RAMIS

A biophotonic physiological plant sensor

(Radiomètre portatif de mesure *in situ*)

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Description

RAMIS is a biophotonic physiological plant sensor which measures the water, dry matter, and chlorophyll content of plant leaves. It was developed in the Laboratoire Environnement et Développement of the University of Paris 7 – Denis Diderot.

How does it work?

RAMIS is a prototype based on the interaction of the electromagnetic radiation, i.e. the transmittance, with a plant leaf, i.e. the absorption of the leaf biochemical constituents and the scattering within the leaf due to its anatomical structure.

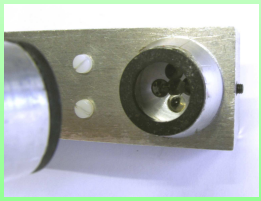

Figure 1: Light source made of five light emission diodes at 656, 721, 843, 937 and 1550 nm.

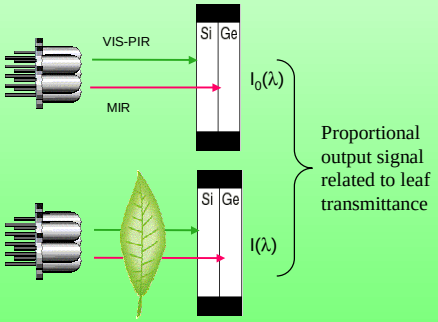

Figure 2: Light sensor made of a double layer Si/Ge photodiode sensitive to the 500 nm to 2000 nm range.

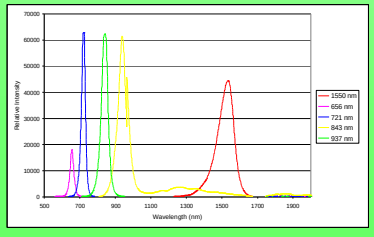

Figure 3: Distribution of the spectral emission from the RAMIS source of photodiode array.

In order to determine the leaf biochemical contents using **RAMIS**, we shall consider the spectral emission function of the diodes (source) and the filter function of the photodiode (detector). The characteristics of the optoelectronics components have been chosen according to the leaf optical properties.

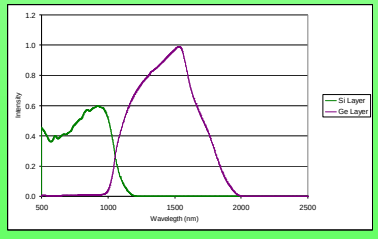

Figure 4: Distribution of the spectral response of the Si/Ge sensor from RAMIS.

Physical model

The commercial devices based on the same principle (e.g., SPAD and CCM series) only determine the leaf chlorophyll content in an semi-empirical way. **RAMIS** uses a radiative transfer model, PROSPECT, to determine the leaf biochemistry in a physical way.

PROSPECT computes the hemispherical reflectance (R) and transmittance (T) of plant leaves of different anatomical structures from 400 nm to 2500 nm. The knowledge of the specific absorption coefficients of the leaf constituents is an important issue in that wavelength range.

The **RAMIS** transmittance has been simulated with PROSPECT by varying the model input parameters and, in inversion, a neural network algorithm has been implemented to estimate the leaf equivalent water thickness C_w, leaf mass per area C_m, and chlorophyll concentration C_{ab}. **RAMIS** proves to perform well in the determination of these constituents.

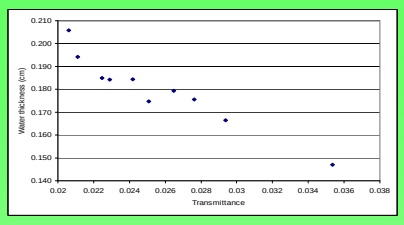

Figure 5: Relationship between the transmittance of the leaf measured by **RAMIS** at 1550 nm and the leaf equivalent water thickness (*Tradescantia fluminensis 'variegata'*)

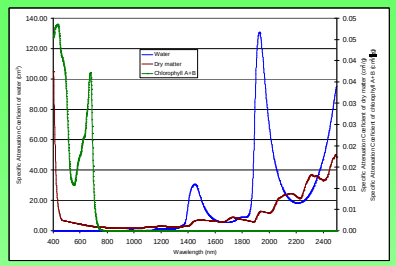

Figure 6: Specific absorption coefficient of water, dry matter and chlorophyll.

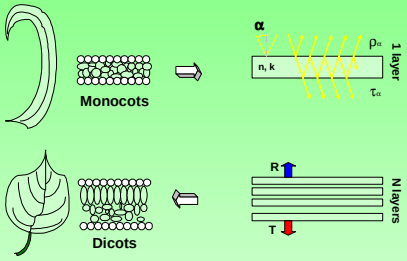

Figure 7: Optical leaf model of light interactions.

Applications

The **RAMIS** prototype allows to perform accurate analytical measurements of physiological leaf variables. It can be used to validate satellite products at the canopy level for different kinds of applications (environmental pollution, precision agriculture, fire risk assessment, ecosystem research).

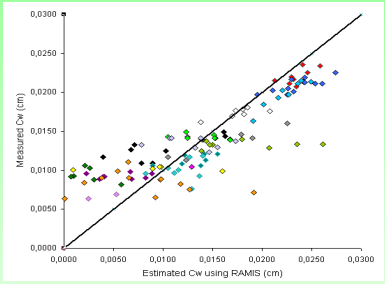

Figure 8: Estimation of leaf equivalent water thickness using RAMIS (after Vendola, 2006)

References

• J.-P. Frangi, S. Jacquemoud, G. de Rosny, B. Equer, P. Roca I Cabarrocas, R. Vanderhagen (2003), *Dispositif et procédé de radiométrie pour déterminer in situ le contenu biochimique de feuilles, et appareil portatif intégrant ce dispositif*, brevet INPI n°01 09334.
• G. Pavan, S. Jacquemoud, L. Bidel, C. Francois, G. de Rosny, J.-P. Frangi (2004), RAMIS: A new portable field radiometer to estimate leaf biochemical content. *7th ICPA Int. Conf. on Precision Agriculture and Other Precision Resources Management, 25-28 july 2004, Minneapolis, USA.*
• *Environmental Innovative Technology Awards 2006 11th Edition. Caractéristiques biochimiques de feuilles. Winners:* J.-P. Frangi, S. Jacquemoud, G. de Rosny.

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