The Wilting Coefficient and Its Relation to Soil Water Content and Potential

A PRIMARY FUNCTION OF SOIL in natural environments is to store water from rain and irrigation, and to make the stored water available to plant roots for uptake and transpiration. Not all of the water stored in the soil, however, is available to the plants. In some clay soils, half the pore space may be filled with water unavailable to plants. For water budget analyses and irrigation management, it is important to know how much water the soil can store.

Plant water requirement study.

In 1912 L. J. Briggs and H. L. Shantz published an amazingly complete study of the water requirements of plants. Briggs, at the time, was a soil physicist for the USDA Bureau of Plant Industry. He later transferred to the Bureau of Standards (now National Institute of Standards and Technology; NIST), becoming its director in 1933. In that post he was given the responsibility to oversee the early stages of the Manhattan Project, which developed the first nuclear weapons in World War II. After his retirement he went back to the soil physics questions from his early career. He sought to measure the limiting tension in a column of water, and was able to produce tensions as high as 300 bars. Shantz also went on to a distinguished career, becoming president of the University of Arizona.

Wilting coefficient of plants.

Briggs and Shantz measured the wilting coefficient of plants, which is the soil water content below which plants wilt and do not

continued on page 2 >>

Mars Phoenix Mission 2007

FOR THE MARS Phoenix 2007 Scout Mission, Decagon Devices is developing a instrument with a suite of sensors to measure 3 principal physical properties of the Martian regolith (soil) and atmosphere.

This instrument is composed of three metal sensing needles mounted into a plastic and aluminum housing on a robotic arm. The robotic arm also has an articulated scoop that will be used to excavate a trench in the Martian surface, allowing the instrument to probe the floor and walls of the trench.

The 3 principal series of measurements:

Regolith Thermal Properties

The TECP (Thermal Electrical and

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INSIDE

The Wilting Coefficient and Its Relation to Soil Water Content and Potential

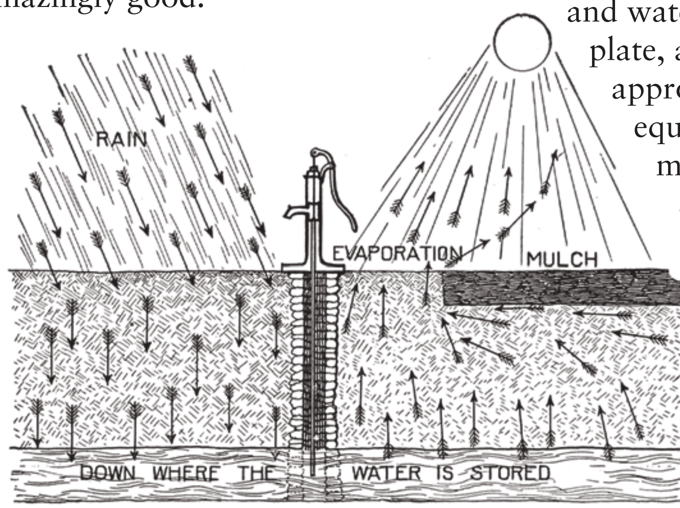
continued from cover

recover when placed in a humid atmosphere. This measurement was made for a wide range of soil textures. The wilting coefficient was then correlated with a number of measurements on the soil itself including the "hygroscopic coefficient" and the "moisture equivalent." The hygroscopic coefficient is the water content of soil "equilibrated" through the vapor phase with pure water, and the moisture equivalent is the water content of the soil after it is centrifuged at 1000g for 40 minutes in a screen-bottom tube. Both correlations were amazingly good.

Water potential a new concept.

We know that the wilting coefficient is best described in terms of a water potential, and one might wonder why Briggs and Shantz used hygroscopic coefficient or moisture equivalent. They used these measures because no means existed, at that time, for measuring water potential. The concept of capillary (or matric) potential had just been applied to soils by Brigg's colleague, Edgar Buckingham.

Buckingham was a soil physicist with the Bureau of Soils and worked under Briggs for a few years around the turn of the century. He and Briggs had a long association, later working together again in the Bureau of Standards. Briggs was therefore well acquainted with the concept of water potential, but methods had not yet been invented for measuring it.



