Designing organic cropping systems for improved nutrient cycling and soil health

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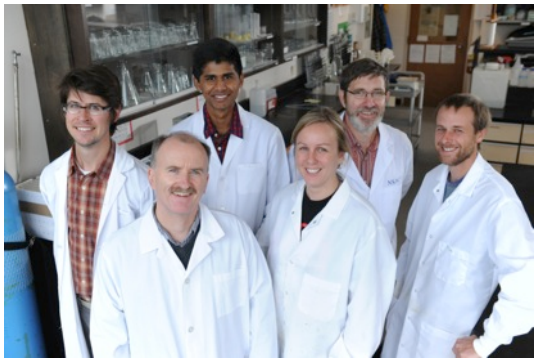
Canada's Organic Sector

- 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

- Productivity
- Nutrient dynamics
- Biodiversity
- Soil health
- Plant-microsymbiont interactions
- Energy efficiency
- 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

Lynch 2014 Sustaining soil organic carbon, soil quality and soil health in organic field crop management systems. *In* Martin, R.C and MacRae, R. [Eds] Managing Energy, Nutrients and Pests in Organic Field Crops. CRC Press.

A short note on SOM

Authors	Period (yrs)	ORG<CONV	ORG=CONV	ORG>CONV
Mahli et al	12		✔	
Bell et al.	18	13-15%		
Pimental et al.	22			20-25%
Teasdale at al.	9			19%
Wortman et al.	11		✔	
Robertson et al.	8	12%		
Leifeld et al.	27		✔	
Kirchmann et al.	18			16%
Hathaway-Jenkins et al.	1-58		✔	
Chirinda et al.	11		✔	

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

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

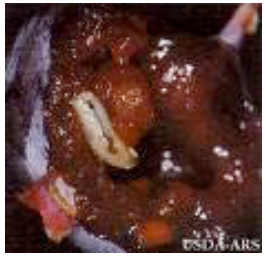
<u>Mulches influenced</u>: Weed species biomass, composition and time of onset

Burkhard et al Hortscience 2009

Mulches and weeds. Effect on blueberry maggot emergence and predators (Carabidae & Staphylinidae)

Rhagoletis mendax (Curran)

