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

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Research work conducted under the European Union HySens funded 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 olive (*Olea europaea* L.) and vine (*Vitis vinifera* L.) canopies. Successful demonstration of a model-based approach for accurate estimation of leaf biochemical constituents and canopy biophysical characteristics in these high-value crops in the EU are critical for the development of effective precision agriculture management practices. Leaf chlorophyll *a+b* (C_{a+b}), dry matter (C_m), water (C_w) and leaf area index (LAI) are indicators of stress and growth that can be estimated by radiative transfer modelling from hyperspectral data in the 400-2500 nm spectral region. Nutritional deficiencies due to nitrogen (N), phosphorous (P), potassium (K), or iron (Fe) cause leaf chlorosis that may be mapped with remote sensing techniques used in this study.

Estimation of such leaf biochemical and canopy biophysical variables from remote sensing data requires 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. Little such work has been done which models the radiation interception by olive canopies and applies radiative transfer and hyperspectral remote sensing methods. This research project uses 1m pixel-size ROSIS hyperspectral reflectance data in the red edge and NIR region to estimate C_{a+b} and LAI. The high spatial resolution ROSIS data allowed targeting of crowns, minimizing structural mixed pixel effects. DAIS 7915 data at 5 m spatial resolution were used to estimate C_w using the 960nm, and 1500-2500 nm spectral regions, and C_m using the 2000-2500 nm region, through canopy modeling which includes the effects of vegetation crowns, sunlit and shadowed background soil.

Linked leaf (PROSPECT, LEAFMOD) and canopy models (SPRINT, SAILH, GeoSAIL, and GORT) were assessed for their ability to estimate leaf and canopy parameters by inversion. A field sampling campaign was carried out for biochemical analysis of leaf C_{a+b}, C_m and C_w content, and leaf sampling was conducted in study areas of *Olea europaea* L. and *Vitis vinifera* L. in northern and southern 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 instrument, and atmospheric measurements collected at the time of over-flights for atmospheric correction of image datasets. Results of this project focused on the application of remote sensing techniques in precision agriculture studiying, i) the optimum vegetation indices for estimating leaf biochemistry in *Olea europaea* L. and *Vitis vinifera* L. leaves, and a protocol for determining the optical properties (ρ,τ) of thick and small olive tree leaves; and ii) validate the link of a leaf model (PROSPECT, LEAFMOD) with a canopy model (SPRINT, SAILH, GeoSAIL, GORT) for olive tree and vine canopy simulation using 1m ROSIS (targeting crowns) for C_{a+b} and LAI estimation, and 5m DAIS (including structure and shadows) to estimate leaf C_m and C_w, and canopy LAI.

The present research project demonstrates the applicability of hyperspectral remote sensing for mapping biochemical constituents and biophysical properties in agriculture. The high spatial resolution used with airborne sensors enabled the estimation of such variables at 1 and 5 m resolutions, therefore studying the within-field variability in *Olea europaea* L. and *Vitis vinifera* L. canopies.