CIRCULATION OF WATER IN THE SOIL
"Before the people of the land
Had learned to grapple with strong hand
Soil culture problems, hearts were sore
And poverty hung 'round the door."

A vintage text book drawing and verse from "SOILS: Their Properties, Improvement, Management, and the Problems of Crop Growing and Crop Feeding" By Charles William Burkett (1907)

The advent of the pressure plate.

In the 1930s L. A. Richards developed a method for bringing soil to a known water potential. He used a ceramic plate which had pores sufficiently fine that they would pass water and solutes, but would retain soil and air. Wet soil samples were placed on these plates inside a chamber where air pressure could be applied to the soil and water in the sample. The bottom of the plate was open to atmospheric pressure. When air pressure was applied to the samples, the water potential of the soil water increased, and water flowed out through the plate, allowing the sample to approach equilibrium. If equilibrium is attained, the matric potential of the sample equals to the pressure applied to the sample.

The relationship of water content and water potential.

With the invention of the pressure plate, thousands of samples were run to determine relationships between water content and water potential. As this body of data became available, correlations were made between the wilting coefficient and water contents at various potentials. From these, the water content at -15 bars, or -1.5 MPa correlated best. Briggs and Shantz found that soils vary enormously in their wilting point water contents, but the wilting water potential for all soils was near -1.5 MPa.

Flawed data– no equilibration.

This enormous amount of work to obtain pressure plate moisture release data had one

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serious flaw: until quite recently, no independent method existed to determine that the samples were, in fact, equilibrated (a requirement for correct determination of matric potential). A recent paper by Gee et al. (2002) examines the assumption of sample equilibrium on a pressure plate and concludes that hydraulic conductivities of samples at -1.5 MPa are so low that they never equilibrate, even after many days on a plate. Measurements with thermocouple psychrometers showed that actual sample water potentials ranged from 0.66 to 0.99 MPa after 10 days on a pressure plate at 1.5 MPa pressure. Simulations confirmed that hydraulic conductivity is too low for equilibration in any reasonable amount of time at these low potentials. Amazingly, Briggs actually understood and discussed the problem of low unsaturated conductivity and non-equilibrium over short distances, in relation to the measurement of the wilting coefficient, in his 1912 paper.

Response by scientists?

What has been the response of the soils community to the revelation that the thousands of 15 bar measurements on soil are wrong? Surprisingly, there doesn't appear to have been much response. Certainly, there is a reluctance to redo all that work, but wishing doesn't change the facts. Fortunately, the practical consequences of these errors may not be great. The moisture release curve for soils tends to be quite steep around the wilting point (large change of water potential for a small change of water content). Thus, even when there are quite large errors in the permanent wilt water potential, the permanent wilt water content is still nearly correct. Thus, calculations of moisture holding capacity and available water are not affected to any great degree.

All of this suggests the need for a new Briggs and Shantz study where water potential, rather than the water content, of the soils at wilting is measured. Hopefully someone will accomplish that before the centennial of their important contribution is reached. ■

References: Briggs, L. J. and H. L. Shantz. 1912. The wilting coefficient for different plants and its indirect determination. USDA Bureau of Plant Industry Bull 230. U. S. Gov. Printing Office, Washington, DC.

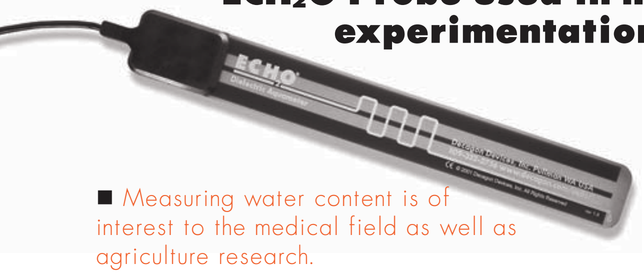
Gee, G. W.,A. L. Ward. Z. F. Zhang, G. S. Campbell and J. Mathison. 2002. The influence of hydraulic nonequilibrium on pressure plate data. Vadose Zone Journal 1:172-178.

Landa, E. R. and J. R. Nimmo. 2003. The life and scientific contributions of Lyman J. Briggs. Soil Sci. Soc. Am. J. 67:681-693.

