DECAGON
2004

Soils News

SOIL • PLANT • WATER • SEED

INSIDE

Grazing Impacts Subalpine Hydrology

Richard Gill Ph.D., Environmental Science, Washington State University.

HIGH plateaus in the western U.S. provide perhaps the most important commodity for local communities—water for drinking, irrigation, and industry. As the ecologist Lincoln Ellison once wrote, "As surely as canyon from the plateau opens upon the valley floor, so surely will one find a farm, a village, or a town. Each of these small islands of civilization is nourished, as by a silver umbilical thread, from snows that accumulate in the nearby highlands." In the early 20th century westerners were beginning to realize that activities on these high plateaus, particularly intensive livestock grazing, had the potential to dramatically alter the timing and quality of water supplied to the valleys. In 1913 Dr. Arthur Sampson built fences to exclude livestock from parts of the Wasatch Plateau to

continued on page 4 >>

▲ Original enclosures built in 1913 and instrumented with ECH_2O probes.

Field Capacity Is Not Saturation!

E. Philip Small of Land Profile, Inc., Yakima, Washington.

Published in Soil Profiles
Vol. 5 No. 2 Spring 1995

FIELD capacity and saturation involve two different water contents. In medium textured soils, field capacity is about 50% of pore volume. By definition, saturated soil has soil water filling 100% of soil pore volume. Soil moisture at field capacity may meet a limited colloquial definition of saturation, but my observations are that field capacity soil moisture will not induce anaerobic conditions. Although we who identify jurisdictional wetland conditions have been strongly directed to include all of the capillary fringe in deducing depth to saturated soil conditions, my observations with the dipyridyl indicator are that only the first few inches of the capillary fringe are sufficiently restrictive of oxygen transfer to induce anaerobic soil conditions.

The above statement

continued on page 2 >>

has some history to it. I was out with another wetland professional [T. J. Stetz, Army Corps] a couple of weeks ago and we were discussing the definition of saturated soil conditions. I regret to say that I mistakenly agreed with him that when soil scientists describe soil as "saturated", we can mean "above field capacity". We went on to deduce that since saturation induces anaerobic conditions, soil moisture anywhere above field capacity induces anaerobic conditions. I knew this was somehow wrong at the time, but we were so balled up in figuring out our delineation

Where grows?—Where grows it not? If vain our toil, We ought to blame the culture, not the soil.
—Pope.

that we didn't get back to this subject. Anyway, I now thoroughly regret ever thinking of saturation as anything other than chock full of water. I've put a lot of thought into this and I am here to tell you that it takes a full load of water to induce redoximorphic features: up until the soil pore space is almost full of water, oxygen replenishment can meet microbial demand.
The math used to compare oxygen transfer to soil demand for oxygen is pretty straight forward. It points to a soil moisture content near maximum as needed to induce anaerobic conditions. I used a formula passed on to me by a soil scientist at North Carolina State University. It is soil-texture and moisture-specific. I routinely use it to calculate oxygen demand treatment capacity for wastewater sprayfields. The formula addresses soil pore volume limitations on oxygen diffusion, based on a work authored by Francis Clark, an USDA-ARS microbiologist. It assumes ideal temperatures promoting maximum microbial activity and root respiration. It goes into a lot of detail as to what occurs at the root surface.
The Clark article is of additional interest to soil scientists who work with wetlands in that it projects the length of time of soil saturation needed to induce low oxygen soil conditions: 96 hours to cause crop damage in the flood irrigated example given by Clark.

$$T = D - R \qquad [1]$$

Where, T= kg-O_2 $ha^{-1}dy^{-1}$ available to meet total oxygen demand (TOD)
Where, R= kg-O_2 $ha^{-1}dy^{-1}$ demanded by root respiration, microbial activity

$$D = K\,A \qquad [2]$$

Where, D= kg-O_2 $ha^{-1}dy^{-1}$ of oxygen diffusion rate in soil
K= 1740 kg-O_2 $ha^{-1}dy^{-1}$ oxygen diffusion rate in air
A= cm^3/cm^3 of air filled soil pore volume at field capacity

$$A = V - S - W \qquad [3]$$

Where, V= Total volume, 1 cm^3cm^{-3}
S= Soil particle volume, cm^3cm^{-3}
W= Water volume, cm^3cm^{-3}

$$S = S_d/P_d \qquad [4]$$

Where, S_d= Density of soil mass, 1.25.
P_d= Density of soil particles, 2.63.

$$W = W_gS_d \qquad [5]$$

Where, W_g= gravimetric percent of water held within soil.

