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Quantifying Greenhouse Gas Flux In A Restored Tallgrass Prairie: Does Chamber Material Matter?

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ABSTRACT  Tallgrass prairie ecosystems play a vital role in the carbon cycle; their restoration may be an important component of mitigating future climate change. To quantify the biosphere-to-atmosphere exchange of greenhouse gases, enclosure based chamber systems are frequently used because they are simple and inexpensive to construct, and can be easily replicated in a variety of ecosystems. We tested for differences between paired PVC and galvanized steel chambers in methane, nitrous oxide, and carbon dioxide emissions within a restored prairie at Nachusa Grasslands in June and July 2014. We found that there were no significant differences between PVC and steel chambers in CO$_2$, CH$_4$, and N$_2$O flux in either month. These results suggest that researchers can use steel chambers to quantify greenhouse gas flux in frequently burned prairies without having to remove chambers.

INTRODUCTION

Tallgrass prairie ecosystems play many vital roles on our planet. As summarized by Samson & Knopf (1994), native prairies once comprised the largest vegetative regions in North America and the grasses which inhabit them are key components in directly or indirectly providing the bulk of human nourishment, providing habitats for numerous wildlife species, and the most important contribution of native grass prairies in the face of global warming, is the role they play in carbon sequestration. The Environmental Protection agency cites electricity production (32%), transportation (28%), industry (20%), commercial and residential (10%), agriculture (10%), and land use and forestry (15%) as the primary sources of greenhouse gas emissions in the United States (United States EPA, 2012). Emissions to the atmosphere evolve through soil and plant respiration. Therefore the restoration of tallgrass prairies may be an important component of mitigating future climate change.

Evaluating greenhouse gas levels in the atmosphere plays an important role in understanding global change.

Radiatively active gases, by definition, occur both naturally and anthropogenically, effecting atmospheric radiation while photochemically active gases lead to the formation of pollutants like ozone (CITEPA, 2015). Radiatively active gases, according to Robertson et al. (1999), can have an atmospheric lifetime of 10 to 120 years for species like N$_2$O, while photochemically active gases typically exist for 1 to 3 days. CH$_4$ is classified as both radiatively and photochemically active, making it of particular interest, as both photochemically active and radiatively active gasses are pivotal to climate change. Increasing N$_2$O and CH$_4$ emissions are altering atmospheric composition; N$_2$O emissions are also contributing to the depletion of stratospheric ozone. Additionally the rate at which ultraviolet radiation is increasing, impacting the earth’s thermal balance, as a response to increased N$_2$O concentrations in the atmosphere is of growing concern (Goodroad and Keeney, 1984). These increases in atmospheric CO$_2$, CH$_4$, and N$_2$O concentrations are the result of human enterprises, namely fossil fuel combustion and extraction and

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industrial agriculture as described by Vitousek et al. (1997).

To quantify the biosphere-to-atmosphere exchange of greenhouse gases, enclosure based chamber systems are frequently used because they are simple and inexpensive to construct, and can easily be replicated in a variety of ecosystems (Dabberdt et al. 1993). There are two basic types of enclosure chamber design, static and flow-through (Robertson et al., 1999). For measuring methane and nitrous oxide fluxes, Robertson et al. (1999) suggest the use of a static vented chamber for periodic sampling followed by sample analysis with a gas chromatograph, methods deemed appropriate to accommodate the design of this study. Static chambers are non-steady-state enclosures, which are characterized by continuous concentration changes within the enclosure, as the result of diminishing gas concentration gradients, which are most appropriate for use with the conditions of this study, primarily time limitations.

