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Canada

Management and the microbiome: practices that promote beneficial microbes

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Soils and Crops 2018 Agronomy Workshop
March 7, 2018

What is soil health?

soil health ⟷ soil quality

"the continued capacity of a soil to function as a vital living ecosystem that sustains plants, animals and humans"

USDA, 2016

What is soil health?

soil health ⟷ soil quality

"Soil health…. ***Healthy soils maintain a diverse community of soil organisms*** that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots; recycle essential plant nutrients; improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production" (FAO, 2008)

What are the biota doing?

Ecosystem services
Decomposition & cycling of organic matter
Regulation of nutrient availability
Suppression of pests and disease
Maintenance of soil structure & hydrology
Gas exchange and carbon storage
Soil Detoxification
Plant growth control

Estimated value: \$1.5 trillion y^{-1} (FAO)

Supporting soil microbial communities

Agric. soil management practice
Reduced physical disturbance
Continuous cropping
Diverse cropping rotations
Cover cropping
Balanced nutrient management
Organic amendment application
Use of inoculants

Increased microbial abundance and diversity

Improved soil functioning

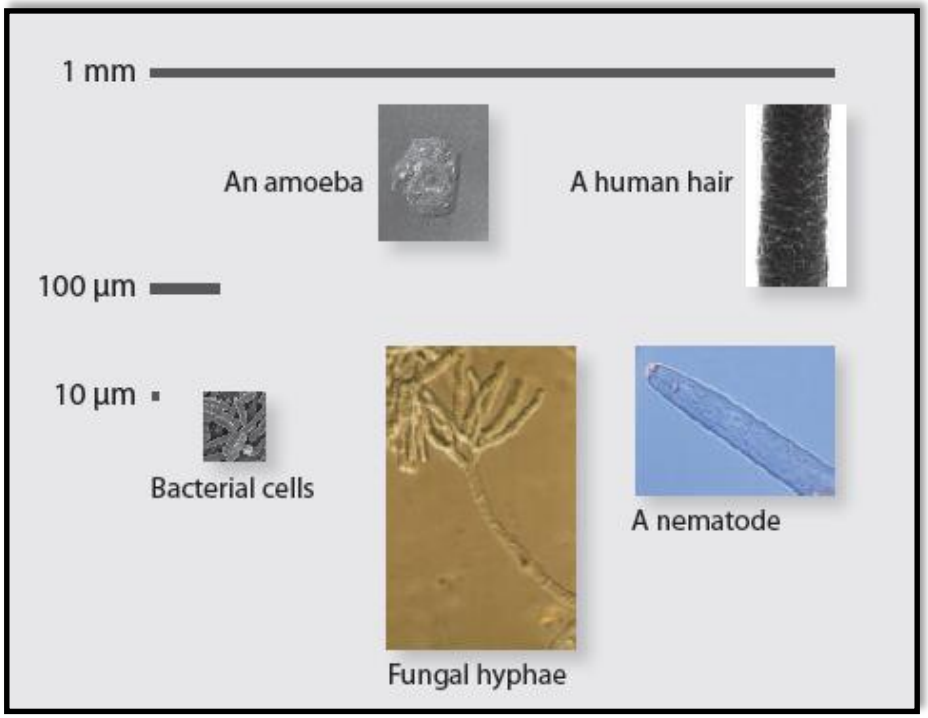
=

healthy soil!

But…*micro*bes are *micro*scopic, so how do we study them?

Studying soil microorganisms

How small are they?



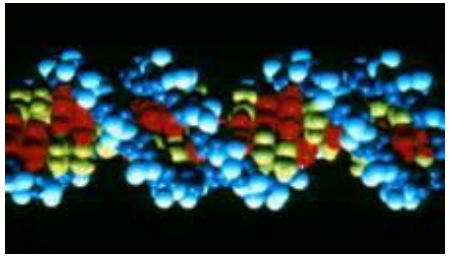
Traditional:
Lab culture and isolation; microscopy

*Modern:
Biomarkers (nucleic acids, cellular components)

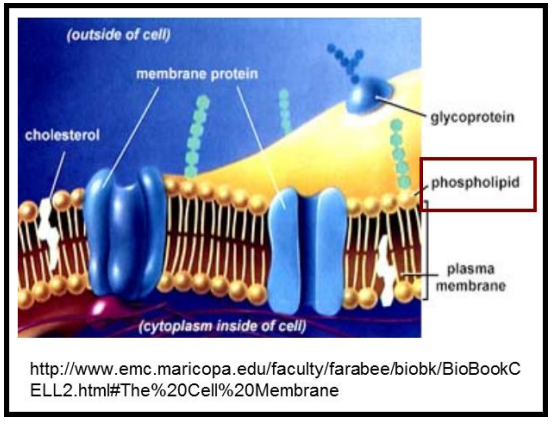
*Functional assays:
What are they doing?

Studying soil microorganisms

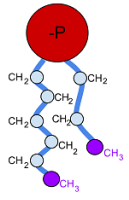
Biomarker: measurable indicator of a biological condition



DNA



http://www.emc.maricopa.edu/faculty/farabee/biobk/BioBookCELL2.html#The%20Cell%20Membrane



Phospholipid fatty acid (PLFA)

^{13}C tracer: stable isotope of carbon with 6 protons and 7 neutrons

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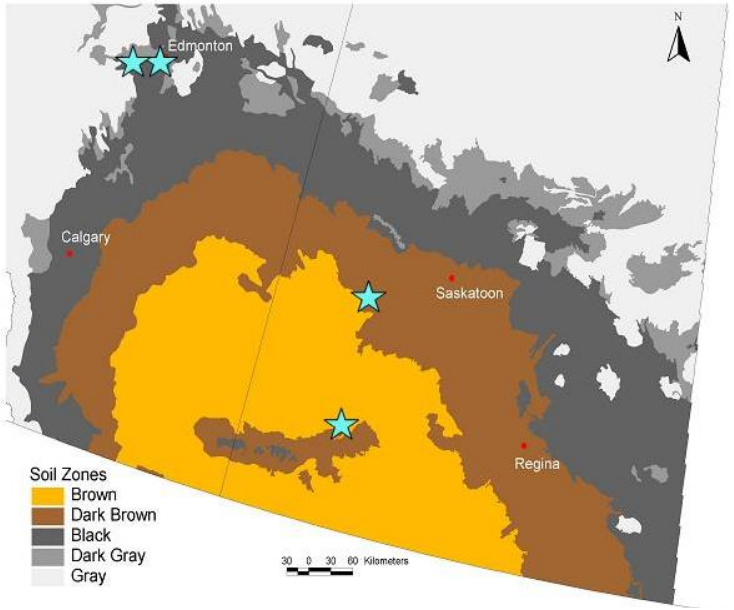
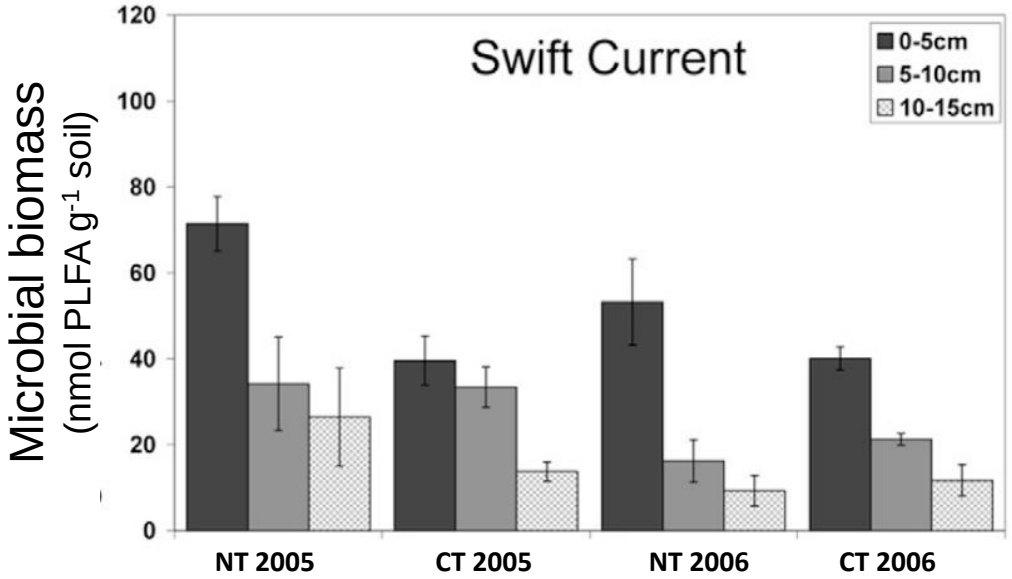
Reduced physical disturbance