Inputting various soil moisture values yields the following results:

The formula addresses soil pore volume limitations on oxygen diffusion.

For anaerobic conditions to be induced at field capacity, soil respiration-based oxygen demand (R) in the above example would have to increase from 161 kg O_2 $ha^{-1}dy^{-1}$ by another 715 to 776. This increase could arguably be due to a higher carbon content in wetland soils promoting respiration. I would expect a wetland soil to have a higher O_2 demand than an adjacent upland soil, but certainly by no more than 200 kg O_2 $ha^{-1}dy^{-1}$. An increase of 200 kg O_2 $ha^{-1}dy^{-1}$ would imply to me a tremendous amount of rotting vegetation, a condition not sustainable under naturally occurring circumstances.

Increasing respiration from 161 kg O_2 $ha^{-1}dy^{-1}$ by another 200 to 361 produces a calculated oxygen equilibrium moisture content of 92% of saturation (177% of field capacity; W:S:A = 49:47:4). Even at a high rate of respiration, anaerobic conditions would not be expected until well above field capacity.

I do not mean to oversimplify an exceedingly complex process: formulas can never do full justice to the interplay of factors in soils. There may be all sorts of factors (tortuosity, microsaturation, thin horizons of compaction or cementation) that serve to further decrease oxygen diffusion in soil. These complications will certainly increase with depth. Serving to reduce the effect of these complications is the fact that hydric soil formation is largely a surface soil and root zone phenomenon.

My observations support the applicability of the

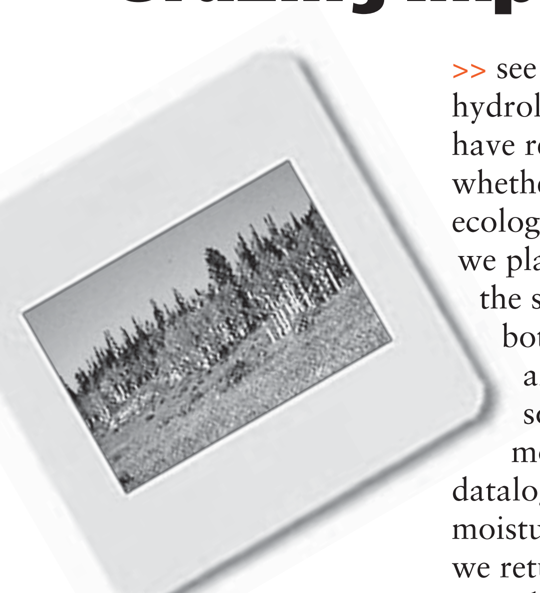
continued on page 7 >>

▲"Decagon receives the Pacific Northwest section of American Society of Agricultural Engineers–Industrial achievement award for innovative solutions for the Food Science and Agricultural Research."

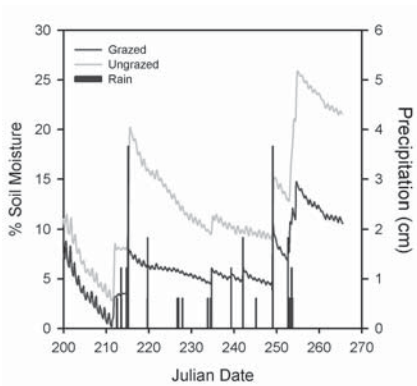
"Dr. Dirt" is intended to serve as a scientific/technical question and answer forum for consulting soil scientists. Please address your questions and/or editorial comments to "Dr. Dirt," in care of the Editor of "Soil Profiles," National Society of Consulting Soil Scientists, 325 Pennsylvania Ave., S. E., Suite 700, Washington D. C. 20083. email: psmall2003@landprofile.com
The following article was written by E. Philip Small of Land Profile, Inc., Yakima, Washington. We are soliciting an objective and critical view of this article by our readers. website: www.landprofile.com

continued from cover

Grazing Impacts Subalpine Hydrology



■ Open meadow on the Wasatch Plateau.



