Surprise! The Probe is Right

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Spatial Variation in Soil Water Content Readings

We sometimes get calls from customers (even soil scientists) complaining that their ECH2O probes are not accurate because probes at different locations in the same field have different water content readings. In contrast, one customer, a retired engineer who had just installed probes in his central Washington vineyard, was delighted to see the variation in water content across his land. “Now I can tell where those pockets of sand are,” he said. Even without formal soil science training, he realized that spatial variation in water content represents valuable information about soil texture, watering patterns, and water use.

Horizontal vs. Vertical Variation

It’s helpful to distinguish variation in the vertical from variation in the horizontal. Most people expect strong vertical variation due to wetting and drying patterns, soil horizonation, and compaction. Water content can vary drastically over distances of only a few centimeters, especially near the soil surface. Horizontal variation is typically less pronounced-in a bare or uniformly planted field at a given depth, it might be quite small. But surprisingly large variations can exist, indicating isolated patches of sand or clay or differences in topography. The retired engineer noticed a few sensors indicating low water content after a heavy rain that had uniformly wetted his vineyard. Knowing that sand has a low field capacity water content, he surmised (correctly) that he had found the sandy areas in his vineyard.

Unexpected Readings

Because properly installed dielectric soil moisture sensors lie in undisturbed (and therefore unanalyzed) soil, they sometimes measure unexpected things. One researcher buried a probe in what appeared to be a very dry location and was startled to measure 25 to 30% volumetric water content. Those readings made the soil appear saturated, but obviously it wasn’t. She dug down to the sensor and found a pocket of clay. As she discovered, it is impossible to get much information from an absolute water content measurement without knowing what type of soil the sensor is in.

So, since we expect variation, how do we account for it? How many probes are needed to adequately characterize the water content in an application or experiment? There is no simple answer to this question. The answer will be affected by your site, your goals, and how you plan to analyze your data. Here are some things you might consider as you plan.

Irrigation: Using Soil Moisture as an Indicator

What information do you have when you know a field’s volumetric water content? That number independently tells an irrigator very little. Soil moisture can be used like a gauge to show when a field is full and when it needs to be refilled, but the “full” and “empty” are only meaningful in context. How far can you go on a quarter of a tank of gas? You’ll only know after you’ve driven the car for a while.

The goals of irrigation are to keep root zone water within prescribed limits and to minimize deep drainage. Understanding and monitoring the vertical variation lets you correlate a real-time graph of water use data with above-ground field conditions and plant water needs. It makes sense to place probes both within and below the root zone.

By contrast, measuring horizontal variation-placing sensors at different spots in the field-is not very helpful. If a field will be irrigated as a unit, it should be monitored as a unit at one representative spot. Because there's no way to adjust water application in specific spots, there's no benefit to quantifying spatial variation in the horizontal. Like a float in a gas tank, a set of soil moisture sensors in the right spot will adequately represent the changing soil moisture condition of the whole field. We recommend a single probe location in each irrigation zone with a minimum of one probe in the root zone and one probe below it. Additional probes at that site, within and below the root zone, will increase the reliability of the information for the irrigation manager, at minimal additional cost.

Crop Studies: Representing Variation in a Homogeneous Environment

In some research projects, it will be important to account for horizontal variation. So, how variable is the water content across a field? We did an experiment in which we set out a transect across a field of bare, tilled soil. Using a Decagon EC-5 soil moisture probe connected to a Procheck meter, we sampled water content at one meter intervals over a 58 meter distance. The individual readings are shown in Figure 1. In this data set the samples are not spatially correlated. The variation is apparent. The mean water content of the data set is 0.198 m3 m-3. The standard deviation is 0.023 m3 m-3. The coefficient of variation is 12 %.

Using some simple geostatistics, we determined that three carefully placed sites would adequately represent the variation present in this very homogeneous environment. Of course, in some environments, samples will not be independent. If a semivariogram indicates that some underlying spatial factor influences soil moisture variability, you will have to consider that in your experimental design.

Ecology Studies: Heterogeneous Environments

On a forested hillside, horizontal variation in soil moisture will obviously be significant. Determining how many sensors to use and where to place them is not at all trivial. Stratified sampling-systematically sampling from more uniform subgroups of a heterogeneous population-may be a better way to deal with this kind of variety. The researcher classifies the site into strata (eg. forested canopy, brush, hillside, valley), and evaluates the number of samples needed to statistically represent the variation present within each stratum. Many people allow for the variation in soil moisture values that come from slope, orientation, vegetation, and canopy cover. Some fail to consider the important soil-level variations that come from soil type and density.

By taking into account the major relevant sources of soil moisture variation, you can plan enough sampling locations to draw reasonable conclusions from your data. Choose too few locations, and you run the risk of missing the patterns that will lead to higher level understanding. Choose too many, and not only will you be unable to afford your experiment, you may miss the patterns altogether as your experiment overflows with random abundance.

Comparing Data from Different Sites or Strata

Comparing absolute water content numbers can give confusing results. Both measurements are volumetric water content, but 35% here vs.

15% there actually tells us very little. Was the site in sand or clay, or something in between? If conditions at the two sites are virtually identical, the comparison may make some sense. But often, researchers want to compare dissimilar sites. Water potential measurements determined by converting absolute volumetric water content to soil water potential using a moisture characteristic curve specific to each soil type can be used to compare results across sites. Comparing relative values–quantities of water used in centimeters for example-can also be both useful and valid.