DECAGON

Soils Notes

SPECIAL FALL EDITION

Capacitance and TDR probe: Differences?

Pros and Cons of Capacitance and TDR

TDR measurements are relatively insensitive to temperature and salinity. ***(Still salinity must not completely attenuate the reflected TDR signal.)***

Capacitance sensors are much less expensive and simpler than TDR because they use standard circuitry and time measurement is less demanding.

Capacitance sensors are more sensitive to salinity and temperature. ***(This is remedied with a soil specific calibration.)***

Capacitance sensors continue to read even when soil electrical conductivity is too high for a TDR measurement.

Capacitance sensor resolution is better than TDR because of noise generated in the TDR process.

For both methods, inferior probe-soil contact (air gaps) from poor probe installation affect accuracy more than the choice method.

Capacitance and TDR techniques are often grouped together because they both measure the dielectric permittivity of the surrounding medium. In fact, it is not uncommon for individuals to confuse the two, suggesting that a given probe measures water content based on TDR when it is actually uses capacitance. With that in mind, we will try to clarify the difference between the two techniques.

The capacitance technique determines the dielectric permittivity of a medium by measuring the charge time of a capacitor which uses that medium as a dielectric.

We first define a relationship between the time, t, it takes to charge a capacitor from a starting voltage, Vi, to a voltage V, with an applied voltage, Vf

$$\frac{V-V_f}{V_i-V_f}=e^{\frac{-t}{RC}}$$

[1]

where R is the series resistance and C the is capacitance (Fig. 1).

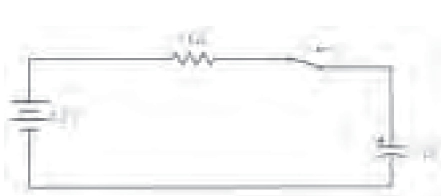


Fig. 1. Simple capacitor circuit.

The change in voltage across the capacitor over time, is illustrated in Fig. 2. If the resistance and voltage ratio are held constant, then the charge time of the capacitor, t, is related to the capacitance according to

$$t=-RC\ln\left(\frac{V-V_f}{V_i-V_f}\right),$$

[2]

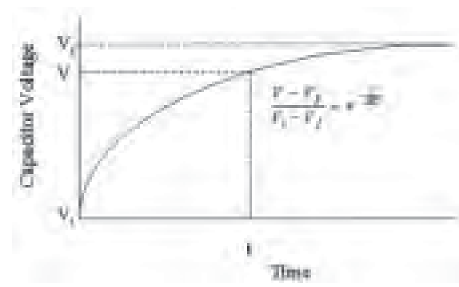


Fig. 2. Charging of capacitor when switch in Fig. 1 closes.

For a parallel plate capacitor, the capacitance is a function of the dielectric permittivity (κ) of the medium between the capacitor plates and can be calculated from

$$C=\frac{\kappa A}{S}$$

[3]

where A is the area of the plates and *S* is the separation between the plates. Because *A* and *S* are also fixed values, the charge time on the capacitor is a simple linear function (ideally) of the dielectric permittivity of the surrounding medium

CONTINUED PAGE 7

Testing of ECH_2O Soil Moisture Probes in Oasis Agriculture of Oman

Short technical report: Florian Wichern, Eike Luedeling, Maher Nagieb and Andreas Buerkert
University of Kassel, D-37213 Witzenhausen (Germany)

Materials and methods

Five ECH_2O Soil Moisture Probes, connected to a data logger with periodic readings every 30 min (CR10, Campbell Scientific, Shepshed, England) were tested on a periodically irrigated, man-made terrace soil profile at the oasis of Balad Seet (23.19° N, 57.39° E, 980 m a.s.l., Fig. 1 and 2) in the Northern Omani Jabal Akhdar Mountains. The selected $4m^2$ irrigation basin was planted with alfalfa (Medicago sativa L.). Four of the probes were placed at 0.1m

