Measuring χ Value

The LP80 makes fast, direct measurements of photosynthetically active radiation in canopies. You get instant PAR measurements when you turn it on. You also get a measurement of leaf area index – LAI. But where does this LAI measurement come from, and how accurate is it? Leaf area index is the one-sided green leaf area of a canopy or plant community per unit ground area. To directly measure LAI, you would have to measure the area of each leaf in the canopy above a unit of ground area. Because this method is both destructive and incredibly time consuming, it is rarely used.

All other measurements of leaf area index, from hemispherical photos to optical sensors, attempt to approximate this value. The LP80 finds LAI by measuring photosynthetically active radiation and converting that PAR value into leaf area index.

The LP80 uses several variables to compute leaf area index (see *How the LP80 Measures Leaf Area Index* in the 2005 issue of Canopy News for mathematical details). One of these variables – χ – describes the orientation of leaves in the canopy.

WHAT IS χ ?

χ is the "canopy angle distribution parameter." It describes the architecture of a canopy -how its leaves are oriented in space. Leaves that are distributed randomly in space are said to have a spherical distribution, meaning that if each leaf in the canopy were carefully moved without changing its orientation, the leaves could be used to cover the surface of a sphere. A canopy with spherically distributed leaves has a χ value of 1.

Many canopy architectures tend to be more horizontal (χ>1) or vertical (χ<1). Some canopy types have published χ values (see the LP80 manual for a short list). But because this value can vary from species to species, it's important to be able to approximate the value for yourself.

LAI or PAR: Who's On First?

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 mathematical models use LAI to predict PAR in their internal equations. Sometimes researchers use PAR to predict LAI, then unwittingly put the LAI number in a model that goes back the other way. 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.

It's tempting to want an exact number for χ, accurate to at least a couple of decimal places. But because of the incredible variation in canopies, this kind of accuracy is impossible to attain. Leaf area index numbers, though valuable, are always just approximations. A good χ value improves the accuracy of this LAI approximation. But even with a less accurate χ value, LAI approximations will probably be fairly accurate depending on other conditions (see Figure 1).

To approximate a χ value for a canopy, find a representative clump of canopy of equal depth and width. Then determine vertical gap fraction (τ_0) – the percentage of light to shade you see vertically through the clump – and the horizontal gap fraction (τ_{90})- the percentage of light you see horizontally through the clump. In a canopy of perfectly vertical leaves, for example, you might see about 10% light to 90 % shade horizontally- (τ_{90}) = 0.1 – and 100% light vertically – (τ_0) = 1. χ is found from the following simple equation:

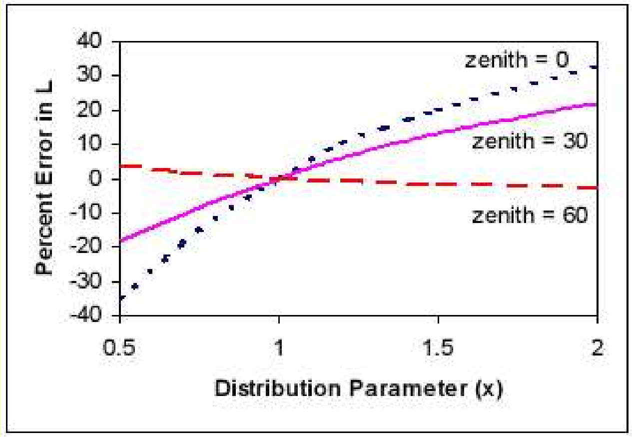
$$\chi = \frac{\ln(\tau_0)}{\ln(\tau_{90})} \quad (1)$$

Using this equation, $\chi = 0$ for a perfectly vertical canopy. If the leaves were spherically distributed, with about 10% light visible both vertically and horizontally, $(\tau_{90}) = (\tau_0) = 0.1$. Then, using this equation, $\chi = 1$. (This is, incidentally, the LP80's default χ setting.)

For practical purposes, it can be difficult to estimate the amount of light visible through a "representative clump" of the canopy. You may find it easier to make a backdrop and use it to help you analyze the canopy (we used a one meter by one meter square of colored poster board.) Find a clump reasonably typical of the canopy you are studying. The clump should include all the typical elements of the canopy - if you are studying row crops, for example, the clump should go from the center of one row to the center of the next to include the characteristic gap in the canopy that occurs between rows. Imagine dissecting the clump into a cube. To estimate τ_{90}, use the backdrop to form the backside of the cube and position yourself at the front side to make your estimate of the percent of light that is transmitted horizontally through that cubic section of canopy. To estimate τ_0, use the backdrop to form either the top or bottom of the cube and position yourself at the opposite end to estimate the percent of light transmitted vertically. Then find χ from equation 1 (shown above).

Check the reasonableness of your estimation by remembering that the χ values for more horizontal canopies are greater than one while those of more vertical canopies are less than one. You can specify the χ value for the canopy by selecting "Set x" in the Setup menu of the LP80. Using this method, you should be able to estimate a chi value that will minimize uncertainty in the final leaf area index value.

Figure 1



This figure shows the percent error in the LP80 calculation of L if the LP80 is set to $\chi = 1$ and the actual distribution parameter of the canopy is the value shown in the figure. It assumes full sun ($f_b = 0.8$). Note that the error depends on the zenith angle of the sun. Most measurements will occur with zenith angles greater than 30 degrees, so the error in full sun, with no canopy distribution parameter information, is at worst 20%. This error decreases with decreasing values of f_b, and becomes zero when f_b is zero. If the canopy distribution parameter can be estimated with an accuracy of 10% or better, the error in LAI will be 5% or better even at zenith angle of zero. Uncertainty in the distribution parameter is therefore not likely to contribute significantly to uncertainty in LAI.

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