Calculation of LAI and Interception of Short Canopies from First Growth Cover Measurements

Gaylon S. Campbell, Ph.D.

First Growth was designed to measure the green cover of short, sparse plant canopies. The camera measures the fraction of its field of view that is green. If the camera views a vegetated surface from a position normal to the surface, then the fraction it measures is the green cover, *c*. With certain assumptions, this value can also be used to estimate the leaf area index, *L*, and the fractional light interception for a plant canopy. For short, sparse canopies, this approach is one of the few indirect methods available.

The fraction of incident light transmitted through a canopy can be calculated from

$$\tau = \exp(-KL_e) \qquad (1)$$

where K is the extinction coefficient for the canopy and L_e is the effective leaf area index. The extinction coefficient depends on the angle distribution of leaves in the canopy and on the angle with which the light intercepts the canopy. We refer here to the effective leaf area index. This is the leaf area index of randomly distributed leaves that would have the same transmission value as observed. If the leaves in the canopy are actually randomly distributed in space, then the actual leaf area index and the effective leaf area index are the same. If the leaves are clumped, then the actual leaf area is larger than L_e. This effect will be quantified later.

The probability of light getting through the canopy is the same, whether the light is coming from the sun to the soil or the soil to the camera lens, so, we can use a First Growth picture of a canopy to get transmission:

$$\tau_n = 1 - c \qquad (2)$$

where c is the fractional green cover registered by First Growth. The subscript n on t is to indicate that this is the transmission at normal incidence. From this value of t_n and eq. 1, we can compute effective leaf area index if we know a value for K:

$$L_e = -\ln(\tau_n)/K_n \qquad (3)$$

It is also possible to compute the canopy transmission for incident light at other angles, and the daily interception of light from this measurement. The details of these calculations can be found in the AccuPAR user manual (available online at www.decagon.com/instruments/agdownload.html).

Finding K_n

The canopy extinction coefficient is determined by the angle distribution of leaves in the canopy and the incidence angle of the radiation. The equation describing this is

$$K = \frac{\sqrt{x^2 + \tan^2\theta}}{x + 1.744(x + 1.182)^{-0.733}} \qquad (4)$$

where x is the leaf angle distribution parameter and ? is the angle of incidence of the radiation (vertical is zero). If the leaves were all vertical, x would have a value of 0. If they were all horizontal, x would be infinite. A typical angle distribution, with leaves having a range of inclination angles, gives a value of x around 1.

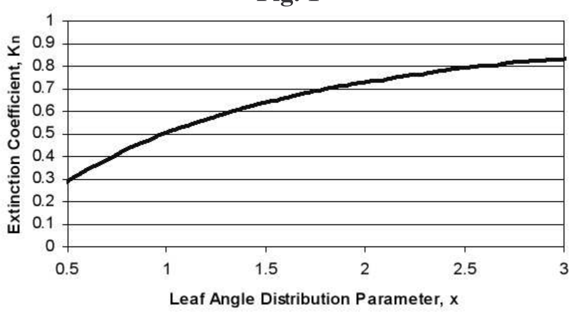
The value of x is the ratio of the vertically projected canopy element area to horizontally projected canopy element area. One could find this by taking a representative individual plant or branch and determine the shadow area with light coming directly down from above and horizontally from one side. Table 1 in the AccuPAR manual lists experimentally determined values of x for a range of crop species.

At normal incidence, θ = 0, so

$$K = \frac{x}{x + 1.744(x + 1.182)^{-0.733}} \quad (5)$$

Equation 5 is plotted in Figure 1.

Fig. 1



For x values ranging from 1 to 2, K_n varies from 0.5 to 0.7. A mid-range value of Kn of 0.6 would therefore be a good approximation for a wide range of canopies, and would result in relatively small errors in estimating L_e.

Non-Uniform Canopies

A basic assumption in deriving eq. 1 is that the leaves in the canopy are randomly distributed in space. With sparse canopies (the type of canopies First Growth is made for), the leaves typically are not uniformly distributed in space. Often the canopy is a row of plants, with bare soil on each side. For a canopy like this, one might assume that the leaves are randomly distributed within the row. The bare soil has no leaves. If the fractional area between rows (bare; with no vegetation) is b, then we can calculate the transmission for the canopy covered (row) area as

$$\tau_r = \frac{\tau - b}{1 - b} \quad (6)$$

where t is obtained from eq. 2 and the First Growth image. Obviously, b must be smaller than τ for this equation to make sense. Equation 3 can be used with this new transmission value to obtain the leaf area index of the row, L_r. That value will be higher than the actual LAI, which is the area of leaf per total soil area. The actual LAI can be computed as

$$L = (1 - b)L_r \quad (7)$$

These equations don't give much of a feeling for how much error is involved in ignoring these clumping corrections. When trying these equations in a spreadsheet, with LAI values around 0.1, differences between L and L_e increased from 3 to 35% as b changed from 0.5 to 0.9. It appears that this correction is important if one wants to determine true LAI. A visual estimate of b, just from the photograph of the crop should be adequate for determining b.

Framing Issues

To get accurate measurements of ground cover and LAI, it is important to have a representative field of view in the picture. In a row crop, for example, the picture should extend from half way between one set of rows to half way between the next. The idea is that the whole field could be made up of multiples of the area photographed. If this does not give sufficient resolution, a smaller area containing the row can be photographed, and the cover in that area multiplied by the ratio of the width of the area photographed to the distance between rows.

Conclusion

The First Growth can be used effectively to determine LAI of sparse canopies. For short canopies, this is one of a very few non-destructive methods available for measuring LAI and light interception. The method is relatively insensitive to canopy structure. Straightforward corrections are available for clumping effects.

Decagon Devices, Inc.
2365 NE Hopkins Court
Pullman, WA 99163 USA
support@decagon.com
www.decagon.com

