Estimation of Leaf Area Index and chlorophyll content in barley by inversion of radiative transfer models at different growth stages

A.J. Berjón, V.E. Cachorro, P.J. Zarco-Tejada and A.M. De Frutos
Grupo de Optica Atmosférica GOA-UVA
Universidad de Valladolid
Valladolid, Spain
alberto@baraja.opt.cie.uva.es

P. Martín
Dpto. de Producción Vegetal y Silvopascicultura
Universidad de Valladolid
Valladolid, Spain

Abstract — **This paper presents research work carry out in barley crop fields located in Valladolid, northern Spain. Validation of barley canopy reflectance was conducted using SAILH-PROSPECT model, comparing the simulations with field-measured reflectance for different illumination angle and different stage of crop development at nadir viewing angle. Validation of leaf optical properties from such crop was also carried out by inversion of the PROSPECT radiative transfer model.**

Keywords - Radiative transfer model inversion; Barley; LAI; Chlorophyll content;

I. Introduction

Retrieval of canopies biophysical and biochemical parameters, by means of remote sensing techniques, is the first step towards a successful crop management and yield estimation at large scales. Alternative procedures to the traditional use of vegetation indices, like the NDVI, to estimate crop parameters are based on modelled reflectance, in which we introduce the effect of each element and his geometry.

We have applied radiative transfer model inversion in vegetal canopy to Reflectance Factor measurements made in barley crop fields located in Valladolid, north-centre of Spain (Castilla y Leon), a wide area, traditionally used for cereal cultures, of continental and dried climate characteristics. Models used are PROSPECT [1] and SAILH [2], widely used in the field of Remote Sensing.

II. Materials And Methos

A. Field Measurements

Canopy Reflectance Factor measurements in a barley field were carry out with a portable espectroradiometer LiCor-1800, on the top of a 3 meters height tower. This espectroradiometer is equipped with a cosine receptor, connected to the monochromator by an optical fibber, that allows optimal measurements from 400 to 900nm, with 6nm of spectral resolution and 5nm sampling. The cosine receptor was attached to a 23º IFOV field limiter, giving a 1.2 m^2 footprint.

In order to obtain the reflectance Factor we need to compare the radiant exitance of the canopy with the radiant exitance of a Lambertian surface. As reference surface we used a barium sulphate ($BaSO_4$) panel previously calibrated respect to a Espectralon panel.

Ground reflectance, LAI measurements and solar irradiance measurements were made. Plant samplings were also made for their later analysis of chlorophyll content and optical measurements in laboratory.

B. Diffuse sky light

Diffuse sky light needed for radiative transfer model is calculated from global and direct irradiances. The global measurement was carry out placing the cosine receptor in the horizontal position, and direct measurement was carry out placing the sensor in the normal direction to the sun, using a 2.3º IFOV field limiter.

The global measurement is as good as is sensor cosine response. We have studied the response of our sensor to different incident light directions, and we had applied this effect to correct the diffuse sky light, obtained from global and direct measurements (see figure 1).

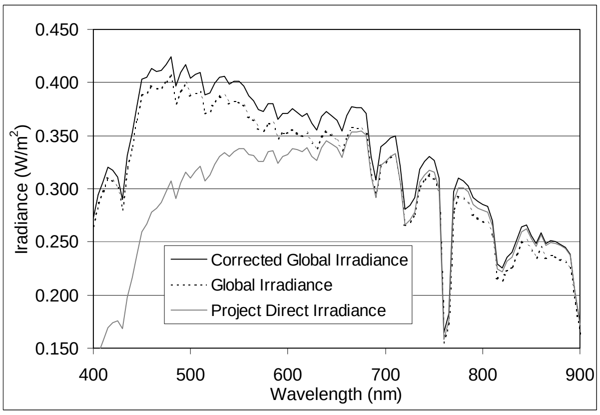

Figure 1. Application of Cosine response correction application

C. *Reflectance and Transmittance leaf measurements*

Leaf level optical measurements of reflectance and transmittance in barley samples were carried out using an integrating sphere attached to our LI-COR LI-1800 spectroradiometer in the 400-900 nm spectral range and 5 nm sampling.

