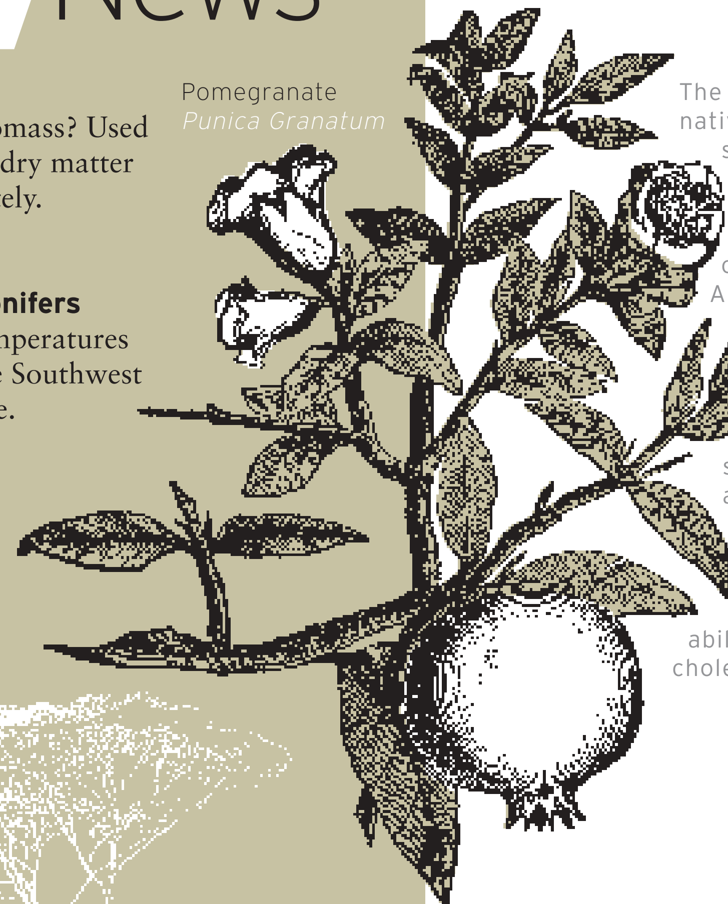
DECAGON DEVICES

CanopyNews



Pomegranate
Punica Granatum

The Pomegranate, native to an area that stretches from Iran to the Himalayas, is now cultivated in the drier parts of California and Arizona. Pomegranates are often referred to as "superfruits." Research suggests that antioxidant rich pomegranate juice has several health benefits, including the ability to lower cholesterol. ■

http://www.decagon.com/ag_research/canopy/

Useful knowledge about canopy research and applications.

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2009

NEXT

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Simple Models for Carbon Assimilation by Plants

The detailed processes in photosynthesis are complicated and hard to model. In many cases, however, it's possible to simplify the model by focusing on one or more of the limitations to assimilation.

Carbon Assimilation Simplified: Light and Water

In simplest terms, carbon assimilation involves the chemical transformation of carbon dioxide and water to carbohydrate and oxygen within the leaves of plants. The process requires energy to proceed, and that energy is supplied by light, usually coming from the sun. The CO_2 comes from the atmosphere, and must diffuse into the leaf mesophyll cells to be fixed. Since the inside of the leaf is much wetter than the atmosphere, water diffuses out as CO_2 diffuses in. The amount of water used in the actual photosynthetic process is minuscule, but the water lost in connection with CO_2 uptake is substantial.

Limited by Light, Limited by Water: Two Separate Approaches

Based on this simple description, we could postulate situations where light would be the limiting factor in assimilation, and others where water would be the limiting factor. Our models, in words, might be: assimilation is proportional to the plant's ability to capture light, or assimilation is proportional to the plant's ability to capture water. Both approaches can be useful in modeling biomass production.

Light Based Model

In an earlier newsletter article we discussed the light-based model. In equation form it is

$$A = efS \qquad (1)$$

where A is the net dry matter assimilation, S is the total incident radiation received during the time the crop is growing, f is the average fraction of radiation intercepted by the crop, and e is a conversion efficiency. If A and S are both expressed in mol m-2s-1, then e is a dimensionless conversion efficiency. In light limiting situations, the value of e is quite conservative for a particular species, and in the range 0.01 to 0.03 mol CO_2 (mol photons)-1 (Campbell and Norman, 1998, p. 237 give additional information and references to do a more complete analysis.)