▲ Effect of grazing on soil moisture

>> see what impacts grazing had on ecology and hydrology of this region. Now, 90 years later we have returned to Dr. Sampson's exclosures to see whether long-term livestock grazing has altered ecological and hydrological processes. In 2002 we placed ECH_2O probes at several locations in the subalpine region of the Wasatch Plateau, both inside and outside of grazing exclosures, all above 10,000 foot elevation. Volumetric soil water content was continuously monitored by logging data using Em-5 dataloggers. After successfully characterizing soil moisture through a growing season and winter, we returned in 2003 and expanded our research to include an analysis of how global warming and increased nitrogen deposition could impact the infiltration and retention of water in subalpine soils. Data are currently being analyzed, but it is clear that ungrazed areas had higher infiltration rates and soil water content than soils from grazed areas. By continuously monitoring soil moisture from winter through the growing season we hope to be able to better understand soil water dynamics as snows melt and release water into the streams that vital to the communities of the Wasatch Front of Utah. ■

Leaf wetness sensor

New Ultra-thin leaf wetness sensor.

THE 0.5mm thin fiberglass sensor will use dielectric technique instead of resistance.

The dielectric technique allows the sensor exceptional sensitivity to changes in surface wetness.

- ■ No need to paint.
- ■ Easily suspends in the plant canopy.
- ■ Thermodynamic properties mimic a real leaf.
- ■ Plug and play with Decagon loggers. Programmable with CSI dataloggers.

Leaf Wetness Sensor Available May 2004

See cover for photo.

▸ Generally, painted-grid style sensors cannot tolerate puddling, which caused corrosion, plating (shorts), and battery drain. The new Decagon leaf wetness sensor will be forgiving of dew or rain puddling and also impervious to the digestive acid in bird dung which etches painted sensors. It's built for the real world.

www.decagon.com/soils/

Hands on Seminar

Work with water content and water potential sensors and recording equipment.

Lecture and practicum

Training Session
Decagon is offering a short course on Soil Moisture Measurement Methods to be held:

Agronomy Society of America 2004
ASA Oct 31st to Nov 4th Seattle, Washington
Date of meeting- 30th of October
www.decagon.com/instruments/shortcourse_ASA.html

Ecological Society of America 2004
ESA Aug 1st to Aug 6th Portland, Oregon,
Date of meeting- 31st of July
www.decagon.com/instruments/shortcourse_ESA.html

Limited to 30 participants.

May 27, 2003

LETTER

Dear Bryan,

Our laboratory recently acquired a set of Decagon's ECH_2O probe capacitance sensors. One of our current research projects involves the use of tree sap flux measurements to quantify tree transpiration and canopy conductance. The goal of this research is an analysis of the influence of tree height and size on leaf level gas exchange, plant water use, and forest productivity.

We measure a number of physiological and site environmental parameters in this study. Important variables include plant water status and soil water content. The ECH_2O probe sensor provides a convenient means to quantify soil water content on a daily and seasonal basis.

Measurements of plant tissue water potential are available through the use of a pressure chamber. However, measurements of soil water potential require either pre-dawn plant tissue measurement, or the use of temperature sensitive soil psychrometers. We use plant tissue pre-dawn water potential to estimate the soil water potential. However, this method is time consuming, and intensive daily and seasonal measurements require a substantial commitment of time and resources. The availability of a data-logger compatible capacitance probe greatly simplifies our daily measurement of soil water status change. The combination of measurements of daily soil water content and occasional measures of plant pre-dawn water potential provides us an expedient method to assess plant and soil water status.

We appreciate the advice and support provided by the staff at Decagon Devices. Your company has been influential in helping us meet our instrumentation requirements for this research.

Thanks again,

Robert Pangle
Department of Forest Resources
University of Idaho

ADVERTISEMENT

Use the WP4-T to generate moisture release curves.

