Spatial and temporal variation of soil CO_2 and N_2O fluxes, and environmental drivers, in a highly-instrumented SMARTFARM corn field in Illinois, USA.

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Soil greenhouse gas (GHG) emissions from agricultural fields are important drivers of climate change. Improved understanding of these fluxes, particularly of N_2O "hot spots" and "hot-moments", could improve Earth System Models, and support development of the field-level GHG estimations needed to quantify regional carbon intensity. We set out to identify potential environmental drivers of spatial and temporal variation in soil GHG emissions. In June 2021, we installed 20 continuous soil flux chambers (4 clusters, 5 chambers) in a 4 ha section of 32 ha corn-soybean rotation system planted in corn in central, IL, USA. Soil CO_2 and N_2O fluxes were measured hourly from late June 2021 until late April 2022. Concurrent with flux measurements, we also measured continuous temperature, moisture, and oxygen in soils at two depths (5 and 15cm).

Mean soil CO_2 flux across the 10-month sampling period was 1.89 μmol m^{-2} s^{-1}, but varied by a factor of two between chambers (chamber means ranged from 1.24 to 2.64 μmol m^{-2} s^{-1}). Mean soil N_2O flux was 0.47 nmol m^{-2} s^{-1}, but varied by a factor of five between chambers (chamber means ranged from 0.20 to 1.07 nmol m^{-2} s^{-1}), indicating that N_2O emissions across this field was dominated by hot spots (e.g. half of cumulative emissions were from the "hottest" 25% of chambers). Likewise, hot moments accounted for a large fraction of N_2O emissions (e.g. the "hottest" 1% and 10% hourly fluxes at each chamber accounted for 21 and 62%, respectively, of cumulative N_2O emissions). Non-growing season N_2O fluxes were greater than expected, at approximately half of the growing season rate. Path analyses using soil temperature, moisture, and oxygen as predictors explained much of the variation in soil CO_2 flux ($R^2 = 0.69$), with soil temperature (at 15cm) as the most important predictor, and soil moisture and oxygen only improving the model marginally. All environmental variables we measured were weak predictors of N_2O flux ($R^2 = 0.063$). These results suggest that soil GHG fluxes (especially N_2O) in a relatively homogenous agriculture field have considerable spatial and temporal variation that must be accounted for in GHG estimates. They also suggest a need to explore additional soil chemical, microbial, and meteorological drivers of soil N_2O flux in both surface and deep soil, and through seasonal shifts.

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