SOIL MOISTURE APPLICATIONS

Elements

2009

DECAGON DEVICES

With 60% of the world's fresh water used for irrigation, soil moisture research will ultimately impact how well this thirsty planet deals with its impending water crisis.

"When the well is dry, we learn the worth of water."
—Benjamin Franklin

INSIDE

Complexities of Soil Moisture Data

Two probes buried at the same depth in the same field give different water content readings. At another site, a probe in bone dry soil measures near-saturation water content. Find out why you might not get the information you expect from your soil moisture sensors and figure out what they're really saying.

go to page 2

Five Options for Effective Profiling

Evaluate strategies for monitoring the moisture in soil profiles. Discover how a little digging can produce an array of single sensors that mimic—and even improve on—measurements from expensive all-in-one profile probes.

go to page 7

Six Installation Tips

Save time, reduce digging, outsmart rodents, and make your time in the field a little easier with these tips contributed by every day users. Also find a link to contribute a useful tip of your own. If it's new to us, we'll publish it in the next newsletter and send you a free sensor.

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$20,000 Worth of Instruments Awarded

On January 15th, the G.A. Harris Research Instruments Grant committee awarded over $20,000 worth of instruments to three graduate students. Read about the winning projects and find out how you or a graduate student you know can apply for next year's Fellowship.

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Surprise! The Probe is Right

SPATIAL VARIATION IN SOIL WATER CONTENT READINGS

We sometimes get calls from customers (even soil scientists) concerned that their ECH_2O 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.

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Finding Explanations for Disagreement between Sensors

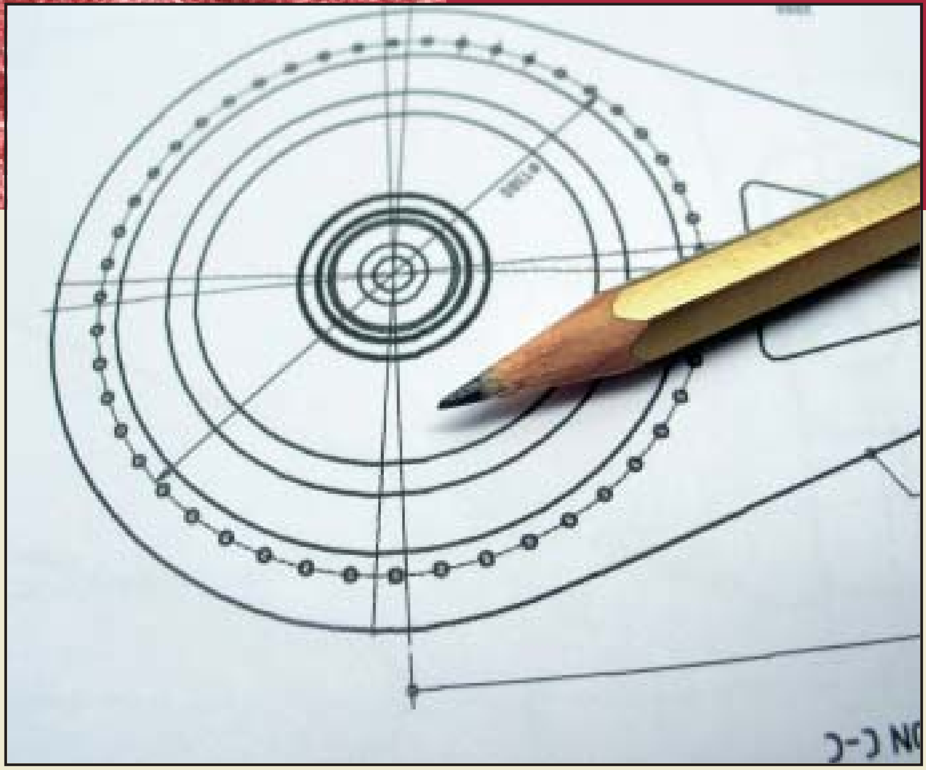
It’s helpful to distinguish variation in the vertical from variation in the horizontal. Most people expect strong vertical variation due to wetting and drying patterns, soil horizonation, and compaction. Water content can vary drastically over distances of only a few centimeters, especially near the soil

Surprisingly large variations in soil moisture represent valuable information.

