MODELING LEAF OPTICAL PROPERTIES USING A RADIATIVE TRANSFER MODEL

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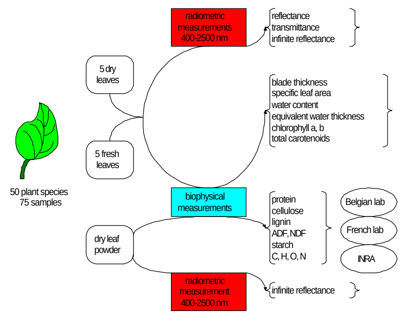
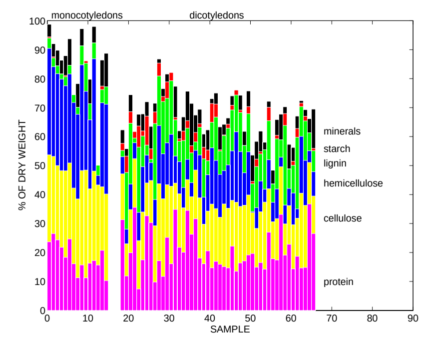
GOAL: to simulate the leaf spectral reflectance and transmittance as a function of the leaf biophysical characteristics

MODELING LEAF OTPICAL PROPERTIES

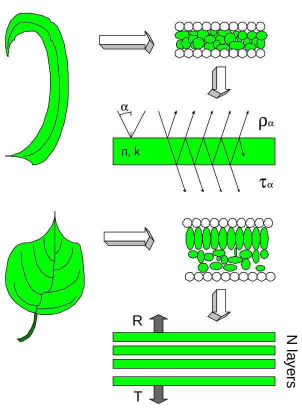
- ray tracing models: detailed description of the leaf internal structure (Allen et al., 1973; Kumar and Silva, 1973; Brakke et al., 1989; Govaerts et al., 1995)
- stochastic models: Markov chain (Tucker and Garatt, 1977)
- radiative transfer models: the leaf is considered as a slab of diffusing and absorbing material (Allen and Richardson, 1968; Allen et al., 1969; Jacquemoud and Baret, 1990; Fukshansky et al., 1991; Yamada and Fujimura, 1991; Conel et al., 1993...)

THE EXPERIMENT

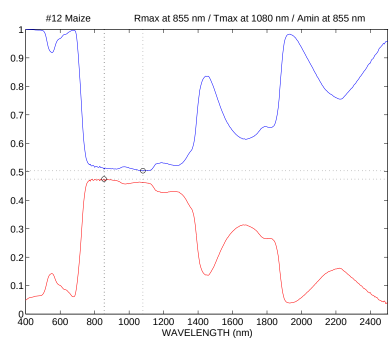




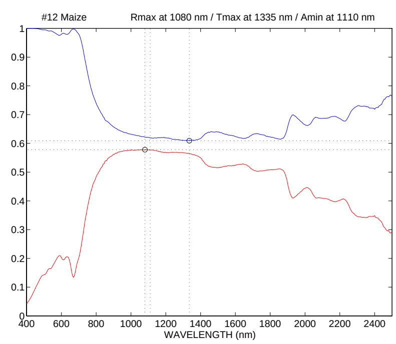
CONSTRUCTION OF THE PROSPECT MODEL



① **Estimation of the structure parameter N at 3 wavelengths: reflectance maximum, transmittance maximum, and absorptance minimum**



Fresh leaf



dry leaf

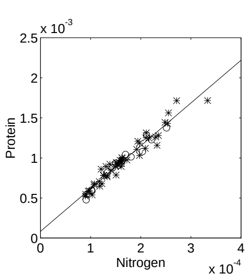
②**Inversion of the Stokes system** ⇒ **determination of the reflectance and transmittance of an elementary layer: [ρ(λ),τ(λ)]=fct(R(λ),T(λ),N)**
⇒ **determination of the absorption coefficient: k(λ)=fct(ρ(λ),τ(λ))**

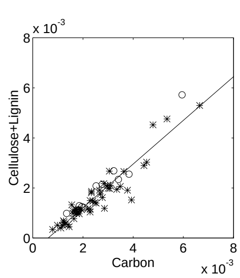
③**Estimation of the specific absorption coefficients of the leaf biochemical components:**

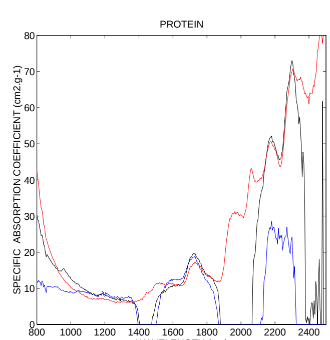
$$k(\lambda) = \sum_i k_i(\lambda) \times \frac{C_i}{N}$$

where concentrations are expressed in mass per unit leaf area

$$\frac{\text{cellulose} + \text{lignin}}{\text{protein}} = \frac{C}{N}$$

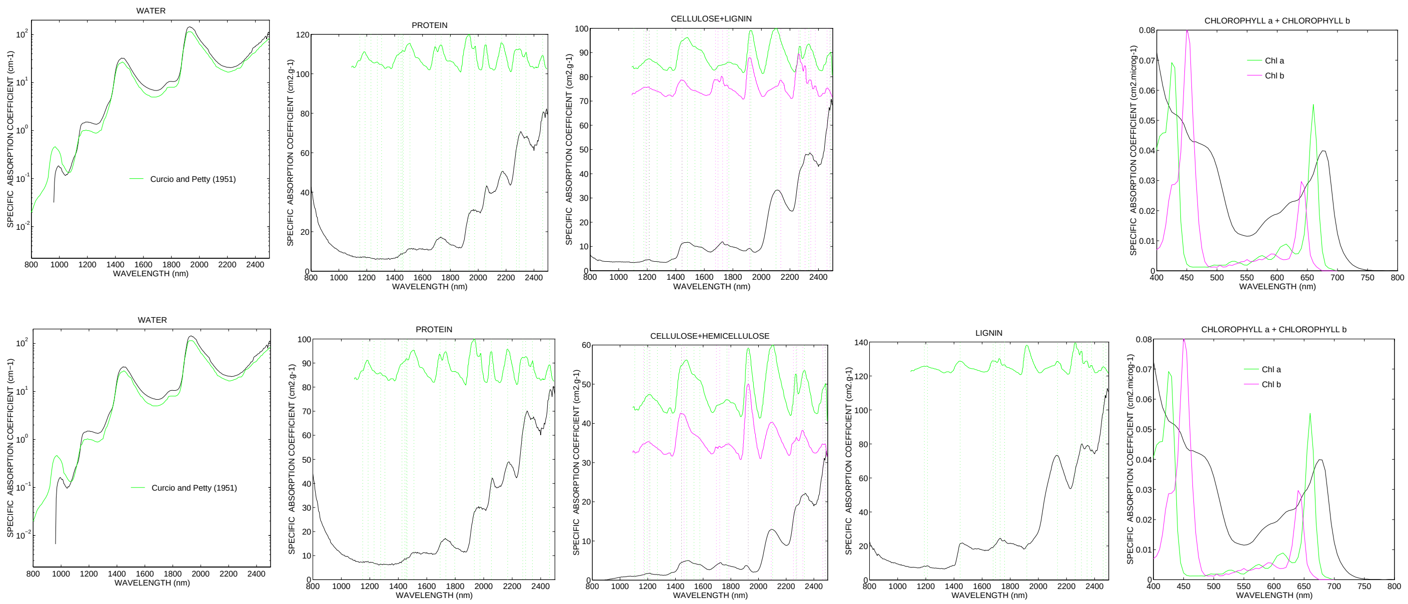




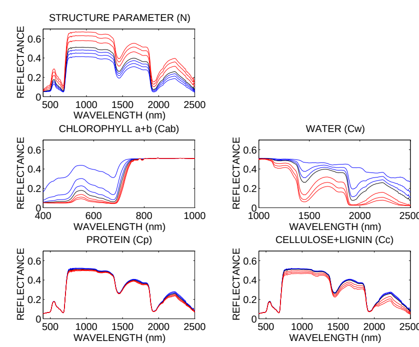


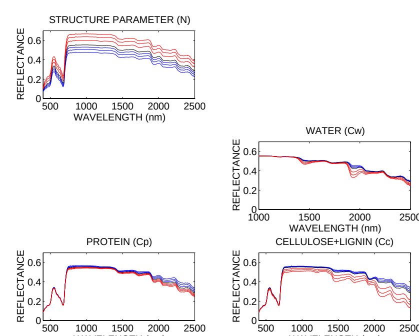
Use of 48 dry leaves and 63 fresh leaves

- **water → fresh+dry leaves**
- **biochemistry → dry leaves**
- **chlorophylls → fresh leaves**



SENSITIVITY ANALYSIS



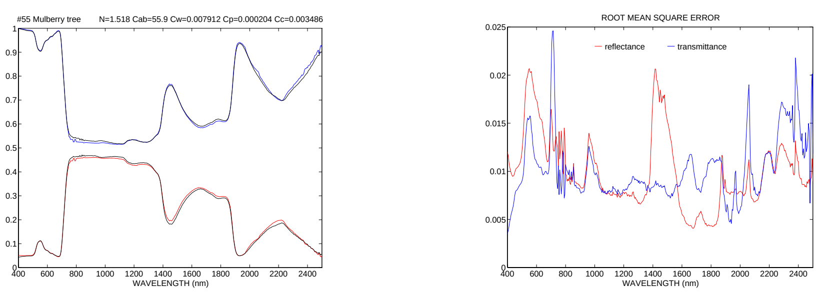


INVERSION OF THE PROSPECT MODEL

Minimization of the merit function:

$$\chi^2(\theta) = \sum_{\lambda 1}^{\lambda 2} \left\{R_{mes}(\lambda) - R_{mod}(\lambda,\theta)\right\}^2 + \left\{T_{mes}(\lambda) - T_{mod}(\lambda,\theta)\right\}^2$$

		Coefficient of Determination R^2					
leaf type	**spectral range**	**chlorophylls**	**water**	**protein**	**cellulose + hemicellulose**	**lignin**	**cellulose + lignin**
dry	1100 nm - 2500 nm		0.54	0.67	0.88	0.39	
			0.54	0.65			0.84
fresh	1000 nm - 2500 nm		0.95	0.02	0.07	0.37	
			0.95	0.02			0.50
	400 nm -2500 nm	0.68	0.95	0.02			0.39



CONCLUSION

☺ leaf biochemistry is retrievable on dry leaves by using leaf optical properties

☹ leaf biochemistry is partly retrievable on fresh leaves by using leaf optical properties: good estimation of chlorophyll pigments and water, reasonable estimation of cellulose+lignin (carbon pool of the leaf), and no sensitivity to protein (nitrogen pool of the leaf)

☹ the estimation of leaf biochemistry using PROSPECT is less accurate than when using statistical approaches; however, the physical approach allows extension of model to canopy and satellite levels.