CONTINUED PAGE 2

Oman

Testing of ECH_2O Soil Moisture Probes in Oasis Agriculture of Oman *Continued from cover*

depth with probe 1 and 2 being placed from the top (soil surface) and probe 3 and 4 being pushed in laterally after a pit had been dug and a small hole was made with a steel blade. Probe 5 was also pushed in laterally from within the pit at 0.8 m profile depth. All probes were positioned about 0.2 m inside the border of the irrigated basin. The soil texture was clayey at the top (0 to 0.6 m) and sandy in the bottom layer (< 0.6m). While placing probe 1 to 4 at 0.1m either from the surface or laterally was relatively quick and a close connection with the sourrounding soil material was easily obtained, placement of probe 5 at 0.8m in the bone-dry, compacted soil was almost impossible. After this probe had been finally pushed into the profile, we were unable to bring it into close contact with the surrounding soil material. The subsequently reported data therefore only include measurements of probe 1 to 4. During an initial calibration period, the averaged voltage output reading of probe 1 to 4 was regressed against the gravimetrically determined volumetric water content at 0 to 0.2m. The regression equation obtained ($y = 0.0508x-11.48$, $r2=0.964$; Fig. 3) was then used to derive the estimated volumetric water readings for all four probes. Soil moisture curves were plotted for a 27-day period, comprising three irrigation events.

Results

Probe readings were parallel and steady as long as battery voltage did not fall below 11 V. When this happened, erroneous increases in sensor readings were noticed (days 73 to 76, Fig. 4). We were, however, unable to investigate this input voltage induced error in more detail. The standard deviation of the pooled measurements from probe 1 to 4 was much higher immediately after irrigation, with 35mm of water than thereafter (data not shown). This might have been due to irregularities in the soil structure and surface of the plot. It was surprising that the moisture readings of probe 1 and 2 seemed to be continuously affected by the day and night cycle with increasing soil moisture readings around noon (Fig. 5). Probes 3 and 4, in contrast, did not show such differences of which the causes remain unknown.

Conclusions

If properly connected to a data logger and in close contact with the soil, the ECH_2O Soil Moisture Probes seem to offer a low-cost, automatic and sturdy method to monitor soil moisture under field conditions. For soil moisture measurements at lower depth, however, the probes will have to be placed after digging pits. This will necessarily lead to the destruction of the soil structure and subsequent alteration of the hydraulic conductivity around and above the probes. Our findings confirm the reliability of the probe readings but also indicate that soil-specific calibrations are helpful to increase their precision which otherwise depends on the factory calibrations. The causes for the differences in the readings of the four probes also merit further investigation.

Figure 1. *Overview of the mountain oasis of Balad Seet (Oman). The arrow indicates the position of the experimental site.*

