Estimation of leaf and canopy variables on EU high-value crops with hyperspectral remote sensing and 3-D models: integration of methods with precision agriculture

P.J. Zarco-Tejada[1], A. Berjón[1], A. Morales[2], V. Cachorro[1], J. Agüera[3], J.R. Miller[4], A.J. Rodríguez[5], P. Martín[1], and A. de Frutos[1]
[1] *Escuela Técnica Superior de Ingenierías Agrarias, Universidad de Valladolid, Spain*
[2] *Escuela Universitaria de Ingeniería Técnica Agrícola, Universidad de Sevilla, Spain*
[3] *Escuela Técnica Sup.de Ingenieros Agrónomosy Montes, Universidad de Córdoba, Spain*
[4] *Department of Physics and Astronomy, York University, Toronto, Canada*
[5] *D.A.P., Consejería de Agricultura y Pesca, Junta de Andalucía, Sevilla, Spain*
pzarco@iaf.uva.es

Abstract

Research work conducted under the European Union HySens project aimed to investigate physical methods with ROSIS and DAIS 7915 high-spatial hyperspectral remote sensing imagery to estimate leaf biochemical and canopy biophysical variables in *Olea europaea* L. and *Vitis vinifera* L. canopies. Successful demonstration of accurate estimation of biophysical variables in these crops is critical for the development of effective precision agriculture management practices. Leaf chlorophyll *a+b* (C_{a+b}) and leaf area index (LAI) are indicators of stress and growth that can be estimated by remote sensing in the 400-2500 nm region.

Keywords: hyperspectral, remote sensing, radiative transfer, olea europaea, chlorophyll

Introduction

Traditional remote sensing methods for vegetation monitoring rely on the calculation of normalized indices such as NDVI as indicators of LAI. However, it is documented that these indices saturate at high LAI values and are affected by canopy structure. The application of physical models has been shown to have particular promise to accurately estimate canopy variables from remote sensing to account for canopy architecture and scene components. However, despite the prevalence of *Olea europaea* L. and *Vitis vinifera* L. landscapes within the EU and worldwide, little research has been conducted examining the reflectance properties of olive tree and vineyards at the leaf and canopy levels. Research that deals with modelling the radiation interception by olive canopies has begun to emerge, with the work by Villalobos *et al.* (1995) for LAI estimation. A potential indicator of vegetation stress is C_{a+b} content because of its direct role in the photosynthetic processes of light harvesting. Differences in remote sensing reflectance between healthy and chlorotic vegetation due to changes in C_{a+b} levels have been detected in the green peak and along the red edge spectral region, thereby enhancing the feasibility of remote detection of crop stress. Chlorosis in olive trees caused by nutrient deficiencies can be treated improving yields and fruit quality (Fernández-Escobar *et al.*, 1993); Fe and N deficiencies developing chlorosis in vineyards cause depression of fruit yield and quality (Tagliavini and Rombolá, 2001).

Materials and methods

Estimation of leaf biochemical and canopy biophysical variables from remote sensing data required appropriate modelling strategies for *Olea europaea* L. and *Vitis vinifera* L. canopies, accounting for structure through its dominant effect on the bi-directional reflectance (BRDF) signature. 1m pixel-size ROSIS and DAIS 7915 hyperspectral reflectance data in the red edge and NIR region were used to estimate C_{a+b} and LAI (Figure 1). The high spatial resolution ROSIS data allowed targeting of crowns, minimizing structural mixed pixel effects. Linked leaf (PROSPECT) and canopy models (SAILH, SPRINT, FLIM) were assessed for their ability to estimate leaf and canopy parameters by inversion (Figure 1). A field sampling campaign was carried out for biochemical analysis of leaf C_{a+b} content, and leaf sampling was conducted in study areas of *Olea europaea* L. and *Vitis vinifera* L. in Spain. Reflectance (ρ) and transmittance (τ) measurements of olive and vine leaves were carried out using a Li-Cor 1800-12 sphere coupled with a spectrometer. LAI was measured using a PCA LAI-2000, and atmospheric measurements collected at the time of over-flights.

