Long-term C and N20 monitoring, and climate-smart management of organic grain production systems

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Report from 2024/2025 research

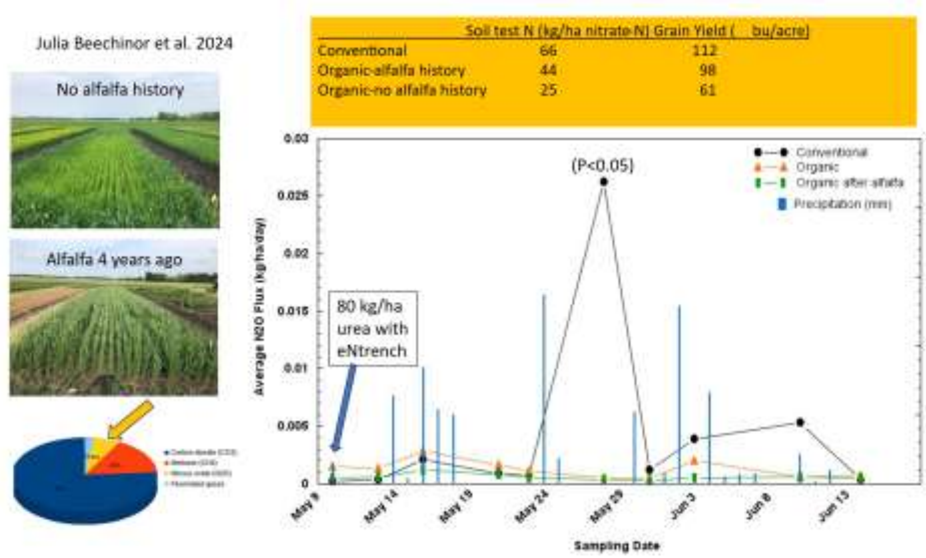
Introduction

Oats are an ecologically friendly crop that can be produced with minimal pesticides, can be easily incorporated into organic rotations for good returns, and provide nutritional benefits to people. The Canadian and indeed global agricultural industries are looking for ways to make crop production even more environmentally friendly by reducing greenhouse gas (GHG) emissions. This project, which is sponsored by the Prairie Oat Growers Association, asks the question of how organic production compares with conventional oat production in terms of nitrous oxide emissions. Year one of the study was conducted in 2024; the second year will be conducted in 2026.

The research was conducted on the Glenlea plots, where conventional and organic production have been compared since 1992. The first set of measurements included GHG losses to the atmosphere (nitrous oxide emissions). Nitrous oxide (N_2O) has been identified as an ozone-depleting GHG and synthetic nitrogen is the biggest contributor to the total N_2O emissions and is released after N field application. The second objective was to measure GHG gains in the soil (Carbon increases in surface and subsoils) and we asked the question of whether organic systems have more soil C than conventional systems. Finally, we looked at the GHG budget all together of a 12-year period using the HOLOS greenhouse gas calculator.