Measuring f with the AccuPAR LP-80

It is clear that f, the fraction of incident light intercepted by the plant canopy is a critical factor in determining assimilation. This factor is directly measured with the AccuPAR LP-80. In light limited environments one can predict dry matter production knowing the amount of incident PAR and the light conversion efficiency, e, and then measuring f over time with the LP80.

Water Based Model

In water limited situations a different equation applies. It is

$$A = \frac{kT}{D} \qquad (2)$$

where T is transpiration, D is the atmospheric vapor deficit, and k is a constant for a particular species and

References

Campbell, G. S. and R. Diaz (1988) Simplified soil-water models to predict crop transpiration. p. 15-26 in Drought Research Priorities for the Dryland Tropics (F. R. Bidinger and C. Johansen eds.) Parancheru, A. P. 503 324, India: ICRISAT

Campbell, G. S. and J. M. Norman. (1998) An Introduction to Environmental Biophysics. 2nd Ed. Springer Verlag, New York.

Kunkel, R. and G. S. Campbell (1987) Maximum potential potato yield in the Columbia Basin, USA: model and Measured values.Am. Potato J. 64:355-366.

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Computing Fractional Interception

The fractional interception, *f* used in both of these models is the value averaged over whole days. The measurement by the LP-80 typically is made at a particular time of day, and is not the average over the day. The LP-80 manual gives equations and an example (p. 57) to convert from the single observation to the daily average. The LP-80 measures transmission of radiation by taking the ratio of PAR measured below the canopy to PAR measured above. This is the transmission at a particular sun zenith angle, *t (q)*. The transmission averaged over whole days is the same as the transmission for diffuse radiation, and is given by

$$\tau_d=\tau(\theta)^q$$

where *q* depends on leaf area index, leaf angle distribution and sun zenith angle, as shown in the manual. The fractional interception for these models is

$$f = 1- \tau_d$$

To request a reprint of ***Campbell, G. S. and R. Diaz (1988)*** which includes the transpiration model and a computer program in BASIC, email marcom@decagon.com.

Pineapple A tropical plant (Ananassa sativa); also, its fruit; – so called from the resemblance of the latter, in shape and external appearance, to the cone of the pine tree.

atmospheric CO_2 level. Tanner and Sinclair (1983) and Campbell and Norman (1998) give derivations for this equation, but its validity has been repeatedly confirmed in experiments going back more than a century. Among other things it predicts that humid regions will produce more dry matter per unit water used than arid areas. Thus, an irrigation project in Wisconsin, say, would produce a lot more dry matter per unit water used than one in Arizona. While there may be differences, from one species to another, in the amount of dry matter produced per unit water used, all dry matter production requires a substantial quantity of water. Dreams of making deserts blossom by genetically engineering plants that fix carbon without using water are just that – dreams.

Interception in the Water Limited Model

The evaporation-based dry matter model also depends on light interception. The water lost by a crop includes water transpired by the plants and water evaporated from the soil. Only the water lost by transpiration relates to carbon assimilation. It usually isn't practical to measure T in eq. 2, but we can make a simple computer model that will compute it each day if we know the rain or irrigation and some soil and environmental variables. For the model we need to define a quantity called potential evapotranspiration, which is the rate of water loss when water supply limits neither evaporation nor transpiration. Potential transpiration and potential evaporation are then computed from

$$T_p = f E_{tp} \qquad (3)$$

Since evaporation from the soil surface also uses up water, we need to compute it as well. Potential evaporation is computed from:The evaporation-based dry matter model

$$E_p = (1-f) E_{tp} \qquad (4)$$

where *Etp* is potential evapotranspiration. As before, f is the fraction of radiation intercepted by the canopy, and can be measured with the LP-80. Campbell and Diaz (1988) give a simple computer model for computing *Etp* as well as algorithms for computing actual evaporation and transpiration from the potential quantities given by eqs. 3 and 4.

Knowing Which Model to Use

The most efficient way to determine whether light or water is the limiting factor is to simply calculate both mathematical models daily to see which one predicts the lowest value. That value is the best predictor of dry matter production for the particular day on which it is performed.