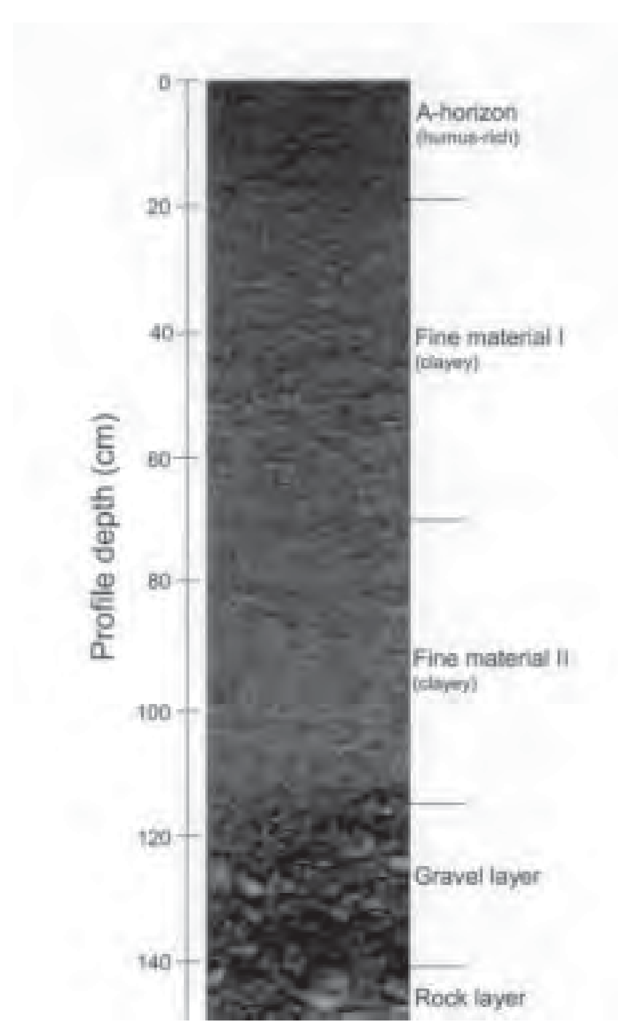


Figure 2. *Soil profile of the experimental terrace site 30*

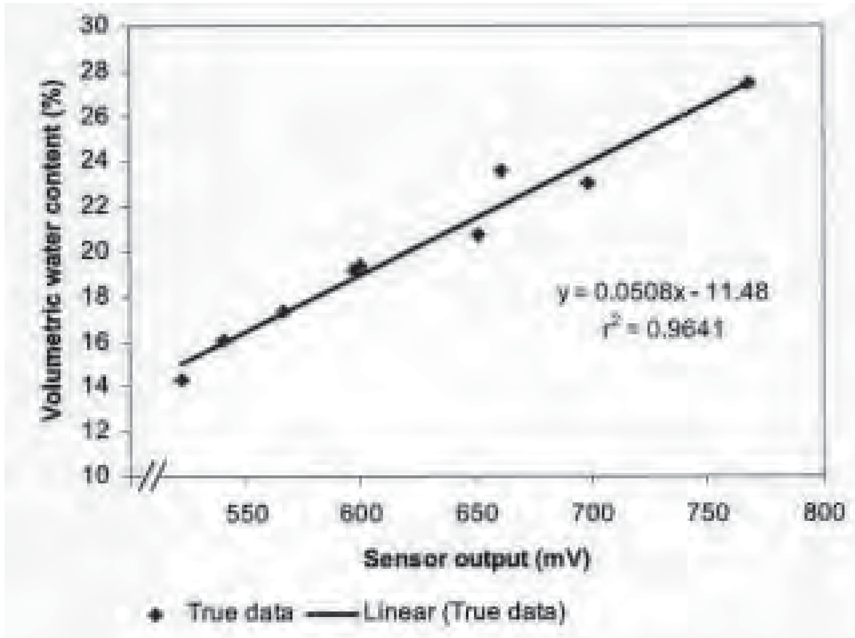


Figure 3. *Regression between ECH20 Soil Moisture Probe readings and gravimetrically determined volumentric water content (%).*

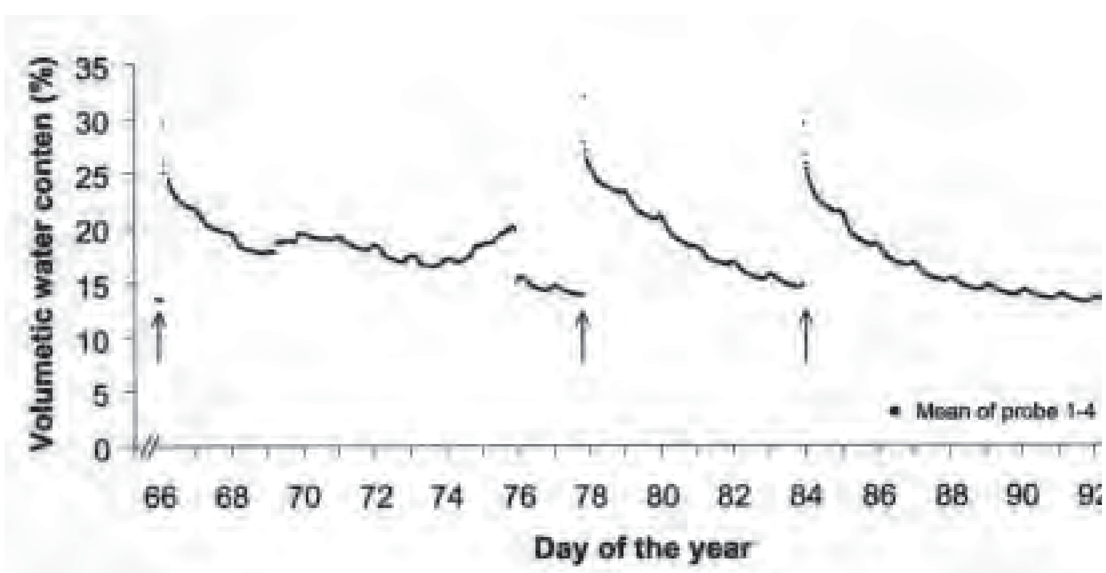


Figure 4. *Time course of soil water content (%) at 0.1m depth after four irrigation events of 35mm (indicated by arrows) at Balad Seet, Oman (2002).*