Increased microbial biomass (0-5cm) 8 to 202%



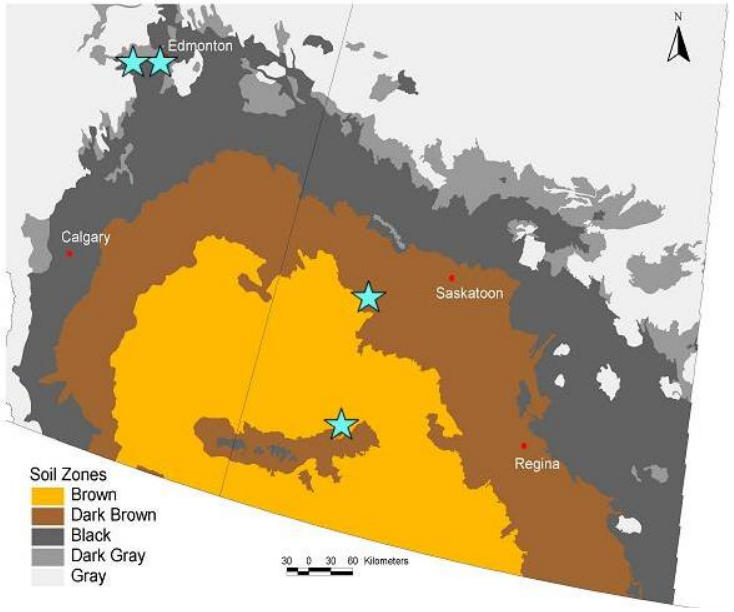
NT vs CT
Long term sites (~25yr)
4 locations
2 years

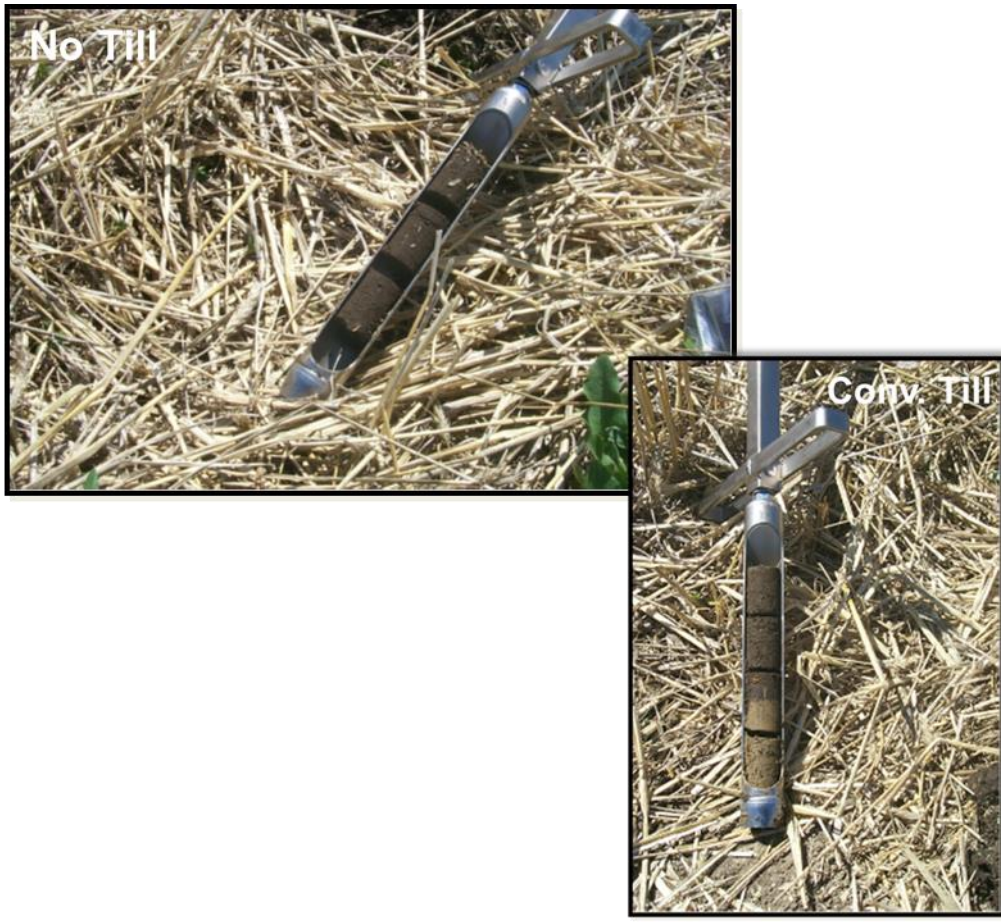


Why???

Reduced physical disturbance

Increased microbial biomass (0-5cm) 8 to 202%





NT vs CT
Long term sites (~25yr)
4 locations
2 years

Reduced physical disturbance

Fall 2007, microcosms set up (Lethbridge + Ottawa)

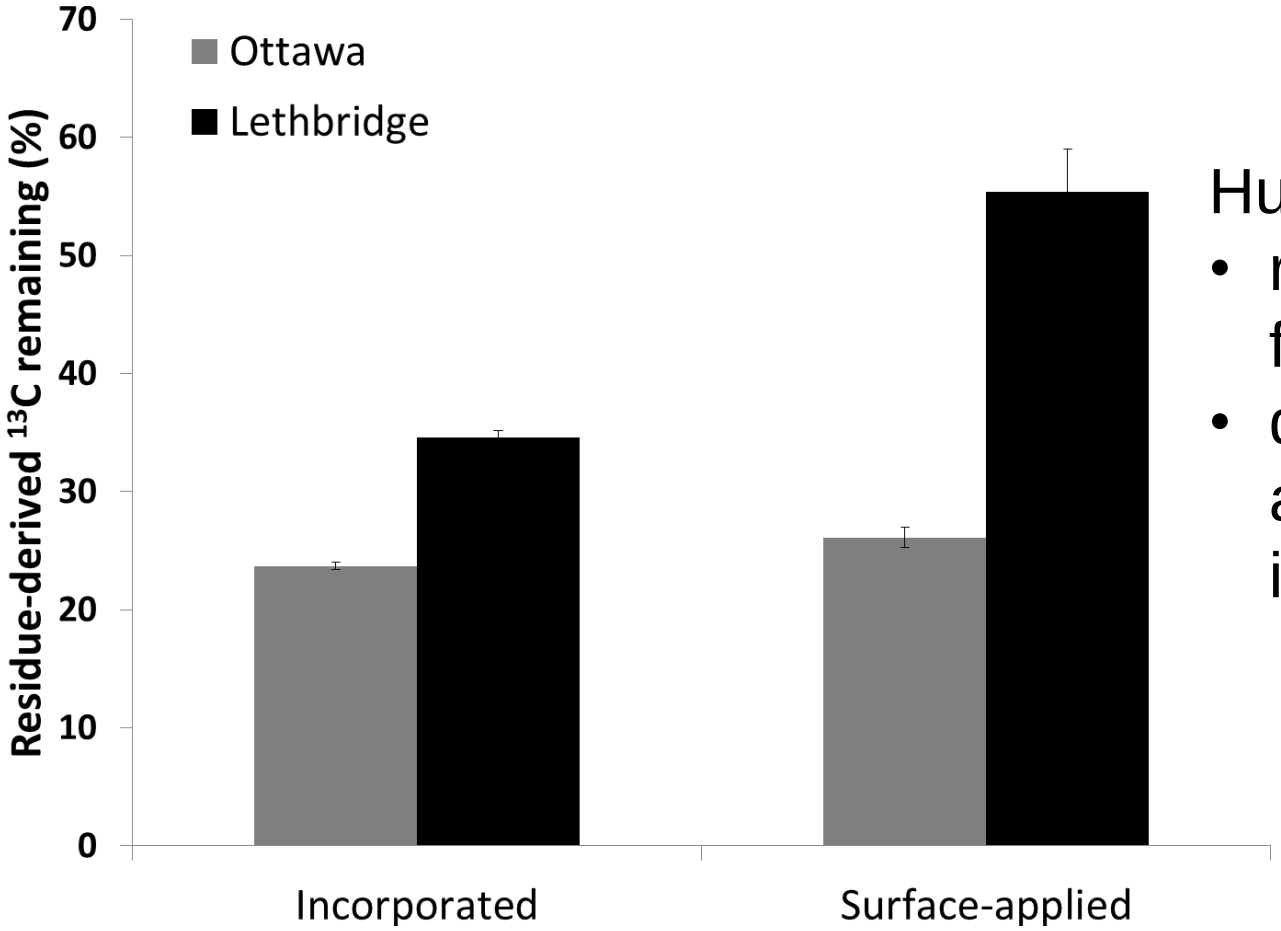
Barley residue (^{13}C at ca. 10 atom %) added either:

a. incorporated (0-10cm)
b. surface applied

(unlabelled residues every fall)