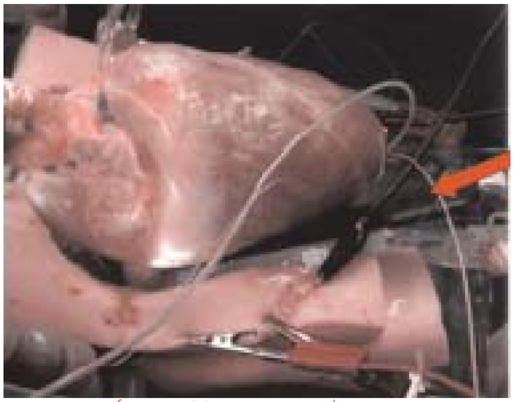
Free reprint available

"The Influence of Hydraulic Non-equilibrium on Pressure Plate Data."
Reprinted from Vadose Zone Journal Vol. 1, No.1
For a free reprint, email kristy@decagon.com

ECH$_2$O Probe used in medical experimentation.



■ Measuring water content is of interest to the medical field as well as agriculture research.



ECH$_2$O probes have been successfully used in research-level medical experiments to measure changes in water content of swelling tissues (edema) near the tissue surfaces. Measuring edema is important to the medical community because when unchecked, it causes premature failure of bodily tissues. This work has important implications for improving acceptance and viability of donor organs in their new hosts.

ECH$_2$O probes were chosen because they are easy to use, and the simple millivolt output corresponding to water content allowed the doctors to use instrumentation for nerve testing to monitor and record the data for evaluation.

TECHNOLOGY AWARD

■ The annual AE50 award honors companies that overcome engineering challenges to bring innovation to the marketplace. Products receiving the AE50 award are selected by a panel of experts in the agricultural, food and biological systems industries for the ability of a new product design to save producers time, cost and labor while improving user safety and operating in an environmentally-friendly fashion.

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■ The Mini Disk Infiltrometer being used to identify water-repellent soil conditions after the Roberts Fire, Flathead National Forest.

Postfire Timber

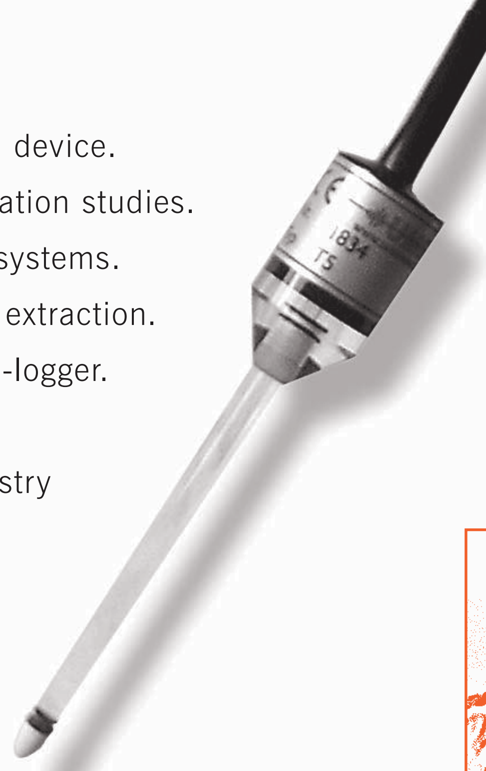
Peter R. Robichaud, PhD, PE, Res. Eng.,

VARIOUS SOIL monitoring methods will be evaluated to determine which methods can best assess soil quality. This evaluation process will be implemented during the summer of 2004 on 12 National Forests in Northern Idaho and Montana. The information generated by this study will be used to evaluate current Best Management Practices associated with salvage logging activities and guide future monitoring protocols.