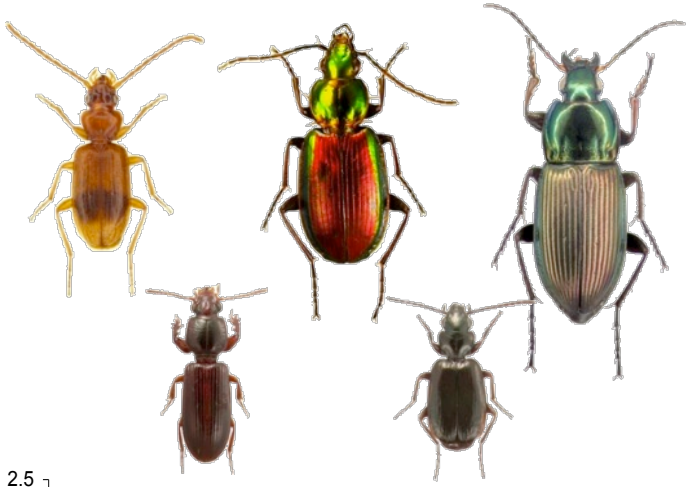
late June & July



August

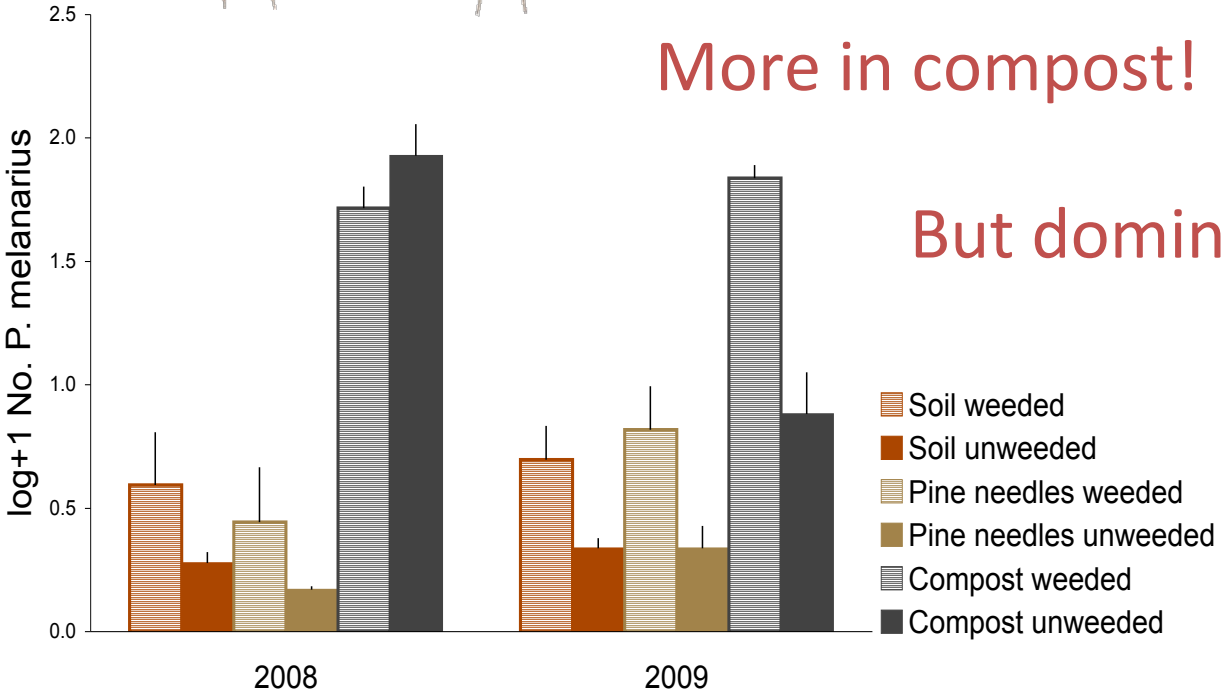
Sept. to June - overwinter in soil below bushes

Predatory carabids and staphylinids



Pella glooscapi

More in compost!



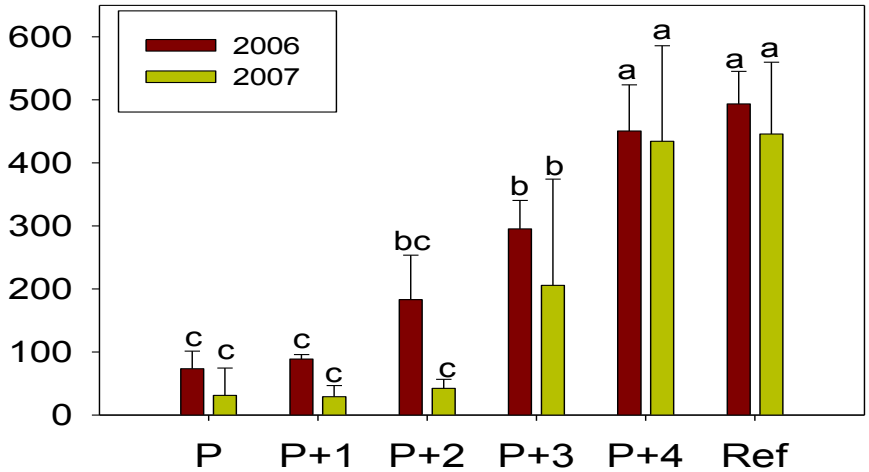
But dominated by -

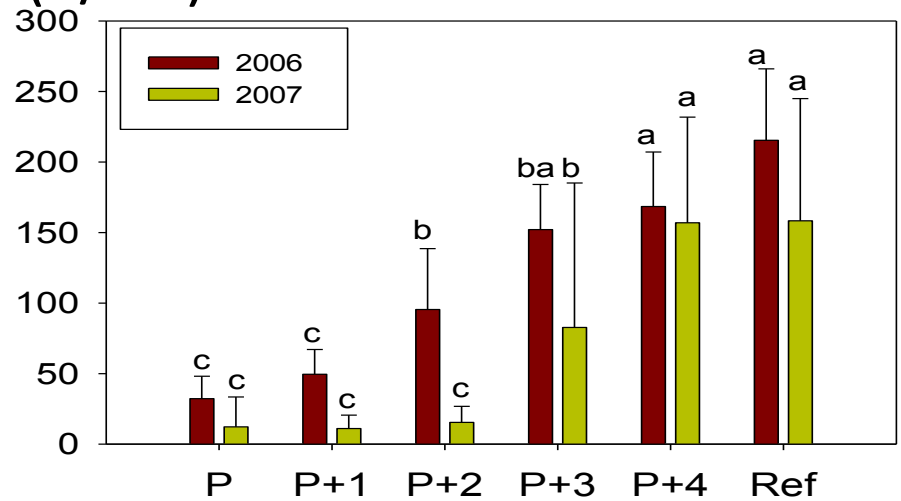
Pterostichus melanarius (Illiger)

Renkema et al 2012 Env. Entomol; Renkema et al 2012 Biol. Cont; Renkema et al 2012 Acta Hort; Renkema et al 2011 J. Pest Sci.; Klimaszewski et al. 2009. Zookeys

