Carbon losses and gains from agricultural ecosystems – what happened, where are we, and where do we go from here?

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A generally accepted understanding of carbon in agricultural fields is that (1) a significant amount of carbon was lost from soils when land was converted from natural vegetation to agricultural ecosystems, (2) over time a steady-state soil carbon concentration is reached with standard agronomic practices, and (3) that improved management practices or optimal crop species selection can result in increased carbon storage over time. The extent of the carbon lost from conversion from native to agricultural ecosystems is variable, but multiple studies show that carbon losses were large and consistent (supporting point 1). While an assumption of steady state is generally accepted (point 2), there are significant challenges in measuring whether mature agroecosystems are gaining or losing carbon. Multiple strategies are continually proposed to increase soil carbon storage (point 3), yet data is sparce given the plentitude of potential opportunities being considered. Furthermore, direct analysis of soil carbon is prone to substantial heterogeneity, leading to challenge in detecting signals relative to noise in heterogeneous soil environments. Eddy covariance measurements, while unable to measure pools of carbon in the soil directly, can infer changes in ecosystem carbon storage when measurements are integrated over time. Here, long-term eddy covariance datasets were used to measure carbon and water fluxes over agricultural ecosystems in the Central Midwestern United States over multiple years for different crop and management practices. The measurements show that conventionally tilled Midwestern row crops, maize and soybean, integrated on a rotational basis typical for this region represents a large carbon source to the atmosphere, counter to point 2 above. However, similar measurements over the same agroecosystem but with conservation tillage practices indicate long-term carbon storage, even after 20+ years of conservation tillage with significant climate variability. These results suggest that large-scale adoption of no-till practices can significantly reduce the large-scale losses of carbon associated with conventional tillage and, potentially, lead to small but meaningful increases in soil carbon storage, supporting point 3. Similar measurements were also collected over perennial grass ecosystems with potential for bioenergy production, including *Miscanthus giganteus*, *Panicum virgatum*, and high species diversity prairie. While these agricultural ecosystems show promise for offsetting fossil carbon emissions, they are also predicted to be better at storing carbon than annual row crops. Multiple years of analysis from these ecosystems show that perennial bioenergy crops are much more likely to lead to ecosystem carbon storage than minimally-tilled annual row crops as early as the first year of transition, but the amount of storage varies based on which species is planted. While this research is focused on one location, the results suggest that the assumptions of steady-state and increases in storage over time may not hold for all agricultural ecosystems and in all locations.

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