Estimating $\delta^{13}C$ of grassland soil-respired CO_2 using an optimized automated chamber system and novel CO_2 isotope Analyzer

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Introduction

- Soil carbon dynamics are affected by various biological and geochemical processes and tracking the evolution of soil-respired CO_2 provides a powerful solution toward understanding carbon cycling in both natural and managed ecosystems.
- The stable carbon isotope ratio ($\delta^{13}C$) of soil-respired CO_2 is an isotopic “fingerprint” which is dynamically affected by soil characteristics, above- and below-ground biological activity, and climate variability.
- This study demonstrates application of a novel, automated chamber-based soil gas measurement system to monitor $\delta^{13}C$ of soil-respired CO_2 in a managed grassland. The Keeling approach was used to estimate source $\delta^{13}C$ of respired CO_2 from natural and manipulated plots, revealing variation due to substrate source and diurnal cycling.

Methods

Four automated soil gas flux chambers were installed in a managed grassland site near Lincoln, NE, USA in early June 2024. On July 3, 2024, two of the chambers were moved on to sealed collars, one containing *Glycine max* (soybean, C_3 photosynthetic physiology) residue and one containing *Zea mays* (maize, C_4).

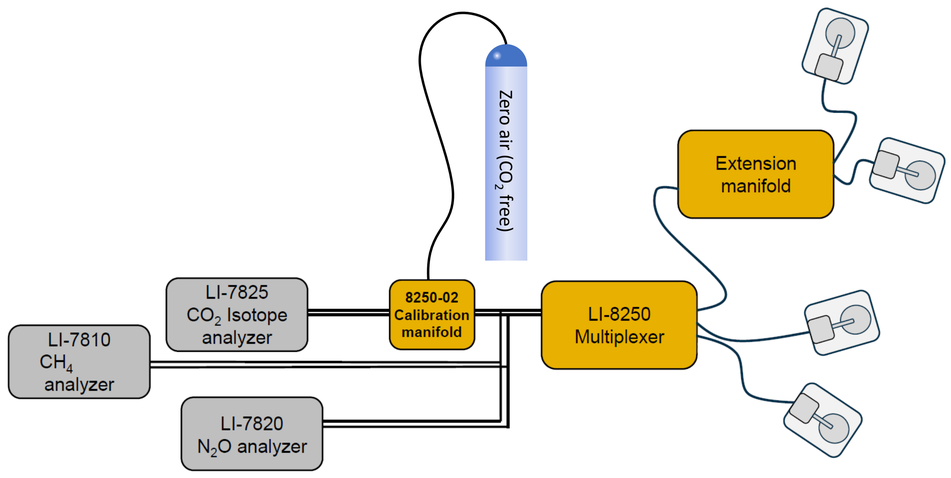
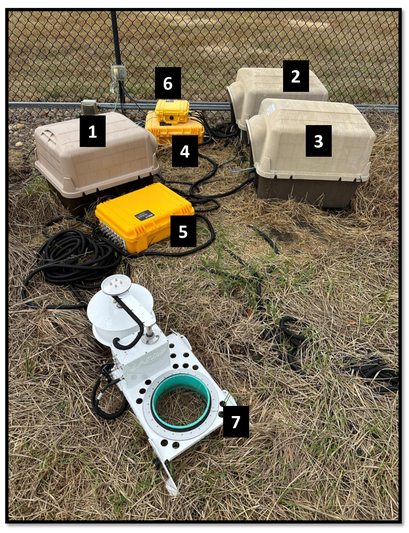


Figure 1: Schematic of automated soil gas measurement system. Soil gas flux chambers are connected to a Multiplexer which manages gas sampling and data logging. An LI-7825 CO_2 Isotope / NH_3 Trace Gas Analyzer interfaces with the multiplexer via a calibration manifold. The manifold provides a novel, passive H_2O equilibration system and facilitates automated daily baseline calibration. Other trace gas analyzers can be connected as well to simultaneously measure fluxes of gases such as N_2O and CH_4.



