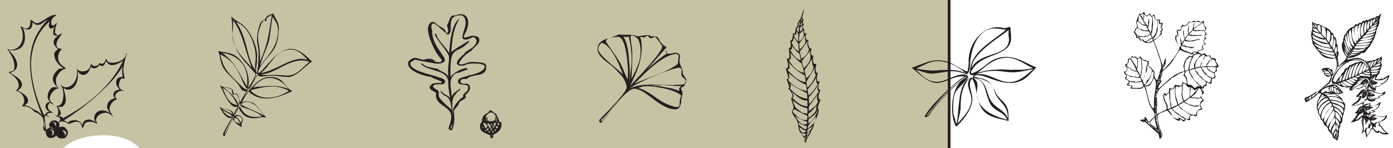

CanopyNews

Cayenne
Eugenia michelii

How the LP80 Measures Leaf Area Index

Leaf area index (LAI) is just a single number—a statistical snapshot of a canopy taken at one particular time. But that one number can lead to significant insight, because it can be used to model and understand key canopy processes, including radiation interception, energy conversion, momentum, gas exchange, precipitation interception, and evapotranspiration.

Leaf area index is defined as the one-sided green leaf area of a canopy or plant community per unit ground area. It can therefore be found by harvesting and measuring the area of every leaf in a canopy covering one unit area of ground. In 1971-, Anderson developed a less destructive method for finding LAI. Using hemispherical photographs looking upwards, she estimated the fraction of light which penetrated the canopy and applied a predictive mathematical model to approximate leaf area index.

Evaluating "fish eye" canopy pictures was pretty tedious work. An assistant would usually lay a grid over each picture and count what fraction of the squares were light. One lab tech recalls, "After too many hours looking at those pictures, I used to dream in checkers." The "checkers" evaluation allowed investigators to find the probability that a random beam of light would penetrate that particular section of canopy.

The mathematical model that converts this fraction of light into an estimate of leaf area index is relatively simple. To understand how it works, picture holding a leaf with an area of ten square centimeters horizontally over a large white square. It would cast a shadow of ten square centimeters. Then randomly place an identically sized leaf over the square. In all probability, the shadow cast would now be

►► Continued on page 2

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DECAGON
2005

Light Interception and Biomass Production

G.S. Campbell

The conversion of light energy and atmospheric carbon dioxide to plant biomass is fundamentally important to both agricultural and natural ecosystems. The detailed biophysical and biochemical processes by which this occurs are well understood. At a less detailed level, though, it is often useful to have a simple model that can be used to understand and analyze parts of an ecosystem. Such a model has been provided by Monteith (1977). He observed that when biomass accumulation by a plant community is plotted as

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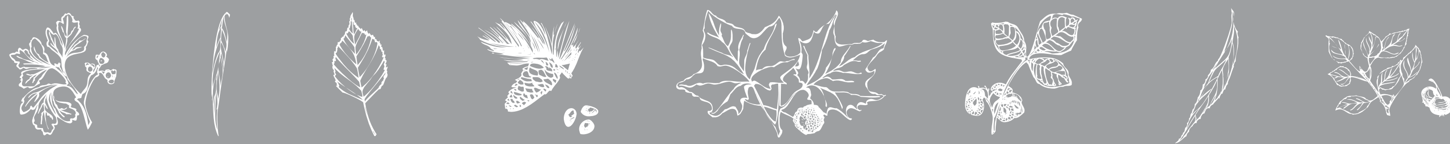
Flowering branch of
Everlasting Pea
Lathyrus venosus



How the LP80 Measures Leaf Area Index (continued from cover)

LAI Conversion

Getting a value for leaf area index is often just a point along the way. If you plan to use LAI to model environmental interactions of the canopy, measuring photosynthetically active radiation (PAR) may be a more direct route. That's because many of these models are using LAI to predict PAR in the first place. It's possible to go back the other way—to use PAR to estimate LAI. But why do that if PAR is the number you really want? You may want to evaluate whether LAI is the most useful parameter in your particular application. It is sometimes more straightforward, and usually more accurate, to simply measure intercepted PAR and use that data directly in an appropriate model. If you'd like more information about this possibility, or references to models that directly use PAR data, contact an applications engineer at Decagon. ■

Hemlock

▶▶ twenty square centimeters, although there is a small chance that the leaves might overlap. When a third leaf is added, the probability of overlap increases, and as more and more leaves are randomly placed, eventually the white square will be completely shaded, and though leaf area will increase as leaves are added, the shaded area will remain constant because all light has been intercepted.

