ON THE PREDICTIVE MODELING OF VISIBLE LIGHT INTERACTION WITH FRESH AND ENVIRONMENTALLY STRESSED MONOCOTYLEDONOUS LEAVES

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Plants are essential resources on which all human and animal life depend. Accordingly, they are among the most investigated remote sensing targets, and the measurement and modeling of their foliar optical properties are object of extensive research in remote sensing and related fields [1, 2, 3]. It has also been recognized that plant leaves are complex systems whose growth and development are regulated by an array of photobiological processes and environmental factors. To understand and predict their responses to environmental changes, scientists are increasingly employing computer simulations, or *in silico* experiments [4]. In alignment with this trend, a number of foliar optical models have been applied to the study of photosynthesis [5] and to the assessment of leaf water content [6].

Due their increasing global demand (used not only for food, but also for fuel production), monocotyledonous C_4 plants, such as corn (*Zea mays* L.; maize) are regularly becoming the focal point of studies involving the impact of abiotic stress factors on crop photosynthetic efficiency [7]. Clearly, the availability of simulation tools specifically designed for these plants can contribute to expand the current understanding about their tolerance to less favorable environmental conditions. Furthermore, these tools can be used to assist the investigation of open questions involving their physiological responses to changes in water soil levels and the effects of limited water availability on their growing process [8]. From an agricultural and ecological point of view, one of the key benefits of employing such "virtual" experiments is that they can be performed rapidly to determine the tradeoffs *in silico* of different means for increasing water use efficiency of these crops given a set of possible environmental conditions [9].

Recently, a light transport model, namely the ABM-U (algorithmic BDF (bidirectional scattering distribution function) model for unifacial leaves), was specifically designed to simulate light interactions with monocotyledonous (unifacial) leaves [10, 11]. Its results showed good qualitative and quantitative agreement with measured data with respect to the infrared domain. In this paper, its predictability in the visible (photosynthetic) domain is assessed along with its applicability to the study of processes relating nutrient and water stress to light absorption in this domain. As mentioned by Carter & Knapp [12], this is the region of the light spectrum where foliar spectral signatures are altered by abiotic stress factors more consistently.

Initially, the ABM-U is employed to compute the directional-hemispherical reflectance and transmittance profiles of turgid corn leaves. These profiles are quantitatively and qualitatively compared to measured data to evaluate the fidelity of the simulations. The root mean square error values obtained for the modeled reflectance and transmittance curves with respect to the measured curves were below 0.01, which indicates a high level of fidelity, specially considering that values below 0.03 are usually associated to good spectral reconstruction in remote sensing of vegetation [13]. Simulations are then performed to verify the model predictive capabilities with respect to the effects of nutrient deficiency. The results of these simulations are also qualitatively compared to experimental results reported in the literature [14, 15], and clearly depict the changes observed in the actual experiments. The model predictive capabilities are further demonstrated through the simulation of apparently conflicting reflectance profiles resulting from experiments involving corn specimens under moderate water stress (in which foliar pigment contents are not affected) and neutral illumination conditions. In these experiments [16, 17, 18], *in vitro* (through air drying) and *in vivo* (by withholding water from the soil) water reduction procedures were applied to the specimens, and their directional-hemispherical reflectance curves were measured. While monotonically lower directional-hemispherical reflectance values were observed for the *in vivo* water stressed specimens in comparison to values obtained for control specimens, monotonically higher values were observed for *in vitro* water stressed specimens. The results of the simulations are completely consistent with the experimental observations in both cases, and they suggest that the lower values obtained for the *in vivo* water stressed specimens may result from an intensification of light detour effects [19] in their foliar mesophyll tissue. Since these effects depend on the distribution of chloroplasts in this tissue, the paper closes with a concise examination of foliar adaptive mechanisms that can affect the intracellular arrangement of these organelles.

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