Agronomy, Soil Health and N Dynamics

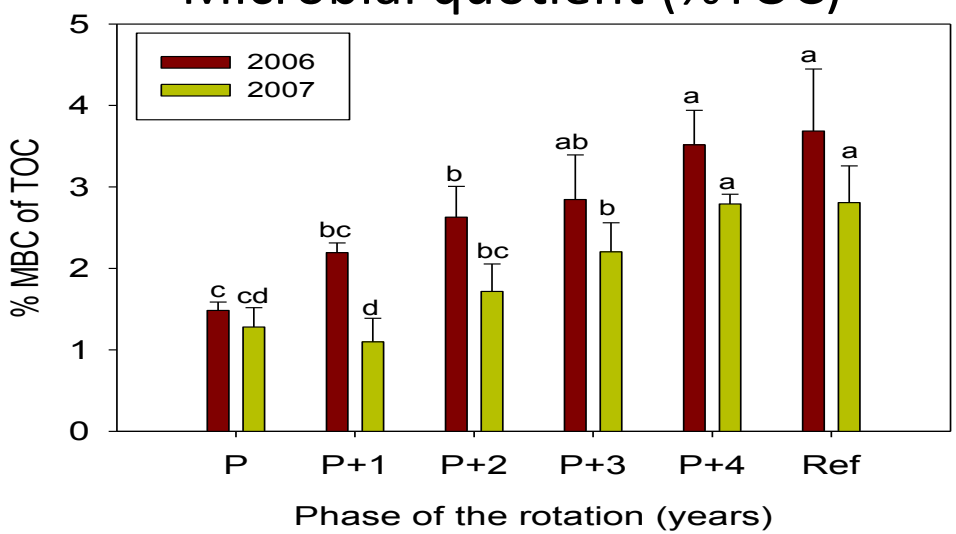
Earthworm Abundance (#/m^2) and Biomass





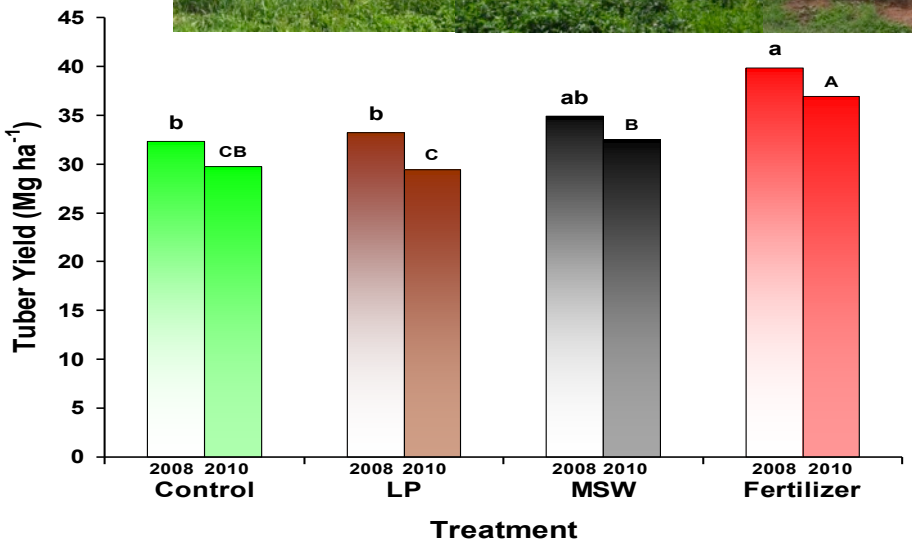
Phase of the rotation (years)

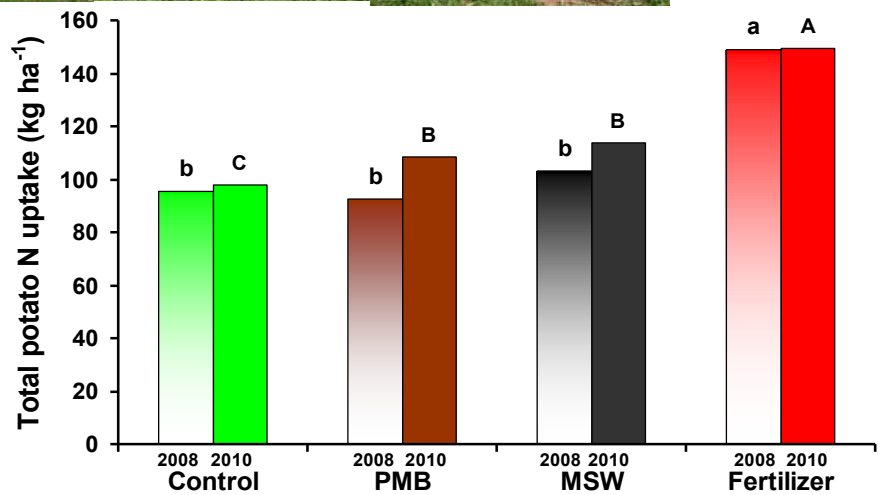
Microbial quotient (%TOC)