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.

Sensors Discover the Unexpected

Because properly installed dielectric soil moisture sensors lie in undisturbed (and therefore unanalyzed) soil, they sometimes measure unexpected things.



Soil moisture can be used like a gauge to show when a field is full and when it needs to be refilled.

Planning for Variation

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.

How many sensors do you need?

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.

Using Soil Moisture as a Gauge

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 fuel? You'll only know after you've driven the car for a while.

Volumetric water content readings are only meaningful in context.

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.

Like a float in a fuel tank, a set of soil moisture sensors in the right spot can represent changing conditions in the whole field.

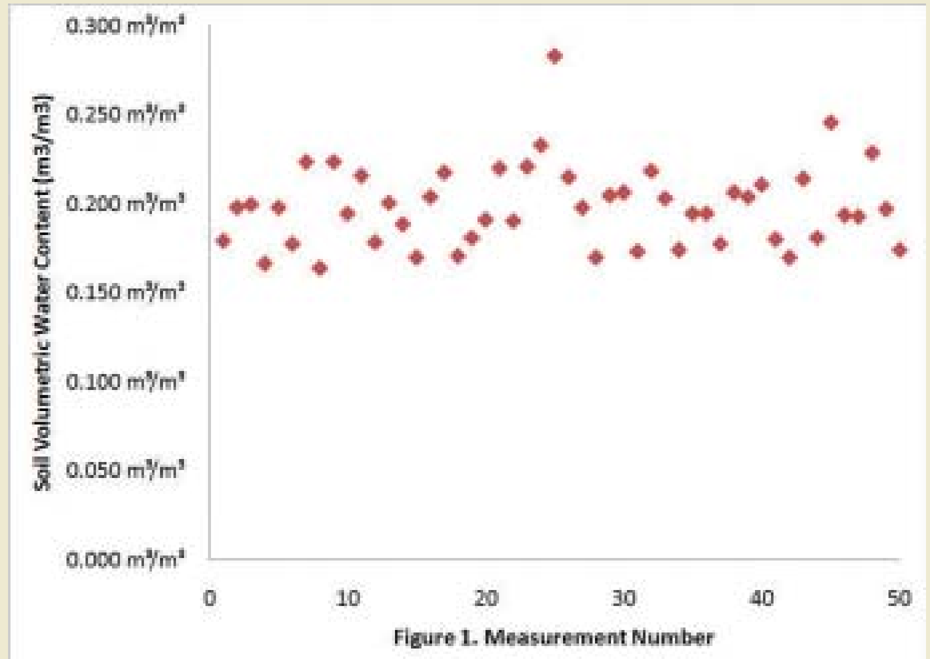
By contrast, measuring horizontal variation—placing sensors at different spots in the field—is not very helpful. If a field will be irrigated as a unit, it should be monitored as a unit at one representative spot. Because there's no way to adjust water application in specific spots, there's no benefit to quantifying spatial variation in the horizontal. Like a float in a fuel 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 conducted an experiment in which we set out a transect across a field of bare, tilled soil.

Figure 1



$$N = \frac{x_{\alpha'}^{2}\,\sigma^{2}}{d^{2}}$$

N = number of observations required
σ = standard deviation
d = magnitude from the difference from the mean
when α' = 0.05, 0.10, 0.50
then $x_{\alpha'}$ = 1.960, 1.645, and 0.842, respectively

You can determine how many samples are necessary to characterize a homogeneous area in about an hour using an EC-5 and a ProCheck

Monitor important soil-level variations that come from diversity in soil type and density.

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 as shown by the apparent variation between the individual samples. The mean water content of the data set is 0.198 m^3/m^3 with a standard deviation of 0.023 m^3/m^3 and a coefficient of variation of 12%.