While static vented chambers are a commonly used method to quantify greenhouse gas fluxes, chambers are commonly constructed from different materials (PVC, steel, aluminum, plastics); we are unaware of any comparative studies evaluating different chamber materials. One challenge in quantifying greenhouse gas flux in prairies is that these ecosystems burn semi-annually; thus chambers must be cost-efficient, durable, consistent, and fire-resistant. PVC chambers are often used, but are not fire-resistant; steel chambers do not appear in studies as common practice and are fire-resistant. The system that the Nachusa Grasslands presents would require chambers that could withstand annual burnings when prolonged sampling periods are desired. Thus, we tested for differences between paired PVC and galvanized steel chambers in methane, nitrous oxide, and carbon dioxide emissions within a restored prairie at Nachusa Grasslands. We expected to see higher flux rates from galvanized steel chambers, as steel is more conductive of heat, which tends to elevate flux rates. Higher flux rates within the galvanized steel chamber systems rather than the PVC systems would indicate either more adequate retention of emissions, or that the steel chambers are subject to environmental conditions such as solar radiation.

METHODS

EXPERIMENTAL DESIGN

We installed greenhouse gas flux chambers within a 20-year old prairie restoration (plot “19C”) at Nachusa Grasslands (The Nature Conservancy), a chronosequence of restored tallgrass prairie in Franklin Grove, Illinois. We used a paired design to compare greenhouse gas flux from static chambers constructed out of two different materials: PVC piping and galvanized steel. These materials were selected because they have non-reactive properties (Parkin & Venterea, 2010), were cost-efficient, durable, and easy to construct. Four east-west transects were established and chambers were installed every ~15m, and offset 5m north or south of transects. At each sampling location, one PVC and one galvanized steel ring were installed to 10cm depth within 50cm of one another. In total, 12 PVC and 12 galvanized steel rings were installed in early June 2014.

Since the Nachusa Grasslands are a tallgrass prairie ecosystem, the chamber heights were greater than the height of 15cm recommended by Parkin and Venterea (2010) and instead were 25cm tall with a diameter of approximately 15cm. The chambers included vent tubes meeting minimum requirements of the protocol, 10cm long with a diameter of 4.8mm. Rubber septa were installed into the chamber caps as a sampling port for gas extractions.

The Nachusa Grasslands are subjected to controlled burns making fire resistance of the chambers an area of interest. As recommended by Matson and Harriss (1995) we installed the chambers 10cm-20cm deep in soils and a month prior to sampling, agreeing with Parkin and Venterea (2010), having installed the chambers a minimum of 24 hours before the first samplings were taken. The chambers were driven into the densely packed soil 10cm-15cm leaving a 10cm-15cm of headspace above the surface for gas evolution.
GAS SAMPLING AND ANALYSIS

We collected gas samples using the guidelines outlined by Perkin and Ventera (2010) and Robertson et al. (1999). To estimate changes in gas concentration over time, gas samples were collected once in June and July 2014. Samples were only collected in June and July as a means to gather a baseline for comparison to implement into future studies. Time constraints for this study also limited the number of samplings that could be conducted. Chamber caps were placed on the rings and four 30mL gas samples were collected over 30 minutes, at ten-minute intervals. Sampling began immediately after the caps were placed on the rings at times zero, ten, twenty, and thirty. Sampling vials were flushed with sample gas and then over pressurized with 5mL of sample. Air temperature was recorded immediately before and after gas samples were collected. Soil moisture levels were recorded prior to each sampling with a Dynamax soil moisture probe.

DATA ANALYSIS

The sampling vials were transported back to DePaul University for analysis. We quantified greenhouse gas concentrations using an SRI gas chromatograph equipped with an ECD to estimate N\textsubscript{2}O concentration and FID with methanizer to estimate CO\textsubscript{2} and CH\textsubscript{4}. The measured concentrations of the collected samples were converted to mass units and corrected to field conditions by applying the Ideal Gas Law (Morse et al., 2012).

For the June and July sampling campaigns, we tested for differences in flux rates for each of the three gases (CO\textsubscript{2}, CH\textsubscript{4}, N\textsubscript{2}O) between chamber materials using paired t-tests, for a total of six t-tests. Data were analyzed using paired t-tests because the experimental value of interest was to see if there were statistically significant differences in the two chamber materials. Data analysis was conducted using Microsoft Excel.