Nelson et al. 2009 AEE; Lynch et al. 2012. RAFS

Yields, Nitrogen Use Efficiency, Soil Health





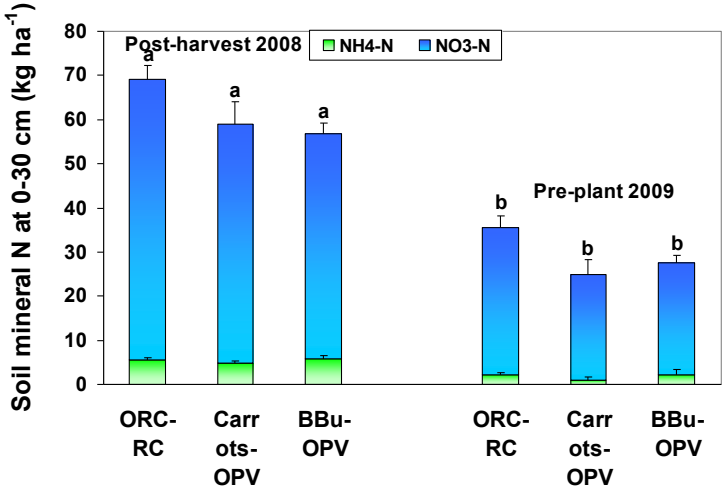
- Yields 20-25% lower for organic systems, but NUE higher (34 kg N per 10 T yield vs 38 kg N per 10 T yield)
- N losses to air and water proportional to N inputs generally, regardless of source.

Lynch et al 2012, Moller et al. 2007

Yields, Nitrogen Use Efficiency, Soil Health

Green manures and supplemental composts improved soil physical, biological, and chemical properties

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



Sharifi et al 2014 Nutr. Cycl. Agroecosys

Over-winter N Losses From Green Manures – Influence of Incorporation Timing

Rotation: red clover–**red clover**–**wheat**–soybean

Nitrogen losses include:

- NO_3^- in drainage H_2O
- N_2O-N as soil flux
- Dissolved N_2O in drainage H_2O

Clover Incorporation Treatments

1. Early Fall + $N_{(70)}$

September incorporation
Spring NH_4NO_3 (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

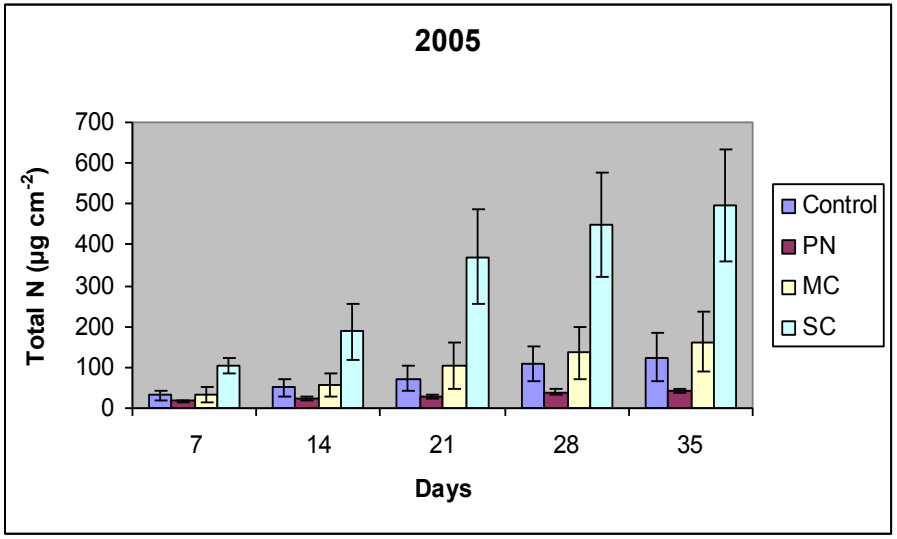
Treatment	Wheat N uptake (kg N ha^{-1})		Annual N_2O Emissions (kg N ha^{-1})		Annual NO_3 leaching (kg N ha^{-1})	
	Yr 1	Yr2	Yr 1	Yr2	Yr 1	Yr2
Early Fall + N_{70}	121	176	0.69	1.44	32	21
Late Fall (hay + manure)	98	158	1.58	1.68	18	11
Late Fall	90	167	0.58	1.37	14	18
Spring	74	163	0.96	0.84	15	12