Ecology Studies

Using Stratified Sampling in Heterogeneous Environments

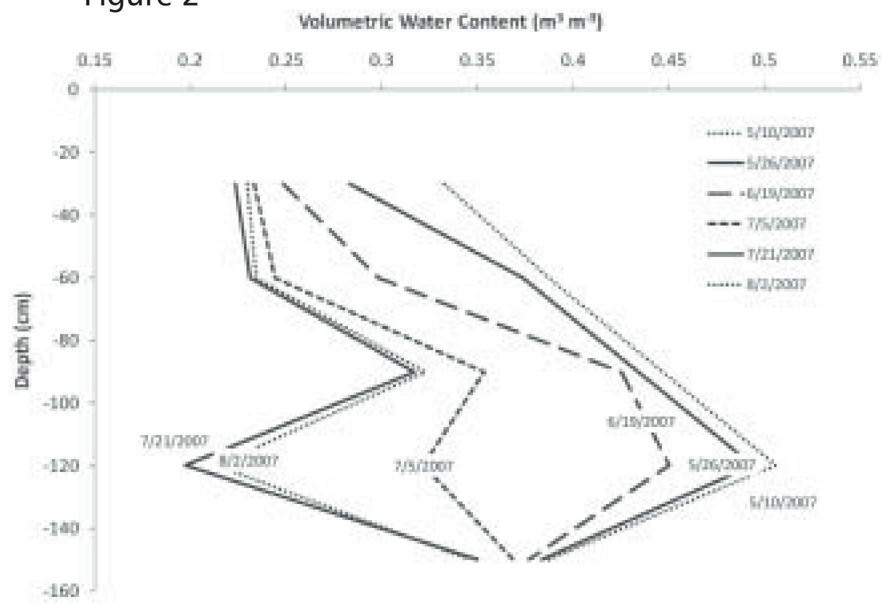
Using some simple geostatistics *(see equation on page 4),* we determined that three carefully placed sites would adequately represent the variation present in this very homogeneous environment. Of course, in some environments, samples will not be independent. If a semivariogram indicates that some underlying spatial factor influences soil moisture variability, you will have to consider that in your experimental design.

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.

Comparing Data from Different Sites or Strata

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.

Figure 2



You can use soil moisture profiles plotted at different time periods to determine water use over time.

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.

Use relative values—quantites of water used in centimeters, for example-to compare moisture content at dissimilar sites.

An article in this issue *(Sampling Moisture in the Soil Profile)* details an experiment where water content measurements were made over a growing season at 30, 60, 90, 120, and 150 cm below a wheat crop. The graph of soil moisture data shows how water is taken up from successively deeper layers. By subtracting one profile from another and summing over the layers where change occurs (for instance, in Figure 2, subtract the far left line from the far right line to see how much water was used from May 10th to August 21st), you can determine the amount of water used by the plants over a particular period. If similar data were taken at different sites or in different strata, these relative values, in terms of quantified water use, could form the basis of solid comparison studies.

Next: Can you sample the profile without a profile probe?

FIVE OPTIONS FOR EFFECTIVE PROFILING

Patterns of water replenishment and use give rise to large spatial variations in soil moisture over the depth of the soil profile. Accurate measurements of profile water content are therefore the basis of any water budget study. When monitored accurately, profile measurements show the rates of water use, amounts of deep percolation, and amounts of water stored for plant use.

An Example Installation

Figure 3 *(next page)* shows water content measurement data collected at one of the sites located on Decagon's experimental plots at Cook Farm, Pullman, Washington. These measurements were made using 5TE probes installed one per hole at 30, 60, 90, 120, and 150 cm depths below a winter wheat crop. To install the sensors, we augured to the correct depth, pressed the probe (using the simple homemade installation tool shown on page 11) into the undisturbed soil at the bottom of the hole, backfilled with about six inches of native soil packed to the approximate bulk density of surrounding soil, sealed the hole with 200–300 g of bentonite to prevent water from flowing preferentially down the sensor cable, and refilled the hole with native soil tamped to the approximate bulk density of surrounding soil.

Profile measurements show the rates of water use, amounts of deep percolation, and amounts of water stored for plant use.

Common Obstacles to Accuracy

Installation Pitfalls to Avoid

Three common challenges to making high-quality volumetric water content measurements are: 1) making sure the probe is installed in undisturbed soil, 2) minimizing disturbance to roots and biopores in the measurement volume, and 3) eliminating preferential water flow to and around the probe. All dielectric probes are most sensitive at the surface of the probe. Any loss of contact between the probe and the soil or compaction of soil at the probe surface can result in large measurement errors.