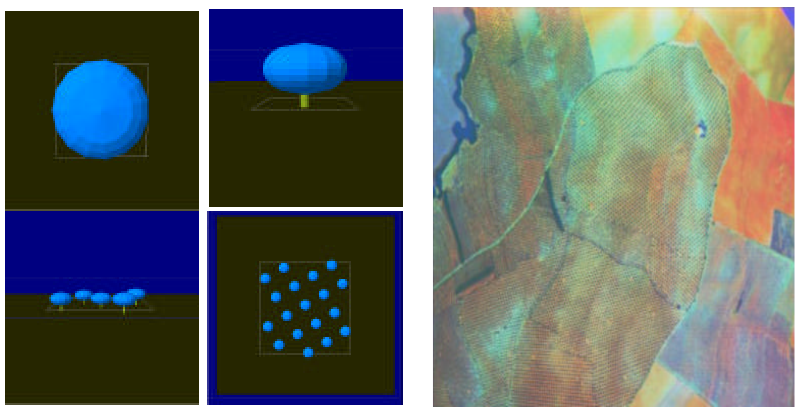
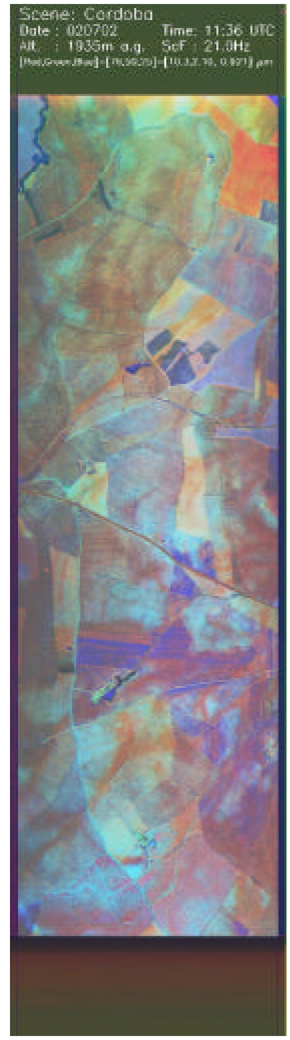


Figure 1. 3-D modelling of olive tree canopies using SPRINT (left). DAIS 7915 imagery (right) collected over olive tree canopies of 5-m spatial resolution and atmospherically corrected (Córdoba, Spain).



Results and Conclusions

Results of this research work focused on the application of remote sensing techniques in precision agriculture, studying vegetation indices for leaf biochemistry estimation in *Olea europaea* L. and *Vitis vinifera* L. canopies. The link of PROSPECT and SAILH+FLIM was studied for biochemical estimation in olive canopies, generating relationships between red edge indices and chlorophyll concentration for a set of canopy variables such as LAI and crown density. Validation was conducted using ROSIS and DAIS 7915 for C_{a+b} and LAI variables, and results of the model inversions and *scaling-up* approaches presented in the poster. This methodology enables the estimation of leaf and canopy variables on a tree-by-tree basis, critical for the development of effective precision agriculture management practices.

References

Fernandez-Escobar, R., D. Barranco, and M. Benlloch. 1993. Overcoming iron chlorosis in olive and peach trees using a low-pressure trunk-injection, *Hortic. Sci*. 28:192-194.

Tagliavini, M., A.D. Rombola. 2001. Iron deficiency and chlorosis in orchard and vineyard ecosystems, *European Journal of Agronomy*, 15, 71-92.

Villalobos, F.J., F. Orgaz, and L. Mateos. 1995. Non-destructive measurement of leaf area in olive trees using a gap inversion method, *Agr. and Forest Meteorology*, 73, 29-42.