QUANTIFICATION OF CO_2, WATER VAPOR AND ENERGY FLUXES FROM NO-TILL WHEAT-SOYBEAN SYSTEMS WITH CONTRASTING TILLAGE HISTORIES

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Introduction

The carbon and energy balance of agroecosystems depend on such factors as crop sequence, productivity, and initial soil organic carbon content. Not only CO_2 is relevant as a greenhouse gas, but also agricultural systems are relevant as possible sinks/source of CO_2 (Paustian et al., 1997, Houghton, 2007). The quantification of the net balance as well as the annual dynamics are critical to understand the main factors governing net ecosystem CO_2 exchange (NEE), particularly under intensively managed systems like croplands (Chen et al., 2006).
Cropping practices have continuously evolved in Uruguay during the last 30 years (Ernst et al., 2011) as a consequence of, a) intensification with changing proportions of cultivated pastures vs. crops within a crop sequence, and b) change in management practices with the practically complete adoption of no-till. Economics force farmers to practice double crop (winter cereal-soybean), or a single crop (fallow-soybean) crop sequence, where soybean tends to be present year after year. These crop sequences are widely used by farmers, but are regarded as unsustainable due to negative carbon and nitrogen balances and high risk of soil erosion (Siri Prieto et al, 2009).
This study was established to gather, quantify, and analyze basic information for modelling carbon and energy fluxes of typical no-till sites cropped with a soybean-wheat sequence in Uruguay.

Materials and methods

Two fields were selected based on their close proximity and antecedent tillage history in southwest Uruguay. Both sites had been in a predominantly pasture-crop sequence for the last few decades, but recently when the proportion of crops in the sequence increased, one site was managed with occasional tillage while the other site was strictly no-till. Determination of CO2, water vapour and energy balance using the eddy covariance method was initiated at each site in August 2010 and continue uninterrupted through 2012. During this period the crop sequence was Wheat-Soybean-Wheat (Barley)-Soybean at the site NM and Wheat-Soybean-Barley-Soybean at the site SM. Data pre and post processing followed regular standard procedures for quality check and correction of flexes. At both sites leaf area index and above ground biomass was measured on a weekly basis.

Results and discussion

The present study quantifies the temporal dynamics of carbon loss and gain to help identify critical periods within the sequence where major imbalances occur. Figure 1 presents the carbon flux at both sites, clearly depicting the periods where the crop is growing and NEE becomes negative due to photosynthesis, and the fallow periods where NEE is positive due to soil respiration.