1. LI-7810 $CH_4/CO_2/H_2O$ Trace Gas Analyzer
2. LI-7820 N_2O/H_2O Trace Gas Analyzer
3. LI-7825 CO_2 Isotope/NH_3 Trace Gas Analyzer
4. LI-8250 Multiplexer
5. LI-8250-01 Extension Manifold
6. LI-8250-02 Calibration Module
7. LI-8100-104 Long-Term Chamber

Figure 2: Photograph of measurement system

Results

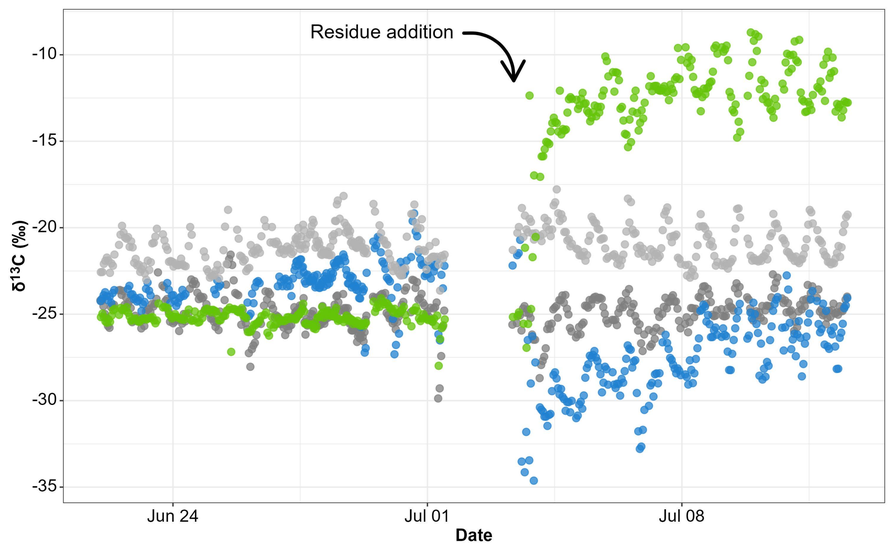


Figure 3: Measured $\delta^{13}C$ values for four automated chambers. Week 1 shows data collected over untreated grassland plots while week 2 shows one plot dosed with C_3 soybean residue (blue) and another with C_4 maize residue (green). Grey points remained on grassland. The observed $\delta^{13}C$ values are consistent with those associated with C_3 and C_4 plants: approximately −28‰ and −13 ‰ respectively.

