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The effect of canopy structure on photochemical reflectance signal

Matti Mõttus[1] and **Miina Rautiainen**[2]

[1]*Department of Geosciences and Geography, PO BOX 64, FI-00014 University of Helsinki,*
[2]*Department of Forest Sciences, PO BOX 27, FI-00014 University of Helsinki, Finland*
**correspondence:* matti.mottus@helsinki.fi

Highlights: We measured the angular distribution of spectral scattering properties of Scots pine shoots. We were able to scale the photochemical reflectance index (PRI) between two canopy structural levels using photon recollision probability. We found non-negligible anisotropy in shoot PRI possibly caused by reflectance of the needle wax coating.

Keywords: photon recollision probability, canopy structure, PRI, Scots pine

Leaf-level photosynthetic efficiency can be estimated by measuring leaf reflectance at 531 nm. This spectral region reveals physiological adaptations aimed at coping with excess photosynthetically active radiation: interconversion of the xanthophyll cycle pigments, and reversible chloroplast conformation changes. Thus, including for reference an additional wavelength (570 nm) where the interconversion should have no effect as a reference, Gamon et al. (1992) proposed the photochemical reflectance index (PRI) to monitor plant functioning. Unfortunately, at the level of a vegetation canopy, the PRI signal conveying information on leaf photochemical processes is distorted by multiple interactions within the canopy and variations in illumination and viewing geometry. Only canopy structural models which can account for multiple photon-vegetation interactions and take into account angular effects in radiation scattering can provide a means of retrieving leaf-level PRI from canopy-level remote sensing data.

We present a mathematical model for scaling normalized difference vegetation indices (such as PRI) between different vegetation structural levels. The model is based on the novel concept of photon recollision probability which allows for a physical and robust parameterization of the structure of a vegetation canopy. To validate the model, we used spectral measurements of ten Scots pine (*Pinus sylvestris* L.) shoots made from many viewing directions. Next, we scaled the needle-level PRI values to the level of a shoot using the photon recollision probability value calculated from measurements of shoot geometric properties. Finally, we analyzed the angular dependence of PRI and compared it with the shoot scattering directionality model proposed by Mõttus et al. (2012).

We found that the approach based on photon recollision probability can reasonably well scale PRI between the two structural levels. However, this model cannot predict the considerable angular variation in shoot-level PRI. Using previous knowledge on the general scattering properties of pine shoots, we found indication that the angular variation in PRI signal can be attributed to specular scattering of the wax coating on needles. These results provide a strong basis for further development of accurate models for coping with dependence of canopy-level PRI on view and illumination conditions as well as scaling the measured signal between different levels of canopy structure.

LITERATURE CITED

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