Dethroning a king: Canola's rise to supremacy and what it could mean to the atmosphere

Lemke, R., Baron, V., Liu, L., MacWilliam, S and Farrell, R.
• Canola has become the most valuable cash crop in Canada generating > $19 billion CAD in 2013

• About 40% of canola seed is exported primarily to China, Japan, Mexico and the USA

• About 60% of seed is crushed in Canada

• 80% of canola oil and meal is exported primarily to the USA and China but also Korea, Japan, Malaysia and other countries

• Emerging uses include bio-diesel, plastics, protein isolates, adhesives and sealants
Virtually all canola production in Canada is grown in the three prairie provinces of Alberta, Saskatchewan, and Manitoba.

GDD < 1000 (base 5°)
MAP 400 mm
FFD 115
M. Deficit 200 mm

GDD 1600 (base 5°)
MAP 250 mm
FFD 125
M. Deficit > 450 mm

GDD - 1650 (base 5°)
MAP – 700 mm
FFD – 135
M. Deficit - 200 mm
• 1908 - 60% of seeded acreage in spring wheat
  30% oats
  10% barley

• 1958 – 30% wheat (~ 100% Canadian Western Red Spring)
  24% oats and barley
  40% summerfallow

• 2008 – 35% spring wheat (~ 6 classes)
  12% oats and barley
  31% canola, 3% flax, 1% mustard,
  12% pulses (lentil, field pea, chickpea)
  7% summerfallow
Seeded Hectares of Canola and CWRS Wheat: Prairie Provinces

Source: Statistics Canada
Typical field scheduling

• Last frost in mid/late May; first frost in late Sept
• Soils deeply frozen Nov – March (-20°C @ 10 cm)
• Seed in late April – mid May; Harvest Aug – early Sept.
• Common crop sequence in recent years:
  • Oilseed-Cereal
  • Oilseed-Pulse-Cereal
• All fertilizer (N,P,K,S) requirements applied in “one-pass” seeding system; alternatively early spring or late fall banding of N
• Nitrogen N rates ranging 50 – 150 kg N ha⁻¹
Seasonal Pattern of soil-emitted N$_2$O

Spring Thaw

First soil "wet up" following N application

N applied

Source: Lemke et al. 1998
Percentage of fertilizer N lost as N\textsubscript{2}O averaged across soil zones in western Canada

<table>
<thead>
<tr>
<th>Soil Zone</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>number of studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown (Great Group)</td>
<td>0.0</td>
<td>0.4</td>
<td>0.2</td>
<td>3</td>
</tr>
<tr>
<td>Dark Brown</td>
<td>0.0</td>
<td>0.4</td>
<td>0.2</td>
<td>3</td>
</tr>
<tr>
<td>Black</td>
<td>0.2</td>
<td>1.9</td>
<td>0.9</td>
<td>4</td>
</tr>
<tr>
<td>Grey/Dark Grey</td>
<td>0.1</td>
<td>1.0</td>
<td>0.4</td>
<td>2</td>
</tr>
</tbody>
</table>

Emission factor as a function of local climate

\[ EF = f \left( \frac{P}{PE} \right) \]

\[ EF_{eco} = 0.022 \frac{P}{PE} - 0.0048 \]

- Québec & Ontario: \( n = 72 \)
- Grey & Black soils: \( n = 155 \)
- Brown & Dark Brown soils: \( n = 48 \)

\[ EF_{eco} < 0.0016 \text{ were set } = 0.0016 \]
\[ EF_{eco} > 0.017 \text{ were set } = 0.017 \]

(Source: Rochette et al., 2008)
Estimated $N_2O$ loss (3-yr mean) from N applied as urea or anhydrous ammonia at four sites in Saskatchewan, Canada

(Source: Lemke unpublished data)
Estimated $\text{N}_2\text{O}$ loss (3-yr total) from N applied in fall or spring at four sites in Saskatchewan, Canada

(Source: Lemke unpublished data)
Annual estimated N$_2$O loss from selected crop-residue combinations at Scott, Saskatchewan, Canada

<table>
<thead>
<tr>
<th>Residue Type (previous crop)</th>
<th>Crop</th>
<th>2008/09</th>
<th>2009/10</th>
<th>2010/11</th>
<th>3-year cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat(-N)</td>
<td>Wheat (-N)</td>
<td>515 abc</td>
<td>160 d</td>
<td>380 b</td>
<td>1110 bc</td>
</tr>
<tr>
<td>Wheat (+N) †</td>
<td>Wheat (+N) †</td>
<td>570 ab</td>
<td>310 ab</td>
<td>540 ab</td>
<td>1360 b</td>
</tr>
<tr>
<td>Pea</td>
<td>Pea</td>
<td>400 cd</td>
<td>160 cd</td>
<td>430 b</td>
<td>990 c</td>
</tr>
<tr>
<td>wheat</td>
<td>Pea</td>
<td>340 d</td>
<td>170 cd</td>
<td>610 ab</td>
<td>1120 bc</td>
</tr>
<tr>
<td>Pea</td>
<td>Wheat (+N)</td>
<td>330 d</td>
<td>430 a</td>
<td>510 ab</td>
<td>1270 bc</td>
</tr>
<tr>
<td>Wheat (+N) †</td>
<td>Canola (+N) ‡</td>
<td>400 bcd</td>
<td>460 a</td>
<td>580 ab</td>
<td>1440 b</td>
</tr>
<tr>
<td>Canola (+N) ‡</td>
<td>Wheat (+N)</td>
<td>810 a</td>
<td>380 ab</td>
<td>930 a</td>
<td>2120 a</td>
</tr>
</tbody>
</table>