Part 1. Nitrous Oxide losses from organic vs conventional oat crops

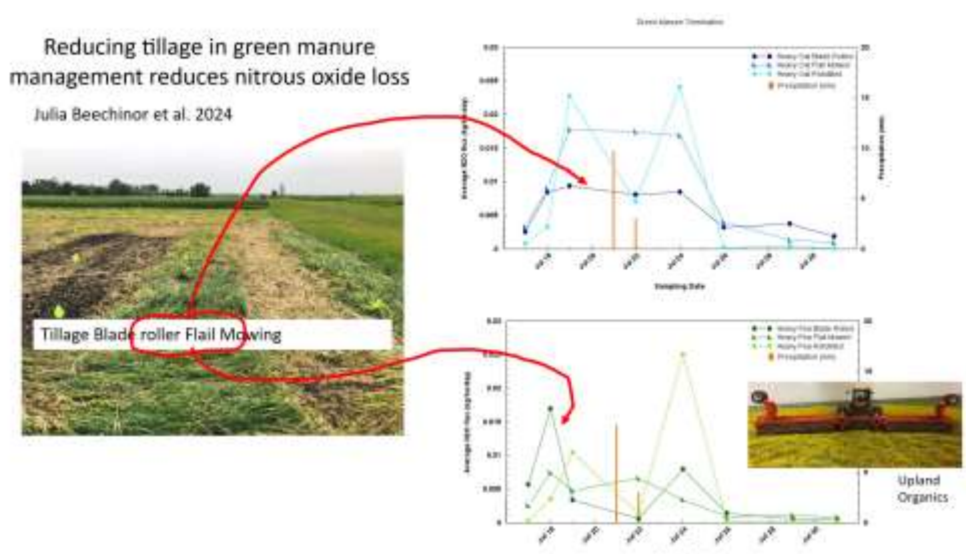
Study 1 focusses on nitrous oxide emissions in the crops within the long-term study. The work was conducted by undergraduate student Julia Beechinor, who received financial support from the RBC scholars program. Results are given in the figure below.



Results show several interesting trends:

- Emissions during the critical early season period increased significantly once precipitation occurred in the conventional compared with the organic systems. This occurred even though the N fertilizer source in the conventional system included an inhibitor. Similar results were measured when nitrous oxide emissions were measured in organic vs conventional wheat in a previous study (https://www.sciencedirect.com/science/article/abs/pii/S0167880917304954).
- There were two organic oat systems tested; one that had a past history of a 5-year alfalfa stand and one that was in the Glenlea base rotation (cover crop-wheat-flax-oats). Even though the first system had higher levels of available soil N (see table above), it did not release any more nitrous oxide than the low N organic system. This shows that raising N supply biologically (important to increase oat yield potential) did not result in an increase in nitrous oxide emissions.
- Based on nitrous oxide emissions during the period from seeding to oat heading, the nitrous oxide footprint of organic oats was much lower than that of the conventional oats; even though there was only a 10% yield difference.

Study 2 focusses on nitrous oxide emissions in green manure crops as influenced by termination technique. When legume green manure cover crops are terminated, there is a risk that nitrous oxide will be released as the legume plant material decomposes. In her 2024 research, Julia Beechinor asked the question: “Would there be less nitrous oxide released if the cover crop was terminated with less soil disturbance?” The treatments (tillage, flail mower and blade roller (which crimps the crop down to the soil surface)) were applied to two green manure crops, one dominated by oat and one dominated by peas. Results showed that using the blade roller to terminate the green manure resulted in the least nitrous oxide emissions; the tillage had the most and the mowed green manure was intermediate. Minimum tillage tools now available to organic farmers include wide blade cultivators and blade rollers.