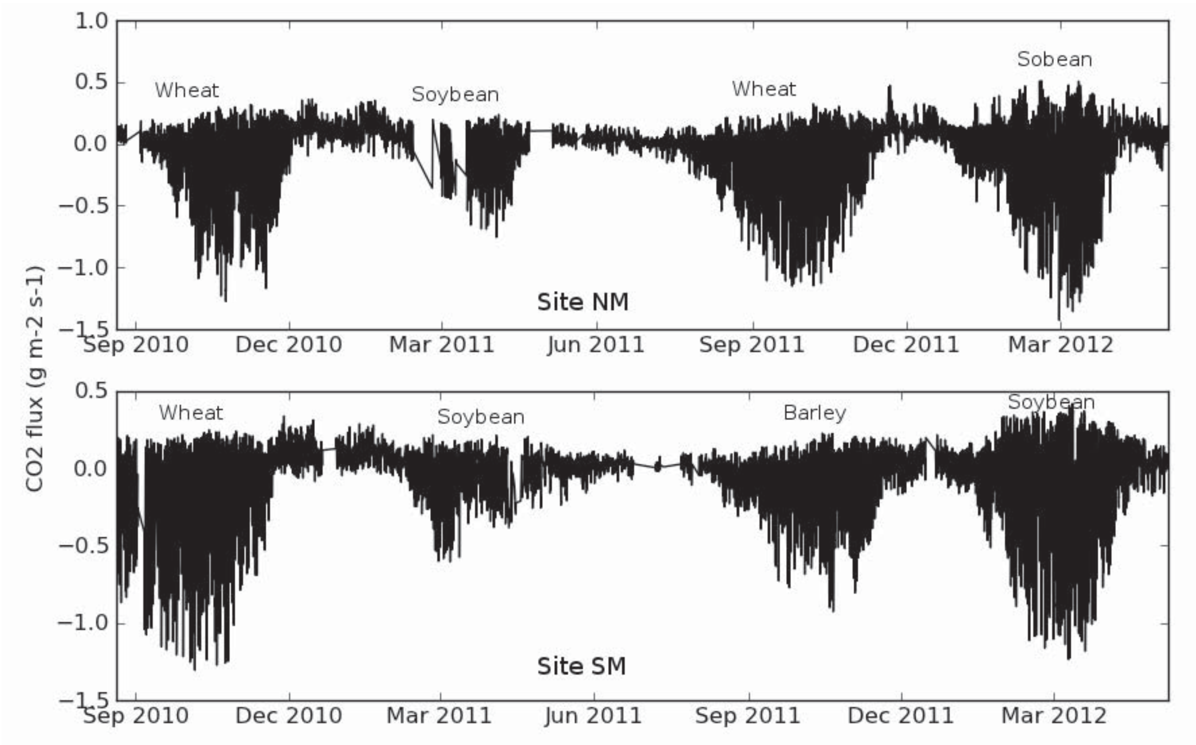

Figure 1. Carbon fluxes at NM (a) and SM (b) sites during the study period.

The summer-fall of 2011 from December through May was dryer than normal, and therefore crop growth and fluxes were decreased. This is notorious when compared to fluxes in the same period in 2012, and the leaf area of the crop (Figure 2). Fallow periods represent sources of carbon, particularly during spring and fall, and to a lesser extent during summer and winter. Presumably the reduction of such periods and the efficient use of resources (i.e. soil nutrients and soil water) will lead to the identification of a more sustainable crop sequence in terms of carbon budget. The comparison of daily aggregated fluxes for the different crop types at contrasting stage of development (leaf area index, LAI) (Figure 3) highlights the tight relationship between LAI and NEE. This relationship may prove to be robust enough to infer NEE by the monitoring of LAI through the year with remote sensing. Interestingly the intercept of the linear regression fit to the initial linear part of the relationship is higher for soybeans than for winter cereals, suggesting that a) rates of respiration grow more than proportionally during warmer periods than rates of photosynthesis, or b) rates of photosynthesis are much smaller for soybean than for wheat. Further analysis of the data, separating daytime vs. night time fluxes, and analyzing radiation use efficiency for the crop will yield a precise answer to this question. Proportionally larger response of respiration than photosynthesis to warming would be relevant in a future scenario of global air temperature increase.