It's easy to determine exactly when the wheat started taking in water at deeper depths in a dryland field.

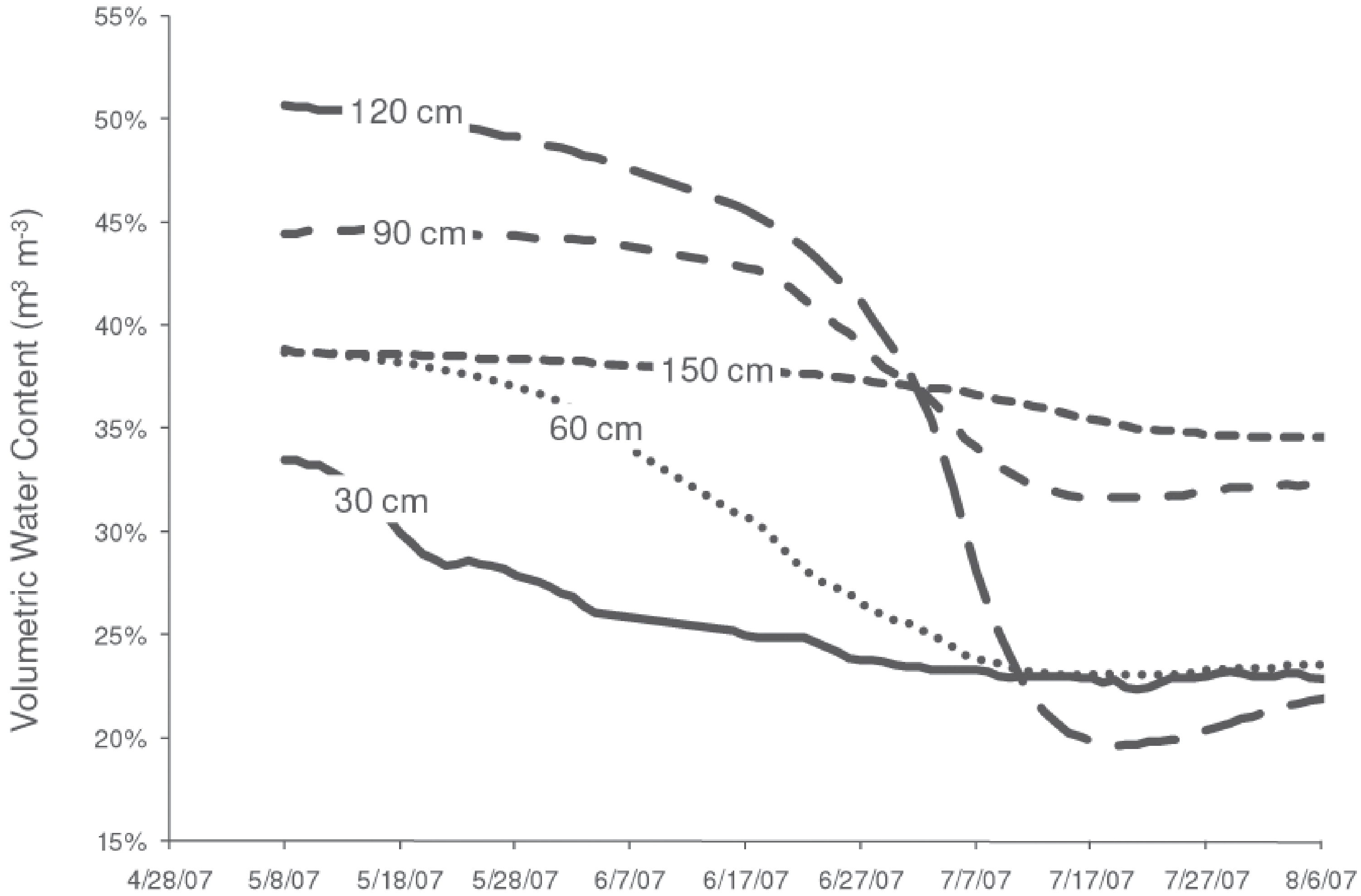
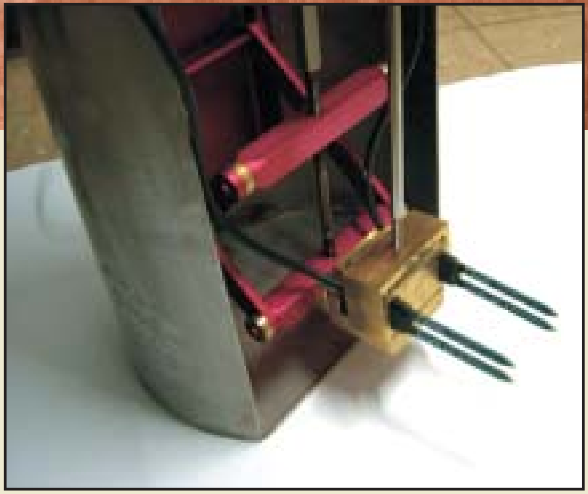