Reduced physical disturbance

24 months after residue addition

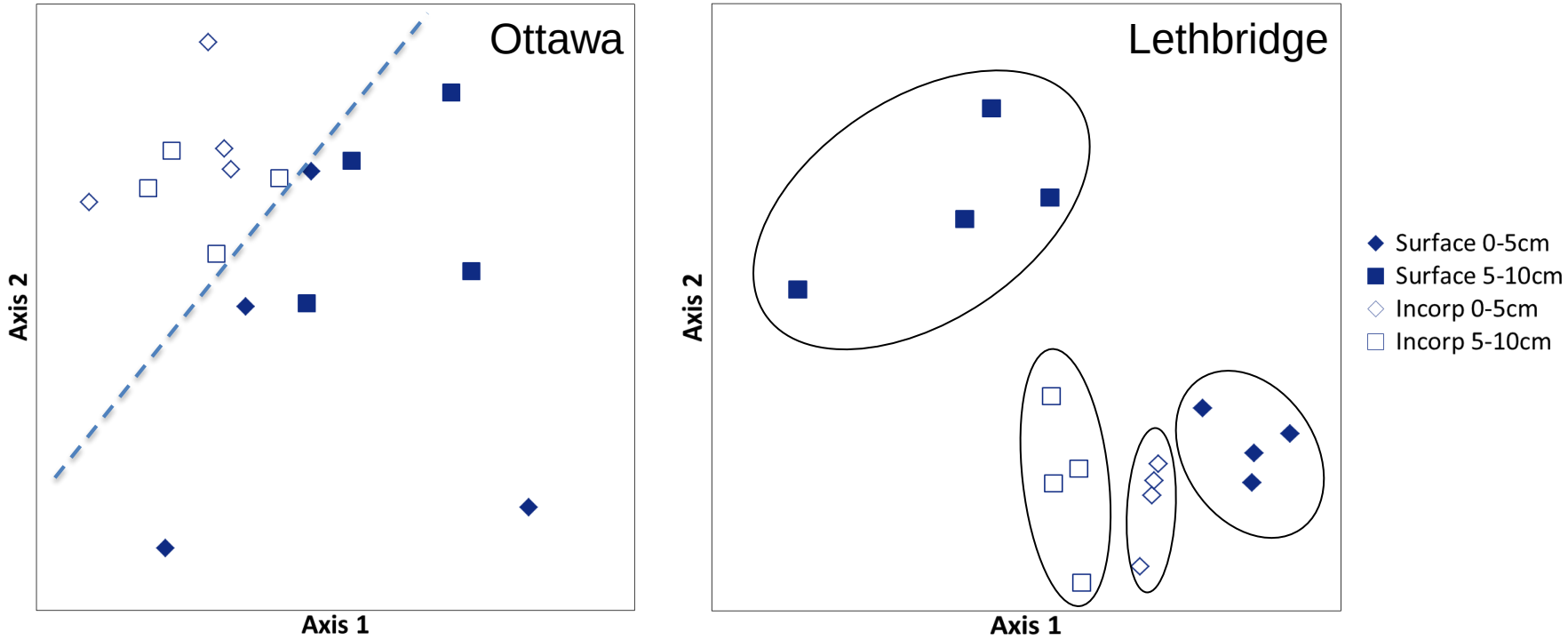


Humid climates:

- residue decomposes faster
- decomposition is less affected by incorporation

Helgason et al. 2014 Soil Biology and Biochemistry

Reduced physical disturbance



"Ordination" visualizes differences between complex communities

Different microbes are more active in NT vs. CT.
How does this change productivity?

Supporting soil microbial communities

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=

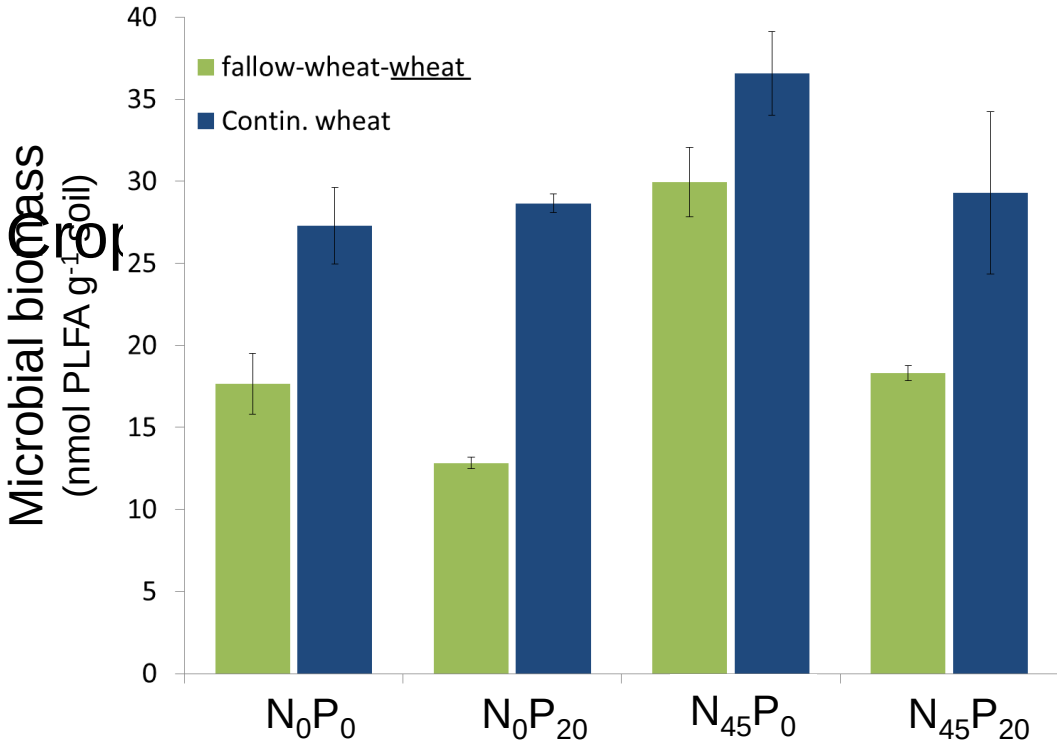
healthy soil!

Continuous cropping

increases microbial biomass, even when nutrients are limiting

Rotation ABC est. 1910
Rot. A: continuous wheat
Rot. C: wheat-wheat-fallow

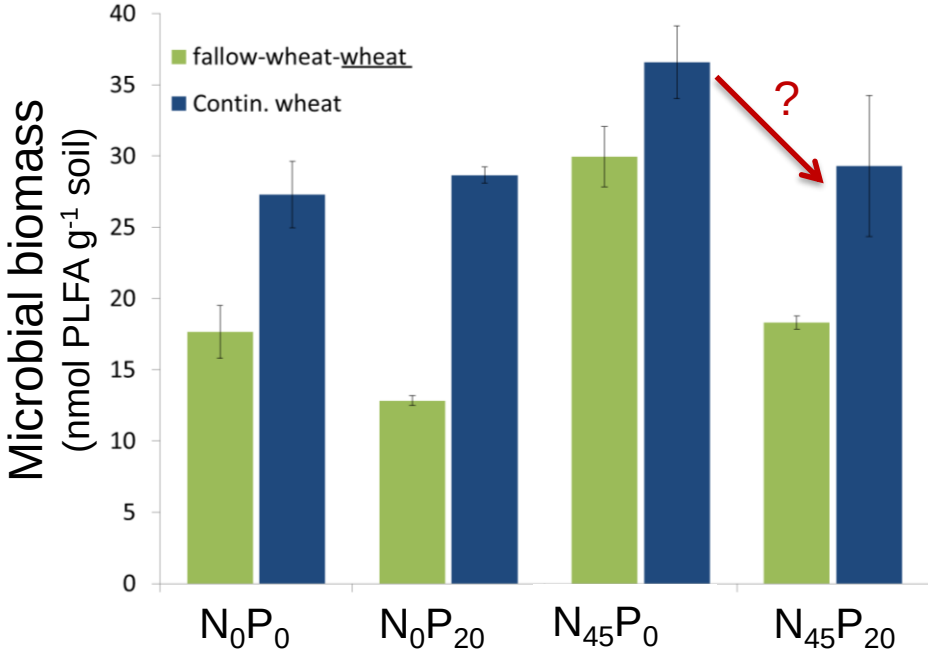
22 -123% increase ($p<0.05$)

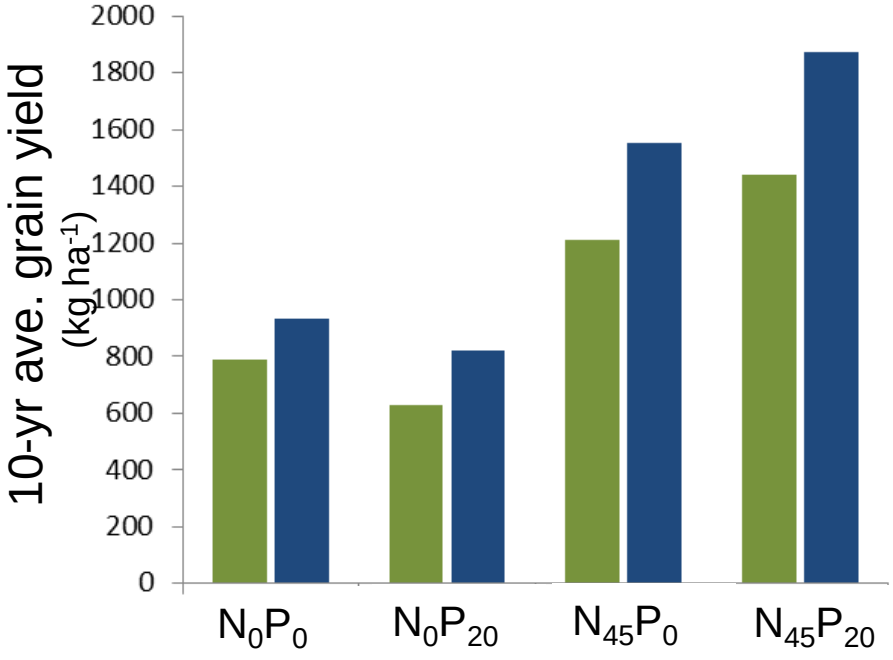


You need to feed the bugs!!!