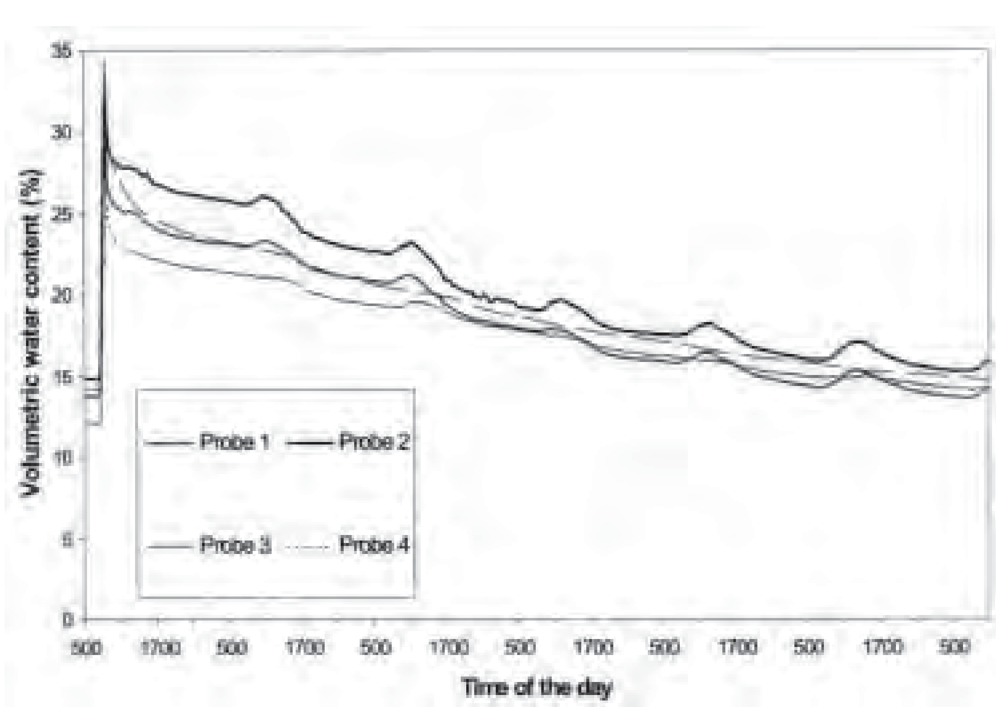


Figure 5. *Time course of soil water content (%) at 0.1m separated for each of the four probes after an irrigation of 35mm. Note the peaks around noon. Balad Seet, Oman (2002).*

FROM GERMANY

5 July 2002

To: Dr. Colin S. Campbell
Environmental Biophysicist
Decagon Devices

Dear Colin,

"Many thanks once more for your valuable help in setting up our soil water measuring data logger with the ECH_2O Probes in Oman. The setup is working fine for many weeks now and I am attaching a report on our results for your use. We will certainly recommend the probes to our colleagues for monitoring surface soil water contents.

In our experiment there still seems to be some dilferences in the readings from the different probes at the same depth in the same plot. These could reflect natural variations in the soil's water holding capacity even if this appears a bit unlikely given the homogeneity of the substrate."

Many thanks and sincerely yours,
Andreas Buerkert

Institute of Crop Science
University of Kassel
D-37213 WITZENHAUSEN
(Germany)


Glendon Gee

The Gee Water Fluxmeter

RESEARCHERS HAVE DESIGNED a simple, inexpensive instrument for measuring water drainage from agricultural fields that will allow farmers worldwide to grow crops more efficiently. The device provides drainage information that helps farmers estimate the amount of water lost below the root zone and can also be used to detect if excess fertilizer or pesticide is being leached from the soil.

