Seasonal dynamics of N_2O and CO_2 emissions

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The magnitude of nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions is affected by diurnal and seasonal fluctuations in temperature, moisture, availability of nitrate (NO_3-N) and ammonium (NH_4-N), and soil microbial activity. Rainfall during the fall and spring result in high N_2O and CO_2 emissions due to spikes in microbial activity upon soil rewetting. Thawing events during the winter result in an increase of greenhouse gas (GHG) emissions followed by a reduction in emissions in subzero temperatures. Application of fertilizer nitrogen prior to winter wheat planting in the fall increases the likelihood of GHG emissions due to increased availability of NO_3-N and NH_4-N. The current study was designed to assess the seasonal dynamics of N_2O and CO_2 emissions in dryland, no-till winter wheat systems.

IMPACT

Predicting the effects of agricultural management practices on global climate change requires an accurate assessment of diurnal and seasonal dynamics of soil greenhouse gas emissions. The study addresses the role of soil moisture, temperature, and freeze-thaw events in the production of nitrous oxide and carbon dioxide. The project is designed to provide a better estimate of annual greenhouse gas emission rates.

The no-till winter wheat site at Cook Agronomy Farm near Pullman, WA, was equipped with the Li-Cor 8100A combined with the LGR 23r N_2O analyzer and 16 long-term Li-Cor chambers placed in four replications at four elevation positions along the slope. Each chamber was paired with a Decagon 5™ soil temperature and moisture probe. Before installing the setup, we planted the wheat and fertilized the site with the agronomic rate of anhydrous ammonia fertilizer. The experiment ran continuously from October 2013 to September 2014. During snowfall events, we interrupted the measurements to prevent damage to the chamber domes due to snow obstruction. At the end of each snowfall event, we removed the snow from the chamber closure to ensure resumption of measurements in a timely manner. In the spring and summer, we trimmed the wheat inside the chambers to prevent CO_2 uptake, which could affect the measurements.

Emissions of N_2O increased following the rainfall in November, likely due to an increase in microbial activity leading to nitrification (Figures 1a, 1b, and 1c). In early December 2013, we observed a decrease in N_2O emissions as the temperatures dropped to near zero at night (Figure 1d). An increase in soil moisture during the day fron the end of December 2013 to early January 2014 resulted in spikes of N_2O emissions to 20 to 30 g N_2O-N meters^2 per hour (Figure 1b). During several consecutive snowfall events and thawing in January through March 2014, N_2O rates went up to 50 to 70 grams N_2O-N meters^2 per hour, with a

Snow removal from automatic static chambers at the long-term nitrous oxide and carbon dioxide monitoring site. Photo by Sarah Waldo.

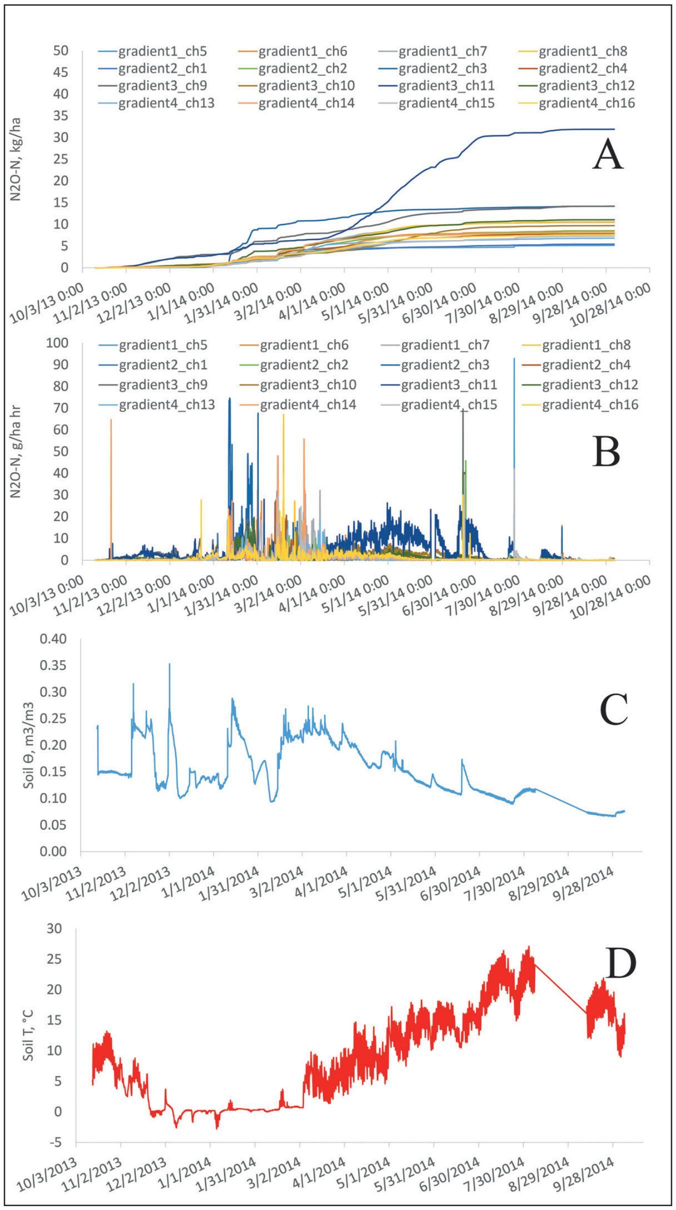

Figure 1. *Emissions of nitrous oxide (N_2O) and cumulative N_2O rates from October 2013 to September 2014 in a no-till winter wheat site in the PNW. Conversion factor: grams per hectare x 0.0009 = pounds per acre.*

