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Quantifying Greenhouse Gas Flux of Restored vs. Unrestored Wetlands: A Case Study at Prairie Wolf Slough

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ABSTRACT Wetlands provide ecological services such as cleansing the water supply, sequestering carbon, and providing habitat for wildlife, however wetland restoration often alters the greenhouse gas flux of the site. Our study aims to investigate the effects of wetland restoration on greenhouse gas flux at Prairie Wolf Slough. We did this by comparing greenhouse gas flux on matching hydric soil series from the restored wetland with an adjacent abandoned agricultural field. We measured known controls of greenhouse gas flux such as soil moisture and soil temperature. We found that there was no detectable methane and nitrous oxide flux at either site, and that there was no significant difference in carbon dioxide flux between the restored wetland and unrestored agricultural field. These results show that wetland restoration did not affect greenhouse gas flux; however, the restored wetland displayed similarities in greenhouse gas flux to older restored sites.

INTRODUCTION

Wetlands play a significant role in the landscape. They stabilize and cleanse water supplies, protect shorelines, recharge groundwater aquifers, and provide habitat for wildlife (Mitsch and Gosselink, 2000). In spite of these ecosystem services, a large portion of wetlands have been disappearing globally. In the United States, less than 50% of natural wetlands remain since European settlement (Feierabend & Zelazny, 1987; Tiner, 1984). Through understanding the ecosystem services provided by wetlands, there has been increasing interest in their restoration.

The ability to cleanse water of pollutants is the result of biogeochemical processes that transform nitrogen and carbon into different chemical compounds. A few products of these nitrogen and carbon transformations are greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Carbon transformations include microbial respiration that produces CO_2 and CH_4 under anaerobic conditions. Nitrogen

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transformations include denitrification, where microbial organisms use available nitrate (NO_3) to produce N_2O (Mitsch and Gosselink, 2000).

Although wetland restoration provides many benefits, these benefits may be offset by their contribution towards climate change. Studies on GHG flux suggest that CH_4 emissions, which have a global warming potential 25 times that of CO_2, can be higher from restored wetlands than from unrestored fields (Morse et al. 2012; Audet et al. 2013; IPCC, 2007). However, when comparing natural wetlands to restored wetlands, higher CH_4 fluxes are only seen in recently restored wetlands while older restored wetlands have GHG fluxes similar to that of natural wetlands (Bortolotti et al. 2016). A study on GHG fluxes of a restored wetland in North Carolina found that GHG fluxes in terms of net CO_2 equivalents were lower from the restored wetland than the unrestored agricultural field (Morse et al. 2012). Due to their anoxic conditions and slow decomposition rates, the net carbon sequestration of restored wetlands may outweigh their CH_4 emissions in the long run allowing them to help mitigate climate change by acting as carbon sinks (Bridgeham et al. 2006; Mitsch et al. 2013).

Although there have been studies on greenhouse gas flux in restored wetlands, there is limited information on how restoration alters greenhouse gas flux in urban wetlands with mineral soils. In this study we compared two hydric soil series in a recently restored wetland with these same series found in an adjacent abandoned agriculture field to better understand the effects of the restoration on GHG fluxes. We predicted that the restored site would have lower GHG fluxes than the unrestored site. Previous studies have indicated that restored wetlands have lower greenhouse gas fluxes than unrestored agricultural fields (Morse et al. 2012; Audet et al. 2013) due to their ability to sequester carbon (Mitsch et al. 2013). These differences may exist due to several soil properties such as soil moisture, soil temperature, and carbon and nitrogen concentrations. We predicted a positive correlation between soil moisture and GHG flux under aerobic conditions due to increased microbial activity and respiration. We predicted a negative correlation between soil moisture and GHG flux under anaerobic conditions due to the slow decomposition of organic matter under anoxic conditions. We predicted soil carbon to correlate positively with CO_2 flux and soil nitrogen to correlate positively with N_2O flux due to its availability to microorganisms. We predicted soil temperature to correlate positively with greenhouse gas flux due to the increase in microbial activity. We predicted bulk density to correlate negatively with greenhouse gas flux due to lower soil porosity for gas to flow.

