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Soil Trace Gas Emissions Across Landscape Transition from Agricultural Field to Riparian Buffer

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Abstract

In 2015, a new riparian buffer initiative aimed at enhancing protection of Minnesota’s water quality was signed into law. The new regulations clarified that all bodies of water listed on a buffer protection map were to have an average 15 m of perennial vegetation buffer, impacting nearly 45,000 ha of land throughout the state (2016 TIPF46). While improving water quality via mitigation of runoff and erosion is a likely outcome of the legislation, the impact of transitioning from agricultural fields to riparian buffer on Minnesota’s soil trace gas emissions is not fully understood. This study aimed to examine the fluxes of carbon dioxide (\(CO_2\)), nitrous oxide (\(N_2O\)), methane (\(CH_4\)), and ammonia (\(NH_3\)) from soils along a landscape transition from agricultural field to a small, relatively riparian riparian buffer zone near Collegeville, MN. A microcosm study was designed to quantify fluxes of trace gas emissions from soils collected along a transect gradient from an actively cropped field into a riparian buffer. Emissions of \(CO_2\), \(N_2O\), \(CH_4\), and \(NH_3\) were measured for 17 d with a mobile-FTIR gas analyzer integrated with a modified microcosm gas-sampling lid. Preliminary results from the microcosm study suggest that \(CO_2\) fluxes from the riparian soils were significantly higher than the field soils, correlating with higher \(TOC\) concentrations in the riparian soil. Emissions of \(N_2O\) were highest in the transitional zones between field and riparian buffer, and no significant difference between overall field and riparian fluxes was recorded. Fluxes of \(N_2O\) were measured shortly after initial wet-up of soils to 50% water-holding capacity and again on day 8 when soils were re-wetted to the initial moisture content, but seldom during relatively dry conditions. Results from this study may offer additional information to understand soil biogeochemical processes, as well as provide greater understanding of potential impacts that new Minnesota legislation may have on soil/landscape greenhouse gas budgets.

Introduction

- Riparian buffers surrounding water bodies are mandated by Minnesota legislature to mitigate fertilizer runoff, but may also result in areas of elevated soil GHG emissions (2016 TIPF46, Goldman et al. 2000).
- \(N_2O\) emissions have nearly 300 times the global warming potential as \(CO_2\) and is commonly associated with agricultural \(N\) sources.
- The goal of this study was to determine the relationship between soil GHG emissions across a gradient of land transitioning from agricultural field to riparian buffer.

Hypothesis

Soils located in riparian buffers adjacent to an agricultural field will have more soil GHG emissions than adjacent cropland due to possible enhanced microbial activity and nutrient cycling in the perennial vegetative area downgradient of nutrient sources.

Methods

Materials
- An agricultural area and riparian buffer with an adjacent stream (Fig. 1) was selected for study in Stearns County, MN.
- Riparian buffer consisted of deciduous trees and perennial grasses.
- Agricultural field was planted to oats and received 67 kg N ha\(^{-1}\) as anhydrous ammonia before spring planting.
- Soil samples were obtained from 6 zones (Fig. 1) measuring 2.35 m by 120 m.
- Soil trace gas emissions were measured from soil microcosms using a Gasmet DX4040 mobile-FTIR.
- Microcosms were built using 1.9 L Mason jars with a detachable lid with fittings to integrate with the gas analyzer.

Soil Analysis
- On June 26th, 2016, a total of twenty-one 2-cm diameter soil cores were collected to a depth of 15 cm within each zone, composted, weighed, oven-dried for 7 d at 60°C, and served to pass 2 mm.
- Soil pH was determined using a 1:2 soil to water ratio, and soil texture was determined by the Bouyoucos hydrometer method.
- A subsample of collected soil was sent to the University of Minnesota Research Analytical Lab for determination of soil nitrate, total organic carbon (TOC), and total nitrogen (TN) tests.

Trace Gas Analysis
- In July 2016, 20 g of soil from each zone (with 3 replications) was weighed into a plastic cup and refrigerated to 50% WHC, placed in the microcosm jars, weighed, and maintained at 50% WHC throughout the study.
- An antiglue lid was sealed over the jar while measurements of \(CO_2\), \(CH_4\), \(N_2O\), and \(NH_3\) were collected every minute to 20 min.
- Microcosms were kept in a 22°C room for 14 d, and then moved to a 28°C greenhouse for the final 3 d to stimulate microbial activity.
- Flux rates were calculated by determining linear regressions of gas concentrations versus time. Cumulative emissions were calculated via linear integration over 17 d. The effect of sample zone on cumulative \(CO_2\), \(CH_4\), \(N_2O\), and \(NH_3\) losses was tested using an ANOVA in Microsoft Excel with significance criteria of P<0.05.

