N_2O and CO_2 production in wheat-based cropping systems

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Rainfall, irrigation, and soil nitrogen (N) fertilization are factors that drive emissions of the highly potent greenhouse gas nitrous oxide (N_2O), a major contributor to climate change from agriculture. Changing climate could promote shifts of agroecozones (AEZs) due to increased temperatures, as well as expansion of irrigated agriculture and increased irrigation requirements. An accurate assessment of N_2O and carbon dioxide (CO_2) emissions in irrigation scenarios is required for predicting the effects of changes in agricultural management practices on global climate change.

IMPACT

Soil nitrogen fertilization leads to production of carbon dioxide (CO_2) and nitrous oxide (N_2O), greenhouse gases that contribute to global climate change. This study increases our understanding of the scale of these emissions in dryland and irrigated systems under conventional tillage and no-tillage. The project is designed to develop better greenhouse gas predictions in order to improve nitrogen fertilization and irrigation strategies to reduce greenhouse gas emissions.

No-till management is a conservation practice that can sequester soil carbon, preserve soil moisture, and reduce erosion. Its effects on greenhouse gas emissions are less well known. Therefore, we conducted a study on greenhouse gas emissions (CO_2 and N_2O) in response to water and N additions on long-term inland Pacific Northwest research sites (Pendleton, Oregon; Moro, Oregon; and Kambitsch Farm, Idaho). Cropping systems were conventional tillage (CT) and no-tillage (NT) dryland wheat. A more recently established irrigated site (Prosser, Washington) was also included.

We implemented the system of Li-Cor 8100A automatic chambers coupled with LGR 23r N_2O analyzer for continuous monitoring of CO_2 and N_2O emissions in a short-term micro-plot study with the following treatments: (1) no water or fertilizer, (2) water added to 80% water-filled pore space and amended with 150 kg NH_4NO_3-N ha^{-1}, (3) water added to 80% water-filled pore space, but no fertilizer. Application of N and water took place at 9:00 a.m., and the measurements continued from that time until 7:00 a.m. the following day, for a total of 22 hours (Figure 1). The study was conducted in July 2013, when greenhouse gas response to applied N and water would be expected to be maximal.

In the dryland wheat system scenario, N_2O peaks were higher for water plus N treatments than for water only treatments (Figure 2). Both water plus N and water only treatments had higher N_2O emissions than did the no water treatments. CT treatments resulted in higher levels of N_2O than did NT treatments.

Figure 1. *Dr. Kirill Kostyanovsky applies water and nitrogen treatments to no-till winter wheat stubble. Automated static chambers monitor subsequent greenhouse gas emissions on micro-plots. Photo by Dave Huggins.*

Significantly, N_2O emissions from water plus N NT treatments were less than those from water only CT treatments.

Emissions of CO_2 tended to increase in the water plus N treatments for both CT and NT, compared to water only NT treatments during the first several hours of the study. All water plus N and water only treatments had higher CO_2 emissions than treatments without water added.

The total losses of N to N_2O emissions were 0.02% of the total N applied under CT, compared to 0.017% from NT plots with water plus N during the first day of measurement. With water additions only, an equivalent of 0.017% N was lost from CT plots, and an equivalent of 0.010% N was lost from NT plots. Emissions of N_2O from the plots with no water or N added were negligible.

The irrigated wheat system produced higher N_2O emissions for both N plus water and water only treatments than for the no water treatments. Water plus N treatments resulted in higher N_2O peaks than water only treatments (Figure 2). CT treatments resulted in N_2O emissions 30 to 40% higher than NT treatments.

Emissions of CO_2 were increased in the water plus N treatments and water only treatments compared to the treatments without water added during several initial hours of the study. Water plus N CT treatments also had higher CO_2 emissions than did NT treatments during several initial hours and then decreased to the level of CO_2 emissions from treatments with no water added.