1967: 45 kg ha^{-1} N
1972: 20 kg ha^{-1} P

Continuous cropping





Greater export of nutrients in grain in $N_{45}P_{20}$ system: drawing down soil fertility

Balanced nutrient management

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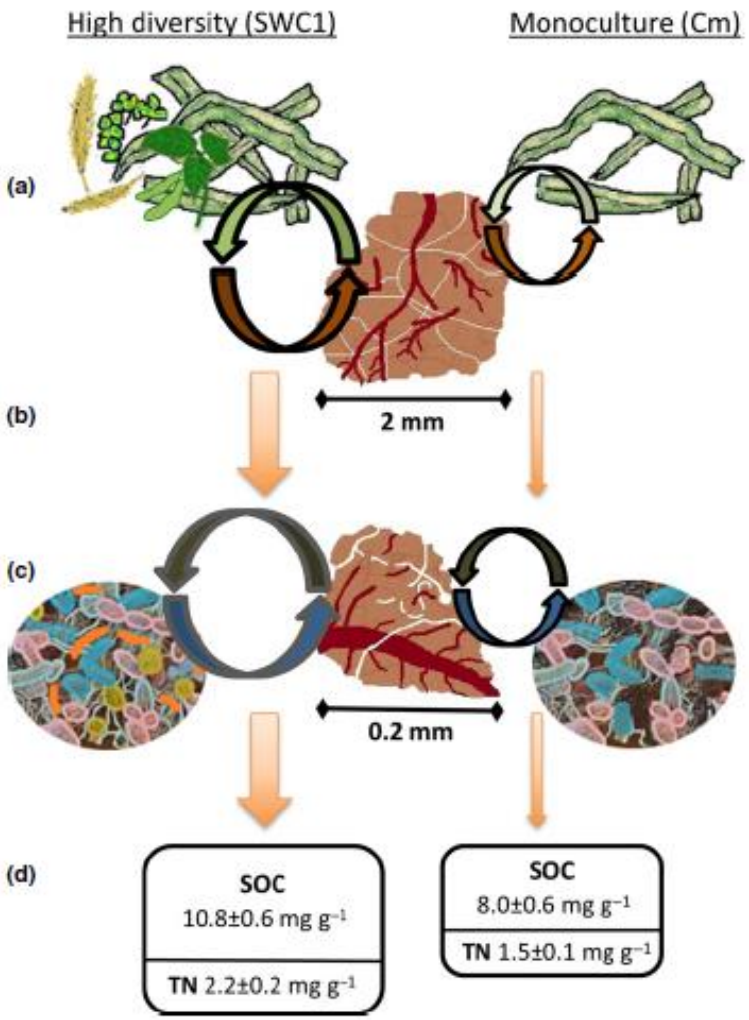
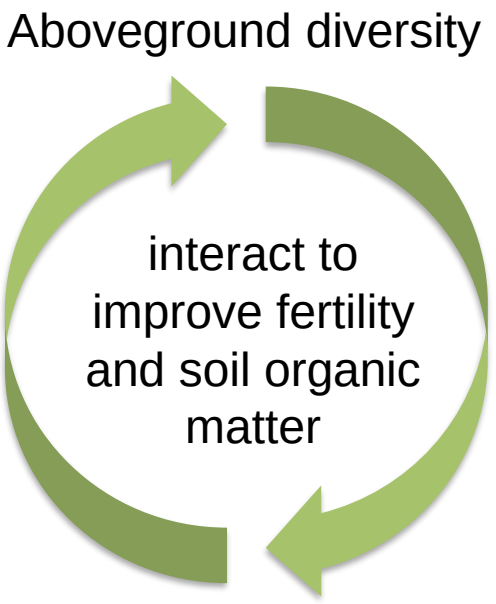
Increased crop rotation diversity