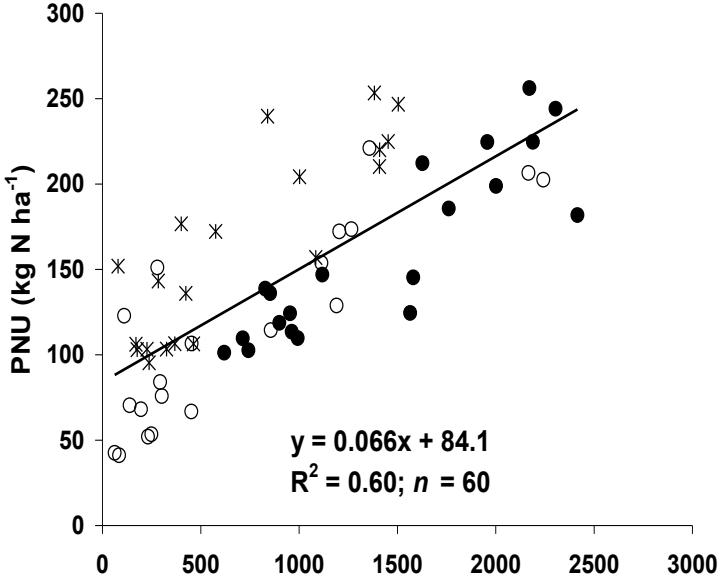
- Seasonal influence dominated N synchronicity
- Overall losses moderate across all systems

Improving N synchronicity

Plant Root Simulators (PRS)™ .

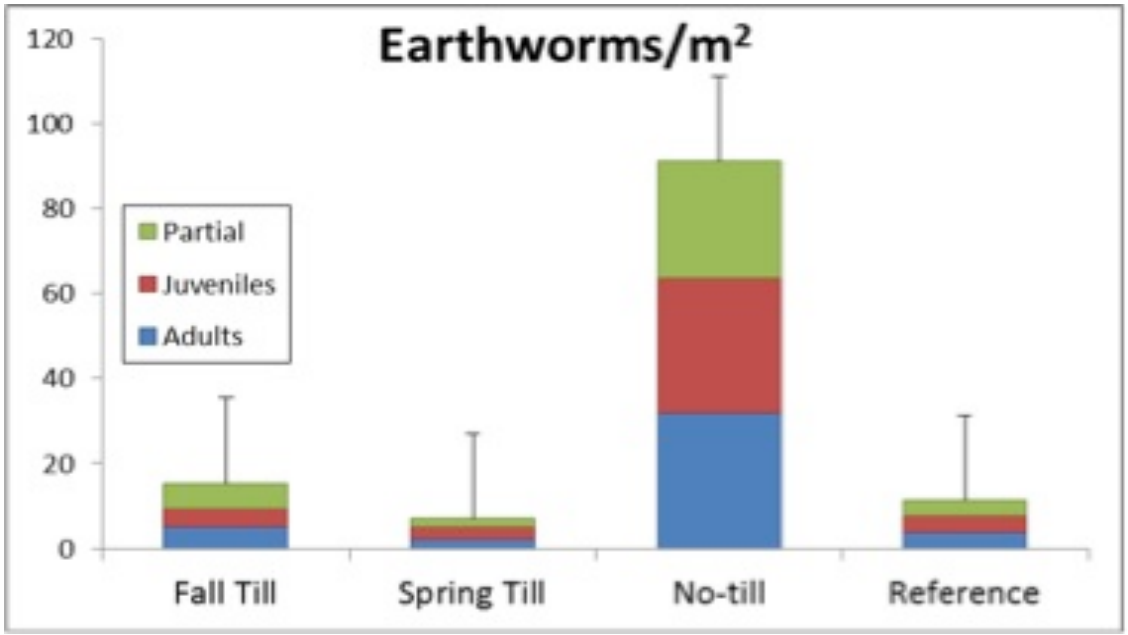
PRS-N flux correlated with crop N uptake and soil N dynamics in agronomic and horticultural settings.