The equation which describes this phenomenon (see sidebar for its mathematical derivation) is

$$\tau = \exp(-KL)$$

τ is the probability that a ray will penetrate the canopy, L is the leaf area index of the canopy, and K is the extinction coefficient of the canopy. If you measure photosynthetically active radiation both above and below a canopy on a bright sunny day, the ratio of the two (PAR below to PAR above) is approximately equal to τ. If you know K, you can find leaf area index (L), by inverting the equation:

$$L = -\ln \tau / K.$$

The LP80 solves this equation to find leaf area index. But there are a couple of complicating factors. In

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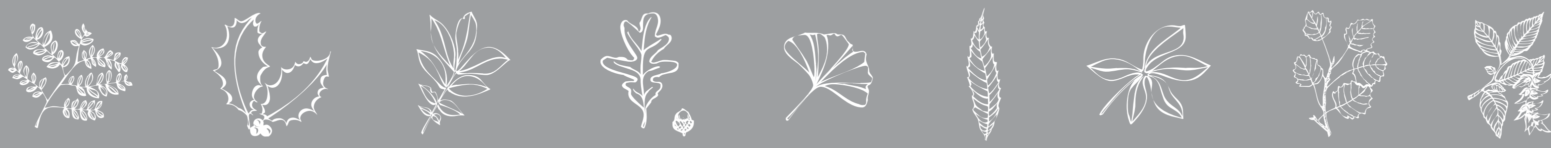


Tupelo nyssa sylvatica

constructing the model, we assumed that the leaves in our artificial canopy were horizontal and black, and that all radiation came directly from the sun. In reality, the angle of the sun changes over the course of the day, and real canopies have quite complex architecture. Also, some radiation is scattered both from leaves in the canopy and from the sky. A full model for finding the leaf area index from a measure of photosynthetically active radiation includes corrections for all of these factors.

$$L = \frac{\left[\left(1 - \frac{1}{2K}\right) f_b - 1\right] \ln \tau}{A\left(1 - 0.47 f_b\right)}$$

This equation, which is the one actually used by the LP80, adjusts for the amount of light absorbed (and not scattered) by the leaves in the term A and for the fraction light which enters the canopy as a beam (as opposed to diffuse light from the sky or clouds) in the term fb. K, the extinction coefficient of the canopy, includes variables for the zenith angle of the sun and for leaf distribution. If you specify your location and set the internal clock to local time, the LP80 calculates the zenith angle of the sun at the time of each measurement. Leaf angle distribution is assumed to be spherical unless you indicate otherwise. ■

Canopy Equation

Solving the Equation

If we divide a canopy of randomly distributed horizontal black leaves into so many layers that each layer contains an infinitesimally small fraction of leaf area (dL), the change in radiation from the top to the bottom of that layer is

$$dS_b = -S_b dL$$

In other words, the change in the average quantity of sunlight passing through this fraction of the canopy (dS_b) is equal to negative (because the amount of light decreases as leaf area increases) the average amount of radiant power per unit area (S_b) times the change in leaf area index (dL). This is a variables separable differential equation. Dividing both sides by S_b and integrating from the top of the canopy downward, we obtain

$$\int_{S_b}^{S_{bo}} \frac{dS_b}{S_b} = -\int_0^L dL$$

Performing the integration gives

$$\ln\left(\frac{S_b}{S_{bo}}\right) = -L$$

Taking the exponential of both sides gives

$$\tau = \frac{S_b}{S_{bo}} = \exp(-L)$$

S_{bo} is the radiation on a horizontal surface above the canopy; τ is the probability that a ray will penetrate the canopy, which is the same as the ratio of the beam radiation at the bottom of the canopy to the beam radiation at the top (since we assume no scattering of radiation in the canopy). For canopies with non-horizontal leaves the result is the same except L is replaced by KL, where K is the extinction coefficient of the canopy. ■

Isatis, tinctoria Woad

▲ Anderson, M.C. (1971) Radiation and crop structure. In *Plant Photosynthetic Production Manual of Methods* (eds Z. Sestak, J Catsky and P.G. Jarvis), Junk, The Hague, pp. 412-66.

NEW MINI DISK INFILTROMETER

Compact size for:

- Class room instruction.
- Field measurements with a limited water supply such as a canteen.
- Ease of use in the lab setting as well.

- Porous stainless steel—Will not rust, cleans easily, no snagging or tearing.