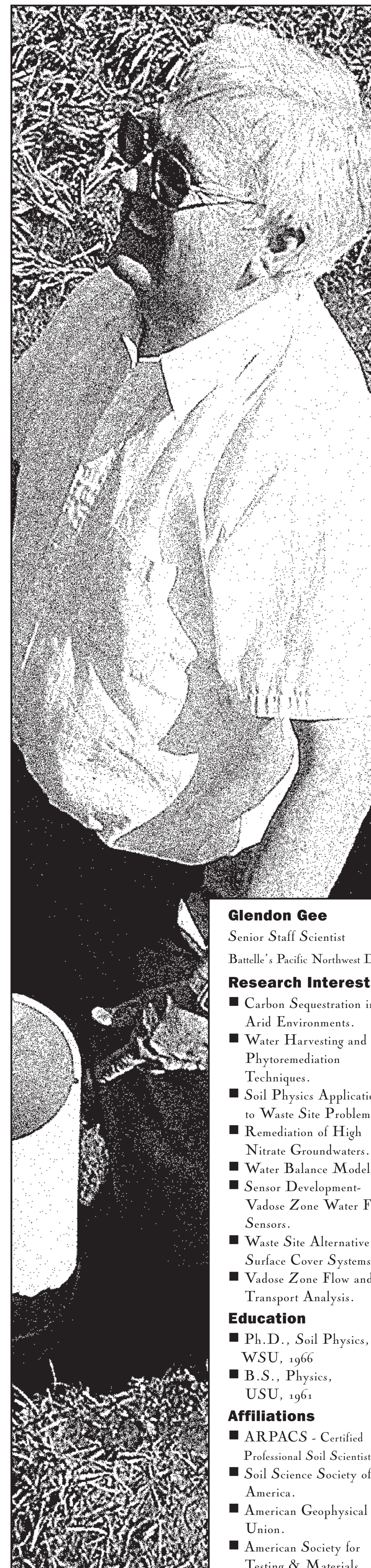
No farmer speculation.
The water "fluxmeter" draws excess water from the shallow vadose zone into a small bucket connected to an electric wire that records the water level, producing a record of the water draining from the land. Gee et al.["A vadose zone water fluxmeter with divergence control"] designed the tool and tested it in the laboratory and in the field, in remote areas, ranging from desert sites in Nevada to a tea plantation in Sri Lanka.

> **"The water fluxmeter provides a first step toward methodology that may be useful for wide application to routine measurement of soil drainage under a variety of soil and climatic conditions throughout the world."**

Measure drainage rates.
Quantifying drainage from irrigated lands, watersheds, and waste sites etc., is important for a variety of reasons, not the least of which is growing economic and environmental concern about excess use of water and chemicals [e.g., fertilizers/pesticides]. Yet there is a scarcity of reliable flux measurements available. The water fluxmeter described in this research provides a direct way to measure drainage rates in the vadose zone without relying on imprecise indirect methods, which depend on the uncertainties of water contents, water potentials or ground-water head measurements.

Minimizing drainage the goal.
Turfgrass managers, landfill operators, and farmers are all becoming sensitized to the need for minimizing drainage. Yet there is no standard method to detect or control drainage. The water fluxmeter provides a first step toward methodology that may be useful for wide application to routine measurement of soil drainage under a variety of soil and climatic conditions throughout the world.

OTHER RESOURCES: Glendon, Gee, Water Resources Research, Vol. 38, No. 8, 10.1029/2001



Glendon Gee
Senior Staff Scientist
Battelle's Pacific Northwest Div.

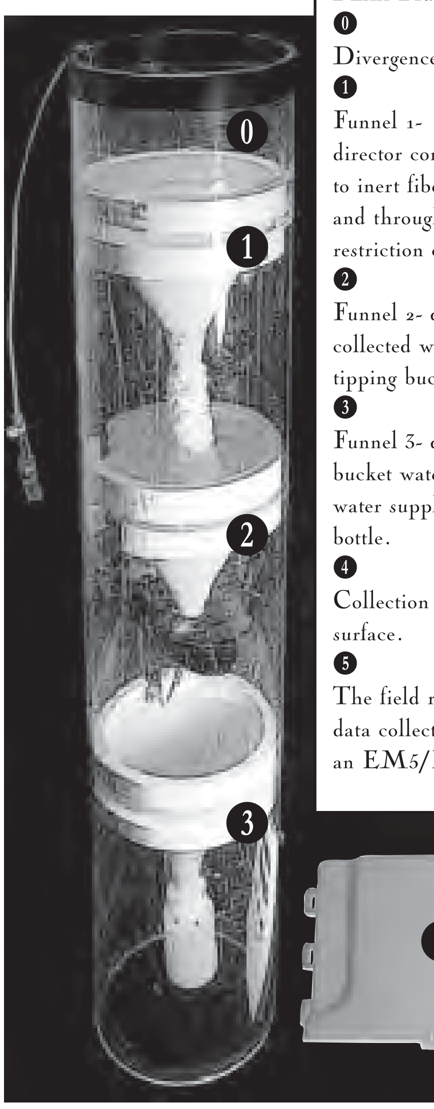
Research Interests
- Carbon Sequestration in Arid Environments.
- Water Harvesting and Phytoremediation Techniques.
- Soil Physics Applications to Waste Site Problems.
- Remediation of High Nitrate Groundwaters.
- Water Balance Modeling.
- Sensor Development-Vadose Zone Water Flux Sensors.
- Waste Site Alternative Surface Cover Systems.
- Vadose Zone Flow and Transport Analysis.

