DECAGON DEVICES

Application Note

Use of the AccuPAR Ceptometer to Quantify Effects of Riparian Vegetation Removal on Stream Energy Balance

When the vegetation along a stream bank is removed, the solar load on the stream increases. This results in increased stream water temperature. Elevated stream temperatures degrade freshwater habitats, shifting species composition, and often endangering some of the species that live in the stream. An increasing awareness of this problem has led to the creation of riparian strips to shade streams when timber is harvested or prescribed burns are undertaken. The challenge is to know how much shade is needed, and how large to make the strips.

Both empirical and physically based models are available for designing the strips. The physically based models use an energy balance for a section of the stream. The energy balance considers all inputs and losses of heat for the stream. The change in temperature is the difference between inputs and losses divided by the heat capacity of the water. The inputs are solar and thermal radiation. Losses are thermal radiation and latent heat. Sensible heat can be either an input or a loss, depending on whether air temperature is above or below stream temperature. Inputs to the stream from ground water can also be inputs or losses, depending on their temperature relative to the stream temperature. Of these, the variable most susceptible to manipulation is the solar radiation, through changing the amount of shade. Manipulating solar radiation also changes the thermal radiation. Incoming thermal radiation from vegetation is greater than incoming radiation from the sky. Thus, increasing cover decreases solar input, but increases thermal input. Since the change in solar radiation is the larger of the two, decreasing solar input reduces stream heating, even though it also increases incoming thermal radiation. Our purpose here is not to present the model. A number of model sources, which give additional information, are cited below. We want to focus on the measurement of solar (and thermal) inputs of radiation to the stream. If the total solar radiation above the canopy is S_o , then the radiation at the stream surface is :

$$S = \tau S_o \tag{1}$$

where *t* is the canopy transmission coefficient. The value of t depends on the leaf area index of the canopy above the stream, the angle of the radiation incident on the canopy, the angle distribution of leaves in the canopy, and spatial distribution of canopy elements. Harvesting or burning the canopy along a stream bank reduces the leaf area index and changes the spatial distribution of canopy elements. If we can measure the effect of management on *t* will have quantified the main effect of management on stream temperature.

The AccuPAR model LP80 makes a direct measurement of τ. It does this by taking a ratio of radiation measured under the canopy to radiation incident on the top of the canopy. The LP80 is particularly well suited to this type of measurement because it measures light at 80 locations with a single button-click. Light under plant canopies has high spatial variability, so many measurements are required for acceptable accuracy. Several button presses, with the probe in different locations, gives a good estimate of below canopy radiation.

Two questions now arise. First, the measurement of τ is at a particular location and time. How does this measurement relate to the energy balance over whole days and months? The second relates to PAR vs. total solar radiation. Since PAR is attenuated more strongly than total radiation by plant canopies, can one be determined from the other? Taking the second question first, Campbell and van Evert (1994) related values of intercepted solar and PAR radiation. Figure 1 shows a similar relationship to theirs, but in terms of transmitted solar and PAR. Note that at total transmission or total interception the two are equal. At 50% transmission of PAR, the transmitted solar is around 60%. At 10% transmission of PAR the transmission of solar is around 20%. The ratio of transmitted solar to transmitted PAR can be computed from

$$\frac{\tau_s}{\tau_p} = \exp\left[-\left(\sqrt{a_s} - \sqrt{a_p}\right)KL\right] \tag{2}$$

where a is the absorptivity of leaves for either solar or PAR, K is the extinction coefficient of the canopy, and L is the canopy leaf area index. Typical values

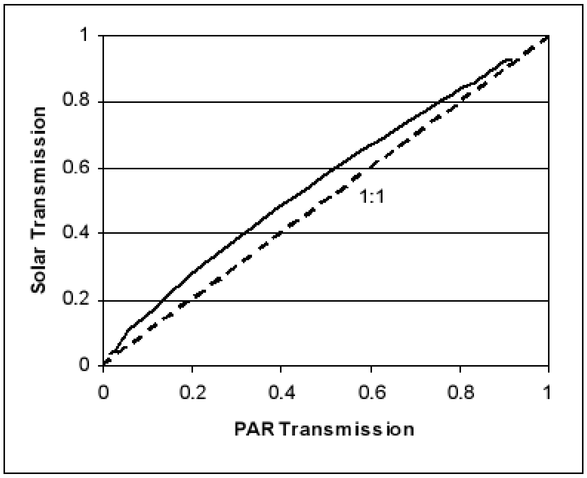

Figure 1 Solar transmission for a plant canopy as a function of PAR transmission. The dashed line is 1 to 1.

for a_s and a_p are 0.5 and 0.8. These are the values used for Fig. 1. Using either Fig. 1 or eq. 2 it is easy to convert PAR transmission from the LP80 to total solar transmission.

We turn now to the question of how a transmission measurement at a single time and location relates to the values needed for computing the energy balance of a stream. One could make repeated measurements throughout the course of a day and average the values. This would be a lot of work. An easier way would be to compute the daily value from measurements at a single time of day.

Two possible situations need to be considered. First is one for fairly small streams, such that the shading of the stream is about the same as the shading of areas around the stream. In other words, the canopy in the vicinity of the stream can be assumed to be randomly distributed in space. Measurements with the LP80 give the leaf area index of the canopy. If we assume that, over the course of a day, the transmission of solar and diffuse sky radiation are similar, then the daily solar input to the stream is the diffuse transmission coefficient for the canopy multiplied by the solar radiation incident on the canopy. The diffuse transmission coefficient can be calculated from

$$\tau_\mathrm{d} = \exp\left(-K_d L\sqrt{a_s}\right) \qquad (3)$$

where K_d is the diffuse transmission coefficient for the canopy. The value of K_d varies with LAI and leaf angle distribution, but a value typical of stream heating conditions is 0.85 (Campbell and Norman, 1998). Thus, the value of L obtained from the LP80 is used, along with known values of extinction coefficient and leaf absorptivity to find the diffuse transmission coefficient. This is used with measured or modeled solar radiation values to get solar input to the stream. Logging or burning decreases L and thus increases the solar input.

The second situation is one where the stream width disrupts the canopy sufficiently that a random distribution of canopy elements can't be assumed. This is a challenging situation for modeling or measurement. An add-on to a GIS is available for doing some of these calculations (Rich et al., 1995). Measurements could also be made over the course of a clear day at representative spots across and along the stream. A weighted average of these, weighted by the sine of the solar elevation angle, gives the diffuse transmission coefficient. This, again, is used with solar radiation measurements or estimates to get solar input to the stream.

Conclusion

When vegetation is removed from stream banks, the increased input of solar energy to the water can cause significant stream warming. Leaving buffer strips along stream banks can mitigate this effect. AccuPAR LP80 measurements can be used to quantify the changes that have occurred through management, and can provide inputs to models of stream temperature.

References

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