Results

- Soils in the study area were acid, coarse textured, and had relatively low organic carbon (Table 1).
- Soil TOC and TN generally decreased with distance from the stream; highest values were observed in 1R, closest to the stream (Table 1).
- There were no significant fluxes of \(NH_3\) or \(CH_4\) during the 17 d study.
- Riparian zones lost significantly (\(P<0.001\)) more cumulative \(CO_2\) than field zones, losing 85% more \(CO_2\) to soil respiration after 17 d (Fig. 2).
- Mean cumulative \(N_2O\) emissions from field zones were slightly higher than riparian \(N_2O\) emissions, but they were not significantly different (\(P>0.05\)) (Fig. 3).
- Transitional zones, 5R and 6F, had the highest \(N_2O\) emissions of any zones; 6F had nearly 10 times more \(N_2O\) lost than zones 1R and 1F (Fig. 4) and was significantly (\(P<0.05\)) higher than all other sampled zones.

Table 1. A summary of measured and lab-analyzed soil properties across sampling zones.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Site</th>
<th>Soil Texture</th>
<th>Bulk Density</th>
<th>WHC</th>
<th>pH</th>
<th>TOC (%)</th>
<th>Total N (%)</th>
<th>C/N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1R</td>
<td>1</td>
<td>90% sand, 8% silt and clay</td>
<td>1.09</td>
<td>34.8</td>
<td>7.0</td>
<td>0.36</td>
<td>0.13</td>
<td>0.57</td>
</tr>
<tr>
<td>1F</td>
<td>4</td>
<td>90% sand, 8% silt and clay</td>
<td>1.08</td>
<td>34.8</td>
<td>7.0</td>
<td>0.36</td>
<td>0.13</td>
<td>0.57</td>
</tr>
<tr>
<td>2R</td>
<td>8</td>
<td>90% sand, 8% silt and clay</td>
<td>1.08</td>
<td>32.7</td>
<td>7.0</td>
<td>0.41</td>
<td>0.12</td>
<td>0.54</td>
</tr>
<tr>
<td>2F</td>
<td>6</td>
<td>90% sand, 8% silt and clay</td>
<td>1.08</td>
<td>32.7</td>
<td>7.0</td>
<td>0.41</td>
<td>0.12</td>
<td>0.54</td>
</tr>
<tr>
<td>3R</td>
<td>5</td>
<td>90% sand, 8% silt and clay</td>
<td>1.08</td>
<td>32.7</td>
<td>7.0</td>
<td>0.41</td>
<td>0.12</td>
<td>0.54</td>
</tr>
<tr>
<td>3F</td>
<td>7</td>
<td>90% sand, 8% silt and clay</td>
<td>1.08</td>
<td>32.7</td>
<td>7.0</td>
<td>0.41</td>
<td>0.12</td>
<td>0.54</td>
</tr>
<tr>
<td>4R</td>
<td>3</td>
<td>90% sand, 8% silt and clay</td>
<td>1.08</td>
<td>32.7</td>
<td>7.0</td>
<td>0.41</td>
<td>0.12</td>
<td>0.54</td>
</tr>
<tr>
<td>4F</td>
<td>1</td>
<td>90% sand, 8% silt and clay</td>
<td>1.08</td>
<td>32.7</td>
<td>7.0</td>
<td>0.41</td>
<td>0.12</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Figure 1. Soils were collected from an agricultural field located near St. John’s University in central MN. Sampling locations were selected to represent the gradient change from agricultural to riparian soils. Zones 1R, 3R, 5R, 6F, 5F, and 6R were collected 1.6, 11.3, 18.5, and 23.5 m from the stream, respectively.

Figure 2. Cumulative \(CO_2\) emissions by land use zone. Mean (\(n=9\)) cumulative emissions are shown with standard error bars.

Figure 3. Cumulative \(N_2O\) emissions by land use zone. Mean (\(n=9\)) cumulative emissions are shown with standard error bars.

Figure 4. Mean (\(n=3\)) cumulative \(N_2O\) emissions by sampled zones are shown with standard error bars. Zone 1R and 1F represent distances closest to and farthest from the stream, respectively.

Discussion and Conclusions

- Pre-experimental data from the University of Minnesota indicated that highest \(CO_2\) and \(N_2O\) emissions should be expected from riparian soils due to the highest \(C/N\) ratio, nitrate presence, and total nitrogen in riparian soils (Table 1). CO2 results confirmed this prediction, and while \(N_2O\) cumulative flux for total field zones was higher than for riparian, results could not be considered significant.
- Results also displayed significantly greater emissions of \(N_2O\) in the transitional zones as compared to the zones at the far ends of the riparian and field parameters (Fig. 4). This may be due to microbial communities in transitional zones having higher access to both carbon and nitrogen when compared to total riparian (high carbon via detritus) and total field tinegrogen availability due to fertilizer application.
- Future field studies should be carried out and compared to current results to determine accuracy in field situations. If proven to be accurate, this could imply that nitrogen metabolism by microbes is highest in field-riparian transitional zones.