METHODS

Site Description

Prairie Wolf Slough (referred to as the "restored site") is a restored wetland located in Lake County, Illinois, which lies west of the North Branch of the Chicago River. The site is 14 ha, where 10ha was converted from an agricultural field to wetland in the 1990s while the remaining 4 ha were left as woodland (Montgomery and Eames, 2008). The restoration process involved reestablishing the hydrology of the area by breaking the drainage tile, while the Lake County Forest Preserve District actively planted native plants and seedbanks. The abandoned agricultural field (referred to as the "unrestored site") is 8 ha and lies immediately east of the North Branch of the Chicago River. The site was not restored, meaning the drainage tile is still intact and native plants were not actively planted. To ensure the closest comparison between the two sites, we matched two hydric soil series present in both sites to conduct our study. The two soil series are Sawmill (1107 A) and Wauconda (697 A) (Figure 1) (Lake County Soil Survey).

Greenhouse gas sampling

Gas sampling followed the enclosure technique described by Holland et al. (1999). Four static PVC chambers were randomly placed within a 20 x 20 m grid for each soil series within the restored and unrestored sites, resulting in a total of 16 gas sampling chambers (Figure 1).

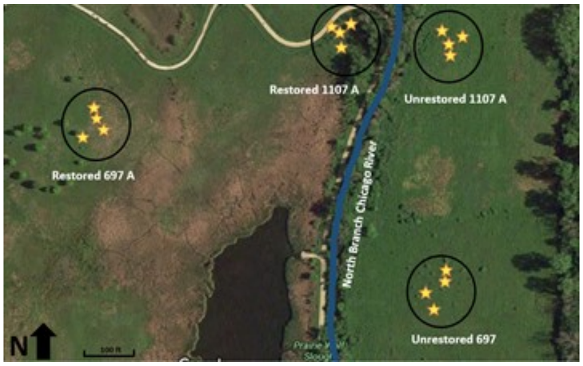


Figure 1. Map of the study site with locations of gas sampling chambers (indicated with stars). The restored wetland lies west of the river while the unrestored agricultural field is located on the east side of the Chicago River.

GHG flux was estimated during two sampling events: at the beginning of the growing season in June and at the peak of biomass production in September. During each sampling campaign, soil moisture, soil temperature, and air temperature were also sampled using a Delta-T WET sensor. Four 30 mL gas samples were taken from each chamber in intervals of 10 minutes, using a nylon syringe. Gas was transferred to 12mL glass vials by flushing the vial with 27 mL of the sample, and then over-pressurizing the vial with the remaining 3 mL of sample. Chamber height was taken at the end of the sampling period to determine the chamber's volume. A total of 64 gas samples were collected per sampling event.

Soil Sampling

Soil cores were taken within 0.3 m of the PVC chambers to a depth of 15 cm using a soil auger in June (n = 16). The same protocol was used for collecting bulk density samples with a split spoon auger in October (n =16).

Vegetation Sampling

Plant communities were sampled for diversity at the peak of the growing season in September 2015 to compare differences in diversity at each site. A 0.9 m^2 ring was placed randomly on untrampled vegetation within 3 meters of each PVC chamber. Visual estimation of percent vegetation cover of each species, percent litter cover, and percent uncovered ground were recorded.

Greenhouse Gas Analysis

Gas samples were run on a SRI 8610 gas chromatograph (GC) within three weeks of collection. A known standard gas was run every 10 samples to ensure consistency with the GC. Concentrations of CO_2, N_2O, and CH_4 were converted into gas flux (mg m^{-2} h^{-1}) following the equations of Holland et al. (1999). To ensure accuracy, the minimum detectable concentration difference (MDCD) was estimated following the equations from Yates et al. (2006), and Matson et al. (2009) to determine if any data should be excluded.

Soil Preparation and Analysis

Soil samples were dried in a convection oven at 105°C for 24 hours. Dry soil cores were weighed using a measuring scale to determine bulk density.

Flux Calculations and Statistical Analysis

Flux calculations, figures and graph were done using Excel while statistical tests were run using R. An ANOVA test was run on the greenhouse gas data to determine if there were any significant differences in GHG flux between the sites, soil series, and sampling dates.

RESULTS

Greenhouse Gas Flux

Taking into account the MDCD for each gas sampling event for each gas species, we found that there were no detectable differences in N_2O, and CH_4 concentrations over time of sampling. Therefore we established these fluxes as zero. We did find detectable differences in CO_2 concentrations.