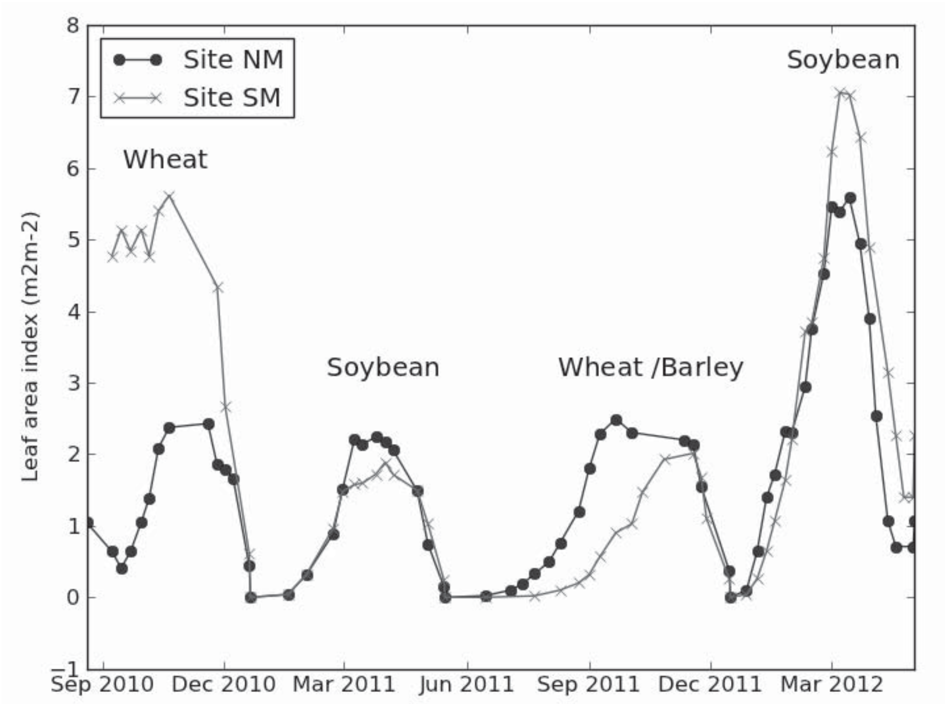

Figure 2. Leaf area index evolution over the two growing seasons at NM and SM.

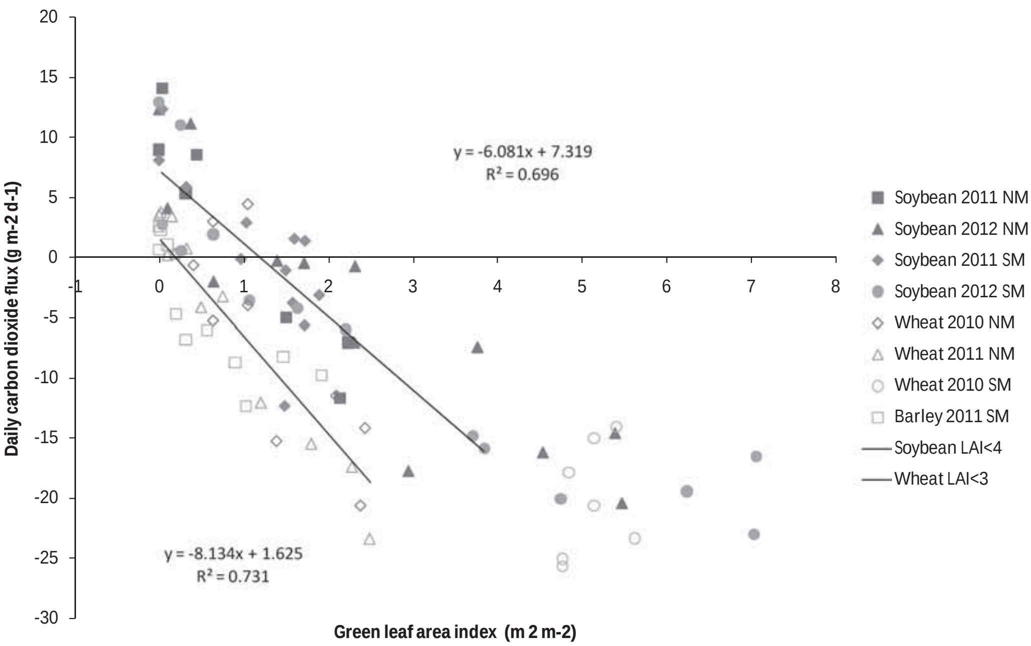

Figure 3. Daily aggregated carbon fluxes for the three mayor crops as a function of leaf area index.

Conclusion

The availability of quantitative data on fluxes of CO_2, water vapor, and energy under no-till systems is very limited. This experiment contributes to the collection of basic observational data as well as quantitative analysis and modeling of no-till cropping systems.
Carbon exchange was governed primarily by phenology and leaf area development, and secondly, but not less important to other factors, air/soil temperature and soil water content. Reducing the length of fallow periods through the year, and rapidly establishing a crop cover, is critical in reducing net losses. Presumably the reduction of fallow periods and the efficient capture of resources (i.e. solar radiation and soil water) will lead to the identification of a more sustainable crop sequence in terms of carbon budget.

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