Designing organic cropping systems for improved nutrient cycling and soil health

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Canada’s Organic Sector

• Approx 2 Billion Dollars in Sales
• Over 4000 Producers
• New National Standards and Logo
• Growth 10-20%/year
CRC research program

**Goal:** To Gauge and Enhance the Sustainability of Organic Agriculture

Field crops

Blueberries

Dairy

- Nutrient dynamics
- Soil health
- Energy efficiency
- Productivity
- Biodiversity
- Plant-microsymbiont interactions
- Weed and pest management
- Environmental impact (water/GHG)

Lynch CJPS 2009; Lynch et al. Sustainability 2011; Lynch et al. Cab Reviews 2012
Soil Health

• What do we mean by soil health?

• Is primary interest in diversity or functioning, and as relate to farm ecosystem or broader ecological intensification?

• Resilience of the microbial community – is it’s diversity *per se* a key goal? Focus on higher trophic levels?

• Are ‘farming systems’ dominant or is ‘intensity’ of management a more important determinant

A short note on SOM

<table>
<thead>
<tr>
<th>Authors</th>
<th>Period (yrs)</th>
<th>ORG&lt;CONV</th>
<th>ORG=CONV</th>
<th>ORG&gt;CONV</th>
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<tbody>
<tr>
<td>Mahli et al</td>
<td>12</td>
<td></td>
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<tr>
<td>Bell et al.</td>
<td>18</td>
<td>13-15%</td>
<td></td>
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<td>Pimental et al.</td>
<td>22</td>
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<td>20-25%</td>
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<td>Teasdale et al.</td>
<td>9</td>
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<td>Wortman et al.</td>
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<td>Robertson et al.</td>
<td>8</td>
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<td>Leifeld et al.</td>
<td>27</td>
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<td>Kirchmann et al.</td>
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<td>Hathaway-Jenkins et al.</td>
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<td>Chirinda et al.</td>
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BUT perhaps data more persuasive re. benefits of Organic systems in enhancing labile pools of SOM – i.e. also providing nutrients and energy for crop and wider ecosystem benefits.
Highbush Blueberry: Ground Floor Management

- Productivity and Quality
- Nutrient dynamics
- Soil Ecology & pest control

Mulches increased: Plant canopy volume and leaf tissue N, P and K. Yields (3X) and berry size.

Mulches influenced: Weed species biomass, composition and time of onset

Burkhard et al Hortscience 2009
Mulches and weeds. Effect on blueberry maggot emergence and predators (Carabidae & Staphylinidae)

Rhagoletis mendax (Curran)

late June & July

Sept. to June - overwinter in soil below bushes

August
Predatory carabids and staphylinids

More in compost!

But dominated by -

Pella glooscapi

Pterostichus melanarius (Illiger)

Earthworm Abundance (#/m²) and Biomass

Microbial quotient (%TOC)

Nelson et al. 2009 AEE; Lynch et al. 2012. RAFS
Yields, Nitrogen Use Efficiency, Soil Health

- Yields 20-25% lower for organic systems, but NUE higher (34 kg N per 10 T yield vs 38 kg N per 10 T yield)
- N losses to air and water proportional to N inputs generally, regardless of source.

Lynch et al. 2012, Moller et al. 2007
Green manures and supplemental composts improved soil physical, biological, and chemical properties.

But average of 50% of soil mineral N at harvest lost overwinter.

Rotation: red clover–red clover–wheat–soybean

Nitrogen losses include:
- $\text{NO}_3^-$ in drainage $\text{H}_2\text{O}$
- $\text{N}_2\text{O}$-N as soil flux
- Dissolved $\text{N}_2\text{O}$ in drainage $\text{H}_2\text{O}$
Clover Incorporation Treatments

1. **Early Fall + N**(70)
   September incorporation
   Spring NH₄NO₃ (70 kg N ha⁻¹)

2. **Late Fall**
   November incorporation

3. **Late Fall (clover cut as hay)**
   November incorporation
   Spring manure (70 kg avail. N ha⁻¹)