▲ **WP4-T**—*Soil or plant water potential is computed using chilled mirror dew point.*

Most researchers know that water potential changes with temperature. When you use the WP4-T you can measure the water potential of all your samples at a set temperature.

Internal temperature control allows you to monitor small changes in water potential from one sample to the next.

Soil Water Potential

DECAGON
950 NE Nelson Court
Pullman, Washington 99163
800-755-2751
fax 509-332-5158
soils@decagon.com
www.decagon.com/soils/

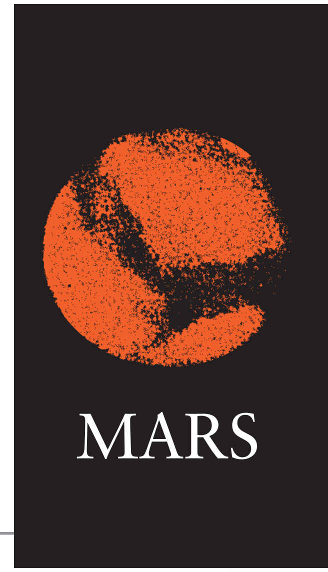
New Em5 and Em5R datalogger firmware

Upgrade your Em5 or Em5R for free. Upgrading improves:

- Improved internal measurement storage to ensure data integrity.
- Improved data downloading to prevent data loss over radio.
- Faster downloads when direct connected to serial port.
- Improved radio operations.
- Improved battery life.

- New ECH_2O Link interface software is, also, available now. Contact Decagon to upgrade.

Decagon measures Mars Soil Properties on the 2007 Phoenix Scout.



DECAGON is working with NASA's Jet Propulsion Laboratory to develop an instrument to measure a suite of physical properties of Martian soil. This probe, the Thermal and Electrical Conductivity Probe (TECP), will fly to Mars in 2007 aboard NASA's Phoenix Lander. TECP will measure Martian soil thermal properties (temperature, conductivity, and diffusivity), and soil electrical properties (conductivity and dielectric permittivity) *in situ*. Direct measurement of soil thermal properties will improve current understanding of how heat penetrates the Martian surface in response to diurnal or seasonal cycles. This information is of keen interest to numerous researchers creating Martian Global Climate Models. Measurements of soil electrical properties will identify the presence of any unfrozen water that might result from exposing icy, subsurface soil to sunlight. TECP has the potential to provide the first direct detection of unfrozen water on Mars. ■

VISIT DECAGON ONLINE
www.decagon.com/soils

Thermal Units Conversion Chart

To convert column 1 into column 2, multiply by:	Column 1	Column 2	To convert column 2 into column 1, multiply by:
heat			
0.000952	Joule	Btu	1054
heat			
0.239	Joule	Cal	4 186
heat flux density			
0.00 143	W/m^2	cal cm^{-2} min^{-1}	698
diffusivity			
10.76	m^2/s	ft^2/s	0.0929
diffusivity			
3.88 x 10^4	m^2/s	ft^2/hr	2.58 x 105
thermal conductivity			
0.578	W $m^{-1}C^{-1}$	Btu $hr^{-1}ft^{-1}F^{-1}$	1.73
therrnal conductivity			
6.93	W $m^{-1}C^{-1}$	Btu in $hr^{-1}ft^{-2}F^{-1}$	0.144
therrnal resistivity			
1.73	C m/W	ft hr F Btu^{-1}	0.578
thermal resistivity			
0.0144	C m/W	ft^2 hr F Btu^{-1} in^{-1}	6.93
specific heat			
2.39 x 10^{-4}	J $kg^{-1}C^{-1}$	Btu lb^{-1} F^{-l}	4179

DEFINITIONS

THERMAL CONDUCTIVITY—The amount of heat conducted over a unit distance when unit temperature gradient is applied.

SPECIFIC HEAT—The amount of heat stored per unit mass or volume for a unit temperature change.

THERMAL DIFFUSIVITY—The ratio of thermal conductivity to volumetric specific heat. A measure of the speed with which a thermal disturbance is propagated in a medium.

continued from page 3

Field Capacity Is Not Saturation!