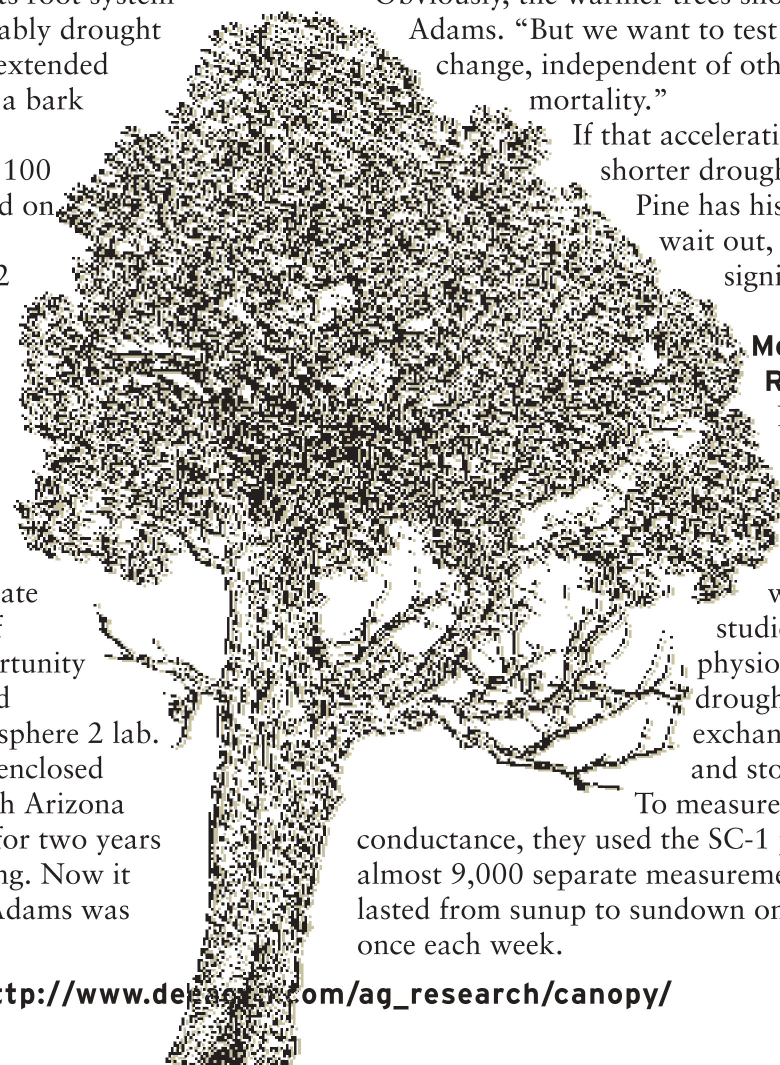
BASIC Computer Modeling

The light-limited and water-limited mathematical models are hard to manipulate by hand but easy to program on a computer. They can be calculated from easily obtained climatic data, and can be quite accurate predictors of crop dry matter production, particularly for annual crops. They have been particularly useful for assessing production potential for particular environments and cultural practices *(Campbell and Diaz, 1988; Kunkel and Campbell, 1987).*

Piñon Pine: Studying the Effects of Climate Change on Drought Tolerance

IN THE NAME OF SCIENCE, Henry Adams has killed a lot of trees. Adams, a PhD student at the University of Arizona, is studying the effect of climate change and drought on Piñon Pines. The Piñon Pine, a conifer with an extensive root system, grows at high elevations in the Southwest. Its root system makes the Piñon Pine remarkably drought tolerant, but in 2002–03, an extended drought in combination with a bark beetle outbreak killed 12,000 hectares of the trees. It was a 100 year drought, the driest period on record, and interestingly it coincided with temperatures 2 to 3°C above recorded averages.

▸ There are eight species of true piñons (Pinus subsection Cembroides) that grow in the southwestern United States and in Mexico. Piñon or pine nuts, a staple of the Native Americans, are second only to pecans in terms of commercial value. ■



Research in Biosphere 2

Adams and his advisors wondered if increasing temperatures due to climate change might exacerbate the effects of drought and accelerate tree die-off. The University of Arizona has an unusual opportunity to test drought conditions and temperature change in its Biosphere 2 lab. Biosphere 2, a unique 3-acre enclosed “living laboratory” in the high Arizona desert, once hosted 8 people for two years of self-contained survival living. Now it hosts research projects, and Adams was able to use space inside to induce drought in two separate treatments of transplanted Piñon pines, one at ambient temperatures and one at temperatures 4°C above ambient.

Sobering Outlook for the Piñon Pine

“Obviously, the warmer trees should die first,” says Adams. “But we want to test whether temperature change, independent of other factors, accelerates mortality.”

If that acceleration in fact occurs, a shorter drought, the kind the Piñon Pine has historically been able to wait out, might cause a significant die-off.