Since we could not use the N_2O, and CH_4 fluxes, we compared the average CO_2 fluxes from each sampling campaign to see if there was a difference between the two sites (Figure 2). When comparing the CO_2 fluxes between the restored and unrestored site (Figure 2), we did not find a significant difference for either June or September (p=0.71). However, when comparing CO_2 flux between sampling campaigns (Figure 3) we did find a significant difference between June and September ($p > 0.001$). We found that there was significantly higher CO_2 flux in June than in September with the exception of the unrestored Wauconda series (697 A). We also found a significant difference in CO_2 flux between soil series in September ($p > 0.001$). We found that the Wauconda series (697 A) had a significantly higher CO_2 flux than the Sawmill series (1107 A).

Figure 2. Average CO_2 flux (±1 SE) in June and September for the restored and unrestored site.

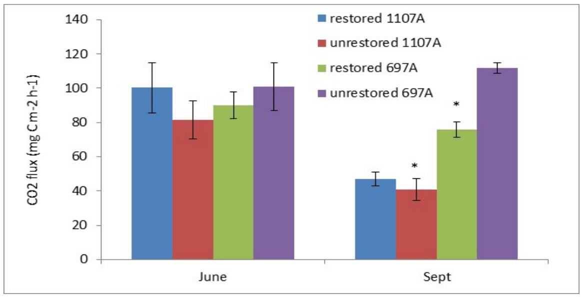


Figure 3. Average CO_2 flux (±1 SE) in June and September for each soil series on the restored and unrestored sites.

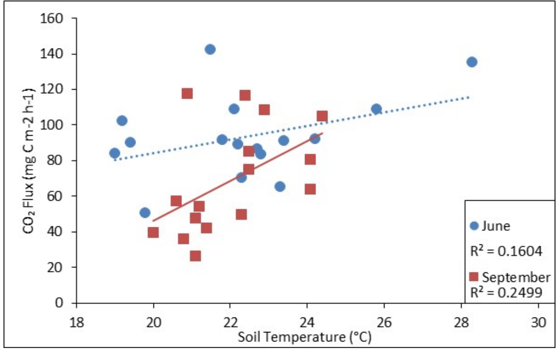
Soil Chracteristics and Gas Flux

To understand how soil characteristics influence GHG flux, we observed soil temperature, soil moisture, and carbon and nitrogen concentrations in relation to CO_2 flux. We observed a positive correlation between soil temperature and CO_2 flux (Figure 4A). In June we see a weak linear relationship ($R^2 = 0.160$) while in September we see a stronger linear relationship ($R^2 = 0.250$). We observed a positive correlation between soil moisture and CO_2 flux in June ($R^2 = 0.161$), and a negative correlation in September ($R^2 = 0.353$) (Figure 4B). Observing the relationship between bulk density and CO_2 flux we see a weak, but slightly positive correlation for June ($R^2 = 0.054$) and September ($R^2 = 0.025$) (Figure 4C).

Species Richness of Plant Communities

To investigate the effects of restoration on plant communities, we compared the species richness of the vascular plant communities at the restored and unrestored sites. We found that both sites resembled mesic prairie communities and that there was no significant difference in species richness (Figure 5).

(4a)



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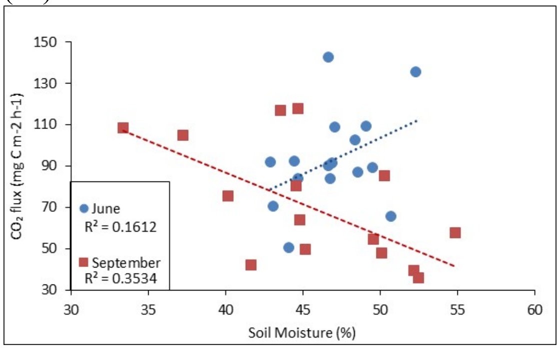

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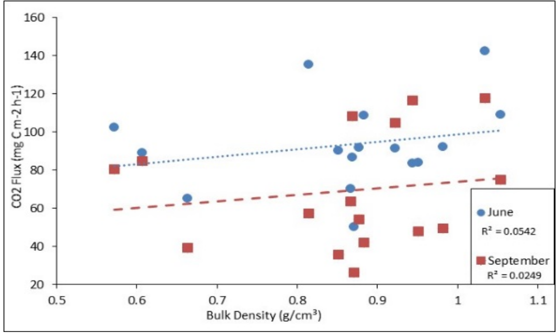