(Source: Lemke & Farrell unpublished data)

† Wheat received 65 kg N ha$^{-1}$  
‡ Canola received 75 kg N ha$^{-1}$
Nitrous oxide emissions from selected crop residues and urea incubated at 50% WFPS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total Emissions</th>
<th>Residue Derived Emissions</th>
<th>Residue Derived Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg N₂O-N</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Control</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Urea</td>
<td>0.04</td>
<td>0.01</td>
<td>0.07 c</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.07</td>
<td>0.02</td>
<td>0.07 c</td>
</tr>
<tr>
<td>Pea</td>
<td>0.18</td>
<td>0.06</td>
<td>0.12 b</td>
</tr>
<tr>
<td>Flax</td>
<td>0.08</td>
<td>0.02</td>
<td>0.08 c</td>
</tr>
<tr>
<td>Canola</td>
<td>0.23</td>
<td>0.10</td>
<td>0.16 a</td>
</tr>
</tbody>
</table>

(Source: Farrell & Lemke unpublished data)
Nitrous oxide emissions from selected crop residues and urea incubated at 70% WFPS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total Emissions</th>
<th>Residue Derived Emissions</th>
<th>Residue Derived Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>—— mg N₂O-N ——</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Control</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Urea</td>
<td>0.84</td>
<td>0.09</td>
<td>0.82 c</td>
</tr>
<tr>
<td>Wheat</td>
<td>2.66</td>
<td>0.26</td>
<td>1.07 c</td>
</tr>
<tr>
<td>Pea</td>
<td>4.26</td>
<td>0.95</td>
<td>1.97 bc</td>
</tr>
<tr>
<td>Flax</td>
<td>6.79</td>
<td>0.93</td>
<td>3.02 b</td>
</tr>
<tr>
<td>Canola</td>
<td>10.89</td>
<td>3.11</td>
<td>4.91 a</td>
</tr>
</tbody>
</table>

(Source: Farrell & Lemke unpublished data)
GHG calculations for this LCA

- Direct N$_2$O emissions calculated using IPCC Tier 2 methodology (Rochette et al. 2008)

- Indirect emissions calculated using IPCC Tier 1 methodology

- N content of crop biomass as presented in Janzen et al., 2003.

- Emissions related to LUC and LMC were provided by Can-AG-MARS system.
Approach to the GHG calculations for this LCA

• Conceptualize as a “Cropping Landscape” upon which all agricultural crops (annual and perennial) are grown.

• Cropping landscape excludes “unimproved/native” pasture

• Current emissions from that “Cropping Landscape” are a reflection of both current and historical farming activities

• Emissions were calculated for entire “Cropping Landscape” and assigned to all crops on a proportional basis

• Emissions associated with farming activities specific to a specific crop were calculated and assigned to that crop
CO₂-footprint Canola production on the Canadian Prairies: circa 2010

<table>
<thead>
<tr>
<th>Soil Ecozone</th>
<th>Production</th>
<th>Land Use Change</th>
<th>Land Management Change</th>
<th>Net</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>_________</td>
<td>Emissions kg CO₂eq tonne⁻¹ Canola</td>
<td>_________</td>
<td></td>
</tr>
<tr>
<td>Grey</td>
<td>580</td>
<td>320</td>
<td>-100</td>
<td>680</td>
</tr>
<tr>
<td>Black</td>
<td>515</td>
<td>-30</td>
<td>-230</td>
<td>260</td>
</tr>
<tr>
<td>D.Brown/Brown</td>
<td>475</td>
<td>-110</td>
<td>-290</td>
<td>80</td>
</tr>
<tr>
<td>Canadian Prairies</td>
<td>525</td>
<td>10</td>
<td>-210</td>
<td>330</td>
</tr>
</tbody>
</table>

LUC = conversion of grassland or forest land to cropland.

LMC = net change in tillage practices, area of land in summerfallow, and conversion of perennial to annual cropping

(Source: MacWilliam, Lemke, Baron unpublished data)
Summary

• Canola is now a major component of the annual crop mix on the Canadian prairies

• Nitrous oxide emissions on the Canadian prairies are driven by external N applications and governed largely by moisture regime

• Nitrous oxide emissions during the canola phase of rotation related to fertilizer N management in a way similar to wheat

• Constraining N$_2$O emissions will be related to our ability to fine tune fertilizer N management strategies
Summary continued....

• Indications of an interaction between canola residue and fertilizer N application in the following crop year

• Displacing wheat with canola in cropping systems on the Canadian prairies will likely result in a modest increase in overall N$_2$O emissions

• Life-Cycle analysis indicates a low CO$_2$ footprint for canola production on the prairies
Thank You for Your Kind Attention!