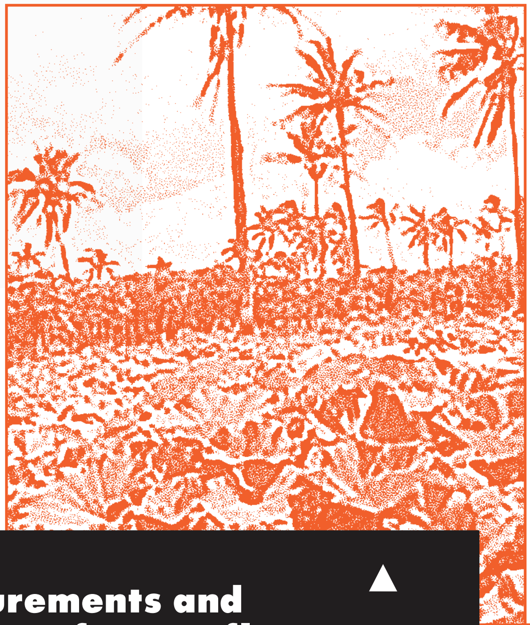
Soil indicators such as soil compaction, displacement, rutting, erosion, mass wasting, cover, bulk density, penetration resistance and infiltration capacity will be

Tensiometer Applications

- Spot readings with handheld device.
- Water balance and transportation studies.
- Control sensor for irrigation systems.
- Control sensor for soil water extraction.
- Monitoring studies with data-logger.
- Lysimeter sites.
- Research in agriculture, forestry or plant physiology.
- Ecological conservation of evidence.
- Precise single-point measurements.
- θ/Ψ and K/Ψ relationships in soil columns.
- Description of leachate movements and capillary water ascent in miniature lysimeters.
- Layer impermeability in landfill and dumpsites.



■ T5 mini-tensiometers are essential for the measurement of water potential in small spaces like soil columns, potted plants and in laboratory water flow experiments.



Tongan squash pumpkin crop exports to Japanese markets.

"Measurements and modeling of water flux through volcanic soil on the island of Tongatapu"

PDF download online:
http://www.alterra-research.nl/pls/portal30/docs/folder/croppro/croppro/p_area_tonga_research.htm

Both Sledge Company and Decagon donationed flux meters for this research project.
(Product: Drain Gauge)

Salvage Monitoring

USDA-FS, Rocky Mt. Research Station

measured. Infiltration will be measured with a single ring infiltrometer and a 0.5cm Mini Disk Infiltrometer from Decagon Devices, Pullman, WA. The team will determine changes in infiltration due to wildfire (effects of water repellent soil conditions) and subsequent salvage operations.

The team consists of undergraduate and graduate soil science students from several western U.S. universities. A two-week training for the soil monitoring crew took place in early May. The team is schedule to travel to all 12 National Forests during the summer of 2004. ■

Free reprint available

"A Modified Vadose Zone Fluxmeter with Solution Collection Capability"
Reprinted from Vadose Zone Journal 2:627-632 (2003)
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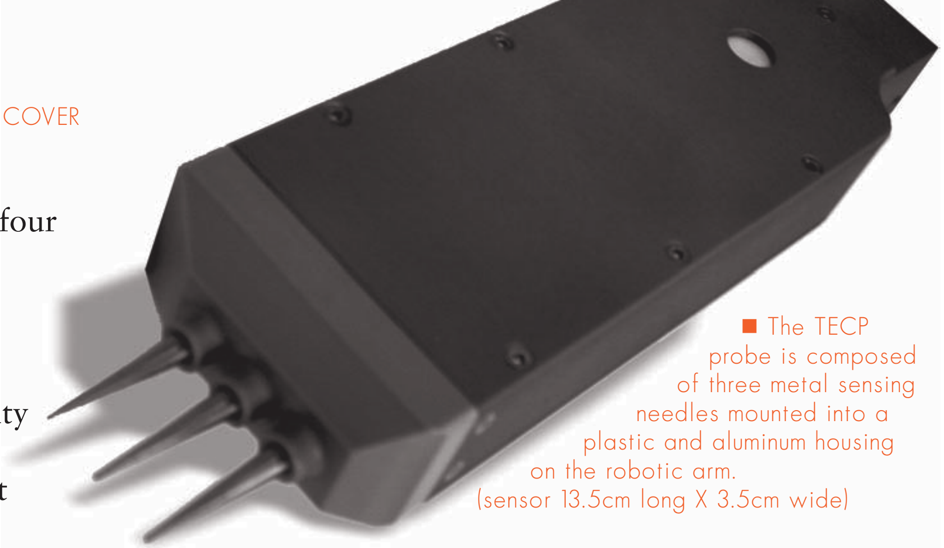
MARS CONTINUED FROM COVER

Conductivity Probe) will measure four thermal properties of the Martian regolith: temperature, thermal conductivity, volumetric heat capacity, and thermal diffusivity. Measurements of thermal diffusivity and conductivity will improve current understanding of how heat penetrates the Martian regolith in response to diurnal or seasonal cycles.



