How can we slow the rate of loss of wetlands on human dominated landscapes?

A new market opportunity for farmers?

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Wetlands are Being Lost at Alarming Rates

At a global scale, wetlands are being lost and degraded more quickly than any other type of ecosystem.

Up to 90% percent of wetlands have been degraded or lost in settled areas of Canada.

High rates of loss in Alberta and Ontario.
Wetlands are Being Lost at Alarming Rates

Link Between Agricultural Activities and Water Resources
Wetlands Can Mitigate Impacts on Water Resources

Motivation
What is a Wetland?

- Water at or near the ground surface (<2 m deep)
- Low oxygen soil conditions
- Plants and animals adapted to low oxygen conditions
Wetlands Provide Ecosystem Services

- Stabilize water supplies (prevents floods, droughts)
- Remove nutrients
- Retain sediments
- Enhance biodiversity
- Create recreational opportunities
Status Quo

Crop Production

Watershed with High Historic Rates of Wetland Loss

↓ Water Quality
↑ Flooding
↑ Drought

Alternative Future

Crop Production

Watershed with Restored Wetlands

↑ Water Quality
↓ Flooding
↓ Drought

Motivation
Priorities for Wetland Restoration?

- Where have wetlands been lost?
- Which wetlands are “easy” (simple and cheap) to restore?
- Which wetlands are “best” to restore in terms of providing ecosystem services to communities?
- How do we prioritize wetlands for restoration?
Estimating Number and Area of Drained Wetlands

Estimating Number and Area of Drained Wetlands

A piecewise 3-segment linear regression was used to determine lower and upper area thresholds.

\[ y = 11233x^{-1.88} \]

\[ R^2 = 0.94 \]

<table>
<thead>
<tr>
<th>Power Law Statistics (all wetlands)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent number lost</td>
<td>86%</td>
</tr>
<tr>
<td>Percent area lost</td>
<td>21%</td>
</tr>
</tbody>
</table>
Percent Wetland Loss by **Area**

- < 20
- 20 to 40
- 40 to 60
- 60 to 80
- 80 to 100

Percent Wetland Loss by **Number**
Power Law Statistics (swamps)
Percent number lost: 84%
Percent area lost: 18%

Power Law Statistics (marshes)
Percent number lost: 90%
Percent area lost: 39%
Small (0.1 to 2.0 ha), isolated mineral wetlands have the greatest restoration potential in southern Ontario.

<table>
<thead>
<tr>
<th>Power Law Statistics (connected)</th>
<th>Power Law Statistics (isolated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent number lost</td>
<td>79%</td>
</tr>
<tr>
<td>Percent area lost</td>
<td>9%</td>
</tr>
<tr>
<td>Percent number lost</td>
<td>94%</td>
</tr>
<tr>
<td>Percent area lost</td>
<td>53%</td>
</tr>
</tbody>
</table>
Priorities for Wetland Restoration

Percent of Lost Wetland Area that is **Isolated**

- Total area: 353,160 ha

Legend:
- < 20
- 20 to 40
- 40 to 60
- 60 to 80
- 80 to 100

Percent of Lost Wetlands Number that is **Isolated**
Field Estimation of Wetland Nutrient Removal Rates

Three DUC project sites identified along this geographic gradient as potential sites from where wetlands could be sampled.
We sampled three marsh wetlands for each of the following: drained, 10, 20, 35 years since restoration, intact
Field Estimation of Wetland Nutrient Removal Rates

Sediment samples taken along a transects at three positions:
- P1 - center of wetland (open-water);
- P2 - emergent vegetation zone;
- P3 – wet meadow zone (i.e., high water mark); and
- P4 – upland where flooding rarely occurs.
Field Estimation of Wetland Nutrient Removal Rates

Three replicate cores were taken to a maximum 30 cm of depth.

Each replicate core was cut into 1 cm intervals and composited in the field.

Sedimentation rates and organic C, N, P pools were determined for each 1 cm interval composited sample.
Carbon sequestration rates estimated from *Cesium 137 (Cs-137)* and Lead 210 (Pb-210) isotopes.

For human-derived Cs-137, there is a peak in Cs-137 that corresponds to the **1963 global peak emission** due to atmospheric testing of nuclear weapons.

Assumed that atmospheric deposition of isotopes is spatially uniform.
Step 1: Sedimentation Rate

Mixing diminishes the peak $^{137}$Cs and extends the depth of $^{137}$Cs into the sediments deposited prior to 1963.
Step 1: Sedimentation Rate

\( ^{137}\text{Cs Activity} (\text{Bq kg}^{-1}) \)

- Depth of sedimentation
- Depth of mixing

\( ^{137}\text{Cs Profile in Sediments} \)
- Sedimentation, no mixing
- Sedimentation, mixing

\( a = \text{source of sediments enriched in} \ ^{137}\text{Cs by preferential transport of clays and organics} \)
Step 1: Sedimentation Rate

$^{137}\text{Cs Activity (Bq kg}^{-1})$

$\text{Depth (cm)}$

$^{137}\text{Cs Profile in Sediments}$

- Sedimentation, no mixing

$^{137}\text{Cs Profile in Sediments}$

- Sedimentation, mixing

Depth of sedimentation

Depth of mixing

b = lower levels of $^{137}\text{Cs}$ in soils and therefore sediments as erosion of surrounding land progresses
Step 1: Sedimentation Rate

137Cs Profile in Sediments
sedimentation, no mixing

137Cs Profile in Sediments
sedimentation, mixing

c = lower levels of 137Cs in soils and therefore sediments as tillage practices mix surface with 137Cs-poor subsoils

Depth of mixing

Depth of sedimentation

1954

1963

1954

1963
Step 2: Carbon Sequestration

Agricultural (Drained) Wetland

Cs-137 (Bq kg⁻¹), Organic C (%)

0 10 20 30 40 50 60 70 80

- Cs-137 ACTIVITY
- Organic C

Sedimentation rate since 1963 is high.
Focused sedimentation from surrounding land.

