.

In October 2011 a semi-wireless network of soil moisture sensors was installed on a steep (average slope 20 degrees), hillslope (4.5 hectares) in North Yorkshire, UK. The soil has formed predominately from a fine-grained mudstone parent material with a large proportion of expansive clay minerals. Decagon sensors (5TE) were placed 10 cm beneath the surface of the mineral soil at 96 separate locations (eight clusters each with 12 sensors). Each cluster was nested according to an optimized unbalanced design over four spatial scales ranging from 0.3 to greater than 9 m. Each sensor recorded the soil moisture content (plus temperature and pore water EC) every 15 minutes. At each time the output from the network was represented by a linear mixed model with random effects for the different spatial scales.

We present the results from the first year of operation of this network. Over monthly time scales the temporal variation in soil moisture content was primarily controlled by monthly rainfall and other seasonally varying factors such as evapotranspiration. However, we did not observe the effect of landscape-scale features such as the tendency of water to accumulate at the bottom of the hillslope after rainfall or spatial variations associated with differences in texture. There was no evidence at 10 cm depth for the influence of rising (or perched) water tables, even after the largest rainfall events.

Over shorter time scales the effects of individual rainfall events were evident. Between rainfall events a substantial proportion of the variation was associated with each scale shorter than 9 m and in total around 75% of the variation was associated with these scales. However during and immediately after rainfall around 80% of the variation was associated with spatial scales greater than 9 m.

Several of the moisture sensors did not respond at all to some of the largest rainfall events although most of the sensors recorded a large increase in water content. We infer that bypass flow occurs in such cases. Some of these isolated sensors responded to subsequent rainfall events, whilst others did not.

We discuss the implications of these results and demonstrate how they might be used to select the optimal spatial intensity and temporal frequency of sensor networks which monitor soil moisture content over specified spatial and temporal scales. We also discuss how we might investigate local variations in soil properties, more specifically the local distribution of pore networks, which may account for hydrological isolation of moisture sensors.