Measuring Drought Response

Naturally, Adams and his colleagues did more than just watch how fast trees would die without water. They also studied the trees physiological response to drought, measuring gas exchange, water potential, and stomatal conductance. To measure stomatal conductance, they used the SC-1 porometer, making almost 9,000 separate measurements in sessions that lasted from sunup to sundown on one very long day once each week.

▸ The **Piñon Jay** *(Gymnorhinus cyanocephalus)* takes its name from the tree, and Piñon nuts form an important part of its diet. The Pinon Jay harvests, transports, caches, and later retrieves pinon seeds. Cached and unused seeds help regenerate Piñon forests. ■

Need more information about using the porometer on conifers? Email marcom@decagon.com to request the new application note *Using the SC-1 Porometer to Measure the Stomatal Conductance of Needles and Grasses.*

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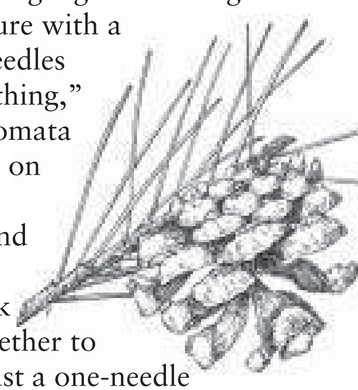
Stomatal Conductance from the SC-01 Porometer More Sensitively Quantified Water Loss than Weighing Lysimeter Data

Stomatal Conductance in Conifers

There isn't much guidance in the porometer manual for people who want to use it on conifers, so Adams "played around with it a little bit" on non-drought stressed trees before he started his study. He found that the best way to get good readings was to cover the aperture with a single layer of needles. "Needles are this three-dimensional thing," he explains. "They have stomata on several sides, depending on the species. If you imagine that the fingers on your hand are needles sticking up from a branch, we just took those and pushed them together to make sure that there was just a one-needle thick covering over the aperture. If you spread your fingers, that's what it would be like if you didn't totally cover the aperture—then you underestimate the conductance. We also found that if we stuck several layers in there, we could drive the conductance number up.



▴ **Piñon Nut Pine cone**
Pinus monophyll

Comparing at Leaf Level

Adams isn't concerned about absolute conductance data. "We're making comparisons at the leaf level between treatments. We're not trying to estimate whole tree conductance or whole stand conductance. I can just compare leaf level in treatment X to the leaf level in treatment Y, and because it's the same species and the same needle shape, I have a lot of confidence in our data. We got pretty good numbers."

Sensitivity to Dry Conditions

Another part of the drought study involved a hydrologist who was interested in using weighing lysimeter data to parameterize some models used by hydrologists to model water loss during drought. "The lysimeters are a pain to run, but they're pretty sensitive," says Adams. "They can measure with a 0.1 kg precision, so that sounds like a good way to quantify water loss. It turns out that stomatal conductance from the porometer actually appears more sensitive than the weighing lysimeter data. Water loss from the scale hits zero pretty quickly, and we can't measure any loss after a couple of weeks, but we can still see water loss with our porometer data from the morning and the evening."

Expanding the Experiment

At the peak of the experiment, Adams had undergraduates and lab techs running up to three porometers at a time all day long, and although he's still buried in data from the first experiment, he's looking forward to accumulating even more data. "One limitation of our study is that the trees had pretty small root balls when they arrived. We've transplanted some trees [at different elevations at a site] in northern Arizona using a full sized tree mover to get as big a root to shoot ratio as possible in the transplant. We'll be using the porometers to try to

▲**Sugar cane**

Tall tropical southeast Asian grass with fibrous jointed stalks whose sap is a source of molasses and commercial sugar. ■

DECAGON DEVICES

Piñon Pine Study

understand the physiology of how these trees die and to predict their temperature sensitivity in the light of global climate change, using elevation change as a surrogate for temperature. We also have trees at the site that are not transplanted to serve as a control for the transplants."

Implications for the Future

Adams acknowledges that not everyone in the Southwest is worried about the Piñon Pine. "We work in a system that doesn't have a lot of economic value. A lot of the ranchers are happy to see the pines go. They just think there will be a lot more grass for the cattle, and firewood cutters are out there cutting up the dead trees and selling them." But if temperature alone makes trees more susceptible to drought, the implications go far beyond economics. Adams puts it succinctly, if somewhat mildly: "It's kind of scary." ■

Flax Flax, genus *Linum.* Fiber from the bark is used to make linen. Linseed oil comes from the seeds.