D. *Chlorophyll retrieval*

The validation of chlorophyll values obtained by inversion of the PROSPECT model at leaf level, and the SAILH-PROPSPECT model at canopy level, was made by leaf sampling and chlorophyll extractions in laboratory. An organic dissolvent, acetone, was used to dissolve the leaves. A laboratory spectrophotometer (JASCO UV/VIS V-530) was used to obtain the dissolution absorbance. Equations from [3] have been used for the determination of the chlorophyll content.

E. *Model Inversion*

Two different levels of radiative transfer inversion were studied in this work: leaf level and canopy level.

At leaf level PROSPECT model was applied. This model use the chlorophyll a+b (C_{ab}), water (C_w), dry mater (C_m) content and a structural parameter (N) to assess the leaf reflectance and transmittance. A recent PROSPECT model modification that include a new parameter (Cs) to account for the brown pigment presence, were also applied. At canopy level SAILH model liked to the two versions of PROSPECT was applied.

The inversion procedure is an iterative optimisation, the classical technique for inverting radiative transfer models in remote sensing [4], and consists of minimising a function that calculates the root mean square error (RMSE) between the measured and estimated quantities by successive input parameter iteration.

In PROSPECT, the inversion parameters N, C_{ab}, C_m , and in the case of the new version of PROSPECT, also Cs, were varied between the values specified in the Table I. The Water Content in the leaf was maintained constant (0.08cm) because his effect is not significant inside the interval in which the inversion was made (from 400 to 900 nm).

TABLE I. VARIATION INTERVALS IN PROSPECT INVERSION

	Initial value	Final Value
N	0.9	4
Cab (μg/cm^2)	0	120
Cm (g/cm^2)	0	0.04
Cs (no units)	0	1.2

As in the previous case, in the SAILH-PROSPECT inversion, parameters N, C_{ab}, C_m, Cs and were varied between the values specified in the Table II. Cw and HotSpot were maintained constant.

TABLE II. VARIATION INTERVALS IN SAILH-PROSPECT INVERSION

	Initial value	Final Value
N	1.5	3
Cab (μg/cm^2)	0	120
Cm (g/cm^2)	0	0.04
Cs (no units)	0	0.9
LAI	0.1	3

III. ANALYSIS AND DISCURSION

As mentioned, inversion of PROSPECT and SAILH-PROSPECT radiative transfer model was used to estimate LAI and chlorophyll content from the canopy reflectance and the leaf reflectance and transmittance. Results are shown in Fig. 2, 3 and 4.

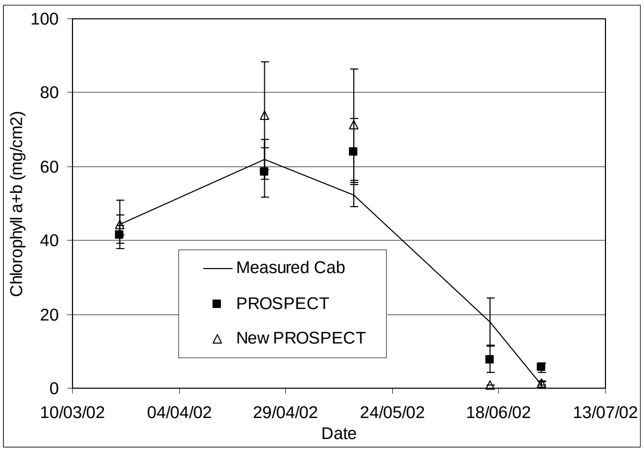

Figure 2. Chlorophyll content measured and estimated by PROSPECT inversion.

