Net ecosystem exchange of carbon over annual and perennial grasses following land use conversion

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Introduction

Land use and land cover changes greatly influence surface characteristics and consequently the energy and mass exchange between the surface and the atmosphere. Recently, undisturbed lands and/or lands previously on conventional agriculture have seen land use changes towards biofuel crop production as part of climate change mitigation. In the US Midwest, grasslands that were recently recruited under Conservation Reserve Program (CRP) of the USDA and agricultural (AGR) lands are being rapidly converted for biofuel crop production in response to increased demand for biofuel feedstock. It is, therefore, important to investigate the net carbon ecosystem exchange (NEE) between such lands and the atmosphere to assess the carbon savings/loss that would be incurred due to land use conversion overtime.

We employ eddy covariance (EC) technique over seven sites in order to examine the temporal long-term dynamics (2009-2013) of carbon NEE in response to land use conversion and management practices in annual (grain) and perennial (cellulosic) biofuel crops in the Midwest US.

Experimental design

The experimental sites are located at W. K. Kellogg Biological Station Long-Term Ecological Research (LTER) (42°24' N, 85°24' W, 288 masl) in Southwest Michigan, along the northeastern edge of the Midwest. Six fields – of which three had been managed under CRP and the other three under AGR – were converted to no-till soybean in 2009 and to no-till continuous annual (corn) and perennial (switchgrass and mixed-prairie) grasses from 2010 onwards (Fig. 1). One additional CRP grassland was kept unchanged (brome grass) as a reference.

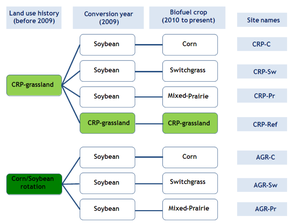

Fig. 1. Experimental design showing land use conversion from CRP and conventional agriculture to soybean and to annual and perennial grasses over time.

Eddy covariance

The eddy covariance method (Fig. 2) is a standard for a direct means of measuring mean vertical turbulent fluxes above extensive surfaces using fast response sensors for measurement of vertical wind speed (w) and scalar entity of interest (CO_2 in this case), and their fluctuations.

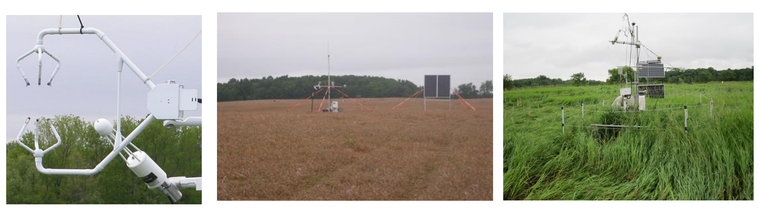

Fig 2. The Eddy covariance and ancillary instruments on site.

Results:

Meteorological conditions

- Weather variables showed the expected seasonality changes (Fig. 3).
- The 2012 growing season was a dry year characterized with very low soil water content (*SWC*).
- The 2010 had high *SWC* throughout the growing season with the other years showing occasional dryness.

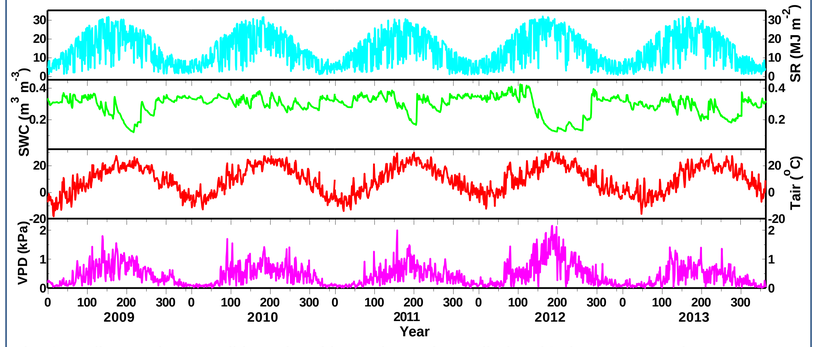

Fig. 3. Daily weather conditions (total incoming solar radiation (*SR*), averages air temperature (*Tair*) and average water vapor pressure deficit (*VPD*)) and daily average soil water content (*SWC*) for the top 30 cm of the soil profile measured at the CRP-Ref site from 2009 through 2013.

Net ecosystem exchange (NEE)

- Generally, carbon sequestration begins early in spring and continues until late summer when plants senesce. Carbon emission then takes over until next spring.
- In 2009, a pulse of carbon emission was observed following herbicide application, more so on CRP than on AGR sites (Fig. 4).
- The CRP-C and CRP-Pr are still showing net carbon emission by 2013, while the CRP-Sw turned into net carbon gain by 2013.
- The AGR lands were at least carbon neutral in the first two years of conversion and showed net carbon gain afterwards (Fig. 4).
- The CRP-Ref NEE fluctuated around the neutral line. The CRP-Ref was never harvested.

