The Friends of Nachusa Grasslands
2024 Scientific Research Project Grant Report

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2024 grant amount: $7,393

Research Project Topic: Effects of ecosystem type, environmental gradients, and prescribed fire on Midwest ecosystem climate interactions

Research Project Purpose: To continue to quantify soil and short-statured vegetation greenhouse gas exchanges with the atmosphere in *restored* Nachusa prairie, woodland, and wetland ecosystem types and along moisture and temperature gradients. A multi-year project is required to capture highly distinctive inter-annual variability in 1) timing of burns, 2) precipitation timing and total amount, and 3) temperature.

Research Project Outcomes to date:

Note: *Due to technical issues with our gas chromatograph that we have only recently resolved (as of June 2025), we have not yet analyzed the full 2024 growing season for greenhouse gas concentrations and flux calculations. Here instead of presenting an update of the full three-year project scope, we present the advances made in measurement and analysis of net soil and short vegetation carbon dioxide fluxes.*

Introduction. An ecosystem's ability to regulate climate depends largely on the balance of carbon dioxide (CO_2) taken up by vegetation versus emitted by soil (Figure 1-left). Transparent chambers allow us to measure both the net flux and the soil respiration component by taking measurements with and without sunlight, respectively. To complement our ongoing work to estimate the greenhouse gas balance of prairie and woodland cover types at Nachusa Grasslands, we made advances this year in the chamber measurement of net CO_2 exchange.

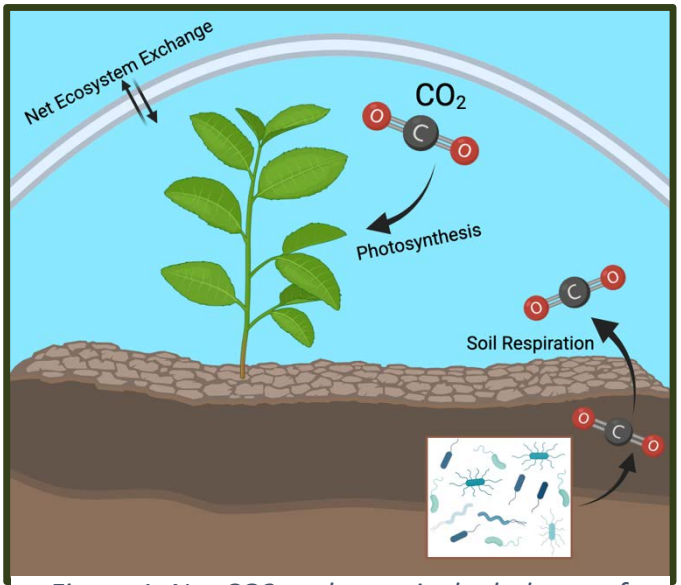

Figure 1. Net CO2 exchange is the balance of photosynthetic uptake and soil respiration

Method. PhD student Michael Yonker developed a low-cost, quasi-continuous carbon dioxide (CO_2) sensor apparatus that would display live CO_2 measurements & log data for future analysis (Figure 2). The system used an Arduino Nano 33 BLE Sense Rev2 Microcontroller with a peripheral carbon dioxide sensor, a MicroSD breakout board to store data, and an LCD to view live data. It was powered by a small lithium battery.

Figure 2. Transparent net carbon dioxide flux chamber including mounted Arduino based automated measurement system

Results: Mean monthly photosynthetic CO_2 uptake rates were highest in the peak growing season (July) in the Prairie cover type, where they remained high in September, but dropped to low levels like other cover types by late October. Overall, photosynthesis offset soil respiration considerably in many cases, with uptake rates reaching as much as 4x that of dark soil respiration. These data support our assumption for the larger project that positive dark soil CO_2 emissions are more than offset by photosynthetic uptake.

Photosynthetic Rate (μmol CO_2 m^{-2} s^{-1})			
Ecosystem	**Mean Photosynthetic Rate (calculated)**		
	7/26/24	**9/20/24**	**10/25/24**
Woodland Shade	-1.25 ± 0.56	-0.69 ± 0.31	*NA*
Prairie	-14.98 ± 3.05	-12.88 ± 5.65	-1.63 ± 0.12
Woodland Sun	-2.59 ± 0.99	-0.82 ± 0.40	-1.47 ± 0.71
Wet Prairie	*NA*	-2.53 ± 0.13	-3.69 ± 1.53

Conclusions. The Arduino based transparent chamber system has higher precision than standard gas chromatograph methods and may also have improved accuracy of our CO_2 flux measurements. We will therefore incorporate these higher accuracy data into final greenhouse gas balance estimates later in the project. We still, however, have to develop formal criteria to assess sensor data quality in all cases.