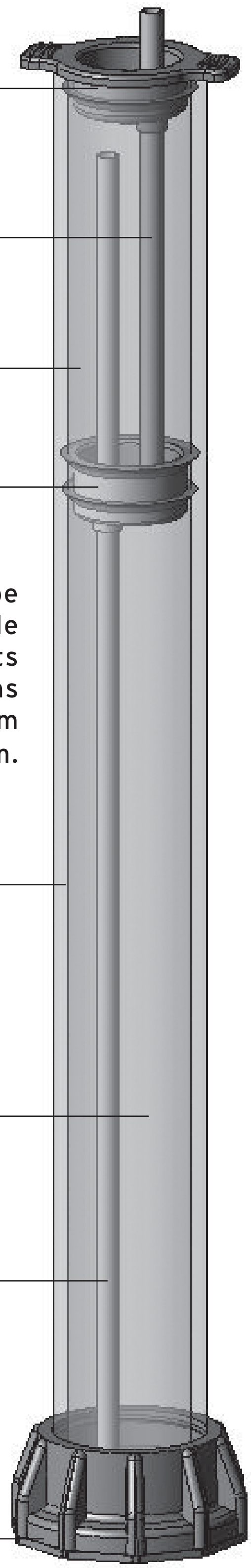
Measure hydraulic conductivity in the field more easily with Decagon's Mini Disk Infiltrometer.

The lightweight and portable minidisk infiltrometer makes the measurement of hydraulic conductivity easy, both in the field and in the lab. All you need is a small supply of water, a timer, pencil and paper, and a general knowledge of your soil texture. You simply record your infiltration rate, which is calculated as the change in water volume in the infiltrometer over time, and look up the parameters for your particular soil type in the provided table. Then, input the infiltration data and the soil parameters into the provided excel macro, and hydraulic conductivity is calculated for you.

Mini Disk Infiltrometer Specifications

Dimensions
Total Length 32.7cm
Diameter of tube 3.1cm
Size of sintered stainless steel disc
4.5cm in diameter 3mm thick.
Length of suction regulation tube 10cm long
Length of water reservoir
21.2cm
Length of air tube 28cm
Suction range
0.5 to 7cm of suction

Less cleaning, more accurate, and tougher.



- **Changing tube height in the bubble chamber permits variable suctions between 0.5 cm and 7 cm.**

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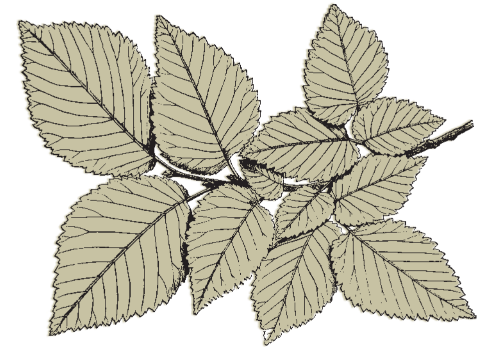


Light Interception and Biomass Production

G.S. Campbell CONTINUED FROM COVER

►► a function of the accumulated solar radiation intercepted by the community, the result is a straight line. Figure 1 shows Monteith's results.

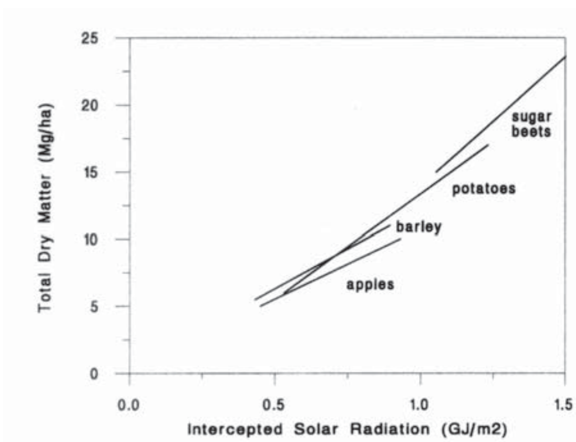


Figure 1. Total dry matter produced by a crop as a function of total intercepted radiation (from Monteith, 1977).

The mathematical model suggested by Fig. 1 is

$$A = efS_t \quad (1)$$

where A is biomass accumulation, S_t is the total solar radiation incident on the canopy, f is the fraction of incident radiation intercepted by the canopy, and e is the conversion efficiency for the canopy. For this calculation A typically has units of kg m-2 day-1. When S_t is the total solar radiation in MJ/day, e has a value of around 0.015 kg/MJ for C3 crop species. A number of experiments have shown that e is very conservative in situations where water, nutrients and temperature do not limit plant growth. Equation 1 is therefore useful for predicting maximum productivity. When stresses limit growth, it is often possible to quantify their effect either in terms of a reduction in conversion efficiency, e, or a decrease in interception, f. This allows experiments carried out under different conditions of light availability to be compared or normalized. ■

Request a reprint of "Comparison of three leaf area index meters in a corn canopy" W. W. Wilheim, K Ruwe, and M. R. Schlemmer

Published in Crop Sci. 40:1179-1183 (2000).

If you would like a free reprint of this paper, please call Decagon 800-755-2761.

DECAGON 2005 Tradeshows

European Geosciences Union
April 24–29, 2005
Vienna, Austria

International Thermal Conductivity Congress
June 26–29, 2005
New Brunswick, Canada

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, Utah

Now measure solar radiation along with soil moisture with the new Em-50.