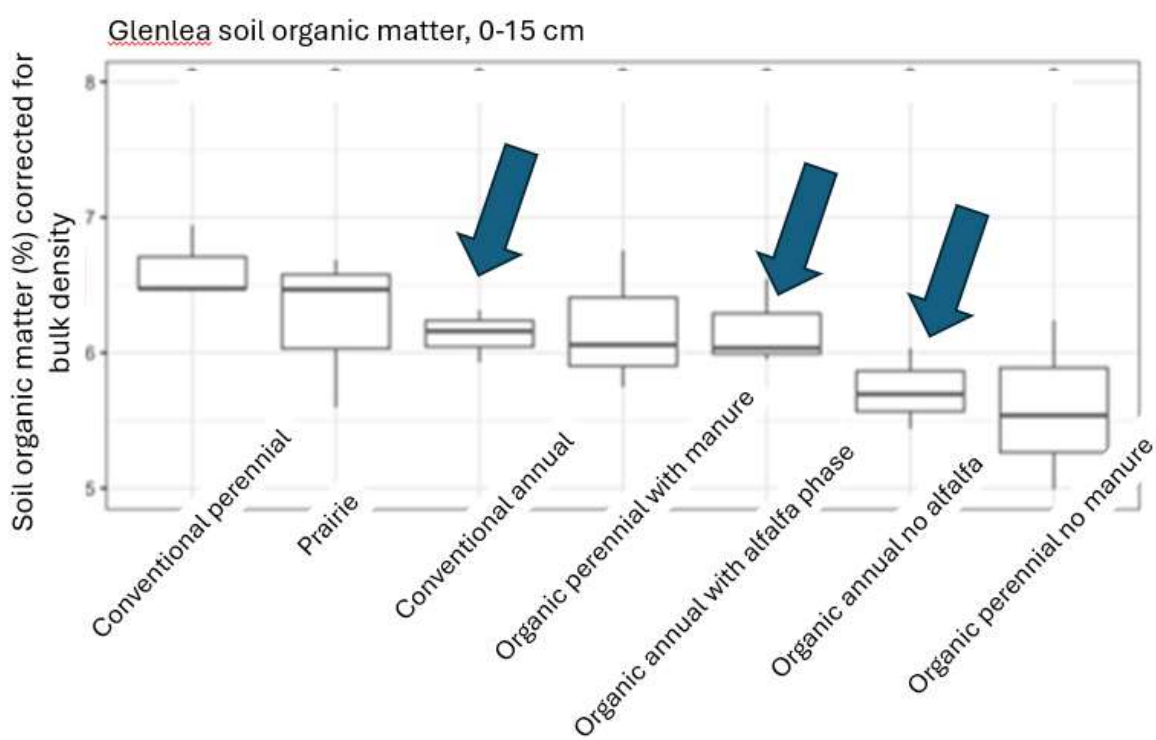


Part 2. Do organic systems have more or less soil Carbon?

Soil organic matter was compared for the three treatments tested: Conventional annual rotation (soybean-wheat-flax-oats) and the Organic annual rotation (cover crop-wheat-flax-oat). The organic annual plots were split to allow half of the plots to grow a 5-year alfalfa phase (2016-2021). Soil organic matter levels were corrected for soil bulk density (which indicates soil compaction and health). Soil bulk density can vary between different crop rotations. Unless the soil C measurements are corrected for bulk density, differences that appear due to crop rotation, or other management, may in fact be due simply to differences in the density (compaction) of the soil. This is actually a common mistake in soil C work, and it is now routine to correct for soil bulk density in any credible soil carbon reporting.

Results for the three treatments under investigation are identied by arrows in the figure below. All three treatments measured were oats in the grain-only (annual) rotation. Conventional annual oat crop rotation was soybean-wheat-flax-oat. Results show that the organic oat plots with the alfalfa history have similar soil organic matter levels as the conventional system but without the alfalfa phase, the organic system has lower organic matter.

The "organic annual no alfalfa" refers to oats in the long-term organic rotation that never had alfalfa inserted (green manure legume-wheat-flax-oat). These plots were split 10 year ago and a five-year alfalfa phase was inserted into the rotation, then went back to the base rotation. The "organic annual with alfalfa phase" rotation was: alfalfa (5 years)-green manure legume-wheat-flax-oat. The alfalfa was terminated four years before the oat crop, tested in that particular rotation, was grown. The alfalfa was inserted into the rotation to improve the nitrogen status of the soil (increase it) and drive down the wild oat population.



Part 3. HOLOS Modelling Research

In addition to field studies, the greenhouse gas footprint was modeled for all rotations in the Glenlea study. A 12-year time period was used for this analysis and instead of just looking at oat, we looked at the whole rotation. Here is a summary of the results.

