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Cost-effectiveness of vegetation biophysical parameters retrieval from remote sensing data

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Due to the availability of hyperspectral and multiangular high-resolution sensors on board of new air and space platforms, Earth Observation (EO) imagery, today available, is rich of information in both spectral and spatial domains. In the context of vegetation studies E.O. data have been extensively used to retrieve biophysical parameters of land surface. In some cases, thanks to the availability of near-real-time data, tools and applications have been developed and implemented in the fields of precision agriculture, water resources monitoring and management. So far, empirical approaches based on vegetation indices (VIs) have been successfully applied. They may provide a satisfactory level of accuracy in the estimation of important vegetation biophysical parameters (e.g. LAI, fractional ground cover, biomass, etc). Such methods, however, require a reliable reference data-set to calibrate empirical formulas on different vegetation types; furthermore, they are generally based on a few spectral bands, with a consistent under-exploitation of the full spectral range available in new generation sensors. Diversely, alternative approaches based on inversion of radiative transfer models of vegetation represent a challenging opportunity for the estimation of vegetation parameters from data with high dimensionality (both in the spectral and the angular domains) and in principle they do not require reference data for calibration purposes; on the other hand, they are often very demanding on the computational side and on the level of parameterization required. This work evaluates the effectiveness, in terms of accuracy and computational complexity, for retrieving the Leaf Area Index either by means of empirical relationships, such as the simple CLAIR model proposed by Clevers (1989) and based on the Weighted Differences Vegetation Index (WDVI),

either by means of mathematical inversion of the combined radiative transfer model PROSAILH, including PROSPECT (at leaf level) and SAILH (at canopy level). Both approaches, i.e. empirical relationship LAI (WDVI) and radiative transfer model inversion, have been tested by using super-spectral and multi-angular data in the solar domain from the Compact High Resolution Imaging Spectrometer (CHRIS) on the PROBA experimental satellite (Project for On Board Autonomy). CHRIS/Proba has the capability of acquiring a set of up to five images -at different angles- during each acquisition sequence. This instrument represents an ideal opportunity for a complete exploitation of the spectral and directional information for canopy radiometric measurements. CHRIS/Proba data were acquired over the agricultural test-site of Barrax during two ESA experimental campaigns in 2003 and 2004 (Spain). Atmospherically corrected CHRIS/Proba data (310 observations for each pixel: five images with different view angles and 62 spectral bands over the visible/near-infrared wavelengths from 400 nm to 1050 nm, with a spatial resolution of 36 meters) were available in July 2003 and 2004.

These image data were used for the inversion of PROSAILH models using the independent Parameter Estimation program PEST. It runs the canopy reflectance models, compares the models results with the observed (measured from satellite) values and adjusts selected parameters using Marquardt-Levenberg optimisation algorithm, until an optimal parameter set is found.

A preliminary analysis on the images was carried out to select a set of spectral bands to reduce the satellite data uncertainties due to possible radiometric calibration and atmospheric correction problems, reported in several bands, especially in the near-infrared region. Data from the view-angle closest to nadir in the red and near-infrared bands was considered for estimating the LAI by means of the empirical approach. The model CLAIR was applied in two different ways: by using library parameters, acquired on different sites and crops, and by means of site-specific parameters, determined from ad-hoc ground-measured LAI values in coincidence of the CHRIS/Proba overpass. The full spectral and angular set of images acquired over the Barrax site was used for the inversion of the PROSAILH model. In this case, a preliminary analysis was carried out by means of statistical techniques to define the optimal spectral sampling; so doing, the correlation among adjacent bands was reduced, with a consequent increase of efficiency in the inversion process of the LAI. In the same time, a sensitivity analysis of the PROSAILH models was necessary to understand the parameters influence in model inversion and to assign proper values to the weights of each variables. The inversion process resulted highly demanding in terms of computational time and complexity. Moreover, the accuracy and the stability of the inversion technique was very variable accordingly to the accuracy of atmospheric correction procedures and identification of model parameters. In particular, the model inversion required a good initial approximation of the parameter prior the inversion through the introduction of a-priori knowledge information. The level of accuracy of the two approaches, however, was comparable. On the other, the simplicity of the empirical approach sacrifices information on other useful information such as the geometry of the canopy, the chlorophyll content and soil reflectance. A feasibility analysis of the implementation of the two approaches is discussed in view of a definition of an operative routine for the application of EO data in irrigation advisory services.