Education
- Ph.D., Soil Physics, WSU, 1966
- B.S., Physics, USU, 1961

Affiliations
- ARPACS - Certified Professional Soil Scientist.
- Soil Science Society of America.
- American Geophysical Union.
- American Society for Testing & Materials.
- Sigma Xi.

Dimensions	total height	top opening width	length of divergence control zone	length of base	bottom opening width
	169cm	**21cm**	**59cm**	**110cm**	**16cm**

▶ DECAGON installed a water flux meter (WFM) in a turf grass field to see if there was any water moving beyond the root zone under our irrigation scheme. For the first three weeks, the WFM did not register a single tip. Although we were confident



Mini-Flux meter

0 Divergence control zone

1 Funnel 1- conical director conducts water to inert fiberglass wick and through the restriction channel.

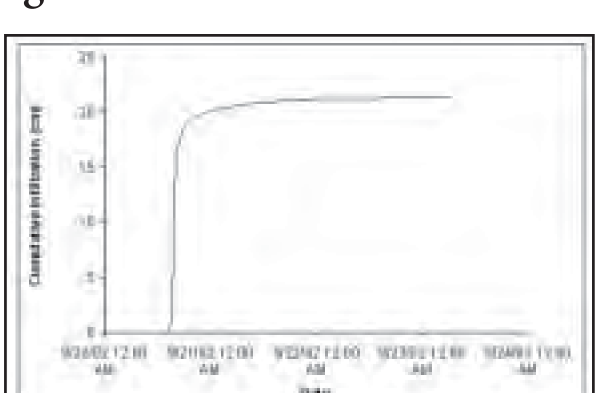
2 Funnel 2- directs collected water to the tipping bucket gauge.

3 Funnel 3- directs tipping bucket water to the water supply collection bottle.

4 Collection tube back to surface.

5 The field readout and data collection device is an EM5/Em5R.

the system was in working order, we still wondered how much water would have to be applied for it to move beyond the root zone of the grass. Our answer came when a mistake was made watering a nearby tree. The graph shows the cumulative infiltration measured by the WFM during a 10 h accidental flood irrigation event.

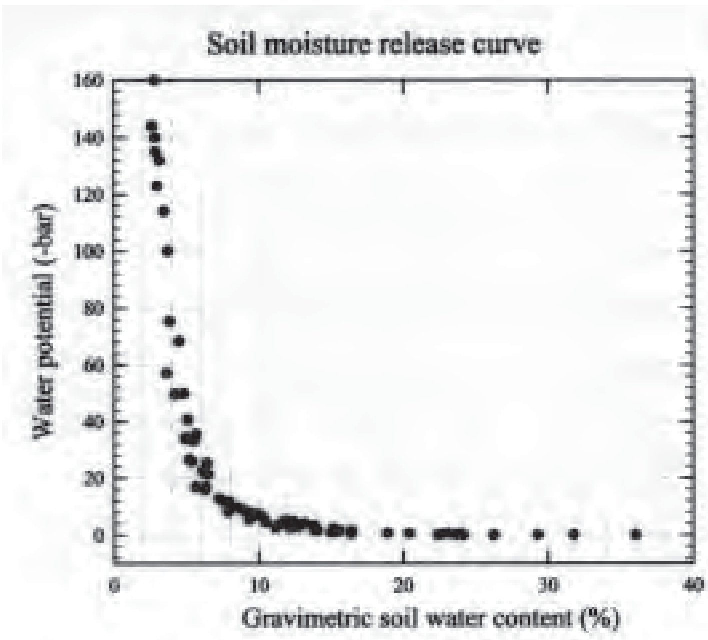


The Gee Water Fluxmeter

The Gee Water Fluxmeter is constructed of 3 pieces of PVC pipe. This Fluxmeter is now installed at a Decagon experimental site. It can be connected directly to Decagon's Em5 or Em5R loggers. Em5R allows radio retrieval of data.

▲ The apparatus can be placed in a normal hole and can be used for any soil type or climactic condition.

Sierra Nevada



▲Soil moisture release curve from the Tonzi Ranch. Taken Feb. 8, 2002 by Dr. Dennis Baldocci.

10 May 2002
To: wp4@decagon.com
From: Liukang Xu
Subject: excellent instrument WP4

Dear Sir:

We just brought a WP4 about two weeks ago, I used it this week to obtain soil moisture retention curve. And it turned out that the result is excellent. See the attached results.

The texture of the soil is about 48% sand, 42% silt and 10% clay, and sample was from the foot hill of Sierra Nevada of California.

