DETECTING CITRUS TREE WATER STATUS BY INTEGRATING HYPERSPECTRAL REMOTE SENSING WITH PHYSIOLOGICAL APPROACHES IN A WATER FLOW – STORAGE MODEL

S. Dzikiti [1*], S. Verreynne[1], A. Strever[2], J. Stuckens[3], R. Swennen[3], W.W. Verstraeten[3], P. Coppin[3]

1. Department of Horticultural Science, Stellenbosch University, South Africa
2. Department of Viticulture and Oenology, Stellenbosch University, South Africa
3. M3-BIORES Faculty of Bioscience Engineering, Katholieke Universiteit Leuven, Belgium

Abstract

Timely detection of drought stress is crucial for optimal fruit production and remote sensing offers this possibility. Although remotely sensed spectral indices for detecting drought stress have been developed for other crops, little is known about the suitability of such indices to detect stress in citrus trees. In addition, most of the spectral indices are based on correlations with various measures of plant water content e.g. the relative water content (RWC) and the equivalent water thickness (EWT). Few attempts to directly relate plant water potential with spectral indices also exist but with poor correlations in the typical water management levels in orchards. Improved correlations between water potential and spectral measurements only emerge when severe drought stress has been imposed [1,2]. From a horticultural perspective, water potential e.g. predawn leaf or midday stem (xylem) water potential, rather than water content is a more practical drought stress indicator which fruit growers are accustomed to. Thus identifying spectral indices that yield high correlations with water potential is a priority although indirect methods e.g. use of models that use remote sensing data to reliably estimate plant water potential should also be considered. In this study we attempt to integrate a hydraulic model of water flow and storage with a radiative transfer model – PROSPECT to derive the stem water potential of citrus trees. Reasons why direct remote sensing of water potential has so far proved problematic are unclear. From a physiological perspective, plant water content and plant water potential are not linearly related quantities, being linked by the plant capacitance which itself is variable and complex to characterize [3]. Thus spectral bands that correlate strongly with water content do not necessarily accurately describe the dynamics of plant water potential. In our proposed approach, water flow into and out of the tree crown is driven by the water potential gradients across resistances Rx and Rs. The resistance Rx is the xylem resistance of the transpiration stream which we assume to be a constant. Rs is the crown water storage resistance which determines the efficiency of water exchange between the crown water storage pools and the xylem. When water loss from the crown (transpiration) exceeds water uptake into the crown, water is withdrawn from the crown storage pools to meet the transpirational demand. This depletes the

crown water storage reserves e.g. in the case of stressed trees. The converse happens (recharge of the crown water storage reserves) when water supply to the crown exceeds transpiration. The change in the crown water storage can be detected using remote sensing techniques and is then used in the hydraulic model to derive the stem water potential rather than water content as the output. Because of the non – steady flow of water into the crown of the trees, we define a plant capacitance (C) which is a measure of the ability of the tree crown to store water. In our proposed approach, the hydraulic constants Rx, Rs and C are determined by model calibration using sap flow measurements at stem and branch levels and the corresponding stem water potentials. Plant material used for model calibration are 25 young potted Satsuma Mandarin citrus trees subjected to different drought stress regimes. Using transpiration and leaf reflectance as the only inputs, the model can potentially derive the stem water potential even in the typical water management levels for orchards with changes in crown water content determined using an inversion of the PROSPECT model and the ratio of the leaf reflectance at 1070 and 1340 nm. The ratio of the reflectance at these two wavelengths and the water content per unit leaf area (EWT) gave an R^2 of 0.80 for the Satsuma citrus trees. Model development is still in progress and preliminary results of the model validation on six different citrus cultivars subjected to different drought stress regimes will be presented.

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