Estimation of Soil $\delta^{13}C$

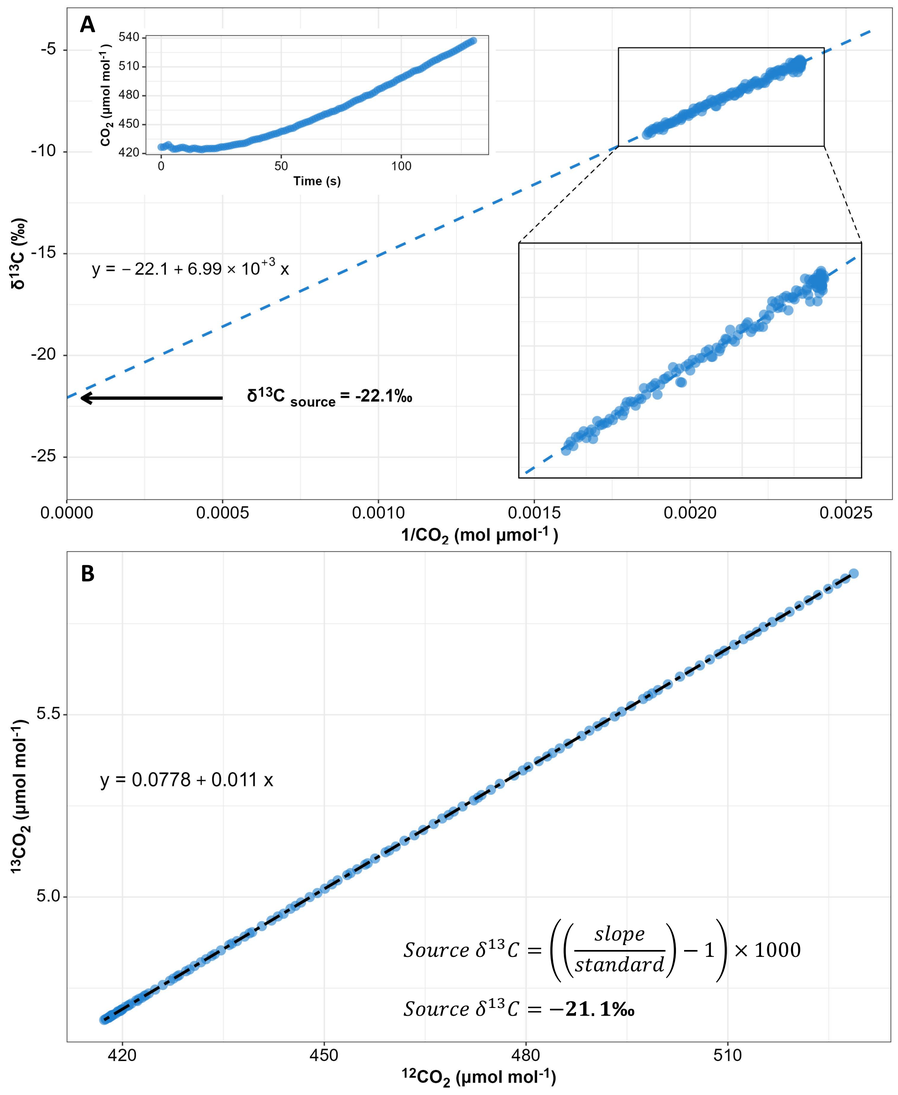


Figure 4: The Keeling and slope methods can be used to estimate the $\delta^{13}C$ of soil CO_2, helping to understand carbon sources and transformation processes. **A**, The Keeling method involves fitting a linear model to the relationship between $\delta^{13}C$ and the reciprocal of total chamber CO_2 concentration. **B**, The slope method provides a novel approach which is less sensitive to analyzer baseline drift. Both approaches are computed in SoilFluxPro software.

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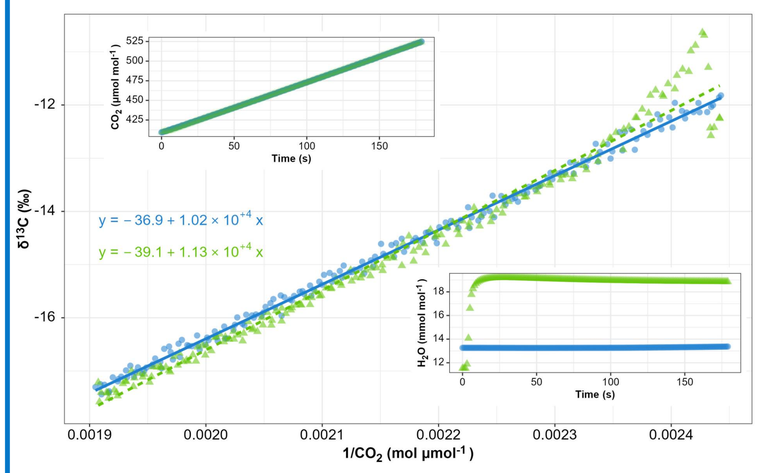

Figure 5: Keeling regression of a controlled flux (0.65 µmol CO_2 s^{-1}) experiment. The background gas $\delta^{13}C$ = -13.7‰, with a flux generated by injection of pure CO2 at $\delta^{13}C$ = -36.7‰. Blue circles, gas passing through a novel H_2O vapor equilibrator. Green triangles, without equilibration. Insets, CO_2 and H_2O change during measurement.

Figure 6: Estimated $\delta^{13}C$ from sealed volumes containing soybean (blue) and maize (green) residue, with no spectroscopic correction for NH_3. The C_4 maize off-gassed NH_3 during decomposition, skewing $\delta^{13}C$ to unrealistic values. The LI-7825 analyzer used in this study quantifies NH_3 to report CO_2 isotopologues with high accuracy.

Conclusions

- An automated soil gas measurement system facilitates measurement of CO2 fluxes and $\delta^{13}C$ over long time periods in field conditions, allowing investigation of changes in carbon cycling due to changes in biological processes.
- A calibration manifold containing a novel, passive water vapor transient equilibration system and automated analyzer baseline system enables long-term, low-power, unattended soil $\delta^{13}C$ measurements with minimal maintenance and consumables.
- A new trace gas analyzer provides high-precision measurements of CO_2 isotopologues in field conditions.

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