Effects of Land Use on Greenhouse Gas Emissions in the PNW

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Lower Columbia Estuary Partnership, May 25th
Blue carbon (BC) is the organic carbon stored in plant biomass and soils in marine and estuarine wetlands.

- Very high soil C densities and sequestration rates
- Widely recognized for many other ecosystem services
- However, high methane (CH$_4$) emissions can offset positive C gains in climate change forcing
BACKGROUND – GLOBAL WARMING POTENTIALS

- The GWP is the time-integrated radiative forcing due to a **SINGLE PULSE EMISSION** of a gas relative to a pulse emission of an equal mass of CO$_2$.
- Values vary based upon the time-frame because of the different turnover times of the gases in the atmosphere.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Atmospheric Lifetime (years)</th>
<th>GWP 20 yr</th>
<th>GWP 100 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide (CO$_2$)</td>
<td>~ 3 yr to $10^8$</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Methane (CH$_4$)</td>
<td>12.4</td>
<td>87</td>
<td>32</td>
</tr>
<tr>
<td>Nitrous Oxide (N$_2$O)</td>
<td>121</td>
<td>260</td>
<td>263</td>
</tr>
</tbody>
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• However, ecosystems emit GHGs continuously so the GWP is misleading.
• The Sustained GWP (SGWP) accounts for emissions over the entire time frame.
The GWP is the time-integrated radiative forcing due to a pulse emission of a gas relative to a pulse emission of an equal mass of CO$_2$.

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Most wetlands will eventually a cooling effect even if takes millennia to centuries to occur.

Frolking et al. 2006
There was a considerable amount of soil C storage and sequestration data available from PNW estuarine wetlands but almost no GHG emission data.

The PNW Blue Carbon Group set out to rectify this data gap at a regional scale embracing the complexity of land uses and environmental drivers that would affect GHGs.
**440+ Acre Restoration**

- 12 GHG sites in restored area, ~1 yr post-restoration
- 3 least-disturbed reference sites (high marshes)
- 3 ag fields, former tidal sites
Complex, Non-Linear Environmental Controls Over CH₄
Huge Variability in CH$_4$ Emissions within the Large Restoration
Complex Dynamics Captured With Classification and Regression Tree Technique

Node 1 (n = 321)

Water Table

\( R^2 = 0.28 \)

\(< -1.5 \)

\( \geq -1.5 \)

Node 3 (n = 115)

Air Temp.

\(< 24.25 \)

\( \geq 24.25 \)

Node 4 (n = 16)

pH

\(< 6.995 \)

\( \geq 6.995 \)

Node 5 (n = 12)

Salinity

\( \geq 2.5 \)

\(< 2.5 \)

Node 6 (n = 7)

\( R^2 = 0.28 \)
Higher CH$_4$ Emissions in Restored Sites Because Wetter.

Low Nitrous Oxide Emissions in All Land Uses

<table>
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<tr>
<th></th>
<th>CH$_4$</th>
<th>N$_2$O x 10$^3$</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Instantaneous (µmol m$^{-2}$ min$^{-1}$)</td>
<td></td>
</tr>
<tr>
<td>Disturbed</td>
<td>0.201 (0.06) b</td>
<td>3.43 (2.2) a</td>
</tr>
<tr>
<td>Restored</td>
<td>2.095 (0.87) a</td>
<td>7.72 (4.7) a</td>
</tr>
<tr>
<td>Reference</td>
<td>0.243 (0.06) b</td>
<td>-1.85 (-7.8) b</td>
</tr>
<tr>
<td></td>
<td>Annual (mol m$^{-2}$ yr$^{-1}$)</td>
<td></td>
</tr>
<tr>
<td>Disturbed</td>
<td>0.111 (0.03) b</td>
<td>1.70 (1.2) b</td>
</tr>
<tr>
<td>Restored</td>
<td>1.509 (0.06) a</td>
<td>3.62 (2.3) a</td>
</tr>
<tr>
<td>Reference</td>
<td>0.134 (0.01) b</td>
<td>-1.01 (-4.2) c</td>
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A regional evaluation of the GHG benefits of estuarine wetland restoration

• Evaluate greenhouse gas (GHG) emissions and C sequestration in natural, restored, and former tidal wetlands.

• What are the carbon benefits of tidal wetland restoration?

• Sample across multiple tidal wetland types across natural salinity gradients.
An evaluation of methane emissions in estuarine wetlands the U.S.

Coastal Carbon Research Coordination Network (NSF funded)

- Evaluation of both chamber and eddy flux tower data in the U.S.
- Development of regional model of GHG fluxes
Vertical line and labels show median CH$_4$ annual emissions for U.S. estuarine wetlands

Arias-Ortiz et al. unpublished
Methane emissions for U.S. estuarine wetlands by class

Arias-Ortiz et al. unpublished
Applied Thoughts

• Emissions of CH₄ will be difficult to predict in a varied landscape because of complex spatial and temporal controls over its production, consumption, and transport.

• The prior state of the site will matter a lot in the change in CH₄ emissions post-restoration. Pre-restoration GHG gas emission data are invaluable.
Applied Thoughts

- Good candidates for restoration may be (i) sites that pre-restoration are emitting a lot of CH$_4$, (ii) sites being restored to a saline condition, and (iii) sites high in the tidal frame.
- Restoration of sites with substantial subsidence may be problematic in terms of CH$_4$ emissions.
- Adequate drainage networks of restored sites may reduce CH$_4$ emissions.
Applied Thoughts

• Nitrous oxide appears be an unimportant GHG in these systems in most cases.

• There are lots of reasons to restore wetlands that are societally more important than their GHG dynamics!