Remote Estimation of Chlorophyll Content and Gross Primary Production in Crops

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Accurate estimation of spatially distributed CO_2 fluxes is of great importance for regional and global studies of carbon balance. The vegetation productivity has been assessed through the use of micrometeorological approaches by means of studying whole-community gas exchange. Many field studies in different ecosystems across the globe have used tower-based eddy covariance techniques to provide information on seasonal dynamics and inter-annual variation of Gross Primary Production (GPP). However, the GPP data are representative of only a small footprint area, and scaling-up beyond the footprint to an entire region is challenging. The synoptic view provided by imaging sensors makes remote sensing an attractive and powerful tool for studying vegetation status and productivity, at scales ranging from local to global. Given that vegetation status and productivity are directly related to the interaction of solar radiation with the plant canopy, remote sensing techniques can be used to estimate status of vegetation (density, LAI and total chlorophyll content) and vegetation productivity.

In this study, we propose a new remote technique to estimate total chlorophyll (Chl) content and mid-day GPP in crops.GPP estimate builds upon Monteith's logic, however, it does not depend on the NDVI/fAPAR linearity assumption, and it does not depend on the constancy, pre-established variability or biome/species specificity of light use efficiency. The approach is based on the remote estimation of crop Chl. Since long- or medium-term changes in canopy Chl are related to crop phenology, canopy stresses and photosynthetic capacity of the vegetation, it can also be related to GPP. It was found that canopy level Chl in crops and grasslands may appear to be the community property most relevant for the prediction of productivity. The specific objectives of this study were: (1) to evaluate existing remote sensing techniques for the estimation of Chl and GPP in irrigated and rainfed maize and soybean; (2) to establish the relationship between GPP and crop Chl in maize and soybean; and (3) to test the accuracy and robustness of a remote sensing technique, developed for canopy Chl retrieval, in the remote estimation of GPP in crops. We concentrated our efforts in the remote estimation of Chl and GPP in crops, because they are the most pervasive anthropogenic biome. Relatively simple in vegetation structure, crops play an important role in the global cycles of carbon, water, and nutrients as well as influencing local and regional weather.

We have found that in irrigated and rainfed crops (maize and soybean) mid-day GPP is closely related to total crop Chl content. The technique has been developed to remotely estimate total crop Chl content. This technique that has been originally developed for leaf pigment concentration retrieval was spectrally tuned for the remote estimation of Chl content in crops and successfully applied for the retrieval of mid-day GPP in irrigated and rainfed soybean. This new technique is solely based on remotely sensed data, and provides a robust estimation of mid-day gross primary production in crops. The technique is based on reflectance in two spectral channels: the near-infrared and either the green or the red-edge. The technique provided accurate estimations of mid-day GPP in both crops under rainfed and irrigated conditions with root mean square error of GPP estimation of less than 0.3 mg CO_2/m^2s in maize (GPP ranged from 0 to 3.1 mg CO_2/m^2s) and less than 0.2 mg CO_2/m^2s in soybean (GPP ranged from 0 to 1.8 mg CO_2/m^2s). Validation using an independent dataset for irrigated and rainfed maize showed robustness of the technique; RMSE of GPP prediction was less than 0.27 mg CO_2/m^2s.

Given the substantial improvement in the accuracy of mid-day gross primary production estimation by the techniques developed in this study, as compared to the currently used methods, it is worthwhile to fully explore the efficacy of these techniques over different crops and grasslands. Further validation of this technique over other crops and vegetation types is required using the green and NIR bands of satellite-based systems such as MODIS, Landsat TM and ETM, and Hyperion (onboard EO-1 satellite) as well as the red-edge and NIR bands of satellite systems such as MERIS and Hyperion. With further validation (using data from already established FluxNet and SpecNet sites), this technique may be found useful in a variety of terrestrial ecosystems. The end result may be an inexpensive yet accurate tool for estimating mid-day GPP.