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Estimation of the Light Use Efficiency (LUE) in Macrochloa tenacissima leaves with hyperspectral indices

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Climate change has increased the need for understanding and modeling carbon fluxes at regional scales. The Eddy covariance technique is one of the most accurate ways to characterize carbon and water fluxes. Despite of the fact that this technique gives very precise and intensive sampling on the temporal domain it represents only a relatively small area around flux tower (footprint). In order to obtain spatial estimates of carbon fluxes several attempts have been made to incorporate optical remote sensing data, as remote sensing data offer synoptic information of biophysical properties of land surface. Indices such the NDVI (related with the fraction of Absorbed Photosynthetically Active Radiation, fAPAR) and the Photochemical Reflectance Index (PRI) (related with Light Use Efficiency, LUE) are widely used for modeling CO_2 fluxes using the Monteith Light Use Efficiency approach calculating Gross Primary Production (GPP). However, in arid lands the relation between biophysical variables and optical indices is not yet as well understood as in other environments. In drylands, water availability is the main environmental constraint limiting LUE. Therefore indices tracking canopy water content may perform better than the PRI to model LUE. The aim of this study is to assess at the leaf level which optical indices are more sensitive to changes in the LUE in a semiarid environment.

The study site is located on a semiarid steppe area dominated by Macrochloa tenacissima in SE Spain. CO_2 gas exchange between the leaves and the atmosphere was measured with an IRGA (Infrared Gas Analyzer) on a sample of six plants of M. tenacissima divided in North, South, East and West aspects. Hyperspectral field reflectance between 400-2500 nm was measured with an ASD (FieldSpec3 Pro) on the same leaves. Both measurements were taken simultaneously at solar noon. The data were collected at the beginning of autumn when vegetation is still recovering from summer drought. The LUE was calculated as the ratio of net CO_2 assimilation divided by the incident Photosynthetically Active Radiation (PAR). Several hyperspectral and multispectral indices were calculated from ASD data: NDVI (greenness), Photochemical Reflectance Index (PRI) (commonly related with LUE), Structure Insensitive Pigment Index (SIPI) (bulk of carotenoids to chlorophyll), Anthocyanin Reflectance Index (ARI) (anthocyanin content), TCARI/OSAVI (cholorophyll content), Normalized Difference Water Index (NDWI) (water content), and Moisture Stress Index (MSI) (moisture stress). LUE was regressed against NDVI (R2 = 0.26), PRI (R2 = 0.67), ARI (R2 = 0.83), SIPI (R2 = 0.82), TCARI/OSAVI (R2 = 0.048), NDWI (R2 = 0.63) and MSI (R2 = 0.44) indexes. These results indicate that hyperspectral indices can be used to track the LUE in semiarid environments. The LUE seems to be more related with carotenoids and anthocyanin content than with chlorophyll content, PRI or water content indices. Further studies will be carried out to include more dates and for measuring simultaneously gas exchange and field reflectance at leaf and canopy levels, in order to fully understand how the relations between LUE and different optical indices change with the season and when up-scaling from leaf to canopy level.