Figure 3. Soil water content in winter wheat measured at 30 cm increaments.



Bogena et. al's side wall installation tool.

Water ponding on the surface and running in preferential paths down probe installation holes can also cause large measurement errors.

Installing soil moisture sensors will always involve some digging. How do you accurately sample the profile while disturbing the soil as little as possible? Let's consider the pros and cons of five different profile sampling strategies.

Commercial Profile Probes
One-stop solution, susceptible to installation errors

Profile probes are a one-stop solution for profile water content measurements. One probe installed in a single hole can give readings at many depths. Profile probes can work very well, but proper installation can be tricky and the tolerances are tight. It's hard to drill a single, deep hole precisely enough to ensure contact along the entire surface of the probe. Backfilling to improve contact results in repacking and measurement errors. The profile probe is also especially susceptible to preferential flow problems down the long surface of the access tube.

SAMPLING MOISTURE IN THE SOIL PROFILE

OPTIONS BEYOND A COMMERCIAL PROFILE PROBE

Trench Installation
Great results, requires heavy equipment

Installing sensors at different depths through the side wall of a trench is an easy and precise method, but unless you own a backhoe, the actual digging of the trench can be a lot of work. This method puts the probes in undisturbed soil without packing or preferential water flow problems, but because it involves excavation, it's typically only used when the trench is being dug for other reasons or when the soil is so stony or gravelly that no other method will work. The excavated area should be filled and repacked to about the same density as the original soil to avoid undue edge effects.

Auger Side Wall Installation
Excellent method, installation tool not commercially available

Installing probes through the side wall of a single auger hole has many of the advantages of the trench method without the heavy equipment. This method was used by Bogena et al. with EC-5 probes. They made an apparatus (see photos on this page) to install probes at several depths simultaneously.