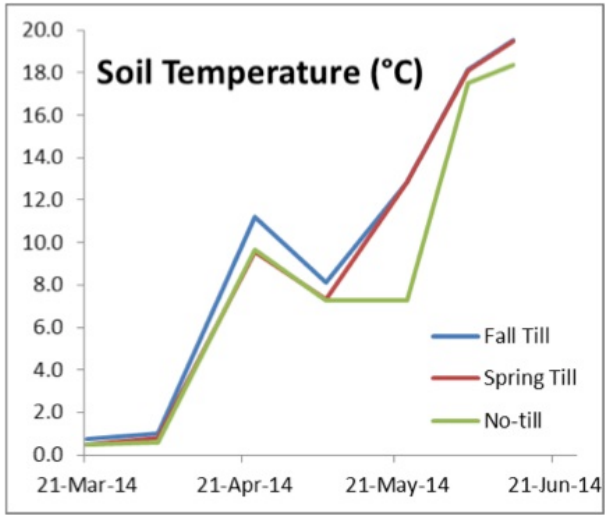


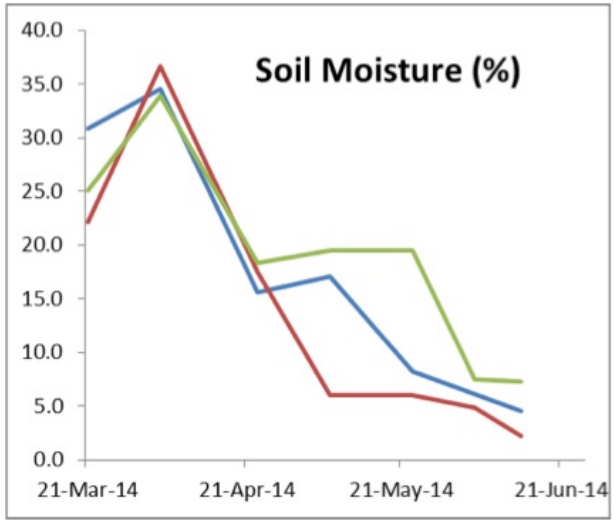


Sharifi et al 2009 Am.J.Pot.Res; Burkhard, 2007.