Figure 4. Measures of soil characteristics and their effects on CO_2 flux. (A) measure of soil temperature, (B) measure of soil moisture, (C) measure of bulk density

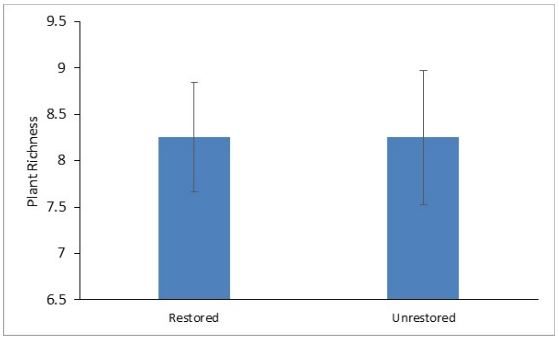

Figure 5. Measure of species richness (±1 SE) of vascular plants from restored and unrestored sites.

DISCUSSION

Our investigation of whether GHG flux differs between a restored and unrestored wetland at Prairie Wolf Slough provides us a better understanding of the effects of the wetland restoration that occurred at the site. Our data suggest that there is no significant difference in GHG flux between the two sites. We found no detectable N_2O or CH_4 flux from either site, and there was no significant difference in CO_2 flux. Therefore, it seems that wetland restoration did not alter GHG flux.

The driving factor of GHG flux is plant and microbial respiration, where under aerobic conditions CO_2 is primarily produced while N_2O, and CH_4 are produced under anaerobic conditions (Mitsch and Gosselink, 2000). Reasons for the undetectable N_2O and CH_4 flux could be due to the aerobic conditions of our study sites. Both sites were relatively dry, with only a small amount of standing water during our sampling campaign in September after a heavy rain the day prior to our sampling.

A possible reason why we found no significant difference in CO_2 flux could be due to the similarities of the plant communities. Both the restored and unrestored site resembled mesic prairie plant communities with many common species and nearly the same species richness. During the restoration process the Lake County Forest Preserve District actively planted and seeded native plants. A possibility why both sites are similar in species richness could be due to the dispersion of native seeds from the restored site to the unrestored site through natural processes.

Our results from measuring soil conditions also indicate that there was not a large difference between the two sites, yet there were differences between sampling periods. These differences could account for the differences in CO_2 flux between the June and September. Our predictions that soil temperature would have a positive correlation with greenhouse gas flux is supported by our results. Greater temperatures increase microbial activity resulting in higher respiration. However, there was more variation in soil temperature during June than there was in September, while September has a stronger correlation between soil temperature and CO_2 flux. We found that bulk density correlates positively with CO_2 flux, while we originally predicted it would correlate negatively due to lower soil porosity for gas to flow. A possible reason for this positive correlation could be due to the higher amount of available carbon for microbial activity.

The results from soil moisture in relation to CO_2 flux are puzzling. We predicted that there would be a positive correlation between soil moisture and CO_2 flux under aerobic conditions, and a negative correlation under anaerobic conditions. We found in June that there was a positive correlation, yet there was an even stronger negative correlation in September. Although there was standing water during our sampling campaign, it is unclear how anaerobic the conditions were. If the conditions were anaerobic we would expect higher N_2O and CH_4 flux (Morse et al. 2012), yet there were no detectable concentrations.

Although we found no significant difference in greenhouse gas flux and plant species richness between Prairie Wolf Slough and the unrestored agricultural field, there is still much to study about the effects of the restoration project. We were limited in our approach by comparing two matching soil series on both sides, rather than comparing greenhouse gas flux across the entire sites. We also were limited by not studying the microbial communities between the two hydric soil series, which could account for most of the greenhouse gas flux between the two sites. It is possible that soil carbon and nitrogen concentrations were driving factors behind the CO_2 flux. Although we intended to measure these parameters, we were unable to due to problems with the C/N analyzer.