4. **Spring**
   May incorporation
Wheat productivity, N uptake and N Losses – Influence of Green Manure Incorporation Timing

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Wheat N uptake (kg N ha(^{-1}))</th>
<th>Annual N(_2)O Emissions (kg N ha(^{-1}))</th>
<th>Annual NO(_3) leaching (kg N ha(^{-1}))</th>
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<tbody>
<tr>
<td></td>
<td>Yr 1</td>
<td>Yr2</td>
<td>Yr 1</td>
</tr>
<tr>
<td>Early Fall + N(_{70})</td>
<td>121</td>
<td>176</td>
<td>0.69</td>
</tr>
<tr>
<td>Late Fall (hay + manure)</td>
<td>98</td>
<td>158</td>
<td>1.58</td>
</tr>
<tr>
<td>Late Fall</td>
<td>90</td>
<td>167</td>
<td>0.58</td>
</tr>
<tr>
<td>Spring</td>
<td>74</td>
<td>163</td>
<td>0.96</td>
</tr>
</tbody>
</table>

- Seasonal influence dominated N synchronicity
- Overall losses moderate across all systems
Improving N synchronicity

Plant Root Simulators (PRS)™.

PRS-N flux correlated with crop N uptake and soil N dynamics in agronomic and horticultural settings.

$y = 0.066x + 84.1$

$R^2 = 0.60; n = 60$

Earthworms - Green manure tillage intensity
**Folsomia candida** as a soil health indicator

- Springtails associated with: Decomposition & Nutrient cycling
- *F. candida* – an existing ISO for metal toxicology (ISO, 1999)

Neonates responded more to organic soils and long rotations than to conventional managed soils

*Nelson et al. 2011 Pedobiologia*
Productivity, NUE and Ecosystem Services


Thorup-Kristensen (2012) – Three vegetable + cereals organic systems varying in autumn catch crops, GMrs and intercrops. GMrs doubled root soil exploration with reduced N leaching

Girard et al (2014) - Higher nestling (young songbirds) food biomass in organic than conventional soybean fields in eastern Ontario – attributed to longer rotations
Soil Phosphorus Concerns

Canadian organic farms have reported low (<10 mg kg\(^{-1}\)) soil test phosphorus (STP) levels (Entz et al., 2001; Martin et al. 2007; Roberts et al., 2008; Welsh et al., 2009; Knight et al., 2010; Main et al., 2013).

– Implications for farm productivity?
  • Crop yield
  • N\(_2\) fixation

– Sustainability of organic systems?
Phosphorus – forage productivity and BNF

- Low farm P surplus and soil test P across dairy farms
- Examine relationship STP and forage BNF and productivity

Roberts et al 2008 CJSS; Main et al 2013 Agron J.
Forage Yield and Biological N$_2$ Fixation

No relationship between soil P status and yield or biological N$_2$ fixation performance.
Glenlea Rotation Study (since 1992)

- Organic – no inputs (ORG)
- Organic – manure application 2007 (ORG-M)
- Conventional (CON)
- Restored prairie (PRA)

- Flax-alfalfa-alfalfa-wheat

Soil test P:  
- ORG: 7.6 mg kg\(^{-1}\)
- CONV: 19.3 mg kg\(^{-1}\)
- PRA: 29.6 mg kg\(^{-1}\)
But higher diversity \textit{phoD} community structure in conventional soils

Diversity ≠ Function

Alkaline phosphatase (ALP) activity higher in soils with lower bioavailable P

Fraser et al Geoderma \textit{In Press}
Can we improve nutrient cycling while maintaining and enhancing soil health?

The distinctiveness of organic systems (legumes, vegetative diversity, high C but low P inputs etc.) is advancing our understanding, and opportunities to manage plant and soil microbial relations for improved nutrient cycling and ecosystem health.

We are adept at promoting soil life. But need to refine our goals as relates to this key linkage between organic farming systems and broader ecosystem services.
Thank you