New Staff

Nick Mower
Nick handles AccuPAR LP-80 quotes and basic application questions. Favorite customer moment: helping a researcher construct a sensor package to get the data she needed with the budget she had.

Jordan Tanasse
Jordan handles SC-1 Porometer quotes and basic application questions. Loving science is part of what drew him to the job.

Chris Chambers, Environmental Instrument Application Specialist
Chris handles customer questions—everything from calibration and compatibility to how and why the instrument works. A former Peace Corps volunteer and professional forester with a master's degree in Physiological Ecology, Chris likes helping people figure out ways to solve their research problems, especially when it involves applying their instruments in new ways. ■

DECAGON DEVICES

Getting Accurate Porometer Data Cleaning and Calibration Q&A

Is your porometer head looking a little green?

THE SC-1 POROMETER IS a robust piece of equipment, but plant material like sap and tiny flecks of leaf can adhere to the sensor head. Water adsorbing and desorbing from that material will distort your readings. So, after a hundred readings or so you should clean your sensors.

Manual dexterity rating: medium.

This is a scientific instrument, so every other sentence in these instructions must use the word "carefully," but anyone with normal hand to eye coordination can successfully accomplish this project.

WHAT AM I SUPPOSED TO BE CLEANING?

An aluminum tube runs from the leaf surface up through the head of the porometer's sensor clip called the diffusion path. That's the critical area, and the easiest way to get at it is to (carefully!) push out the pin on the sensor clip. Lay the pin and the bottom (sensor free) part of the clip aside. A Teflon screen covers one end of the tube. Pry it off (carefully!) with a sharp bladed knife.

How can I clean the path without harming the sensors?

Clean carefully! You can use distilled water, a little mild soap, and (if you're incredibly careful) a razor blade. Don't use solvents of any kind, including alcohol. They mess up calibration of the sensor head.

Why can't I use alcohol to swab it out?

The porometer is very sensitive. That's a good thing, but it means you have to exercise caution around solvents. The sensors on the prototype porometer were thrown out of calibration by fumes from the glue used to hold foam in the original packing case. Calibration can even be messed up by storing the sensor close to a gasoline can. You definitely don't want to attack the sensor head directly with alcohol or (heaven forbid) acetone.

Won't water mess up my relative humidity measurements?

Yes, it will. You need to open up the head and let it dry out for 24 hours after cleaning. Cleaning and drying are easier if you carefully push out the pin that holds the clip together.

The Teflon screen is very dirty. Can I clean it?

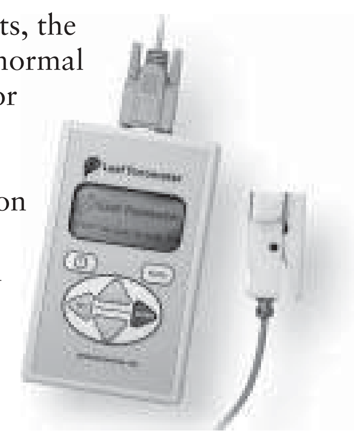
No, don't attempt this. Just pop in a replacement screen. You got five with your porometer, and if you've run out, call Decagon (1-800-755-2751) for replacements.

Anything else I should do while I have the Porometer apart?

Sure. This is a great time to inspect the rubber seals that seal the clip to the leaf when you make readings. If the seals are worn, you can peel them off and replace them with the extra seals that came with your porometer. Of you can't find spares, call Decagon at 1-800-755-2751 to request more.

All this talk about knocking the porometer out of calibration is making me nervous. Do I ever need to recalibrate?

In spite of its sensitivity to solvents, the porometer is pretty stable under normal conditions. It doesn't need daily or weekly calibrations. We do recommend that you send your porometer head in for recalibration once a year. We'll clean it out, check and recalibrate it, and even restock your case with replacement Teflon disks and seals. ■



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$20,000 Worth of Instruments Awarded

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

Acacia There are about 1300 species of Acacia worldwide, 960 of them native to Australia, where their common name is "Wattle." The Golden Wattle is Australia's national floral emblem and Wattle Day is celebrated on September 1st.

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.

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

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.

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

▸ **Asplenium** Spleen-shaped sori on the back of the spleenwort's fronds led ancient herbalists to believe that Asplenium was useful for ailments of the spleen.

The G. A. Harris Research Instruments Fellowship, *awarded annually, provides 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 Carbon 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. ■

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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