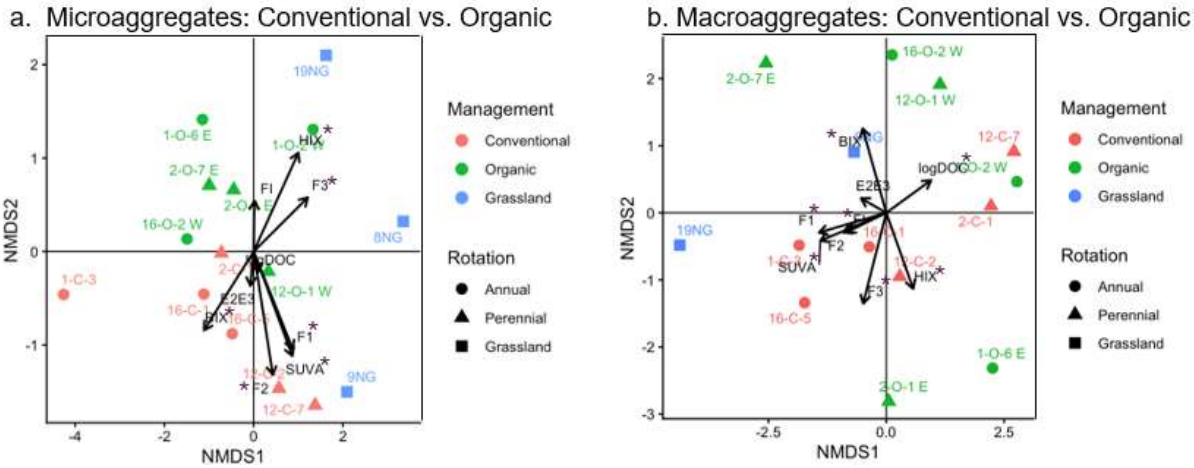
- In terms of below ground C inputs, the organic grain only system performs poorly compared with the organic forage-grain with manure system. This observation supports the direct field measurements reported in part 1 of this report.
- In terms of below ground C inputs, the organic grain only system with the 5 year alfalfa phase shows significant soil C increase during the alfalfa phase. This clearly demonstrates that perennial crops in the rotation can build up soil organic matter.
- In terms of nitrous oxide emissions, the annual grain only organic system has among the highest levels of nitrous oxide emissions. The reason for higher nitrous oxide emissions in the organic grain system is the inclusion of the green manure year. The HOLOS model uses very high nitrous oxide coefficients for legume green manures. This makes research into reducing nitrous oxides associated with green manuring even more urgent.

Part 4. Do organic and conventional systems different in the way they sequester soil C?

This project, which is the PhD research of Charitha Hansima (UM Dept of Soil Science), aims to identify soil carbon (C) sequestration mechanisms in a 34-year-long-term rotation experiment by profiling soil organic matter (SOM) within soil aggregates. The study characterizes SOM along the aggregate hierarchy by fractionating aggregates into distinct pools: particulate organic matter (POM), mineral-associated organic matter (MAOM) and its subfractions, and dissolved organic matter (DOM).

Preliminary results comparing organic vs conventional systems within micro and macro soil aggregates are shown for dissolved organic matter only (DOM), see figures below. Dissolved organic matter is the carbon that is leaked directly out of the plant's root system and makes up roughly 15% of photosynthetic C. DOM is very important for formation of stable soil C since it is readily available to soil microbes for processing into more stable forms of C.

The conventional vs. organic contrast was marginally significant ($P \approx 0.05$) (see figure below) meaning that the pathways for C sequestration do indeed appear different for organic and conventional production. Conventional treatments were associated with fresh plant-like fluorescence components, whereas organic treatments aligned more with humification-related signatures and microbial-associated components. Overall, the results support a trend toward more processed/humified DOM under organic management relative to conventional management. How these results can impact crop management decisions of agronomists and farmers will be provided in the project's final report.


a. Microaggregates: Conventional vs. Organic
b. Macroaggregates: Conventional vs. Organic
NMDS1
NMDS2
Management
Conventional
Organic
Grassland
Rotation
Annual
Perennial
Grassland