Also this machine is very easy to use and very stable. Every morning I check it with the standard KCL solution, never need to adjust the calibration in the past week.

My supervisor, Dr. Dennis Baldocchi, told me that we should share this good result with you.

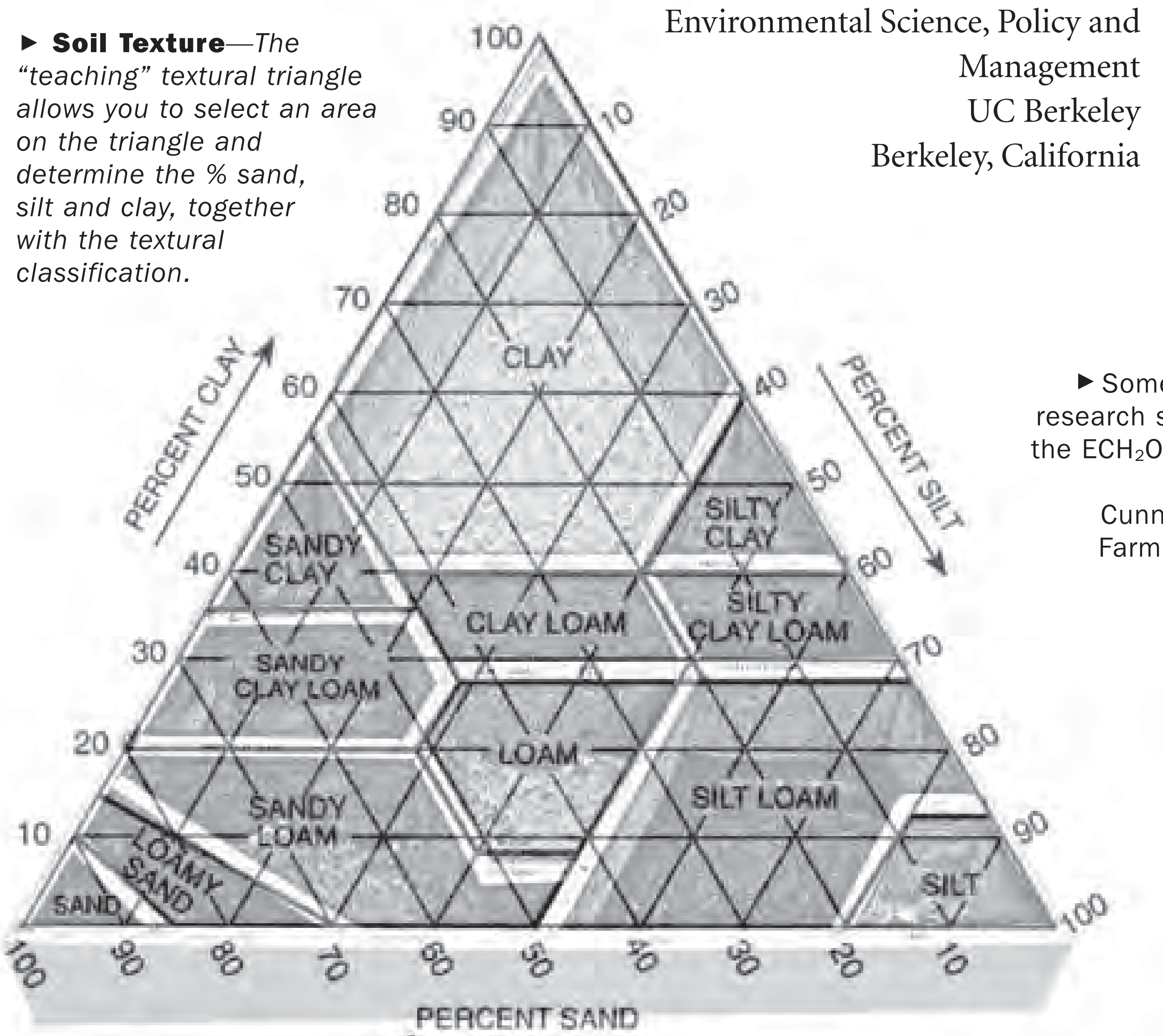
Also I would like to thank Dr. C. S. Campbell for his valuable information on how to use this machine and how to prepare the samples.

Thanks.

