Effects of disturbances on soil carbon in the Mixed Prairie of southern Alberta

Rationale:
- Perception that replacing native grassland with introduced species was degrading soil quality (contrary to the “Improved” designation of those areas);
- Absence of robust experimental evidence to test that perception (long-term, replicated, random experimental error);
Evidence challenging the “Improved” designation

Concentration (%) of soil organic carbon in a Stipa-Bouteloua community in relation to native and seeded communities


Experiment: Do introduced species degrade soil organic C?

Controlled studies to test plant-soil carbon relationships

Study characteristics:

- long-term (1994 - 2006)
- plot size 3 x 10 m; 4 reps

Treatments:
- native control,
- 2 perennial grass monocultures,
- 2 wheat (continuous, summer fallow)
Soil organic C (light, stable and total) 13 years after establishment (0 – 15 cm)

- Site differences expressed by stable fraction;
- The light fraction is almost equal between sites
Soil organic C (light, stable and total) 13 years after establishment (0 – 15 cm)

- Treatment effects were similar between sites.
Soil organic C (light, stable and total) 13 years after establishment (0 – 15 cm)

- The perennial species had no effect on soil organic C
### Soil organic C (light, stable and total) 13 years after establishment (0 – 15 cm)

<table>
<thead>
<tr>
<th></th>
<th>LF OC</th>
<th>Stable OC</th>
<th>Total OC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. cristatum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. juncea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat (c)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat (f)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Only wheat had an effect on soil organic C;
- The effect was expressed primarily in the light fraction.
Average rate of C loss resulting from wheat cropping on two Mixed Prairie sites: Stipa – Agropyron – Bouteloua (SAB) and Stipa – Bouteloua (SB)

<table>
<thead>
<tr>
<th>Duration</th>
<th>SAB</th>
<th>SB</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4yr)</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>(9yr)</td>
<td>0.32</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Adapted from: Janzen et al. 1998. Soil and Tillage Research
Rationalizing results with those of Dormaar et al.

Hypothesis: Dormaar’s sites lost soil organic C through erosion. (sites were grazed by cattle, row orientation not considered)

Other factors may be present (ie sampling Ah, fenceline, reporting concentration rather than stock)
Observations of soil erosion from a simulated rainfall study

Soil characteristics of treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bulk density (kg ha(^{-1}))</th>
<th>Water stable aggregates</th>
<th>Erosion (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>0.72 a</td>
<td>74.7 a</td>
<td>41</td>
</tr>
<tr>
<td><em>A. cristatum</em></td>
<td>0.99 b</td>
<td>44.4 b</td>
<td>110</td>
</tr>
<tr>
<td><em>P. juncea</em></td>
<td>0.87 b</td>
<td>36.1 b</td>
<td>53</td>
</tr>
</tbody>
</table>

Exudates help in the formation of water stable aggregates

<table>
<thead>
<tr>
<th>Exudates (mg C g(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. cristatum</em></td>
</tr>
<tr>
<td><em>A. smithii</em></td>
</tr>
<tr>
<td><em>B. gracilis</em></td>
</tr>
</tbody>
</table>

Controlled studies to test plant-soil carbon relationships

Experiment:

a. How is soil carbon affected by monocultures of introduced and native species?
b. Do seeded mixtures of native species affect soil carbon?

Study characteristics:
- ten years (est. 1995)
- plot size 4 x 10 m
- 5 native, 2 introduced
- monocultures/mixtures
Mass-equivalent C in the stable and labile fraction (0 to 30 cm depth) on a Dark Brown Chernozemic soil.

Contrasts:

**Monocultures: introduced vs native**
- Labile fraction: < 0.01
- Stable fraction: 0.02

**Native: monocultures vs mixtures**

- Bgr, Nvi vs (Bgr, Nvi)
  - Labile fraction: 0.02
  - Stable fraction: >0.05

- Bgr, Psm vs (Bgr, Psm)
  - Labile fraction: >0.05
  - Stable fraction: >0.05

- Nvi, Psm vs (Nvi, Psm)
  - Labile fraction: 0.03
  - Stable fraction: >0.05

- Bgr, Nvi, Psm vs (Bgr, Nvi, Psm)
  - Labile fraction: < 0.01
  - Stable fraction: < 0.01
  - Total OC (in all cases): >0.05
Labile SOC of seeded grasses in the Dark Brown Chernozemic soil 10 yrs after establishment

Differences in labile C are determined near the surface
Conclusions – 10 years after establishment:

- Total SOC not affected by species or mixtures;
- Introduced species yielded more labile C but less stable C;
- Native mixtures tended to yield more labile and stable C than their monocultures;
- Differences mostly expressed near the surface.
Conclusions:

In the Mixed Prairie:

• no clear evidence that monocultures of introduced species degrades soil organic carbon;
• replacing native grasslands with introduced forages increased the risk of soil erosion without compensatory benefits;
• a monoculture provides limited management options compared with a well managed native grassland
Mass-equivalent C in the stable and labile fraction (0 to 30 cm depth) on a Dark Brown Chernozemic soil.

Contrasts:

**Monocultures: introduced vs native**

Labile fraction  < 0.01  
Stable fraction   0.02

**Native: monocultures vs mixtures**

**Bgr, Nvi vs (Bgr, Nvi)**

Labile fraction  < 0.02  
Stable fraction   > 0.05

**Bgr, Psm vs (Bgr, Psm)**

Labile fraction  > 0.05  
Stable fraction   > 0.05

**Nvi, Psm vs (Nvi, Psm)**

Labile fraction  0.03  
Stable fraction   > 0.05

**Bgr, Nvi, Psm vs (Bgr, Nvi, Psm)**

Labile fraction  0.01  
Stable fraction   0.01

Total OC (in all cases)   > 0.05
Mass-equivalent C in the stable and labile fraction (0 to 30 cm depth) on a Dark Brown Chernozemic soil.

Contrasts:

**Monocultures: introduced vs native**
- Labile fraction: <0.01
- Stable fraction: 0.02

**Native: monocultures vs mixtures**
- Bgr, Nvi vs (Bgr, Nvi)
  - Labile fraction: 0.02
  - Stable fraction: >0.05
- Bgr, Psm vs (Bgr, Psm)
  - Labile fraction: >0.05
  - Stable fraction: >0.05
- Nvi, Psm vs (Nvi, Psm)
  - Labile fraction: 0.03
  - Stable fraction: >0.05
- Bgr, Nvi, Psm vs (Bgr, Nvi, Psm)
  - Labile fraction: 0.01
  - Stable fraction: 0.01

**Total OC in all cases**: >0.05
Mass-equivalent C in the stable and labile fraction (0 to 30 cm depth) on a Dark Brown Chernozemic soil.

Contrasts:

**Monocultures: introduced vs native**
- Labile fraction: <0.01
- Stable fraction: 0.02

**Native: monocultures vs mixtures**
- Bgr, Nvi vs (Bgr, Nvi)
  - Labile fraction: 0.02
  - Stable fraction: >0.05
- Bgr, Psm vs (Bgr, Psm)
  - Labile fraction: >0.05
  - Stable fraction: >0.05
- Nvi, Psm vs (Nvi, Psm)
  - Labile fraction: <0.03
  - Stable fraction: >0.05
- Bgr, Nvi, Psm vs (Bgr, Nvi, Psm)
  - Labile fraction: 0.01
  - Stable fraction: 0.01

**Total OC in all cases**: >0.05