There is much evidence that wetland restoration alters GHG flux (Morse et al. 2012; Audet et al. 2013; Mitsch et al. 2013), however there have been studies that refute this claim. A study comparing restored wetlands to croplands demonstrated that there is not always significant difference in GHG flux between restored wetlands and unrestored agricultural fields (Gleason et al. 2009). Since Prairie Wolf Slough and the abandoned agricultural field were in the same proximity, it is very likely that there were many similarities between their land use before restoration. It also can explain the similarities in plant species richness between the two sites.
Although there are similarities between the restored and unrestored sites, Prairie Wolf Slough displays CO_2 flux similar to that of older restored wetlands. When comparing the CO_2 flux from our restored site to the CO_2 flux from the natural and older restored wetlands from Bortolotti et al. (2016) there appears to be no difference. Therefore, the wetland restoration that occurred at Prairie Wolf Slough appears to be successful in terms of CO_2 flux. However, there needs to be further studies on ecosystem function in Prairie Wolf Slough to further describe the effects of restoration. Furthermore, it would be interesting to continue studying the unrestored site to see if the restoration project influenced its function due to the proximity of the sites.

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REFERENCES

Audet, Joachim, Lars Elsgaard, Charlotte Kjaergaard, Soren E. Larsen, and Carl C. Hoffman. “Greenhouse gas emissions from a Danish riparian wetland before and after restoration.” *Ecological Engineering* 57 (2013): 170-182.

Bortolotti, Lauren E., Vincent L. St. Louis, Rolf D. Vinebrooke, and Alexander P. Wolfe. “Net Ecosystem Production and Carbon Greenhouse Gas Fluxes in Three Prairie Wetlands.” *Ecosystems* 19 (2016): 411 425.

Bridgeham, Scott D., Megonigal, J. Patrick, Keller, Jason K., Bliss, Norman B., Trettin, Carl. “The Carbon Balance of North American Wetlands.” *Wetlands* 26.4 (2006): 889-916.

Feierabend, S.J., and J.M. Zelazny. “Status Report on Our Nation’s Wetlands.” *National Wildlife Federation* (1987).

Gleason, Robert A., Tangen, Brain A., Browne, Byrant A., Euliss Jr., Ned H. “Greenhouse gas flux from cropland and restored wetlands in the Prairie Pothole Region." *Soil Biology & Biochemistry* 41 (2009): 2501-2507.

Holland, Elizabeth A. G. Philip Robertson, James Greenberg, Peter M. Groffman, Richard D. Boone, and James R. Gosz. "Soil, CO_2, N_2O, and CH_4 exchange." *Standard Soil Methods for Long-Term Ecological Research.* Oxford: Oxford University Press, 1999.

Matson, Amanda, Pennock, Dan, Bedard Haughn, Angela. "Methane and nitrous oxide emission from mature forest stands in the boreal forest, Saskatchewan, Canada." *Forest Ecology and Management* 258 (2009):1073 1083.

Mitsch, William J., and James G. Gosselink. *Wetlands: Third Edition*. New York: John Wiley & Sons, Inc., 2000.

Mitsch, William J., Bernal, Blanca, Nahlik, Amanda M., Mander, Ülo, Zhang Li, Anderson, Christopher J., Jørgensen, Brix, Hans. "Wetlands, carbon, and climate change." *Landscape Ecology* 28 (2013): 583-597.

Montgomery, James A., Eames, J. Marshall. "Prairie Wolf Slough Wetlands Demonstration Project: A Case Study Illustrating the Need for Incorporating Soil and Water Quality Assessment in Wetland Restoration Planning, Design and Monitoring." *Restoration Ecology* 16.4 (2008): 618-628.

Morse, Jennifer L., Adrón, Marcelo, Emily, Bernhardt S. "Greenhouse gas fluxes in southeastern U.S. coastal plain wetlands under contrasting land uses." *Ecological Applications* 22.1 (2012): 264 280.

Tiner, R. W. "Wetlands of the United States: Current Status and Recent Trends." *National Wetlands Inventory, U.S. Fish and Wildlife Service* (1984).

Yates, T.T., Si, B. C., Farrel, R. E., Pennock, D. J. "Probability Distribution and Spatial = Dependence of Nitrous Oxide Emission: Temporal Change in Hummocky Terrain." *Soil Science Society of America* 70 (2006):753-762.