Geophysical Research Abstracts,
Vol. 11, EGU2009-12717, 2009
EGU General Assembly 2009

Hyperspectral measurements for estimating biophysical parameters and CO2 exchanges in a rice field

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The objective of this work was to monitor the main biophysical and structural parameters as well as the CO_2 exchanges between atmosphere and a terrestrial ecosystem from remote and high spectral resolution spectroradiometric measurements. Estimation of photosynthetic rate or gross primary productivity from remotely sensed data is based on the light use efficiency model (LUE), which states that carbon exchange is a function of the photosynthetically active radiation absorbed by vegetation (APAR) and the radiation use efficiency (ε) which represents the conversion efficiency of energy to fixed carbon. Hyperspectral data were used in this study in order to derived both the APAR of green vegetation and the ε term.

The experimental site was a rice paddy field in North Italy equipped with an Eddy Covariance (EC) flux measurement tower (Castellaro IES-JRC site). Intensive field campaigns were conducted during summer 2007 and 2008. In each sampling day, canopy optical properties, canopy structure, biophysical and ecophysiological parameters were measured.

EC fluxes were calculated with a time step of 30 minutes according to EUROFLUX methodology. Measured half-hourly net ecosystem exchange (NEE) was partitioned to derive half hourly gross ecosystem production (GEP). Canopy reflectance spectra were collected under clear sky conditions using two portable spectrometers (HR4000, OceanOptics, USA) characterised by different spectral resolutions. A spectrometer characterised by a Full Width at Half Maximum (FWHM) of 0.13 nm was used to estimate steady-state fluorescence (F) and a second one with a FWHM of 2.8 nm was used for the computation of traditional vegetation indices (e.g. NVDI, Normalized Difference Vegetation Index and SAVI, Soil Adjusted Vegetation Index) and PRI (Photochemical Reflectance Index, Gamon et al. 1992). F was estimated by exploiting a variation of the Fraunhofer Line Depth (FLD) principle (Plascyk 1975): the spectral fitting method described in Meroni and Colombo (2006) applied at the 760 nm atmospheric oxygen absorption band. An index of F efficiency, the apparent fluorescence yield (NF_{760}) was also computed as the ratio between F_{760} and the incident radiation.

Results show that Leaf Area Index (LAI), the fraction of absorbed photosynthetically active radiation (f_{APAR}) and plant height values were well correlated with SAVI (R^2 from 0.68 to 0.83) while NDVI was poorly or not correlated. The NDVI-f_{APAR} relationship, as well as the relationships NDVI-LAI and NDVI-plant height, is very different in the vegetative and ripening stages. The lower correlation with NDVI in this analysis could be explained by the dependence of the relationship on phenology. In contrast, other indices adjusting for background effects (like SAVI) showed highly linear relationships with f_{APAR}, LAI and plant height for the entire growing period.

Furthermore, the use of innovative spectral indices related to physiological processes such as the activation of photoprotective mechanisms and excess energy dissipation via sun-induced passive fluorescence allowed the development of semi-empirical models between radiometric measurements and GEP. The average of half-hourly GEP acquired between 11 a.m. and 1 p.m. (solar time) was related with hyperspectral indices and fluorescence parameters acquired at the same time with the spectrometers. Different LUE models were tested. SAVI was selected to estimate f_{APAR} because it showed higher correlation than NDVI. Results showed very high coefficient of determination (i.e. $R^2$from 0.88 to 0.98) between GEP and F_{760} and the product (NF_{760} x PAR_i x SAVI) for

both years. The regression between GEP and the product (PRI x PAR_i x SAVI) was instead not significant. The semi-empirical models show high correlation between GEP and chlorophyll fluorescence parameters throughout the two years study period. This result opens up new possibilities for the application of semi-empirical model for the spatial estimation of biophysical parameters and carbon GEP based on aerial and satellite images.

References

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