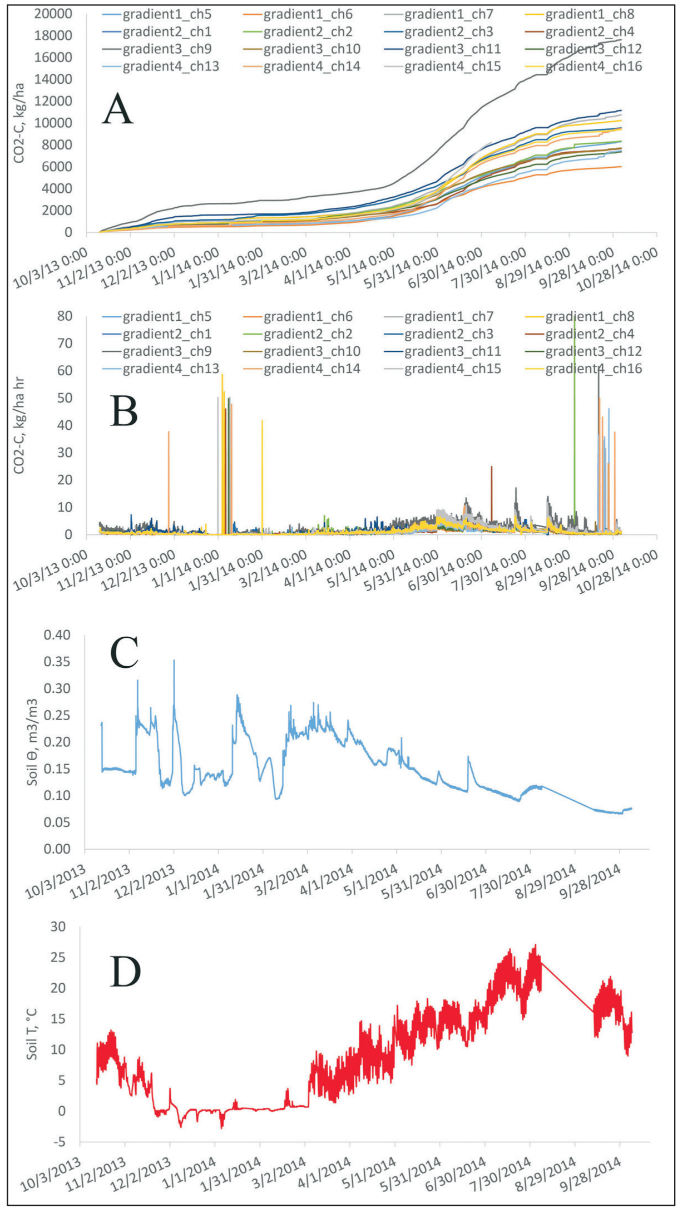

Figure 2. *Emissions of carbon dioxide (CO_2) and cumulative CO_2 rates during October 2013 through September 2014 in a no-till winter wheat site in the PNW.*

decrease in N_2O emissions when the moisture levels decreased. Emissions of N_2O started to decrease from March to May 2014 when increasing temperatures drew down the soil moisture levels. Several N_2O spikes in May through August 2014 occurred during rainfall events.

CO_2 emissions remained steady and then increased during rainfall events, then largely decreased with the reduction in daily temperatures in November and December 2013 (Figures 2a and b). Emissions of CO_2 spiked to 60 kilograms CO_2-C per hectare per hour following the pattern of N_2O emissions during the thawing periods in December 2013 (Figures 2c and d). CO_2 levels decreased rapidly after the freeze-thaw events and were relatively low in February through March 2014, during the times when N_2O emissions were high. As CO_2 followed N_2O only during the freeze-thaw period, it suggested that frozen water film possibly trapped N_2O and CO_2 in the soil pore space, and then released large quantities of GHG when it melted. Another possible factor affecting N_2O and CO_2 spikes was an increase in microbial activity during freeze-thaw events, which supplied water from thawing ice. CO_2 emissions went up during the spring of 2014, but, unlike N_2O emissions, continued to increase into May and June 2014. Increases in CO_2 in July and August occurred following the rainfall events. Several spikes of CO_2 were observed in the second part of September 2014, possibly due to an increase in organic matter following wheat harvest.

The total N_2O-N loss was 5% to 8% of the agronomic nitrogen application rates. Maximum N_2O emissions occurred between December 2013 and April 2014. Late spring and summer emission hot spots were associated with rainfall events. This shows the significance of freeze-thaw events and elevated moisture levels in the winter and early spring as major factors contributing to emissions of N_2O. The study emphasized the importance of N_2O and CO_2 measurements during the winter period in accounting for total GHG emissions.