■ The TECP probe is composed of three metal sensing needles mounted into a plastic and aluminum housing on the robotic arm. (sensor 13.5cm long X 3.5cm wide)

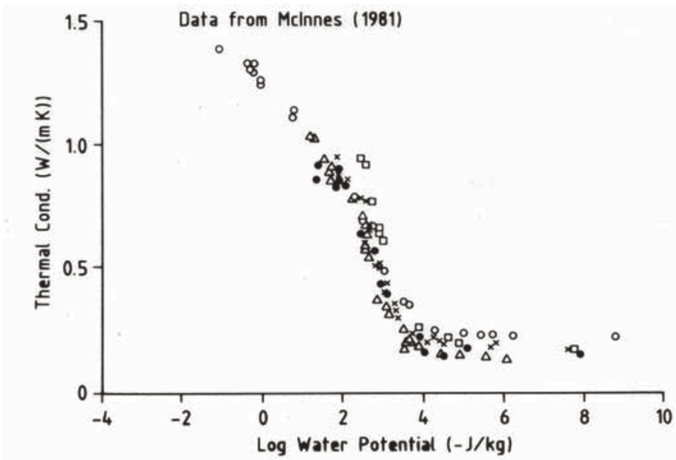
Regolith Electrical Properties

TECP will measure two electrical properties of the Martian regolith: electrical conductivity and dielectric permittivity. It is thought that any unfrozen water on Mars might exist in the form of thin, briny films on the surface of regolith particles. The electrical conductivity measurement can confirm the presence of such films. The dielectric permittivity measurement will identify any bulk unfrozen water in the regolith resulting from exposure of icy soil to solar heating in the robot arm trench.

Atmospheric Measurements

The TECP probe will measure atmospheric temperature, and windspeed with the hotwire anemometer technique. Atmospheric water vapor will be measured with a sensor on the TECP electronics board. The data from this sensor, and measurements of the temperature of this sensor yield the vapor pressure of the Martian atmosphere. These measurements will yield valuable information about vapor phase water transport during and after excavation of the trench by the robot arm. ■

Interesting Application of the KD2



■ Thermal conductivity as a function of the logarithm of water potential for soils ranging from sand to clay.

Thermal conductivity appears to be uniquely related to water potential. In some applications a thermal conductivity measurement might therefore be used to get matric potential.

Reference:
Soil Water Potential Measurement: An Overview G. S. Campbell
Department of Agronomy and Soils, Washington State University, Pullman, WA 99164, USA, Irrig Sci (1988) 9:265—273

■ Soil thermal properties for energy balance studies.

Hi Doug and T-Jay,

You both are so great! Thank you so much for looking at my data and offering to run release curves for me. This TRULY helps me out at a critical time in my studies. Thank you, thank you.

Also: Decagon has such a good reputation in our lab, always helpful and informative: I certainly will be purchasing Decagon equipment in the future!

Thank you so much Doug and T-Jay.

Let me know if I can help out somehow.

Shelly Cole
PhD student
U.C. Santa Barbara

LETTERS

Hello Matt,

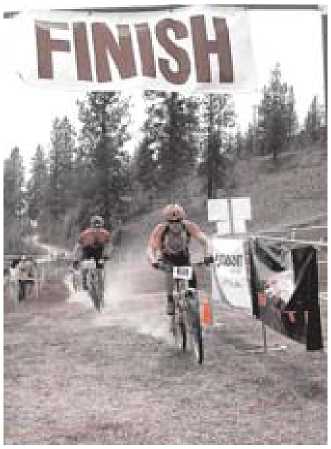
The schedule is as jam-packed as ever with collecting data from all over the state and now harvests tossed on top; but while I had opportunity I wanted to thank you and your design team for coming up with a lightbar that is so well suited in our research with almonds and walnuts. You made it easy to go right to collecting data, you put just the right amount of information on the display to communicate what data is being gathered, and you made it easy to use with one hand by the relocation of the entry button which was something we have been wanting ever since our old Sunfleck ceptometer began showing it's age and heavy use. You came up with a tool we can't do without; thanks!