Earthworms - Green manure tillage intensity

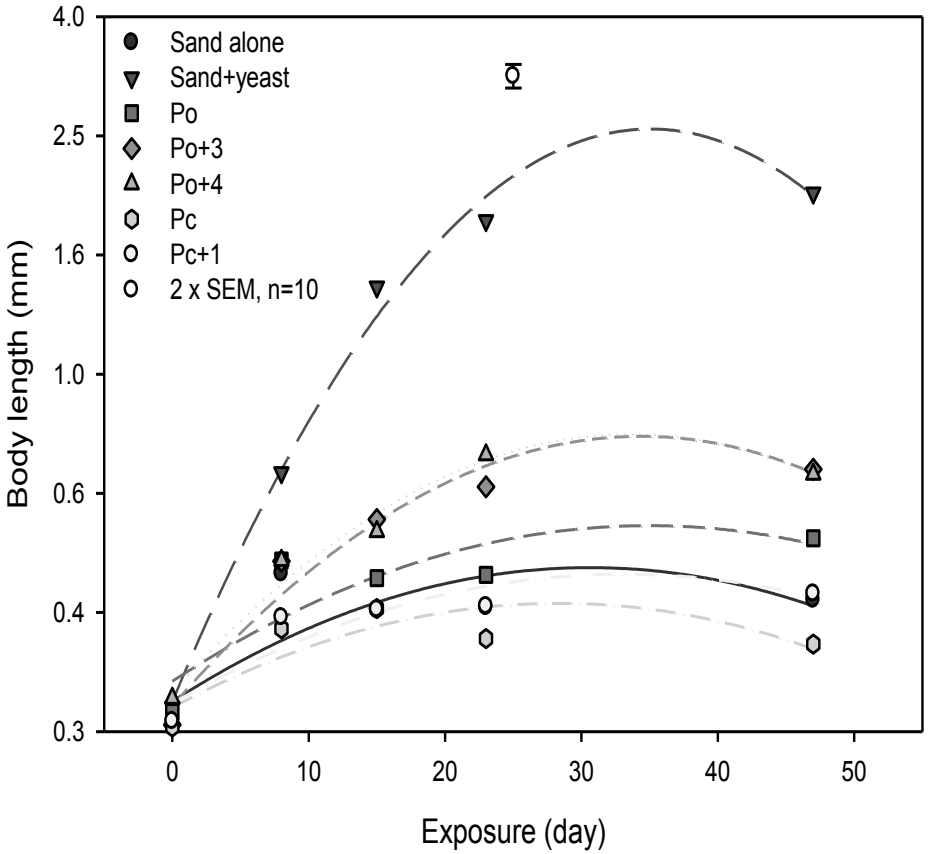






Folsomia candida as a soil health indicator

- 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

Kirchmann et al (2007) – NUE lower for organic in long-term study

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

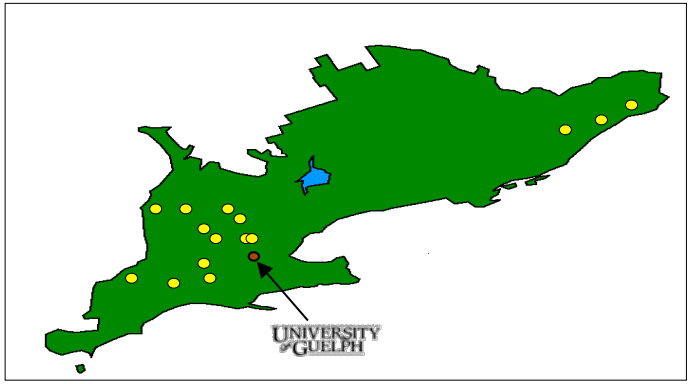
Soil Phosphorus Concerns

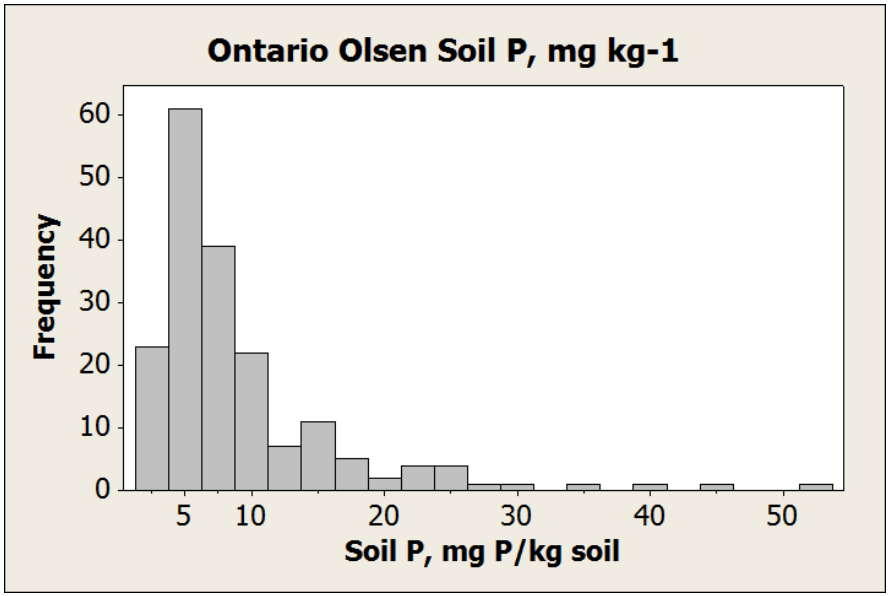
Canadian organic farms have reported low (<10 mg kg^{-1}) soil test phosphorus (STP) levels