Liukang Xu PhD
Environmental Science, Policy and Management
UC Berkeley
Berkeley, California

DECAGON

► **Soil Texture**—*The "teaching" textural triangle allows you to select an area on the triangle and determine the % sand, silt and clay, together with the textural classification.*



WASHINGTON

ECH_2O probes profile water content in dryland wheat systems.

Armen Kemanian,
Ph.D. candidate, Biological Systems Engineering,
Washington State University

In the fall of 2000, we started a research project to monitor spatial and temporal variability of soil water content. We installed 5 research sites containing water content, temperature, and radiation sensors in a dry land system of wheat and legumes. The ECH_2O water content sensors were installed vertically at depths of 1 to 5 feet in the soil to give us a profile of the soil water content.

The ECH_2O probes were useful in showing the earlier depletion of the water in the southern slopes as compared with tophills (or summit) and northern slopes, and were powerful tools for tracking water content deep in the profile and then for doing water balances.

Work was done by Agronomy Department Cunningham Farm of WSU-USDA.

► Some of the research sites for the ECH_2O probes on the Cunningham Farm, WSU.

What is the difference between a capacitance probe and TDR probe? continued from cover

$$\kappa = \frac{t}{\frac{RA}{S}\ln\left(\frac{V - V_f}{V_i - V_f}\right)} \qquad [4]$$

Soil probes are not parallel plate capacitors, but the linear relationship shown in Eq. [4] still holds.

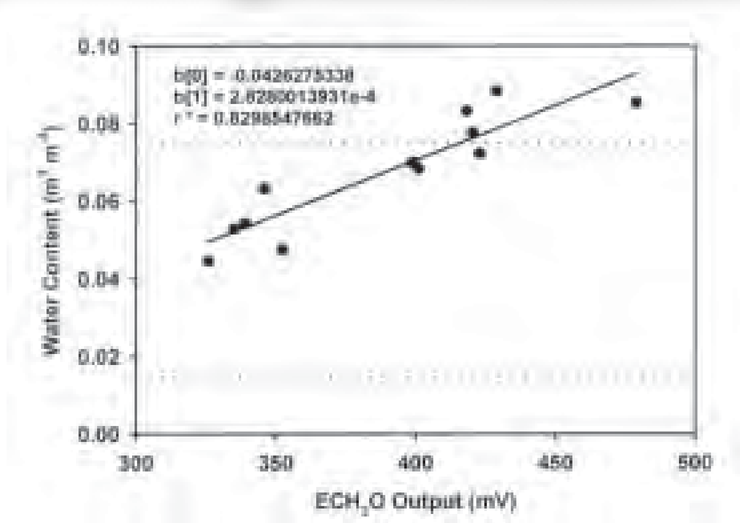
Time domain reflectometry (TDR) determines the dielectric permittivity of a medium by measuring the time it takes for an electromagnetic wave to propagate along a transmission line that is surrounded by the medium. The transit time (*t*) for an electromagnetic pulse to travel the length of a transmission line and return is related to the dielectric permittivity of the medium, κ, by the following equation

$$t = \frac{2L\sqrt{\kappa}}{c} \qquad [5]$$

where L is the length of the transmission line and c is the speed of light in free space (3 x 108 m^{s-1}). Thus, the dielectric permittivity is calculated

$$\kappa = \left(\frac{tc}{2L}\right)^2 \qquad [6]$$

The dielectric constant is therefore proportional to the square of the transit time.



FloridaCitrusResearch

◄ Upper and lower dotted lines represent field capacity and permanent wilting point, respecitively, in the sand soil.

Scheduled Irrigation for citrus.

FOR THE SOIL used in [our] calibration, Field Capacity is approximately 7.5 % volumetrically. Wilting point is assumed to be approximately 1% volume but could be as high as 1.5%.

This is an extremely narrow range of values, making a very low value for plant-available soil water. This is why, although Florida gets a large (>50 inches) amount of average annual rainfall, we need probes that offer a high degree of accuracy in this narrow range during our dry season of October -June.

Thank you for the opportunity to work with your product. The [ECH_20] sensors respond very well in our sand soils. They would make great sensors for scheduling irrigation and monitoring soil moisture.

I have attached a file containing the field calibration data and a plot of my data and the linear calibration provided. The calibration provided extremely low values and good linear fit was made which will make [ECH_20] sensors very useful in our soils.

Kelly T. Morgan
University of Florida
Citrus Research
and Education Center
Lake Alfred, FL

▲Kelly T. Morgan *(L)* and Colin Campbell *(R)* during a Decagon customer visit and product demonstration at the University of Florida Citrus Research Center.

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