■ ECH_2O Probes come in 2 sizes: 10cm and 20cm.

>> formula to field soil conditions. I have spent years trying to get a handle on "anaerobic soil failure" of wastewater sprayfields. I find no evidence in the literature or in my experience that would lead me to believe that we should expect anaerobic soil conditions to be induced by maintaining soil moisture near field capacity soil moisture. Thousands of acres of drip irrigated grapevines and hopvines in Yakima would be in trouble if prolonged soil moisture above field capacity could induce anaerobic soil conditions. ■

1. sat·u·rat·ed: adj. 1. Unable to hold or contain more; full. 2. Soaked with moisture; drenched. Microsoft Bookshelf © 1987 - 1992 Microsoft Corp. All Rights Reserved. The American Heritage Dictionary and Electronic Thesaurus are licensed from Houghton Mifflin Company. Copyright © 1986, 1987 by Houghton Mifflin Company. All rights reserved. Based upon Roget's II: The New Thesaurus.

2. Formula relayed in personal conversation with Larry King, November 18, 1988, as applied in L. D. King, 1982, Land Application of Untreated Industrial Waste Water, Journal of Environmental Quality, 11:638-644.

3. F. E. Clark and W. D. Kemper, 1967, Microbial Activity In Relation To Soil Water And Soil Aeration, in R. M. Hagan, H. R. Haise and T. W. Edminster (ed) Irrigation of Agricultural Lands.

4. 3 to 6 lbs Ady^{-1} or 80 to 161 kg hady^{-1}. ibid., page 474

5. Used 1.25 cm^3 cm^{-3} of soil volume, a typical value for medium textured soils with minimal compaction. For mineral soils, ranges from 1.0 (clay dominated A horizon) to 1.8 (moderately compact sand).

6. Sterling A. Taylor and Gaylen Ashcroft, 1972, Physical Edaphology, page 373.

7. Bruce Wither and Stanley Vipond, 1980, Irrigation Practice and Design, page 71. Used 0.22g water per gram of soil solids for field capacity, a typical value for medium textured soils. For mineral soils, gravimetric field capacity ranges from 0.40g for clay dominated A horizon to 0.70g for coarse sand.

▲ The new Installation kit helps make multiple installations of ECH_2O probes easy, especially if deep installations are desired.

◄ Doug measures the unfrozen water content of the snowbanks near Decagon.

Environmental Biophysicist joins Decagon

Doug Cobos, a recent graduate of University of Minnesota, joined Decagon in October 2003. Doug will be spearheading the work on the TECP project *(opposite page)*. In the interim he is working on sensors like the leaf wetness sensor *(see page 4)* and is currently testing the ECH_2O probes for measuring unfrozen water content in snow. ■

DECAGON
950 NE Nelson Court
Pullman, Washington 99163

Welcome— Images and poetry from turn of the century soils text books garnish this issue. There were some pretty interesting instruments for soils research back then. We'll include more images in future issues.

I teach
The earth and soil
To them that toil,
The hill and fen
To common men
That live just here;

The plants that grow
The winds that blow,
The streams that run,
In rain and sun
Throughout the year;

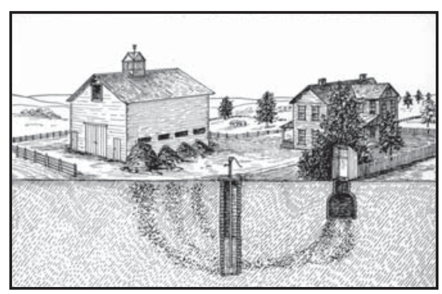
And then I lead
Thro' wood and mead,
Thro' mold and sod,
Out unto God.
With love and cheer,
I teach.

VISIT DECAGON ONLINE
www.decagon.com/soils

New Soil Drainage Sensor

Gee Water Flux Meter

THE Drain Gauge™ is a novel sensor for measuring water movement through the soil profile.



▲ In 1906, the concept of ground water pollution was a concern.

Applications

- Measure and control excess water and nutrient losses
- Maximize processing waste applications
- Measure percolation and recharge rates
- Control Irrigation

VISIT DECAGON ONLINE
www.decagon.com/soils/