Understanding Anthropogenic Impact on Peatlands GHGs

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Drawing from Quinty and Rochefort, 2003
A Proposed Approach

- Measuring GHG fluxes
- Understanding drivers of GHG dynamics
- Understanding GHG dynamics in degraded, rewetted and restored peatlands
- Putting it all together
Peatlands are the main wetlands reservoir for soil C. World-wide they contain about 450 Gt C, most in the northern peatlands & about 60 Gt in tropical regions (this number very uncertain).

Measuring GHG fluxes in northern peatlands (g C m$^{-2}$ yr$^{-2}$)

\[
78 \pm 59 \quad \text{NEE} = \text{GPP} - \text{R}_e
\]

- GPP – Gross primary productivity (CO$_2$)
- \(491 \pm 130\)
- vascular plants
- moss
- water table
- Peat/soil

\[
413 \pm 92
\]

- \(\text{R}_e\) - Ecosystem Respiration
- Plant respiration (CO$_2$)
- Soil respiration (CO$_2$)

\[
8 \pm 7
\]

- Methane flux (CH$_4$)
- methanogenesis
- methane oxidation
- water export (DOC, DIC, CH$_4$)

\[
20 \pm 12
\]

\[\text{NEP} = -\text{NEE}\]

Blain & Lafleur, 2010
Compilation of annual measured C budgets for peatland sites

\[ \Delta C = CO_2-C + CH_4-C + DOC + C_{ppt} \]

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<tbody>
<tr>
<td>C gain</td>
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<td>C loss</td>
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C flux (g C m\(^{-2}\) yr\(^{-1}\))

NEP  CH4  DOC  Precip  Total C
Understanding drivers of Net Ecosystem Exchange

- LAI and pH affect both GPP and NEE
- GPP more variable than \( R_e \)
- Overall: peatland type not a good predictor of NEE

After Lafleur, 2009
Understanding Controls over CH4 emissions

• CH4 emissions highly variable
• Winter emissions contributing about 10% of the annual emissions
• Spatial ‘hotspots’

Lafleur, 2009

WTD a key factor in CH₄ emissions (depth of oxic and anoxic parts of the peat)

Different intercepts: mean or base rate of CH₄ emission controlled by other factors (vegetation, mean climate, etc.)

after Moore TR, unpub.
Carbon is also lost in dissolved form:

DOC losses from peatlands range from <5 to 40 g C m\(^{-2}\) yr\(^{-1}\)

DOC as a percent of NEP range averages from 5% to 70%; in individual years it can be >100%

DOC export is controlled by 1) production in the peat profile and 2) discharge (Q):

- variations in flux at a given peatland are largely determined by Q

- differences among peatlands in similar hydrologic settings are production related
Peatlands Drainage: what happens

\[ \text{NEE} = \text{GPP} - \text{R}_e \]

GPP – Gross primary productivity (CO₂)

\[ \text{R}_e - \text{Ecosystem Respiration} \]

Plant respiration (CO₂)  
Soil respiration (CO₂)

vascular plants

moss

water table

Peat/soil

methylene oxidation

methanogenesis

water export (DOC, DIC, CH₄)

Methane flux (CH₄)

Acrotelm

Catotelm

\[ \text{NEP} = - \text{NEE} \]

Strack and Waddington, 2007
Intensity of post-drainage utilization varies

Intensive forestry

Pasture

Cropping

Peat extraction
Degraded peatlands: losses of functions

Non-functional acrotelm:
Loss of peat hydraulic properties
Price and Whitehead, 2004

Erratic water table regime: drying and rewetting episodes
McNeil and Waddington, 2003

Persistent source of CO2 fluxes to atmosphere (100% - 400% of pristine)
Waddington et al., 2002

Little re-colonization by Sphagnum mosses
Waddington et al., 2008
A peatland may not restore on its own

‘Natural’ recolonization of degraded peatlands is slow, and vegetation establishment dominated by vascular vegetation (herbs and shrubs), with poor moss colonization

Rewetting reduces \( R_e \) but does not stabilize WT fluctuations if functional moss layer is missing

Restoring C sink function involves water table regulation by living moss layer (acrotelm)

Post-mining restoration techniques have been developed and field tested: functional acrotelm and C sequestration function re-established within ~ one decade.
Contrasting GHG dynamics of Peatlands in different states

Pristine peatlands: long-term C sequestration and climate cooling effect; $R_e$ suppression in anoxic zone; hydraulic properties of moss layer key factor in WTD regulation; climate and vegetation controls on NEE and CH4

Degraded peatlands: drained, with moss layer affected to various degrees by subsidence, compaction, removal. High $R_e$ sustained over decades.

Re-wetted peatlands: reduction in $R_e$, WT subject to high fluctuations if not regulated (climate sensitive), harsh environment for moss re-colonization

Restored peatlands: C sequestration function re-established through a functional acrotelm.
### Contrasting GHG dynamics of Peatlands in different States

<table>
<thead>
<tr>
<th>Functions</th>
<th>Pristine</th>
<th>Degraded</th>
<th>Re-wetted</th>
<th>Restored</th>
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</thead>
<tbody>
<tr>
<td><strong>Vegetation &amp; peat</strong></td>
<td>Intact moss cover and peat structure</td>
<td>No moss; peat compaction &amp; subsidence</td>
<td>Little or no moss</td>
<td>Re-established moss layer</td>
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<tr>
<td><strong>Hydrology</strong></td>
<td>WTD fluctuation regulated by moss</td>
<td>WTD highly fluctuating – climate sensitive</td>
<td>WTD highly fluctuating – if not regulated</td>
<td>WTD and acrotelm fluctuations regulated</td>
</tr>
<tr>
<td><strong>C exchange</strong></td>
<td>GEP &gt; $R_e$ &amp; more variable</td>
<td>$R_e$ dominates; GEP $\rightarrow$0</td>
<td>$R_e$ smaller; CH$_4$ loss larger</td>
<td>GEP$&gt;R_e$; CH$_4$ possibly larger</td>
</tr>
<tr>
<td><strong>NEP</strong></td>
<td>Long-term C sink</td>
<td>C source to atmosphere</td>
<td>C source to atmosphere</td>
<td>net C sink</td>
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Vegetation influences restoration pathway: what are the restoration objectives?

Rehabilitation
To re-establish the productivity and some, but not necessarily all, of the plant and animal species thought to be originally present at a site. Ex: re-establish C sink through perennial, vascular vegetation

Restoration
Re-establishing the presumed structure, productivity and species diversity that was originally present at a site that has been degraded, damaged or destroyed. In time, the ecological processes and functions of the restored habitat will closely match those of the original habitat. Ex: re-establish C sink and hydrological regulation by moss layer

Nelleman and Corcoran 2010; FAO 2005.
Improved estimation of anthropogenic emissions and removals in peatlands involves:

Including key elements of C budget: NEE, CH4, DOC

Understanding the state of peatlands and how functions are affected

Determine restoration pathway
References

Blain D. and Lafleur P. 2010 Science advances and estimation of wetland emissionsIPCC Expert meeting WMO Geneva, 20 October 2010