Samuel G Metcalf

Integrated Orchard Management/
Almond and Walnut
University of California
Dept. of Pomology

New face at Decagon.

T-Jay Clevenger is the new Sales Manager for the Research Agriculture Group at Decagon. When you need a price quote for a WP4T, need to place an order for ECH_2O Probes or need technical help; T-Jay will be here to help you find the right products to help your research needs. T-Jay has been a great asset for Decagon and has brought with him a blazing determination and hard ethic, which he shows at work and while racing his mountain bike in the NORBA (North American Off Road Bicycling Association) circuit around the States.



◄ T-Jay coming in first.

DECAGON Tradeshows & Exhibits for 2005

- European Geosciences Union
  April 24–29, 2005 Vienna, Austria
- International Thermal Conductivity Congress
  June 26–29, 2005 New Brunswick, Canada
- American Society of Horticulture Scientists
  July 18–21, 2005 Las Vegas, Nevada
- American Phytopathological Society
  July 30 – August 3, 2005 Austin, Texas
- Ecological Society of America
  August 7–12, 2005 Montreal, Canada
- International Union of Forest Research Organizations
  August 8–13, 2005 Brisbane, Australia
- American Society of Agronomy
  November 6–10, 2005 Salt Lake City, UT

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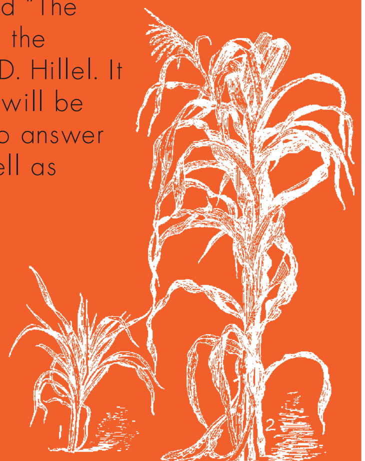
We have been enjoying some interesting wintertime reading (besides designing new sensors). "Principles of Soil and Plant Water Relations" by M.B. Kirkham is excellent. We really enjoy the short biographies at the end of each chapter. We just received "The Encyclopedia of Soils in the Environment", edited by D. Hillel. It is a super reference we will be using here at Decagon to answer our own questions as well as some customers.



We hope you find our newsletter informational and practical.

Regards,

Bryan Wacker

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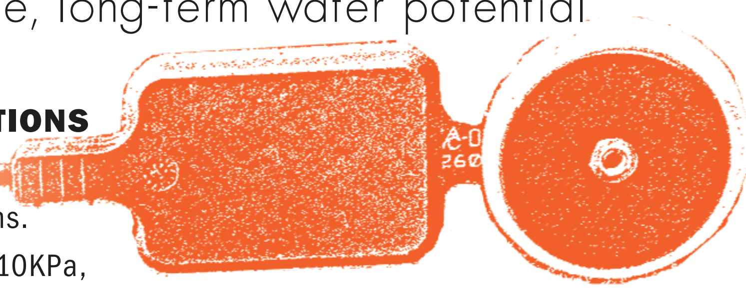
Soil Matric Potential Sensor

No maintenance, long-term water potential monitoring.



PROBE SPECIFICATIONS

Range: 0–300 KPa.

Measurement time: 10ms.

Accuracy: 0–100 kpa: ±10KPa, 100–300 KPa ±25KPa.

Output range: 170 to 400 mV.

Power requirement: 2.5VDC @ 3mA.

Operating temperature: -40° C to +50° C.

Dimensions: 103mm L, 37.33mm W, 6.5mm Thick.

Cable length: 5m.

AVAILABLE MARCH 2005

Matric Probe is being beta tested at the following institutions:

University of Wisconsin-Madison
Tea Research Institute
Oregon State University
USGS
TORO
Washington State University
University of Lleida- Spain
NARC Tsukuba- Japan
Iwate University- Japan

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