Evaluating Nitrate Reduction in a Hydrologically Restored Bottomland Hardwood Forest: Is Reconnection Improving Water Quality Function?

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Nitrogen Fertilization

• Application of fertilizer has allowed for increased global population growth through increased crop production

• Half of the world’s population today could not exist without nitrogen fertilization
Population Compared to Synthetic Nitrogen Fertilizer Use

Source: FAOSTAT 2012
Mississippi River Watershed

7 million metric tons of fertilizer applied in the region annually

Photo Credit:
NOAA/LUMCON
Nitrogen Loading in the Mississippi River

- 1972 average N export: 300,000 metric tons
- Currently: ~1 million metric tons

Goolsby & Battaglin, 2000
Hypoxia in the Gulf of Mexico

2015 Area of Hypoxia in the Gulf: 16,768 square km

NOAA/LUMCON
Nitrogen Cycling in Wetlands

Reddy & DeLaune, 2008
Loss of River/Floodplain Connectivity

Since the 1700s, 2,700 km of levees have reduced floodplain interaction with river water by 90%
Reconnect Bottomland Hardwood Forests

The dominant wetland type along the Lower Mississippi Alluvial Valley
80% of bottomland hardwoods have been converted, primarily for agriculture
Mollicy Farms

- Located in northern Louisiana on the east bank of the Ouachita River
- Restored between 1998 and 2013 after being farmed for ~ 25 years
- Reconnected to the Ouachita River in 2009

Credit: The Nature Conservancy
Bottomland Hardwood Restoration: Mollicy Farms

The largest floodplain reconnection and bottomland hardwood reforestation project in the Lower Mississippi River Basin (6,475 hectares)

Credit: The Nature Conservancy
Research Questions

• How has the microbial community responded to restoration?
• What are the rates of nitrate reduction in Mollicy Farms (restored) compared to a natural site?
• How does Mollicy Farms impact nitrate reduction in the Ouachita River?
Sample Collection

- Twenty-Four, 20 cm long intact soil cores were collected at each site: total of 48 cores
  - 12 to evaluate nitrate reduction
  - 12 to analyze soil & microbial properties
Nitrate reduction analysis

• Cores were flooded with a 1 mg L⁻¹ NO₃⁻ solution and incubated for 15 days in a 20°C water bath in the dark

• Water samples were taken every other day to measure rate of NO₃⁻ loss
Soil Analyses

Soil physiochemical characteristics
• Moisture Content
• Bulk Density
• Total carbon
• Total nitrogen
• Total phosphorus

Microbial property characteristics
• Microbial Biomass N
• Potentially mineralizable N
• β-glucosidase activity
## Results: Soil Characteristics

<table>
<thead>
<tr>
<th>Soil Parameter</th>
<th>Mollicy Farms</th>
<th>Natural Site</th>
<th>P-Value</th>
<th>Percent Restoration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content (%)</td>
<td>38.8 ± 2.7</td>
<td>48.7 ± 10.3</td>
<td>0.004*</td>
<td>79.7</td>
</tr>
<tr>
<td>Bulk Density (g cm⁻³)</td>
<td>0.94 ± 0.03</td>
<td>0.65 ± 0.17</td>
<td>0.01*</td>
<td>144.6</td>
</tr>
<tr>
<td>Total Carbon (g kg⁻¹)</td>
<td>14.2 ± 3.95</td>
<td>38.6 ± 16.6</td>
<td>&lt;0.001*</td>
<td>46.3</td>
</tr>
<tr>
<td>Total Nitrogen (g kg⁻¹)</td>
<td>1.22 ± 0.42</td>
<td>2.69 ± 1.16</td>
<td>&lt;0.001*</td>
<td>44.4</td>
</tr>
<tr>
<td>Total Phosphorus (g kg⁻¹)</td>
<td>395 ± 41.2</td>
<td>524 ± 130.1</td>
<td>0.01*</td>
<td>75.5</td>
</tr>
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</table>
## Results: Microbial Analyses

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<tr>
<td>Potentially Mineralizable N (mg kg(^{-1}) day(^{-1}))</td>
<td>3.90 ± 0.68</td>
<td>8.90 ± 3.0</td>
<td>&lt;0.001*</td>
<td>43.8</td>
</tr>
<tr>
<td>Microbial Biomass N (mg g(^{-1}))</td>
<td>5.90 ± 5.70</td>
<td>33.4 ± 21.6</td>
<td>&lt;0.001*</td>
<td>17.7</td>
</tr>
<tr>
<td>β-glucosidase Activity (nmol g(^{-1}) h(^{-1}))</td>
<td>116 ± 32.6</td>
<td>328 ± 152</td>
<td>&lt;0.001*</td>
<td>35.1</td>
</tr>
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</table>
Results: Nitrate Reduction

On average, nitrate reduction was significantly lower in the Restored Site than the Natural Site (11.8 vs. 16.4 mg N m⁻² d⁻¹).

72% Restoration
Conclusions

After 6 years of hydrologic restoration:

- Soil properties in the restored site have yet to meet those of the control site

- Microbial characteristics
  - 18% Microbial biomass of control
  - 35% enzyme activity of control
Impact of Mollicy Farms Restoration on Nitrate Reduction

Nitrate reduction rates
Average annual flooding days
Portion of site flooded when river rises

Mollicy Farms can remove 48.1 metric tons NO$_3$-N from the Ouachita River annually

28% Nitrogen/15 lb bag = 25,200 bags of fertilizer
Implications

• Not all biogeochemical properties/functions will follow the same restoration trajectory

• Lack of primary production and lower total soil carbon have strong influence on biogeochemical functioning in Mollicy Farms

• Hydraulic reconnection of BLHs can improve water quality and nitrate reduction in river floodwaters more quickly than other functions.

• Nitrate is measures in part per million while Soil Carbon has units of parts per hundred.
Questions?

Nia Hurst