(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

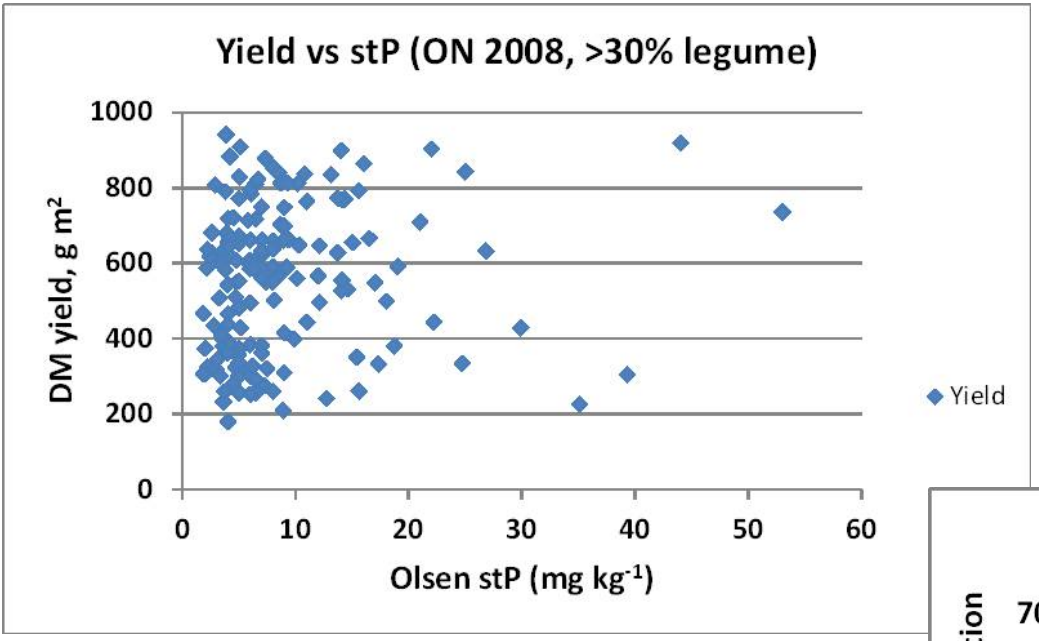




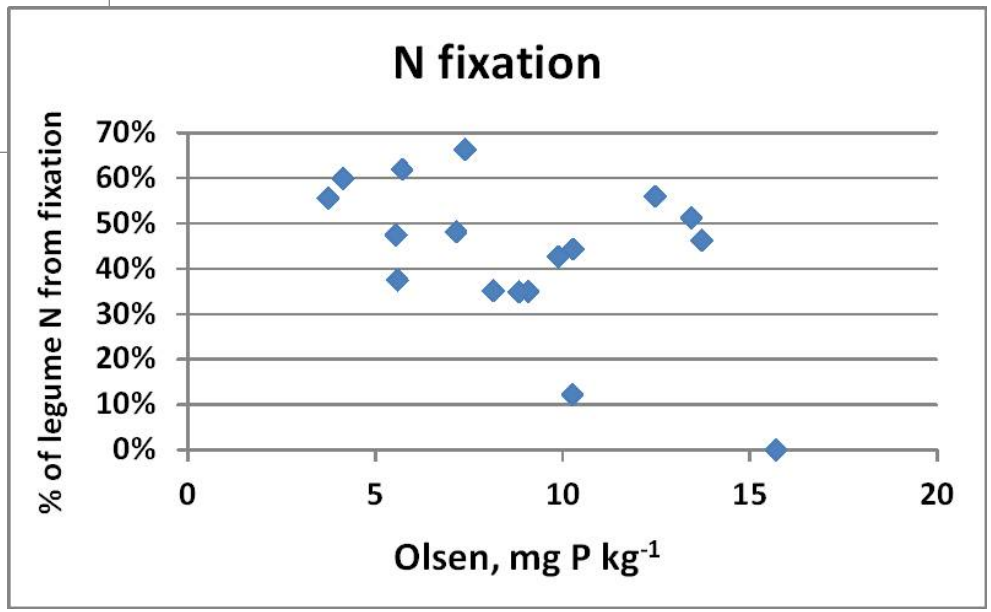
- Low farm P surplus and soil test P across dairy farms
- Examine relationship STP and forage BNF and productivity

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.



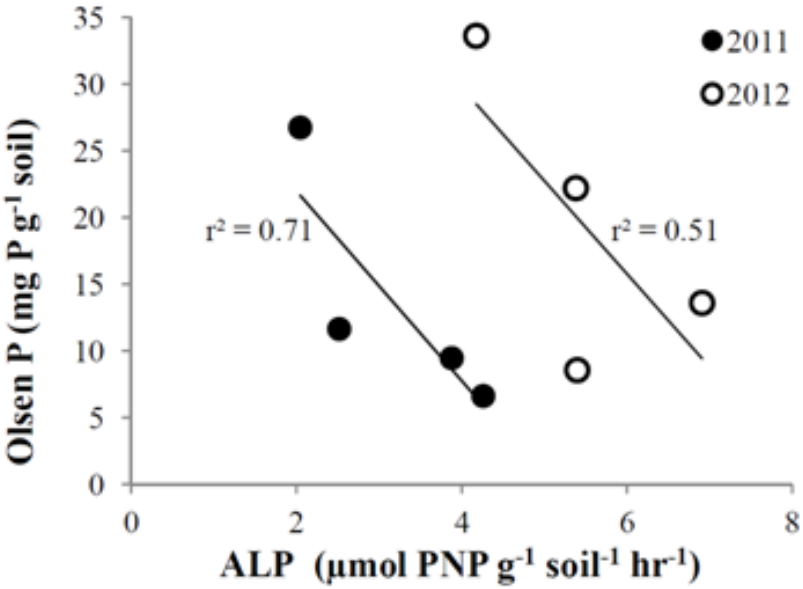
Alkaline Phosphatase and Bacterial *pho*D gene abundance as influenced by long-term management

Glenlea Rotation Study
(since 1992)

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

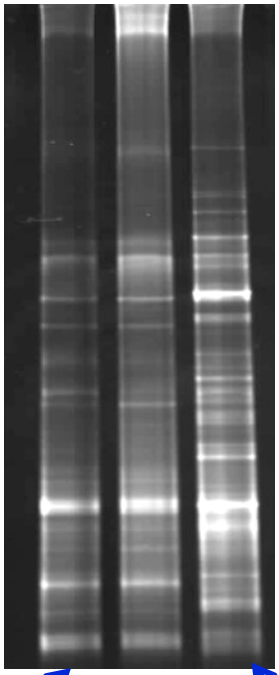
- flax-alfalfa-alfalfa-**wheat**

Soil test P: ORG 7.6 mg kg^{-1}
CONV 19.3 mg kg^{-1}
PRA 29.6 mg kg^{-1}



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

But higher diversity *pho*D community structure in conventional soils



ORG CONV

Diversity ≠ Function

Fraser et al Geoderma *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