enhances microbial activity, aggregation, soil C and N

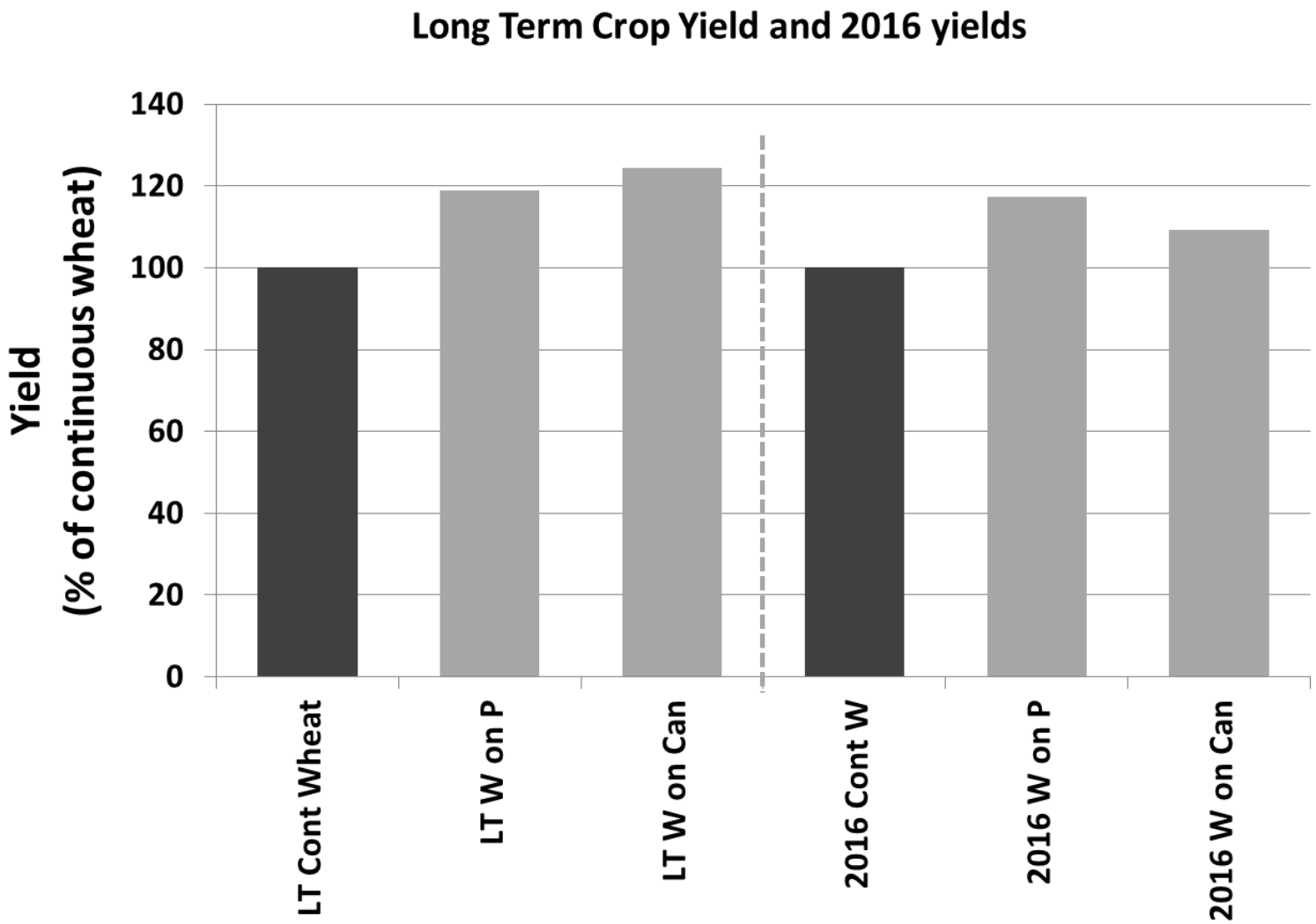




Tiemann et al. 2015 Ecology Letters

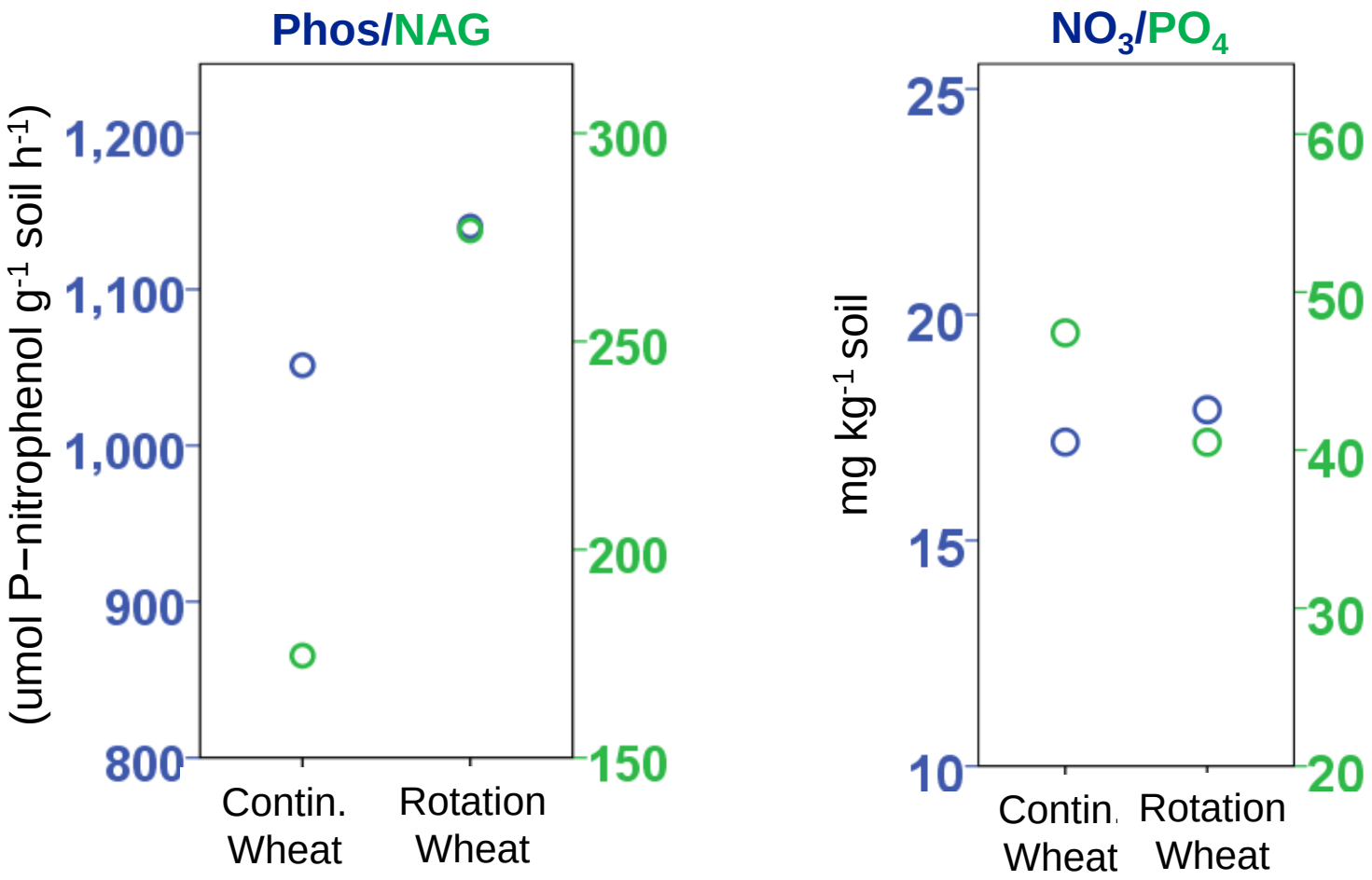
AAFC Crop Rotation Experiment (Swift Current est. 1987)

continuous wheat vs. wheat-canola-wheat-pea



Data courtesy of K. Brandt et al., AAFC Swift Current

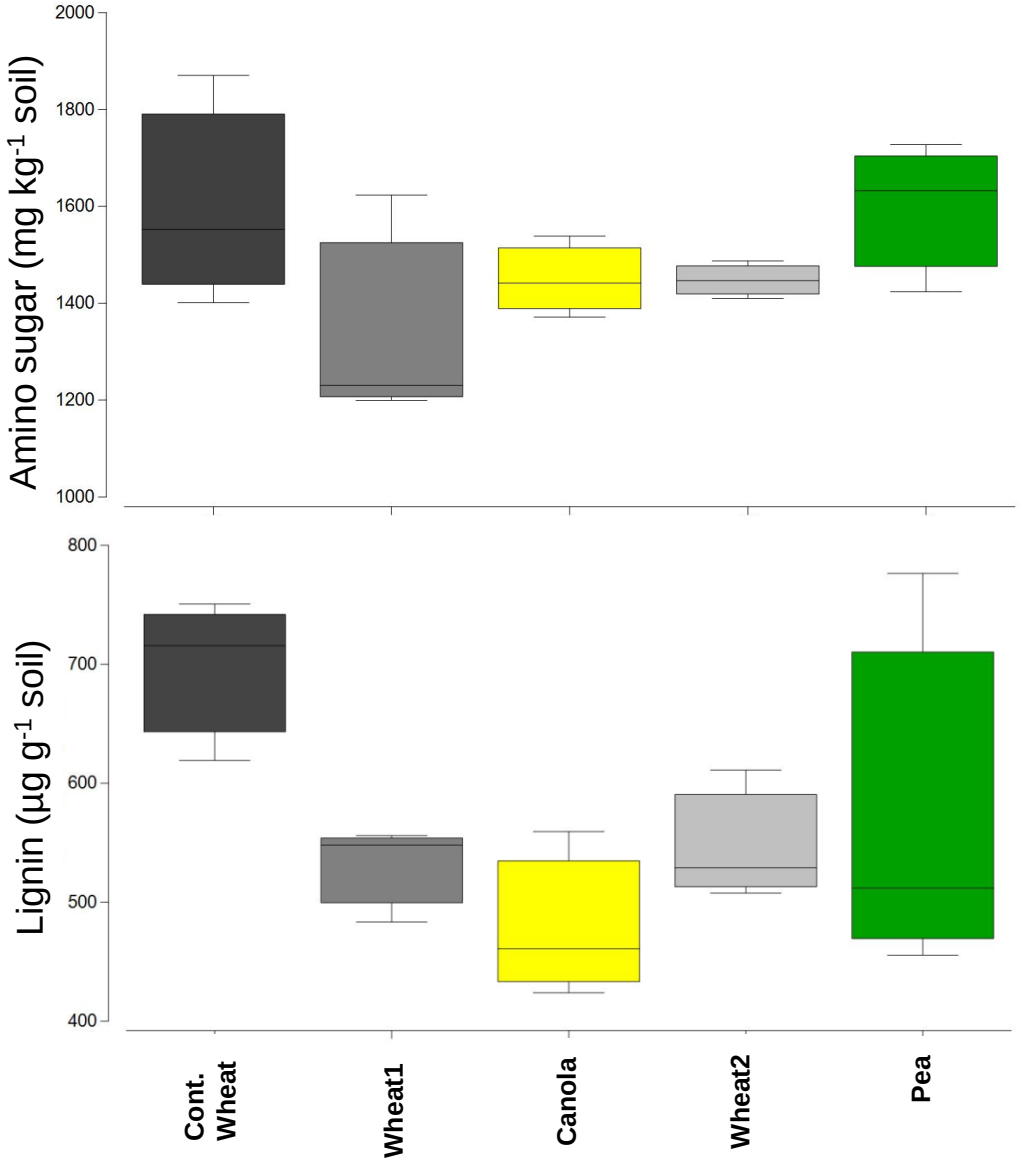
Monocropping vs. diverse rotation



Nutrient cycling is affected by crop rotation diversity

AAFC Crop Rotation Experiment (Swift Current est. 1987)

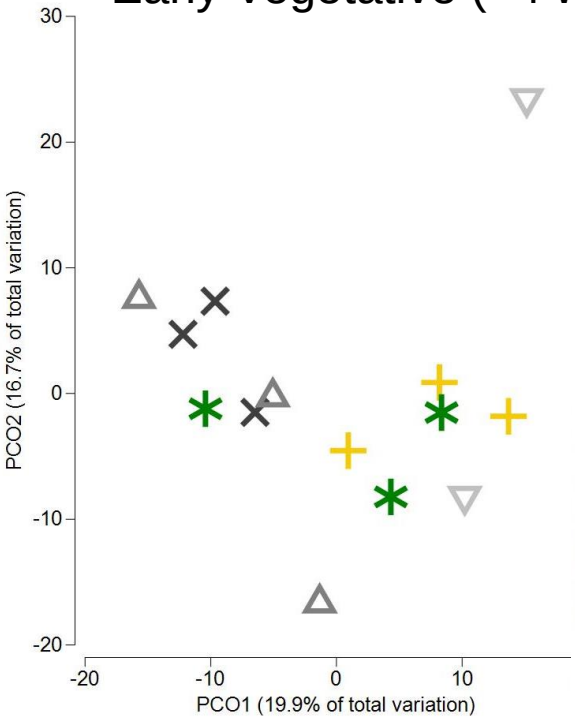
continuous wheat vs. wheat-canola-wheat-pea



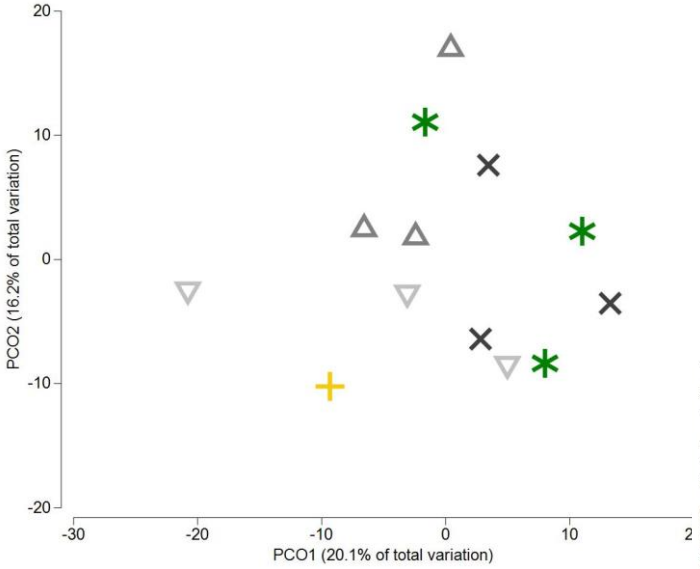
Soil organic matter *composition* is affected by crop rotation