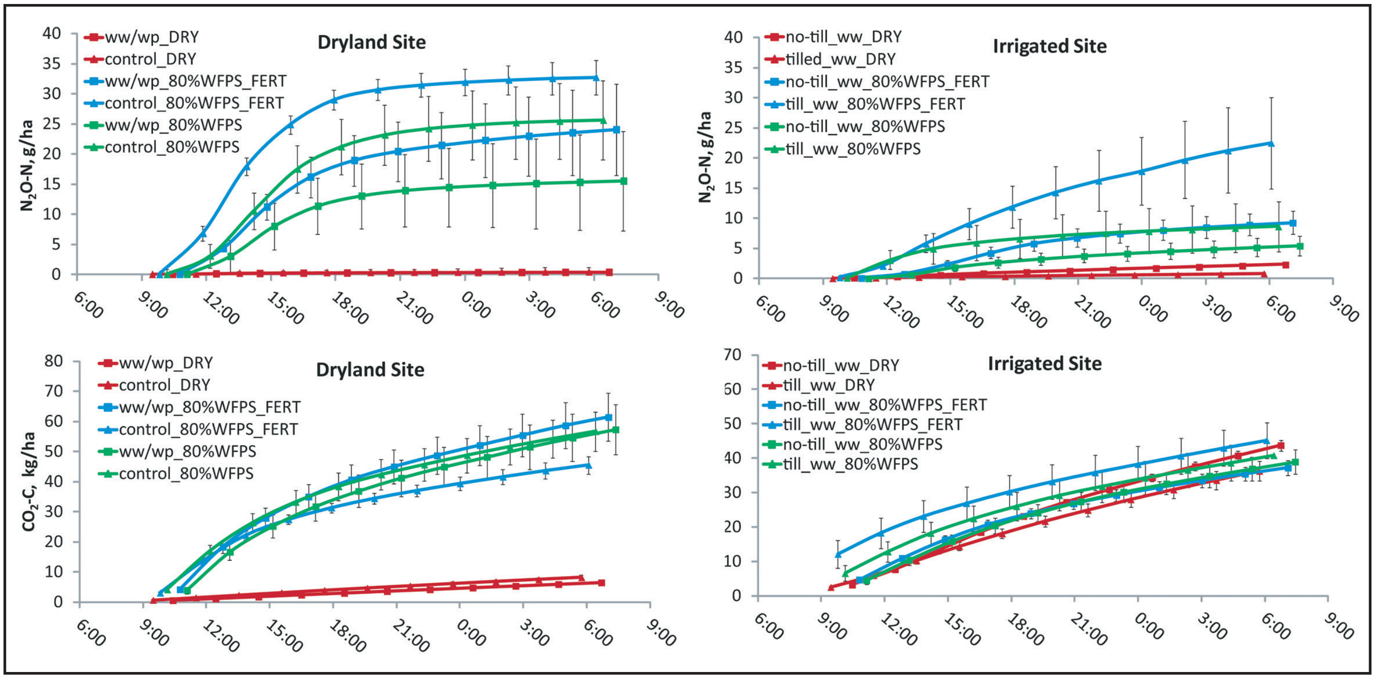

Figure 2. *Cumulative emissions of N_2O and CO_2 during the first day of measurements. Treatments included water only and water plus nitrogen (150 kg N ha^{-1}) under dryland and irrigated no-tillage and conventional tillage management systems.*

Approximately 0.015% of the total N applied was lost to N_2O emissions under CT compared to 0.006% under NT with water and N additions during the first day of measurement. About 0.006% of the total N applied was lost from the CT with only water addition and an equivalent of 0.004% N from NT with only water additions. Emissions of N_2O from the plots with no water or N added were 0.001% of the total N applied for CT and NT during the first day of measurements.

Overall, emissions of N_2O and CO_2 following additions of water plus N and water only were higher from the dryland sites than from the irrigated site. This shows that initial wetting of soil under dryland conditions results in higher spikes of microbial activity than it does on irrigated sites, leading to higher emissions. Emissions of CO_2 and N_2O were likely stimulated by NH_4NO_3 application, due to increased microbial activity from nitrification and denitrification processes, resulting in increased organic matter decomposition in the semi-saturated soil. The processes were more pronounced in CT than NT plots, likely because higher rates of organic matter decomposition and slower internal soil water drainage lead to higher cumulative N_2O and CO_2 emissions. The study demonstrated the significance of NT for reduction of N_2O emissions during fertilization and irrigation events as compared to CT.

Divided slopes and cross-slope farming on hills in Eastern Washington. Photo by Sylvia Kantor.