A Prototype Processor for Vegetation Traits Retrieval from PRISMA Hyperspectral Data

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Abstract. Hyperspectral data, providing reflectance from visible to shortwave infrared wavelength at very high spectral resolution, can greatly contribute to the retrieval of biophysical and biochemical vegetation traits, which are of high relevance for agricultural and ecological applications. In the framework of the Italian Space Agency project "Sviluppo di Prodotti Iperspettrali Prototipali Evoluti" (Contract ASI N. 2021-7-I.0), a prototype processor has been developed, exploiting PRISMA (PRecursore IperSpettrale della Missione Applicativa) imagery, for quantifying parameters such as Leaf Area Index (LAI), Fraction of Absorbed Photosyntetically Active Radiation (FAPAR), Fractional Vegetation Cover (FCOVER), Chlorophyll-a and Chlorophyll-b (Cab) useful for vegetation characterization.
In the scientific literature, the retrieval methods of vegetation traits are categorized into four groups: parametric regression, non-parametric regression, physically-based (including inversion of Radiative Transfer Models – RTMs – using numerical optimization and Look Up Tables –LUT- approaches), and hybrid regression methods. We have developed a prototype processor based on a hybrid method that inverts physical models through machine learning (ML) regression algorithms [1, 2]. In our method, the physical models, based on PROSAIL and relating the vegetation physical parameters to the bottom of atmosphere reflectance, are used to generate simulated plant canopy spectral reflectances (from 400 to 2500 nm at 1 nm spectral resolution). Such simulated data, resampled to the PRISMA band configuration, are used to train the ML regression model. A contamination with noise has been considered in order to improve the generalization capability of the models. In addition, a subspace of the feature space has been selected by means of dimensionality reduction techniques like PCA (Principal Component Analysis), in order to avoid correlated information that may result in suboptimal performances. Different machine learning algorithms, such as Random Forest, Support Vector Machine, Gaussian Process and Artificial Neural Network, have been evaluated and tested for the regression task.
The proposed approach allows retrieving vegetation indicators with lower computational time than other methodologies presented in the literature. In addition, it has a high power of generalization, thanks to the high representativeness of the training

dataset, which has been generated taking into account different combinations of vegetation parameters and illumination/acquisition geometry configurations.

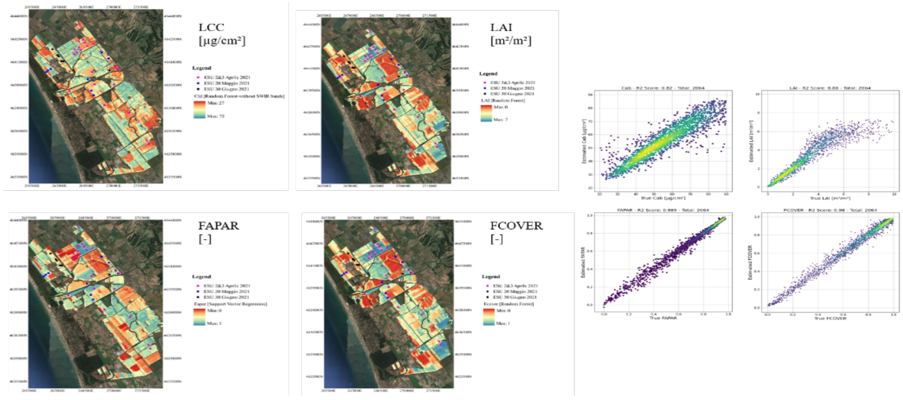

Figure 1.Scatter plot of the best model for each variable (LCC, LAI, FAPAR, FCOVER). Maps of variables extracted over the Maccarese (Italy) study site (on the left). Data/Information generated by e-GEOS, CNR-IMAA, Università degli Studi della Tuscia, under an ASI License to Use; Original PRISMA Product - © ASI – (2021).

Table 1. Theoretical performances on simulated test data set.

Variable	R^2
LAI	0.88
LCC	0.82
FAPAR	0.98
FCOVER	0.99

In order to demonstrate the capabilities of the prototype processor and to measure its performances, the trained models have been validated on several PRISMA data acquired over the Maccarese (Italy) study site with respect to ground data collected in situ, showing good results. A comparison with variables retrieved from Sentinel-2 imagery has been carried out and performances on LAI, FAPAR and FCOVER are comparable. Concerning the retrieval of the leaf chlorophyll content (LCC), the continuous sampling of VIS and red edge leads to a better discrimination of different pigments and the results are more accurate.

Bibliographic References:

1. Weiss, M., Baret, F.: S2ToolBox Level2 Products: LAI, FAPAR, FCOVER. (2016).
2. Danner, M., Berger, K., Wocher, M., Mauser, W., & Hank, T.: Efficient RTM-based training of machine learning regression algorithms to quantify biophysical & biochemical traits of agricultural crops. ISPRS Journal of Photogrammetry and Remote Sensing, 173, 278-296 (2021).