RESULTS

We found no significant differences between PVC and steel chambers in CO\textsubscript{2}, CH\textsubscript{4}, and N\textsubscript{2}O flux in either month (Table 1). The average flux rate (mg X m\textsuperscript{-2} hr\textsuperscript{-1}) per month for each greenhouse gas of interest, CO\textsubscript{2}, CH\textsubscript{4}, and N\textsubscript{2}O were plotted with standard error bars to visually compare the differences between chamber materials and months (Figures 1-3). Standard error bars for June in Figure 2 do not overlap, which would show that there was significance, however the measured flux was deemed negligible in declaring a statistically significant difference. The null hypothesis was not rejected because t < critical value; there were no significant differences between PVC and steel chambers.

Table 1. Test statics (t) from the paired t-tests (df=11) comparing flux rates between PVC and Steel chambers. All p-values were > 0.05 and all critical values were 2.2, therefore, t < critical value, indicating no significant differences in flux rates between chamber materials.

<table>
<thead>
<tr>
<th></th>
<th>June</th>
<th>July</th>
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<tbody>
<tr>
<td>CO\textsubscript{2}</td>
<td>0.35</td>
<td>0.15</td>
</tr>
<tr>
<td>CH\textsubscript{4}</td>
<td>1.81</td>
<td>1.15</td>
</tr>
<tr>
<td>N\textsubscript{2}O</td>
<td>0.96</td>
<td>0.79</td>
</tr>
</tbody>
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Figure 1. Average (± 1 SE) CO₂ flux estimated in June and July 2014 from a restored tallgrass prairie at the Nachusa Grasslands.

Figure 2. Average (± 1 SE) CH₄ flux estimated in June and July 2014 from a restored tallgrass prairie at the Nachusa Grasslands.

Figure 3. Average (± 1 SE) N₂O flux estimated in June and July 2014 from a restored tallgrass prairie at the Nachusa Grasslands.

DISCUSSION

Prairie restoration may help combat global climate change by mitigating greenhouse gas emissions, which are commonly quantified by means of enclosure-based chamber systems. We compared the effect of chamber material on greenhouse gas flux measurements in a restored prairie and expected to see a higher flux rate in the galvanized steel chambers. However, we found no significant differences in gas flux between PVC and the galvanized steel chambers for carbon dioxide, methane, or nitrous oxide during our sampling in June and July 2014.

Our findings are highly relevant to future research on greenhouse gas flux from tallgrass prairies. Because we observed no differences in gas flux rates, we recommend the use of galvanized steel chambers in areas that are frequently burned. Steel chamber anchors could be installed in the soil year round at the Nachusa Grasslands (or other prairies) and will be able to withstand the annual burnings, eliminating the need to remove chamber rings. Permanent installations would allow for longer sampling periods without interruption or the disturbance...
of the chambers. We do not foresee any negative impacts arising from long-term installation on surrounding root systems, as the chambers require a small surface area and remain relatively close to the surface of the soil.

We predicted that steel chambers would have greater gas flux rates due to the greater absorption of solar radiation. However, our study design did not allow us to explicitly measure the internal temperature of the chambers during the gas sampling campaigns. In the future, we recommend installation of an internal thermocouple to improve chamber design. The addition of an internal thermocouple would allow for internal temperature readings to be taken as a means to determine whether environmental factors such as solar radiation contribute to changes in concentrations, allowing future studies to definitively rule out any influences from such environmental factors. Additionally, wrapping the steel chambers with reflective tape may mitigate any effects of solar radiation on internal chamber temperatures, accomplishing the same objective as the implication of internal thermocouples. The current study spanned a two-month period; comparisons throughout the growing season would more thoroughly test the effect of chamber material on gas flux rates. Future studies should again compare chambers constructed of the same materials with the additions of reflective tape and internal thermocouples.

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REFERENCES