Describe how the grant funds you have received from the Friends of Nachusa Grasslands have been used in regard to the above topic, purpose, and/or outcomes:

The primary use of funds in 2024-2025 was to support undergraduate and graduate student participation in approximately monthly gas sampling field trips from UIC to Nachusa Grasslands, plus visits to install and remove chambers. An additional field measurement day was added in March 2025, to capture off-season flux rates for the first time. In total, nine different undergraduates, one lab manager, and two graduate students participated in the field work at different times, providing an enriching outdoor and ecological experience.

Describe how your project has benefited the work and goals of Nachusa Grasslands:

Our project quantifies advances Nachusa Grassland's interest in the enhancement of biodiversity and ecosystem function. The transparent chamber data from 2024 provides the first estimates of key carbon cycle processes, specifically, net carbon dioxide exchange over soil and short-statured vegetation, building on our previous estimates of gross soil respiration from opaque (dark) chambers. As our dataset grows we aim to explore associations between cover type, extent, and diversity, and carbon cycle processes.

Describe how your findings can be applied to challenges in management practices for restoration effectiveness and species of concern:

Please list presentations/posters you have given on your research:

(from 2022-2023)

McNicol G. 2023 *Soil climate interactions across ecological gradients.* 2023 Nachusa Science Symposium. Nachusa Grasslands, Dixon, IL. **Lightning talk**

Yonker M, Breiter J, Babelonia I, Fee R, Pugh S, Meyer-Dombard D, & McNicol G. 2023 *Effects of ecosystem type and environmental gradients on native Midwest ecosystem-climate interactions*. UIC Undergraduate Research Forum. Chicago, IL. **Poster (Honors College)**

Yonker M, Breiter J, Babelonia I, Fee R, Pugh S, Meyer-Dombard D, & McNicol G. 2023 *Effects of ecosystem type and environmental gradients on native Midwest ecosystem-climate interactions*. 2023 Nachusa Science Symposium. Nachusa Grasslands, Dixon, IL. **Poster**

(from 2023-2024)

Yonker M, Breiter J, & McNicol G. *2023 Effects of Ecological Gradients on Soil-Climate Interactions in Restored Midwest Ecosystems.* American Geophysical Union Fall Meeting 2023. San Francisco, CA. **Contributed Poster**

Yonker M, McNicol G. *2024 Effects of Ecological Gradients on Soil-Climate Interactions in Restored Midwest Ecosystem.* Nachusa Science Symposium. Nachusa Grasslands, Dixon, IL. **Invited Oral**

(from 2024-2025)

Yonker M., Ee JS, Finn T, Sanchez T, Lebron T, McNicol G. (2024) Developing an Arduino-Based Chamber System (ABCS) to Measure Net Ecosystem Exchange and

Component Fluxes of Carbon Dioxide over Short Canopies**.** *American Geophysical Union 2024 Fall Meeting*, Washington, DC. Mon., Dec. 9, 2024. **Contributed Poster**

Yonker M., Ee JS, Finn T, Sanchez T, Lebron T, McNicol G. (2025) A Low-Cost, Automated Chamber System to Improve Estimates of Soil and Vegetation Carbon Dioxide Fluxes in Short Canopies. *2025 Nachusa Science Symposium*, Nachusa Grasslands HQ, IL. Sat., Apr. 26, 2025. **Invited poster and Lightning talk.**

Have you submitted manuscripts to scientific journals? If so, which ones? If not, do you anticipate doing so? (Please send digital copies of published articles to the Friends so that we can learn from your work.**)**

Not yet, but we are actively preparing a manuscript (such as *Plant and Soil, Ecosystems,* or *the Journal of Geophysical Research: Biogeosciences)* with input from undergraduates, PhD student Micheal Yonker, and PI Gavin McNicol as lead author, for submission to a journal based on year 1 (2022-2023) of our GHG study. The paper will focus on spatial patterns in GHG fluxes and their relationship to soil properties, elevation, and microbial communities.

A second manuscript will be prepared using 2023-2025 data that will focus on temporal dynamics associated with interannual and/or seasonal changes in photosynthesis, precipitation, and temperature, anticipating submission in spring 2026.

What follow-up research work related to this project do you anticipate (if any)?

We are still generously supported by Friends of Nachusa Grasslands to continue gas flux measurements through the 2025 growing season, which will be the final of three planned measurement campaigns. Micheal Yonker, a PhD student on the project, will complete a Nachusa Science Fellowship in summer 2025 to perform more intensive net carbon dioxide flux measurements with the new transparent chambers. Michael is also preparing a PhD Thesis proposal, leveraging his NSF Graduate Research Fellowship, and focusing on detailed study of gas flux control mechanisms at Nachusa Grasslands will be informed by the present work.

<u>Optional</u>: Suggestions for improving the application and award process for future Friends of Nachusa Grasslands Scientific Research Grants: