The Friends of Nachusa Grasslands
2023 Scientific Research Project Grant Report
Due June 30, 2024

Please answer the following questions with clearly written summaries to give Nachusa Friends' science committee members, officers, and board members a good idea of what you accomplished using your grant money. Unless you object to the Friends doing so, your report will be uploaded into the science section of the Friends' website: nachusagrasslands.org.

1. Please save this form to your desktop with a unique file name that includes "Friends 2023 Science Grant Report" and your last name.
2. Complete the form using the headings in **bold** as your guide.
3. Save the file as a Word document or a PDF.
4. Attach the file to an e-mail, and send it to: nachusafriendsscience@gmail.com no later than June 30, 2024.
5. The subject of the e-mail should be "2023 Scientific Research Grant Report" and your last name.
6. If you have not completed your work, please submit this form anyway by the June 30 deadline and plan to contact Friends after your project is complete so that we may learn from and publicize the outcomes as appropriate.

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2023 grant amount: $8,000

Research Project Topic: Effects of ecosystem type and environmental gradients on native 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:

Introduction. Conserved and restored prairies, wetlands, and woodlands are a tiny (<1%) remnant of native Midwest ecosystem cover and are maintained primarily for biodiversity objectives. However, native ecosystems may also help slow climate change by being net sinks of the major greenhouse gases (GHG) carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). We currently lack data on soil and plant gas exchange rates with the atmosphere in native Chicagoland ecosystems.

Our primary research goals were to:

1) Quantify ecosystem GHG balance at Nachusa woodlands, wetlands, and prairies.
2) Estimate photosynthetic uptake of CO2 using transparent chambers.
3) Record and interpret seasonal and spatial variation with respect to moisture and temperature gradients.

Method. In 2023, we adjusted our 2022 sampling locations slightly to cover more of the wetland conditions and to be able to add photosynthetic measurements to each sampling day. Sites were co-located prairie, woodland, and wetlands in the Tellabs West unit at Nachusa Grasslands, IL (Figure 1). We measured soil gas flux (including short statured vegetation) monthly using static chambers (Jun-Nov, 2023). In each ecosystem type (Woodland, Wd; Prairie, Pr; Wetland, Wt) transects consisting of four chambers each were established at multiple elevation positions (high, mid, low) to capture geohydrological gradients.

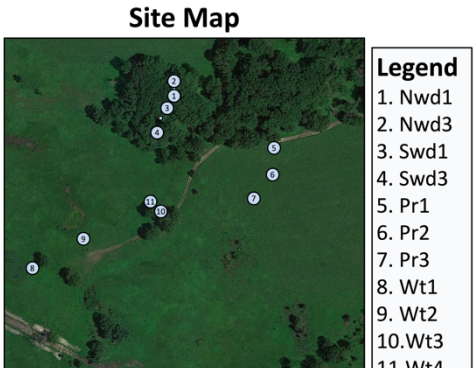

Figure 1. Site map of chamber transects (circles)

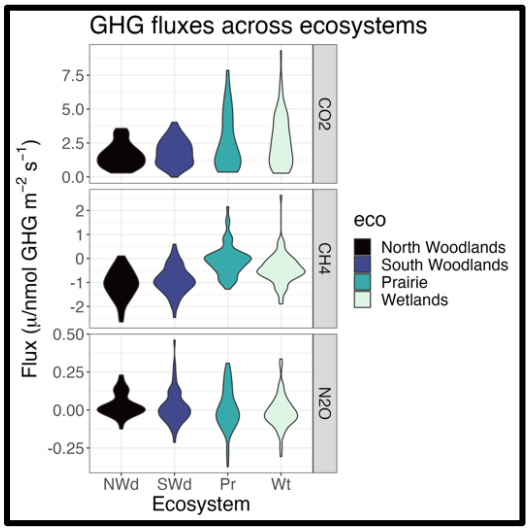

Figure 2. Overall flux distributions for each ecosystem type. Greater width corresponds to more observations.

Results.

Soils were CO2 sources, almost always CH4 sinks, and variable slight N2O sources and sinks (Figure 2). More high CO2 emission rates were observed in prairie and wetland ecosystem types. The stronger CH4 uptake was observed in woodlands, with a few positive emissions in prairies and wetlands. N2O fluxes were close to zero but trended more negative in prairies and wetlands.

Component (Net)	CO2e (kg m-2 y-1)
CO2 (excl. trees)	0.95
CH4	-0.06
N2O	0.00003
GHG balance	*0.89*

Table 1. Greenhouse gas balance components

Accounting for differences in warming potentials, short vegetation photosynthetic uptake estimates, and assuming equally balanced ecosystem cover, annual Tellabs West GHG fluxes are positive at 8.9 kgCO2e m-2 y-1 at the unit scale (Table 1). Note, however, that these fluxes exclude woodland canopy uptake of CO2, which may reduce this positive emission to neutral or negative. For instance, assuming the landscape is net neutral with respect to CO2, then CH4 uptake dominates by three orders-of-magnitude over N2O emission, to yield a negative (climate cooling) net GHG balance.

To interpret, scale, and develop predictive models of Nachusa GHG fluxes, we explored linear functional relationships between CO2 and CH4 flux and soil temperature and moisture. We observed significant and strong linear positive associations between soil CO2 emissions and soil temperature (Figure 3a). Significant, but weaker, positive associations were also observed between CH4 emissions and soil moisture. Unexplained variance in CO2 and CH4 were observed during the warmest and driest soil conditions, respectively, suggesting a more complex model may be required to explain variation during these times.

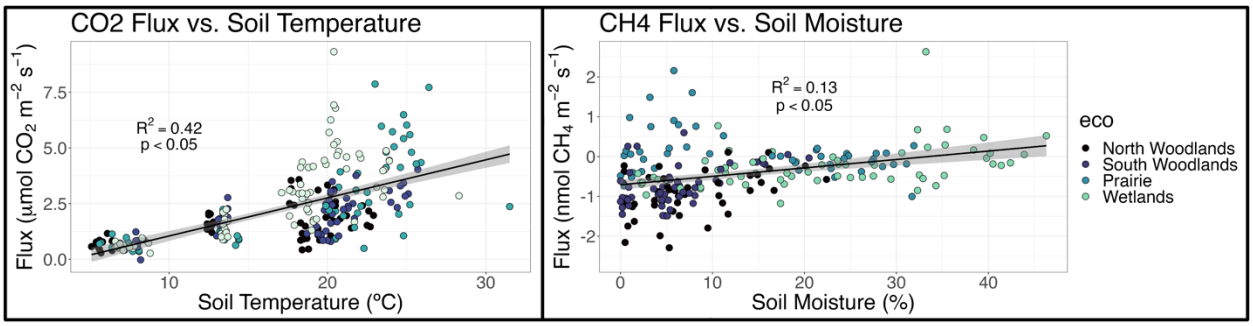

Figure 3. (a) Linear association between soil CO2 flux and temperature and (b) CH4 flux and soil moisture.

In our forthcoming sampling year (2024) we will refine our photosynthesis measurement approach to enable more frequent sampling and will incorporate remote sensing-based estimates of canopy photosynthesis in our GHG balance calculations.

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 Friends funding enabled my graduate student Michael Yonker to design, build, and test transparent chambers to assess net exchange of CO2 (including photosynthetic uptake of short-statured vegetation). The funds also supported monthly transport costs and hourly undergraduate assistant wages for monthly field trips to and from Nachusa grasslands between June and November 2023 using rental and personal vehicles. We also purchased two solar radiation sensors, one for testing during transparent chamber development, and one for field deployment during 2023. We are yet to analyze these data, but they will be explored as a means to interpret our existing data and as part of future predictive modeling efforts.

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

The second year of GHG flux measurements adds more evidence that restored Nachusa Grasslands ecosystems function overall as a net CH4 and N2O sink, and likely as an overall GHG sink with respect to the atmosphere. One key finding is that these patterns were consistent with Y1 despite substantial differences in the timing of precipitation between Y1 and Y2. The Midwest has very high inter-annual variability in precipitation, and building a multi-year dataset will be key to drawing robust conclusions about the GHG balance of Nachusa ecosystems. Overall, these data help demonstrate that the restoration practices undertaken at Nachusa are benefitting long-term climate regulation.

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

Our results are providing a foundation for managing ecosystem climate interactions in restored ecosystems at the landscape scale. This is because we're gaining an understanding of the patterns of greenhouse gas emission or uptake associated with different native Midwest ecosystem types. We have consistently observed the highest uptake rates of methane in our woodland sites, suggesting this cover type leads to the most favorable greenhouse gas at the landscape scale. At the same time, we've not observed the high methane emissions typically associated with wetlands at our wetland locations. This is encouraging that expansion of restored wetland areas to restore habitat for their distinct floral and faunal assemblages may not necessarily come at the cost of high methane release (due to anaerobic soils).

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**

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 and Michael Yonker 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. Michael Yonker is analyzing the DNA data collected in Y1 this summer and will prepare a poster for AGU on this basis, followed by submission of a manuscript in spring 2025.

A second manuscript will be prepared using Y2 (this report) and Y3 (currently underway) data, that focuses 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 currently supported by Friends of Nachusa Grasslands to continue gas flux measurements through the 2024 growing season. We will be using our improved transparent chamber designs to better quantify net carbon dioxide exchange. Scaling the observations across the landscape mosaic of ecosystem management units at Nachusa is still a longer-term goal that requires a critical mass of observations to perform robustly. Other funding sources, including the National Science Foundation Ecosystem Sciences Cluster program and the Walder Foundation Biota Award will be explored as means to

recruit senior personnel (postdocs) and equipment resources (flux towers) to facilitate this scaling.

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