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LETTER TO THE EDITOR

Comment on "Sap flow measurements by a single thermal dissipation probe: exploring the transient regime" — Ann. For. Sci. 66 (2009) by Mahjoub et al. and "Sap flow measurement by a single thermal dissipation probe in transient regime: implementation of the method and test under field conditions" — Ann. For. Sci. 1-9 (2012) by Masmoudi et al.

Maurits W. Vandegehuchte · Kathy Steppe

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1 Introduction

Given its high popularity, further research to improve the practical and theoretical issues concerning the thermal dissipation probe (TDP) of Granier (1985; 1987) should be encouraged. Recently, large improvements have been made by taking into account natural temperature gradients and assessing new calibration factors (Do and Rocheteau 2002a; Do and Rocheteau 2002b; Isarangkool Na Ayutthaya et al. 2009; Reyes-Acosta et al. 2012; Steppe et al. 2010). Besides, Do et al. (2011) suggested to further optimize the TDP design by applying only a single needle with a cyclic heating scheme. However, these improvements still require zero flow conditions to assess the influence of heat conduction in the measured tree and the corresponding temperature difference it induces. This is generally considered a weakness of the TDP as zero flow conditions are difficult to ensure without destructive measurements (Lu et al. 2004; Snyder et al. 2003). Mahjoub et al. (2009) overcame this flaw by relating sap flux density to a defined thermal index using temperature of the probe measured at initial, final, and intermediate times after switching the heater on and off. Although we acknowledge the benefits of excluding zero flow measurements from the method, we would like to point to the species specificity of their method, implying their presented calibration relationships for *Olea europaea* L. are not strictly applicable for other species.

1.1 Species-specific conductive exchange coefficient

Similar as in the original work of Granier (1985), Mahjoub et al. (2009) describe heat transfer φ (watts) from the probe to the wood as:

$$\phi = h(q_s)(T - T_w) \tag{1}$$

with T the temperature of the probe (degree kelvin), T_w (degree kelvin) the average temperature of the wood around the probe (assuming a homogeneous temperature field), and h the exchange coefficient (watts per degree kelvin), expressed as a function of sap flux density q_s (cubic meters per square meter per second):

$$h(q_s) = h_0\left(1 + \alpha {q_s}^{\beta}\right) \tag{2}$$

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Contribution of the co-authors Prof. dr. ir. Kathy Steppe is head of the Laboratory of Plant Ecology and supervisor of the first author during his Ph.D.

M. W. Vandegehuchte (✉) · K. Steppe
Laboratory of Plant Ecology, Faculty of Bioscience Engineering,
Ghent University,
Coupure links 653,
9000 Ghent, Belgium
e-mail: maurits.vandegehuchte@ugent.be

K. Steppe
e-mail: kathy.steppe@ugent.be

with α and β two empirical coefficients (β assumed equal to 1 (Granier 1985)) and h_0 the exchange coefficient at zero flow, representing the conductive part of the heat transfer. This h_0 will, hence, be dependent on the thermal diffusivity of the sapwood, a parameter known to be variable for different species and even within species as it is dependent on dry wood density and moisture content (Green et al. 2003; Hirose et al. 2005; Skaar 1988). In their derivation, Mahjoub et al. (2009) obtain the following relations for the cooling and warming cycle, respectively:

$$\frac{1}{t_i}\ln\left(\frac{T_0-T_\mathrm{w}}{T(t_i)-T_\mathrm{w}}\right)=\frac{1}{C}h_0(1+\alpha q_s) \tag{3}$$

$$\frac{1}{t_i}\ln\left(\frac{T_\mathrm{e}-T_0}{T_\mathrm{e}-T(t_i)}\right)=\frac{1}{C}h_0(1+\alpha q_\mathrm{s}) \tag{4}$$

with T_0 the temperature of the probe just before switching the current off or on, respectively, T_e the equilibrium temperature of the probe when the stationary regime is reached after switching on the heater, and C the probe heat capacity (joules per kelvin). Setting the left-hand side of Eqs. 3 and 4 equal to $I(t_i)$, these equations become:

$$q_\mathrm{s}=\frac{C}{\alpha h_0}I(t_i)-\frac{1}{\alpha} \tag{5}$$

or

$$q_\mathrm{s}=aI(t_i)+b \tag{6}$$

with a and b mentioned as constant coefficients by Mahjoub et al. (2009). However, as coefficient a comprises h_0 which is species-specific, also a will be species-specific. This was partly avoided in the original method of Granier (1985) as h_0 was evaluated during zero flow conditions. Similarly, Masmoudi et al. (2012) recently adapted the single probe method of Mahjoub et al. (2009) by normalizing Eq. 6 to obtain a normalized index K_t:

$$K_t(t_i)=\frac{I(t_i)-I_0(t_i)}{I_0(t_i)}=\frac{q_\mathrm{s}}{-b} \tag{7}$$

As correctly stated by Masmoudi et al. (2012), this normalized index rules out species dependency as parameter a which includes h_0 is now eliminated, even though recently Wullschleger et al. (2011) have shown that even the original method of Granier (1985) was slightly dependent on thermal conductivity. This will, hence, also be the case for the newly proposed method of Masmoudi et al. (2012). Therefore, it is advisable to test this improved method for several species. Moreover, by applying a normalized index, the original objective of preempting zero flow measurements is ignored.

As the calibration procedure of Mahjoub et al. (2009) only considered a single species, *O. europaea* L., the authors were aware that it would be relevant to check if the calibration relationships they obtained are independent of the medium used. However, from a theoretical point of view, we are convinced that this will not be the case. Hence, to our knowledge, no continuous method based on the method of Granier (1985) exists that is not species-specific and does not require zero flow measurements. Moreover, as recent developments indicate that even with the inclusion of zero flow measurements these Granier (1985) methods remain species-dependent (Wullschleger et al. 2011), it is advisable to perform specific calibrations for each species to derivate the correct empirical coefficients.

2 Conclusions

Further improvement of the TDP method seems necessary to ensure more accurate sap flux density determinations. While Mahjoub et al. (2009) did an admirable effort to exclude zero flow measurements, a current weakness of the method is that they overlooked the influence of the conductive heat coefficient, making their calibration coefficient species-specific and, hence, disregarding the original aim of Granier (1985). The only solution to eliminate species specificity seems to be to normalize the applied index as done by Masmoudi et al. (2012). This, however, necessitates zero flow measurements, ignoring the original objective of the method.

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