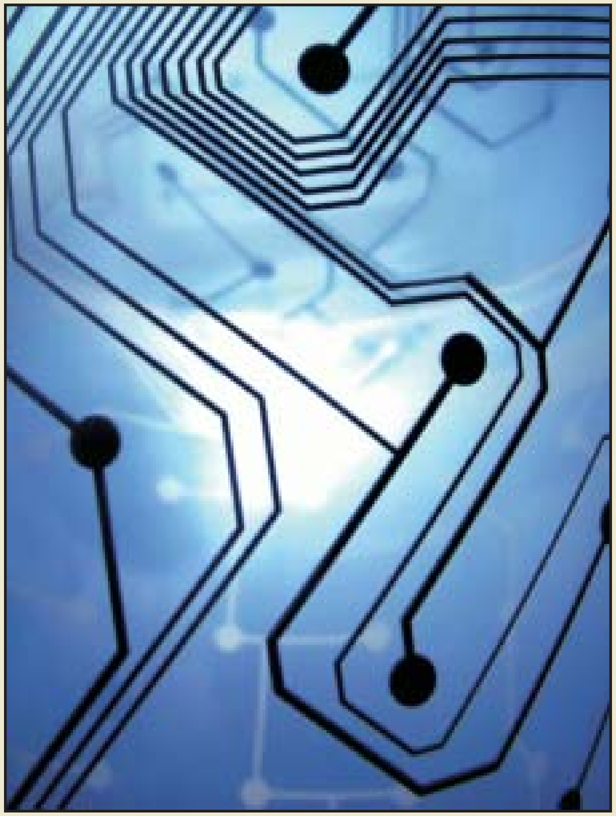
FLEXIBILITY AND ACCURACY FROM AN ARRAY OF SINGLE SENSORS

Multiple Hole Installation

Good results with a little spade work

As with trench installation, the hole should be filled and repacked to approximately the pre-sampling density to avoid edge effects. *(H.R. Bogena, J.A. Huisman, U. Rosenbaum and A. Weuthen. SoilNet – A ZigBee based soil sensor network and first applications. To be submitted in Sensors, Special Issue: Wireless Sensor Technologies and Applications).*

ECH_2O probes are designed to be installed at any depth in any orientation.



The method we used at Cook Farm, digging a separate access hole for each depth, ensures that each probe is installed into undisturbed soil at the bottom of its own hole. As with all methods, you must take care to assure that there is no preferential water flow into the refilled augur holes, but a failure on a single hole doesn't jeopardize all the data, as it would if all the measurements were made in a single hole. The main drawback is that a hole must be dug for each depth in the profile (five holes for five depths, in our case). The holes are small, however (just large enough for one probe), so they are usually easy to dig.

Single Hole Installation

Often used but not recommended

It is possible to measure profile moisture by auguring a single hole, installing one sensor at the bottom, and then repacking the hole, installing sensors into the repacked soil at the desired depths as you go. Because the re-compacted soil can have a different bulk density than it had in its undisturbed state, and because the profile has been completely altered as the soil is excavated, mixed, and repacked, this is the least desirable of the methods discussed. Still, single hole installation may be entirely satisfactory for some purposes. If the installation is allowed to re-equilibrate with the surrounding soil and roots are allowed to grow into the soil, relative changes in the disturbed soil should mirror those in the surroundings.

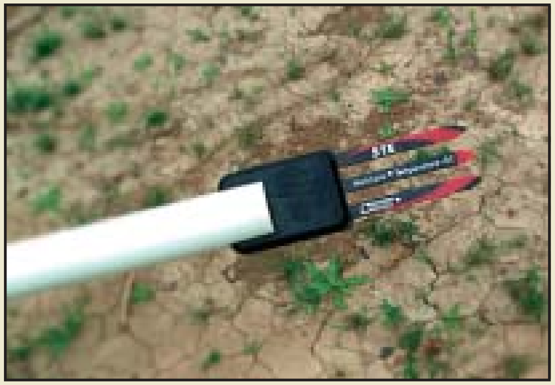
Next: Outsmarting Rodents

Six ECH_2O Installation Tips

6

1. Play with instrumentation in the lab before going out to install sensors.

2. If you can, install the sensors the day after a good rain. It's always easier to install sensors into undisturbed soil when the soil is slightly moist.



Inexpensive supplies from the hardware store can be used to create an almost perfect installation tool.

3. Use a 1/2 inch (1.27cm) notched PVC pipe to push the sensor into the bottom of a deep augered hole.

4. Run the cables through a PVC pipe from just below the surface to the data logger to prevent rodent damage.

Contribute an ECH_2O Tip

If it's new to us, we'll publish it in the next newsletter and send you a free sensor.

To submit an entry, click this link: http://www.DecagonNews.com/elements-info/

5. If your soils are very rocky, use a sensor that measures water potential instead of one that measures volumetric water content. Because water potential measurements are independent of soil type, water potential sensors do not have to be installed in undisturbed soil. Therefore, water potential sensors can be installed by sifting the rocks from the soil and installing the sensor in a pocket of rock-free soil.

6. If you need to remove the data logger from your field area (for planting or harvesting purposes, for example), install an underground valve box to store the cables until you can put the logger out again. This also makes the sensors easier to find.

Next: Winning $20,000 Worth of Sensors

$20,000 Worth of Instruments Awarded

Decagon would like to congratulate the winners of the 2009 G.A. Harris Research Instruments Fellowship.