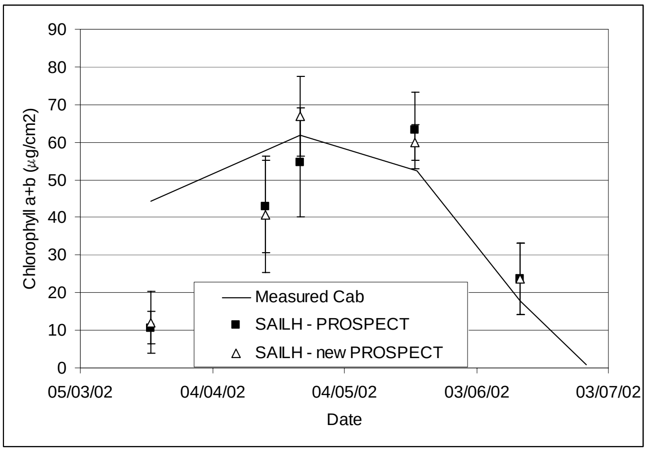

Figure 3. Chlorophyll content measured and estimated by SAILH-PROSPECT inversion.

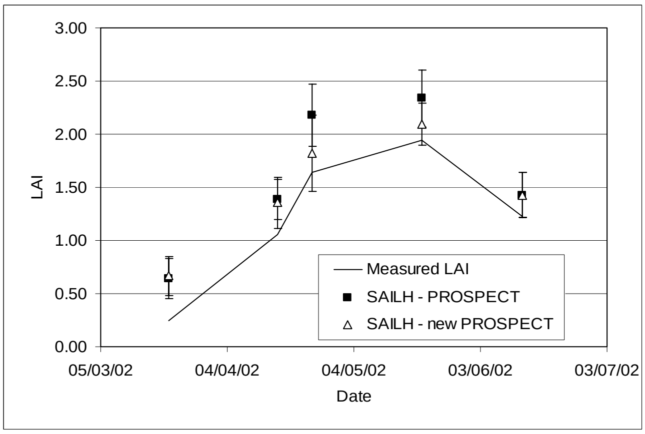

Figure 4. LAI measured and estimated by SAILH-PROSPECT inversion.

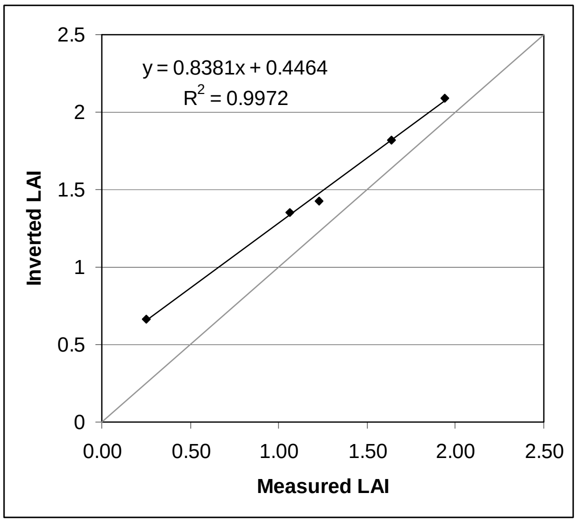

Figure 5. Correlation betwen LAI measured and estimated by SAILH-newPROSPECT.

As we can see in Fig. 5, the high r^2 value (0.997) indicates that there is a very good correlation between the directly measured LAI an the obtained by SAILH linked to the new PROSPECT model, but there is an over estimate, that goes from 8% when LAI=1.9 to 167% when LAI=0.25.

IV. CONCLUSIONS

Because barley is a dry land culture (not irrigated) in the zone in which the study was made, and the little rainfall in the year 2002 throughout all the growth period LAI values stayed very low. It didn't exceed a value of 2. So, we didn't have the variation of values that we hoped.

As we had showed, LAI estimation can be done by means of remote sensing techniques, with an acceptable error. Nevertheless in the case of the estimation of chlorophyll content, the result is not sufficiently good, at least in the first growth stages.

This result indicates that a correct forecast is related to de LAI value. In fact, this result is coherent taking into account that SAIL model considers canopy as a homogeneous layer, and this condition is not fulfilled in the initial growth stages of the culture. This can be also applied to LAI estimation, where the over estimate is much greater as minor is the value of the LAI.

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