Soil microbiome - bacteria

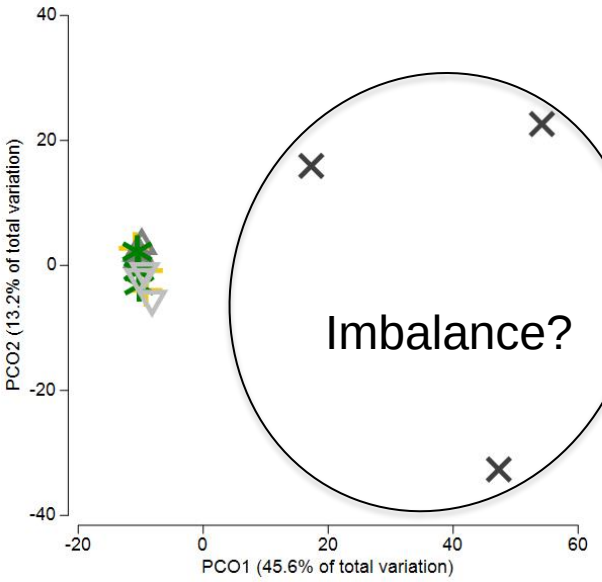
Early Vegetative (~4 week)

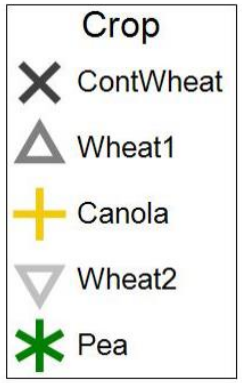


Anthesis



Post-Harvest

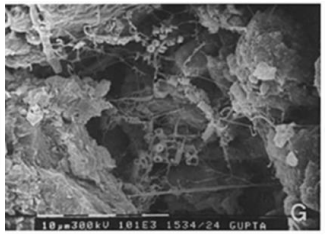




Soil microbiome – bacteria

Crop residues are important for microbial success

Crop rotation provides a "balanced diet" = improved fertility



Microbes are important for crop success

Supporting soil microbial communities

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Alternative Cropping Study (Scott, SK)

Long-term organic vs. conventional management

- **Organic (ORG) management**
  - no synthetic inputs, tillage
- **Reduced input conventional (CON) management**
  - fertilizers and pesticides, no-tillage
- **Diversified crop rotations**

Management system	Crop rotation	Cropping sequence (6 year rotation)
ORG	Annual (ANN)	GM lentil-**wheat**-pea-barley-GM sweet clover-mustard
	Perennial (PER)	Mustard-**wheat**-barley-alfalfa-alfalfa-alfalfa
CON	Annual (ANN)	Canola-fall rye-pea-barley-flax-**wheat**
	Perennial (PER)	Canola-**wheat**-barley-alfalfa-alfalfa-alfalfa

GM=green manure

Alternative Cropping Study (Scott, SK)

Long-term organic vs. conventional management

Model system

Table 1. Soil properties after 20 years of organic and conventional management

Mgmt	Cropping history	Total C (%)	Total N (%)	Inorganic N (mg kg^{-1} soil)	Available P (mg kg^{-1} soil)	pH
ORG	ANN	2.75	0.246	12.90	21.93	5.4
	PER	2.78	0.255	8.75*	15.63*	5.6
CON	ANN	3.45*	0.307*	29.63	50.98	5.2
	PER	2.98	0.272	21.48	70.50	5.7

ORG, organic management; CON, conventional management

ANN, annual grains cropping history; PER, annual grains-perennial alfalfa cropping history

Long-term organic management affects residue decomposition and fertility

Applied Soil Ecology 107 (2016) 347–359

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Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Microbial crop residue decomposition dynamics in organic and conventionally managed soils

Melissa M. Arcand[a], Bobbi L. Helgason[a,b,*], Reynald L. Lemke[b]

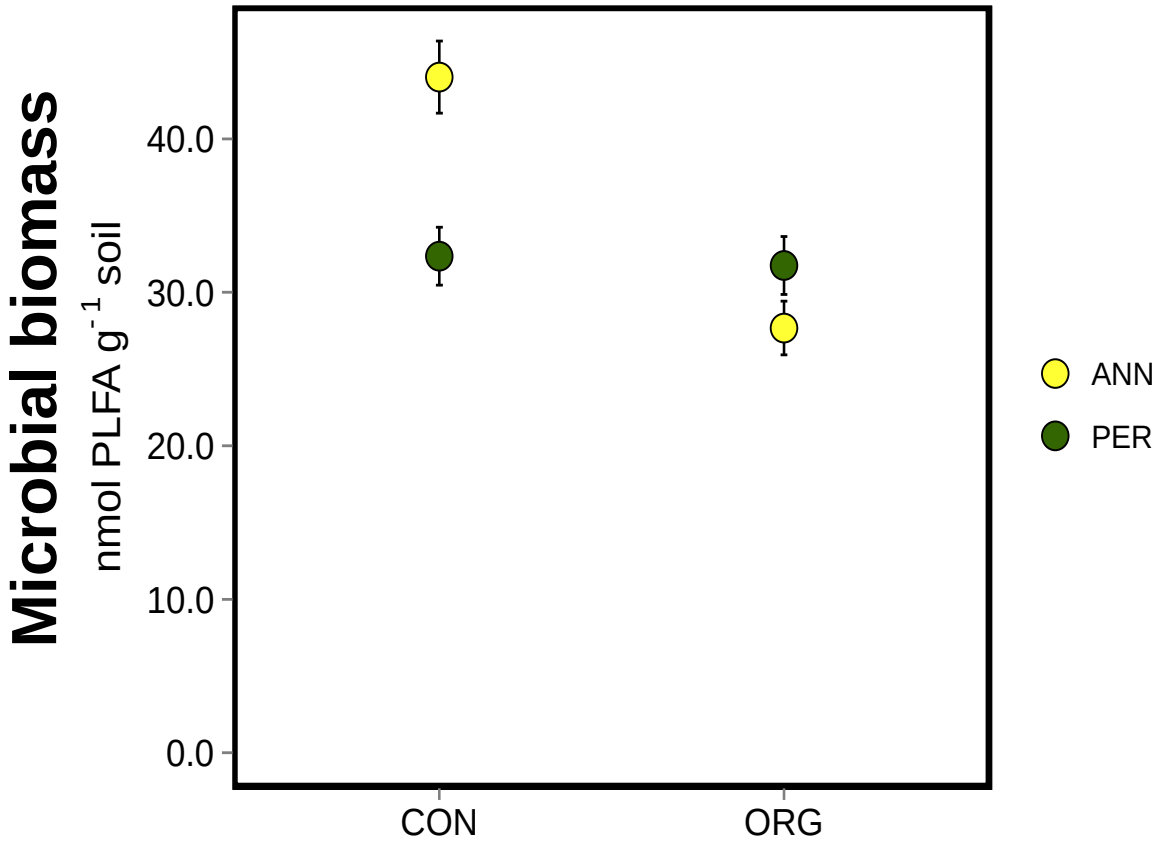
Controls (no residue)

^{13}C-labelled barley residues mixed with soil

10 atom% ^{13}C

Long-term Organic vs. Conventional

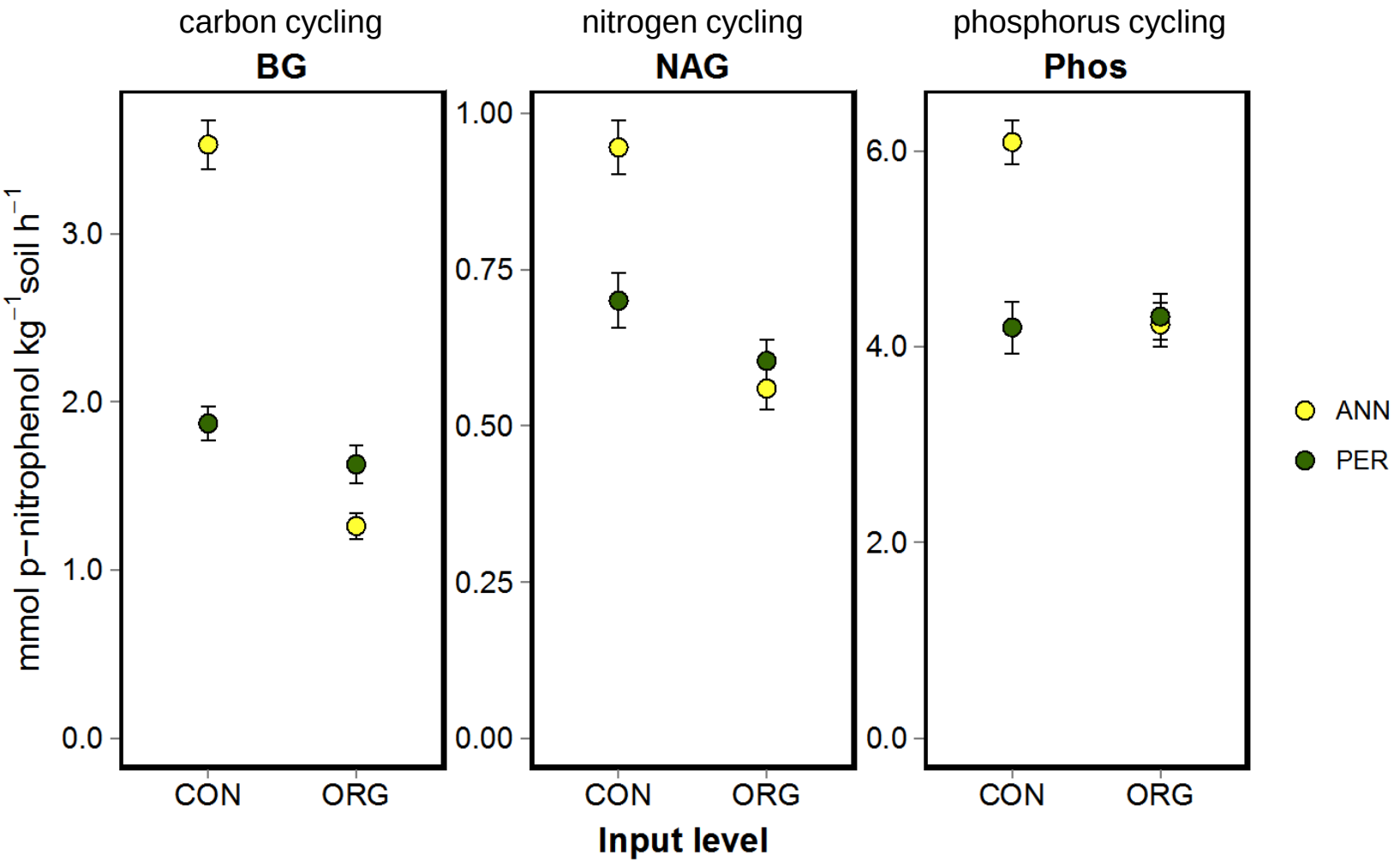
microbial biomass is reduced in the organic system