Total Carbon Pool: **5.1 kg m⁻²**
Carbon Sequestration Rate: **101 g m⁻² yr⁻¹**
Carbon Sequestration

Total Carbon Pool: 7.1 kg m⁻²
Carbon Sequestration Rate: 142 g m⁻² yr⁻¹

Sedimentation rate is low to moderate
Focused sedimentation from surrounding land
20-Year Old Restored Wetland

**Cs-137** (Bq kg⁻¹), Organic C (%)

*Sedimentation rate is high
Focused sedimentation from surrounding land

Total Carbon Pool: **18.4 kg m⁻²**
Carbon Sequestration Rate: **369 g m⁻² yr⁻¹**
35-Year Old Restored Wetland

Cs-137 (Bq kg⁻¹), Organic C (%)

Sedimentation rate is very low
Focused sedimentation from surrounding land

Total Carbon Pool: **2.2 kg m⁻²**
Carbon Sequestration Rate: **44 g m⁻² yr⁻¹**
Natural (Intact) Wetland

Cs-137 (Bq kg⁻¹), Organic C (%)

- Cs-137 ACTIVITY
- Organic C

Sedimentation rate is negligible

Total Carbon Pool: negligible
Carbon Sequestration Rate: 0 g m⁻² yr⁻¹
Step 2: Carbon (and Phosphorus) Sequestration Rates
Step 2: Carbon (and Phosphorus) Sequestration Rates

High Sequestration Rates Create Opportunities for Carbon “Banking” Through Wetland Restoration

Can carbon sequestration rates be enhanced and/or prolonged through restoration design?
Step 2: Carbon (and Phosphorus) Sequestration Rates

What are the Design Criteria for Optimizing Carbon Sequestration in Restored Wetlands?

Things to consider:

- Wetland vegetation community composition
- Riparian buffer composition and width
- Soil amendments
How Can we Slow the Rate of Wetland Loss on Human Dominated Landscapes:

A new market opportunity for farmers?
Can We Create New Market Opportunities For Farmers?

**Fixed Price Payment (Contract)**
- Payment for the supply of wetland area or function
- Price fixed based on pre-determined amount (e.g., number of bushels lost x $/bushel)

**Reverse Auction (Contract or Voluntary)**
- Payment for the supply of wetland area or function
- Price variable based on farmer’s willingness to accept payment

**Education/Extension Programs (Voluntary)**
- Information and outreach support to farmers to educate about the on-farm benefits of wetland retention

Local Suppliers (Farmers)
## Diversification of Farmer’s Markets

<table>
<thead>
<tr>
<th>Restored wetland (ha)</th>
<th>Low carbon storage (52.1 Mg CO₂ eq/yr)</th>
<th>High carbon storage (135.5 Mg CO₂ eq/yr)</th>
<th>Economic Value ($30/yr) of carbon storage based on different estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Market estimate $/Mg CO₂ eq</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>1</td>
<td>52</td>
<td>135</td>
<td>$1,562</td>
</tr>
<tr>
<td>10</td>
<td>521</td>
<td>1,353</td>
<td>$15,620</td>
</tr>
<tr>
<td>100</td>
<td>5,207</td>
<td>13,530</td>
<td>$156,200</td>
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<tr>
<td>1,000</td>
<td>52,067</td>
<td>135,300</td>
<td>$1,562,000</td>
</tr>
<tr>
<td>10,000</td>
<td>520,667</td>
<td>1,353,000</td>
<td>$15,620,000</td>
</tr>
<tr>
<td>353,160</td>
<td>18,387,875</td>
<td>47,782,578</td>
<td>$551,636,264</td>
</tr>
</tbody>
</table>

*Note: 353,160 denotes total value of isolated wetland loss*
Next Steps Towards Operationalization

- Include “bundles” of ecosystem services
- Model cumulative effects of the restored wetlands on provision of ecosystem services on regional watersheds
- Conduct model scenarios of future land development plans under global change
Acknowledgements

Eva Slavicek
Nicole Larsen
Aleksey Paltsev
Michael Steiff
Nico Trick
Naomi Trick
Tong Zou
Dave McLachlin
Erling Armson
Mark Gloutney
This work was motivated by the need to develop alternative ways to protect and restore wetlands on developing landscapes.

Our focus is on mineral wetland water systems in highly managed landscapes.

Wetland provides important ecosystem services:
- Flood control
- Water purification (phosphorus and nitrogen retention)
- Carbon sequestration

We will show how farmers can increase the supply of ecosystem services by restoring wetlands that not only improve their livelihoods, but also the many people living within the regional watershed.