Conclusions and recommendations

- Converting existing grasslands into annual or perennial crop production results in pulse of carbon emission that may last several years after conversion.
- For a better carbon balance, the analysis should include carbon release from the harvested material at another location and time.

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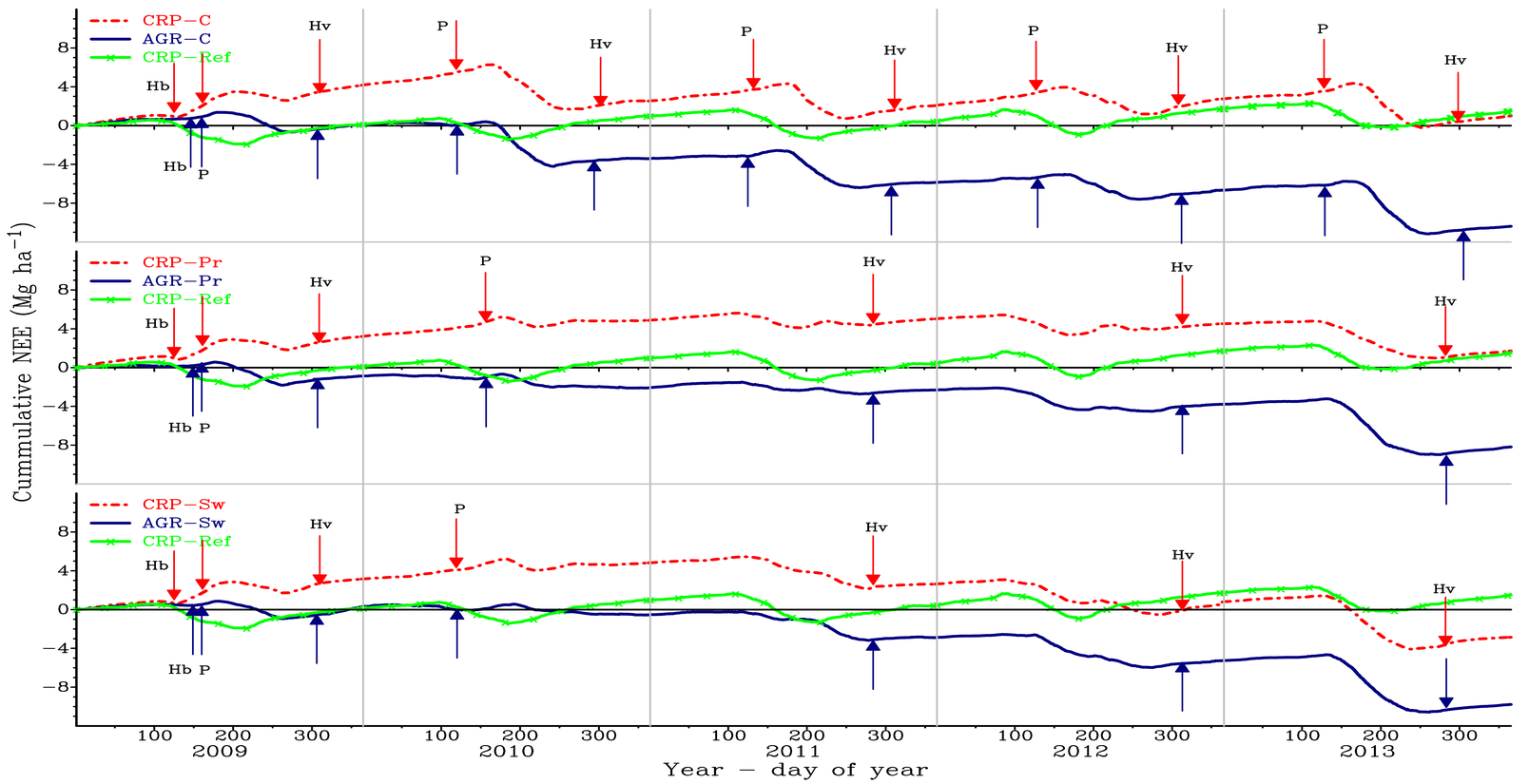

Fig. 4. Cumulative net carbon ecosystem exchange (Mg ha^{-1}) over the six converted fields and the reference site from 2009 through 2013. Arrows indicate timing of management practices (red for CRP, and blue for AGR sites) and Hb refers to herbicide application, Hv to harvest and P to planting. (+NEE is emission while –NEE is absorption)