Lauren Kolb was awarded an AccuPar LP-80 to measure leaf area index of wheat fields with two different weed treatments.

Title of Proposal

Characterizing canopy development in alternative spring cereal production systems.

First Place

Lauren Kolb
University of Maine, Orono.
Ph.D. Candidate in Ecology and Environmental Science

Study

There are two innovative and opposing strategies to improve weed management in cereals grown with minimal or no herbicide inputs (1) enhancing crop competition, achieved by increasing plant populations and sowing in a more uniform pattern and (2) enhancing physical weed control, achieved by sowing in wider rows than usual to permit inter-row cultivation with sweeps, i.e. growing row crops. By measuring crop canopy development over the growing season, I hope to characterize how the dynamics of leaf area index (LAI) vary between planting strategies and determine how this correlates to weed suppression.

Keir Soderberg was awarded data loggers, soil moisture sensors, leaf wetness sensors, and other environmental sensors to quantify fog contributions.

Title of Proposal

Fog, Aerosols, and Nutrient Cycling in the Namib Desert

Second Place

Keir Soderberg
University of Virginia, Ph.D. student in Department of Environmental Science

Study

The Namib Desert on the southwestern coast of Africa is hyperarid in terms of rainfall but experiences frequent coastal fog events. The fog has been suggested to provide sufficient water to certain plants which are endemic to the Namib, some of which occur only in the fog zone (up to 60 km inland). The GA Harris fellowship will be used to set up five fog monitoring stations along a climate gradient in the central Namib utilizing leaf wetness, air temperature and relative humidity measurements along with solar radiation and soil parameters (moisture, temperature, and electrical conductivity). Stable isotope analysis of samples will also be used to help quantify the amounts of fog, groundwater and soil water that plants utilize.

The G. A. Harris Research Instruments Fellowship, awarded annually, provides $20,000 worth of Decagon research instruments to a graduate student studying any aspect of environmental science. The grant commemorates the generosity and enthusiasm of Dr. Grant A. Harris, former chairman of the Department of Forestry and Range Management at Washington State University and former Chairman of the Board of Directors at Decagon.

For more information click this link:
http://www.decagon.com/ag_research/micro/gaharris/

Title of Proposal

Measuring Carbob Sequestration Processes in Subalpine Forest Using Wireless Sensor Arrays

Third Place

Lynette Laffea
University of Colorado, PhD student in Department of Environmental Biology

Study

I propose that scale matters in modeling soil respiration rates. I propose to deploy a suite of soil respiration and environmental sensors at the Niwot Ridge AmeriFlux research site to explore at what scales (temporal and spatial) drivers of soil respiration affect the respiratory flux of CO_2 from the forest floor. This project will test our capabilities to measure soil environmental dynamics across small spatial scales and at high temporal frequencies. We will develop new strategies for sensor deployment and the use of wireless technology to sustain high frequency data collection and archiving in a remote location.

Lynette Laffea was awarded data loggers, soil moisture sensors, and other environmental sensors to explore CO_2 respiration drivers.

Harris Fellowship
Send information about the 2010 Harris Research Instrument Fellowship to an eligible graduate student.

For more information click this link:
http://www.DecagonNews.com/elements-info/

Honorable Mention

Sara Baguskas,
UC Santa Babara, Ecological interactions between epiphytic macrolichen (Ramalina mensiesii) and fog on Santa Cruz Island, California.

Justin Becknell,
University of Minnesota, Soil Moisture and Carbon Uptake in Restored Tropical Dry Forests.

Robert Keefe,
University of Idaho, Model-based optimization of seed germination timing.

Toni Smith,
Boise State University, Spatiotemporal variations in soil moisture with elevation and aspect in a semi-arid watershed; a potential control on the soil carbon pool.

James Parejko,
Washington State University, Determining the ecology and biogeography of phenazine-producing fluorescent Pseudomonas spp. in the wheat rhizosphere.

Jongyun Kim,
University of Georgia, Modeling Water and Fertilizer Use of Greenhouse Crops for Efficient Irrigation.

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