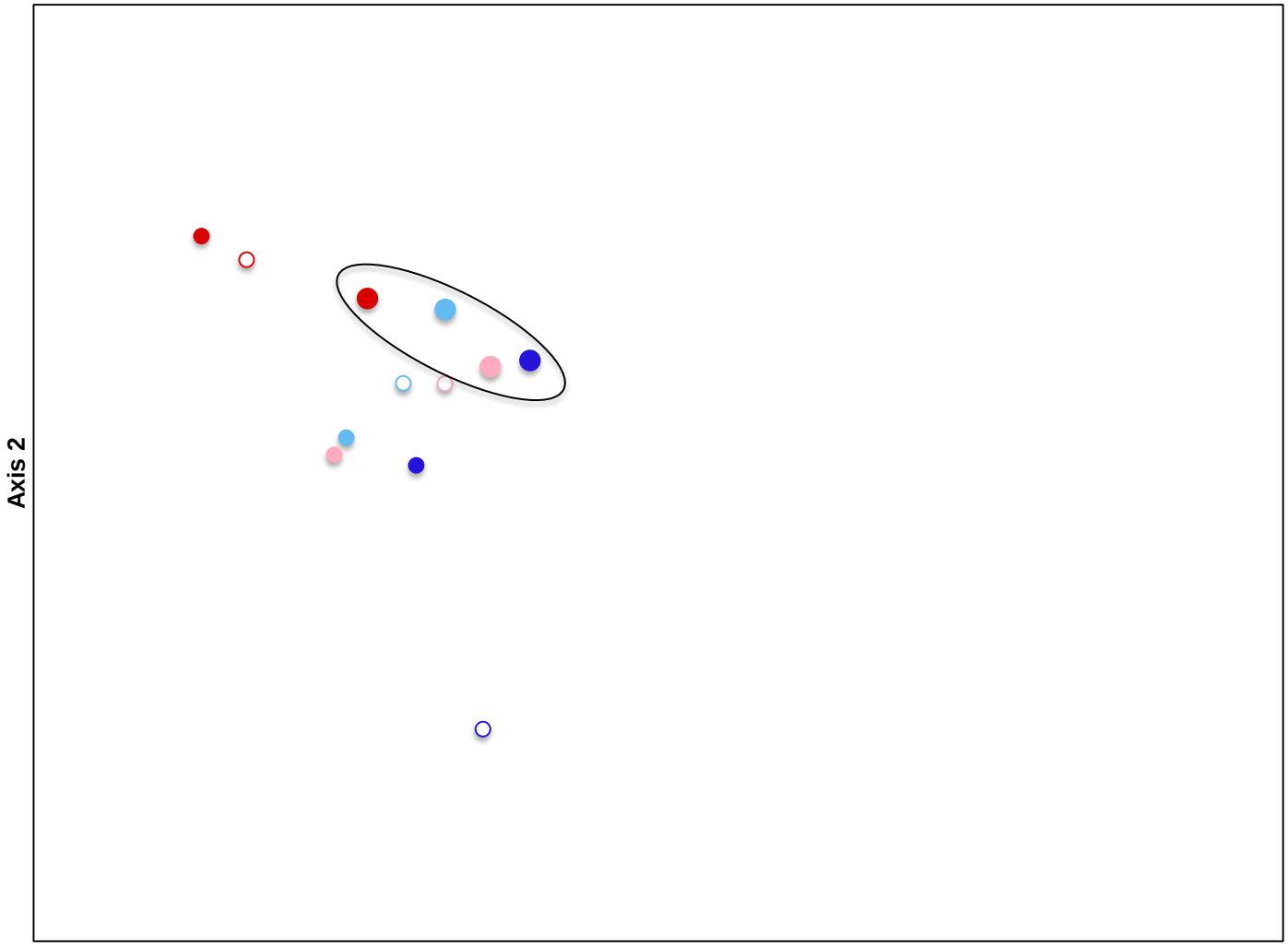
No livestock integration = net export of nutrients

Long-term Organic vs. Conventional

microbial function (soil enzyme activities) are reduced



Long-term organic management affects residue decomposition – community structure changes

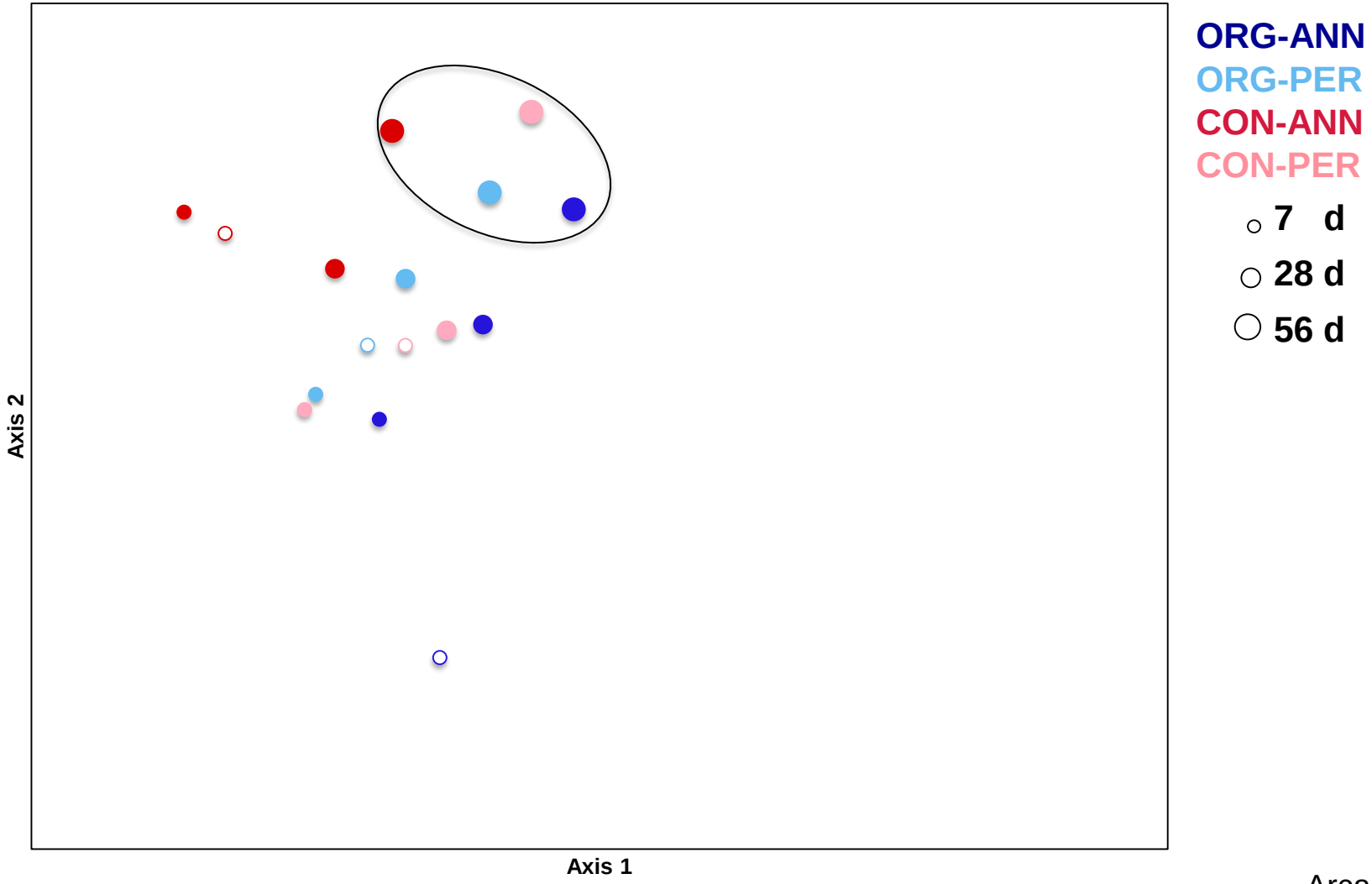


ORG-ANN
ORG-PER
CON-ANN
CON-PER

○ 7 d
○ 28 d

Arcand et al.