Datalogger Specifications

Input Ports 5, with 12-bit digital resolution and 2.5V excitation on each channel
Port type 3.5mm "stereo jack" connector
Data Storage 1MB (36,800 scans on all 5 ports)
Scan Interval User-programmable from 1/minute to 1/day.
Memory type Non-Volatile Flash Data
Battery capacity 5 AA alkaline or Lithium batteries
Enclosure Weatherproof, impact and UV-resistant polymer
Enclosure rating IP45, NEMA4X
Dimensions w. 13cm x h. 20cm x d. 5cm
Operating environment -5° to 45°C, up to 100% RH
Communication Dedicated RS232 port (compatible to USB to serial adaptors), 900Mhz-2.4Ghz spread-spectrum RF on radio-equipped models
Software Interface DataTrac Lite (supplied with Em50)
Sensors Compatible only with Decagon authorized sensors
Batterylife 3+ years logging only, 3+ months with radio telemetry

◄ **Pyranometer sensor**

Now measure Solar Radiation along with soil moisture using Em-50 logger.

Sensor available June 2005

The Em-50 is the new replacement for Decagon's Em-5 logger. The Em-5 was our first low cost datalogger that was easy to use and purpose built. The Em-50 is the culmination of everything we have learned to date about the requirements for loggers for environmental research.

Datalogger Benefits

- Larger memory capacity
- Improved battery life
- Stronger logger enclosure
- Plug and play—no programming required.

► Em-50 available May 2005

New sales manager at Decagon.

T-Jay Clevenger is the new Sales Manager for the Research Agriculture Group at Decagon. When you need a price quote for an LP-80, need to place an order for a First Growth 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 work 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.

Porometer stores and displays diffusive conductance in the field.

History of the Porometer.

The first work on measuring stomatal openings started in the late 1930's with scientists like M.C. Desai, F.G. Gregory, and H.L. Pearse. These pioneers would strip the leaf epidermis, make impressions with collodion, look at infiltration with liquids and observe stomata with direct microscopic investigation.

The 1960's opened new possibilities to make measurements with the advent of the Dunmore electronic humidity sensor. This sensor was not very good in retrospect, but it helped launch the concept of the hand-held porometer with Ellis Wallihan's research and design.

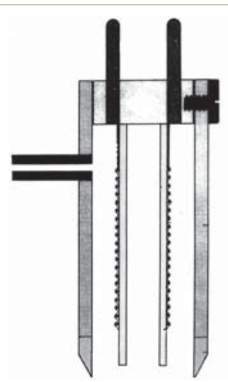
With the advent of the Vaisala fast-response capacitance humidity sensor in the 1970's another leap forward was made. At this point the commercialization of porometers by Licor and Delta-T put the measurement into the hands of researchers that could not build their own equipment. Licor's design was based on work by C. van Bavel , C. Tanner, and E. Kanemasu. Across the Atlantic, Delta-T used designs based on work by J. Monteith.

As in the past, technology progresses, and now new and improved humidity measurement technology is available that allows Decagon to release a new, low cost porometer this fall.

Decagon to release new porometer.

Handheld Steady-state Porometer
Extremely lightweight for ease in portability. The readout stores and displays diffusive conductance in the field. The head is extremely lightweight and easy to manipulate.

Release date
3rd Quarter 2005
Final Specifications to be determined



◄ Ellis Wallihan's porometer design with the Dunmore electronic humidity sensor *(circa 1960.)*

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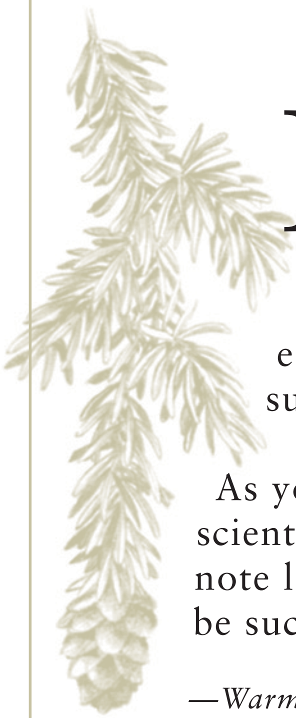
CanopyNews


Hemlock

Recently, I planted 600 Christmas tree seedlings. Before this large endeavor, I read as much as possible about planting, maintenance and pest control of Christmas trees. During the project I applied scientific principals to help increase the viability and stand establishment of seedlings. My self-education will ensure my Christmas tree "experiment" to be as successful as possible.

As you plan your research projects and teach the next generation of scientists, I hope the articles in this newsletter and our application note library will ensure that your projects and educational goals will be successful as well.

—Warm Regards, Bryan Wacker, Product Manager

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