Project: Collecting the carbon data needed for Climate-Smart agriculture in Saskatchewan

Principal Investigator: Dr. Kate Congreves

PhD Student: Daphnée Ferland

Key Messages:

- Our measurements are among the first to provide direct, year-round, field-scale GHG data—specifically N_2O and CO_2 fluxes—for a canola-wheat rotation in Saskatchewan.
- On average, half the annual N_2O emissions were attributed to the growing season (GS), other half attributed to non-growing season (NGS).
- 4R N management reduced cumulative N_2O emissions by 57% without impacting yields, compared to conventional practice.
- N_2O reductions due to lowering mean daily fluxes during GS wet periods after fertilization, and also due to reducing NGS emissions by lowering fall soil nitrate levels.
- The cropping system remained a net C source for three years, but conditions tipped the system to a net C sink in the fourth year. Averaged over the 4-yr period, cropping system was net C neutral.

Arable croplands are a significant source of nitrous oxide (N_2O) emissions, largely due to nitrogen (N) fertilizer applications to support crop production. However, there is limited research measuring N_2O dynamics from canola-wheat rotations in the semi-arid Prairies, an important agricultural region of Canada. Here, we present micrometeorological N_2O fluxes measured using the flux gradient technique from Jan 2021 to Apr 2025 in Saskatchewan to evaluate the impact of N fertilizer management on year-round N_2O emissions from a canola-wheat rotation. A combination of two 4R N management practices (a reduced N rate and an enhanced efficiency N fertilizer source) was compared to conventional fertilizer management practices for the region (urea-N fertilizer for regional yield targets). Two periods at high risk for N_2O flux events were identified i) after N fertilizer application and ii) during spring thaw; but the magnitude of emissions varied over the multi-year period. The crop growing season (GS) contributed, on average, half of the annual emissions, presenting an opportunity to reduce N_2O emissions via improved N fertilizer management. Indeed, in our study, the improved 4R N management treatment reduced N_2O emissions by 57% over the entire study period, without impacting yields.

The reduction of GS N_2O was due to smaller mean daily fluxes during periods with high water-filled pore space (WFPS, > 50%). In other words, by reducing the magnitude of fluxes during wet periods after fertilization, the 4R N management strategy translated into lower total N_2O emissions. But what about the non-growing season? Importantly, the non-growing season (NGS, overwinter and spring thaw periods) represented an equally important source of N_2O—the other half of average annual N_2O emissions. Fall soil nitrate levels were a strong explanatory variable of NGS emissions, but the magnitude of NGS N_2O emissions depended on the thawing conditions (lower fluxes during drier thaws, higher fluxes during wetter thaws). Putting it altogether, better N management reduced cumulative N_2O emissions in the canola-wheat rotation, in part due to lowering N_2O fluxes during wet periods of the GS, but also due to reducing fluxes during the NGS by lowering residual soil nitrate levels.

The next question that our research addressed was if the cropping system represented a net source or sink of carbon (C)? Throughout the study period described above, CO_2 fluxes were also measured using the flux-gradient micrometeorological technique, enabling the calculation of net ecosystem exchange (NEE), net ecosystem carbon balance (NECB), and greenhouse gas budget (GHGB). Total GHG emissions (CO_2 *and* N_2O in CO_2-equivalents) tended to be lower from the improved N management vs conventional N fertilizer treatment. As for whether the system was a C source or sink: 2021 was *exceptionally dry* such that the canola crop did not produce net CO_2 uptake and represented a C source. Wheat in 2022 and canola in 2023 both favoured net CO_2 uptake during the GS, but the balance tipped the system to a net C loss once the grain/oilseed (and the C in it) was removed at harvest. In the final year (2024), wheat production acted as an overall C sink, sequestering 0.19 kg C m^{-2} yr^{-1}. For the complete rotation over the 4-year period, the system was C neutral on average.

When all is said and done, the improved N management reduced N_2O emissions, and for the 4-year period the cropping system was C neutral on average. Flipping the system to a net C sink might involve management that supports vigorous crop growth in-season and favours including wheat in the rotation. Our measurements provide some of the first year-round direct measurements of GHGs in a canola-wheat rotation for Saskatchewan and are a valuable starting place to build from and develop further strategies for reducing emissions and supporting crop production on the Prairies.

Acknowledgements:

Funding was provided by the Saskatchewan Ministry of Agriculture (Agriculture Development Fund), Saskatchewan Wheat Development Commission (SaskWheat), Saskatchewan Canola Development Commission (SaskCanola), and the Saskatchewan Oat Development Commission (SaskOats).