Long-term organic management affects residue decomposition – community structure changes



Arcand et al.

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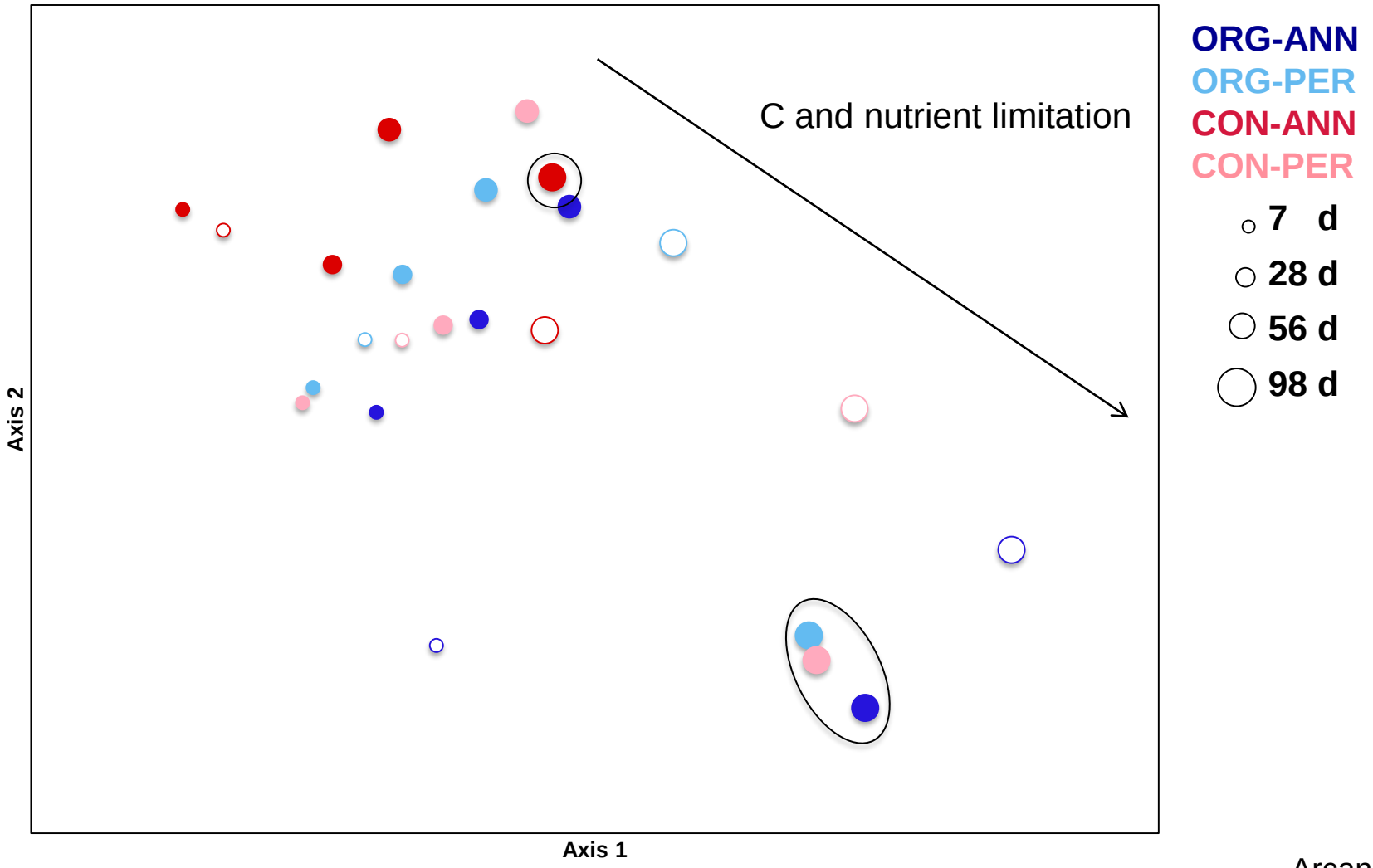


Arcand et al.

Long-term Organic vs. Conventional

how do microbes use resources?

frontiers in Microbiology

ORIGINAL RESEARCH
published: 27 November 2017
doi: 10.3389/fmicb.2017.02293

Resource Legacies of Organic and Conventional Management Differentiate Soil Microbial Carbon Use

*Melissa M. Arcand[1], David J. Levy-Booth[2] and Bobbi L. Helgason[3]**

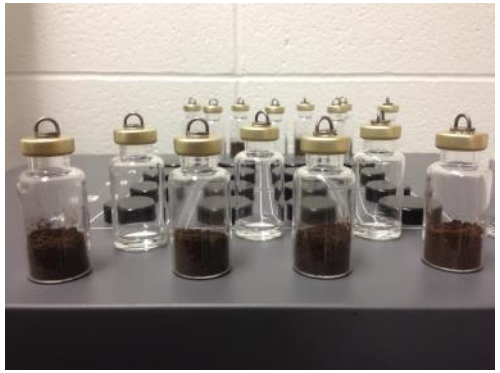
[1] Department of Soil Science, University of Saskatchewan, Saskatoon, SK, Canada, [2] Department of Microbiology and Immunology, University of British Columbia, Vancouver, BC, Canada, [3] Saskatoon Research Centre, Agriculture and Agri-Food Canada, Saskatoon, SK, Canada

Long-term Organic vs. Conventional

how do microbes use resources?

- ^{13}C-glucose added (^{13}C tracer)

- CO_2 respiration and thermodynamics measured over a 48 h period



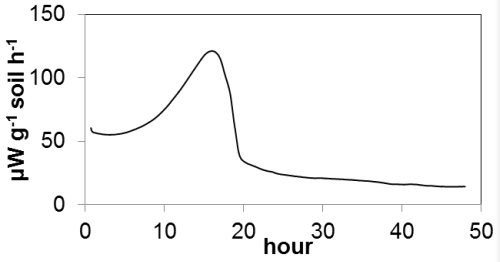
- Microbial community analysis
  - ^{13}C SIP using PLFA and DNA
  - enzyme activity

Long-term Organic vs. Conventional

Thermodynamics of carbon use: *efficiency*

Isothermal (micro)calorimetry

- Measures heat production with high precision (µW scale) to capture net outcome of catabolic and anabolic processes



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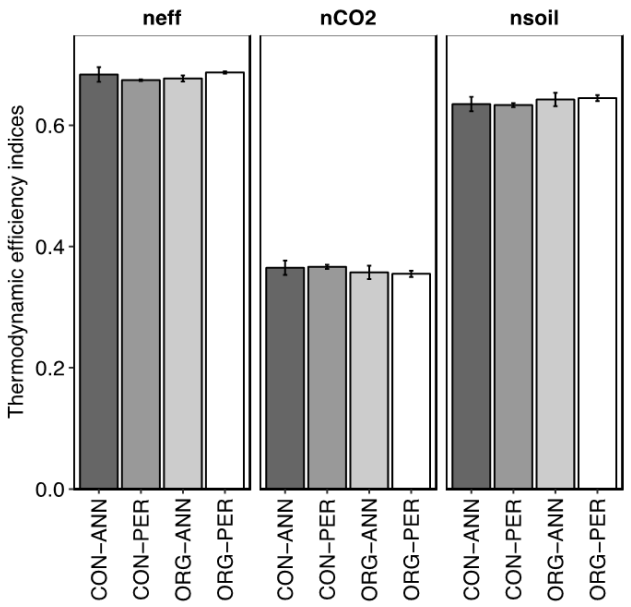
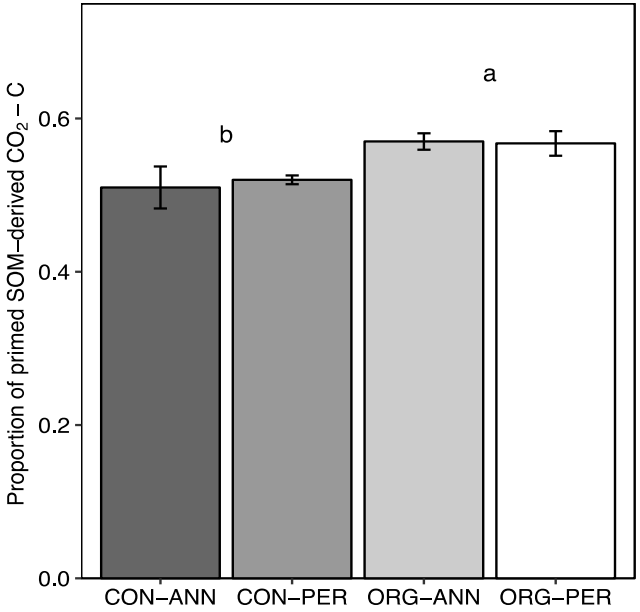
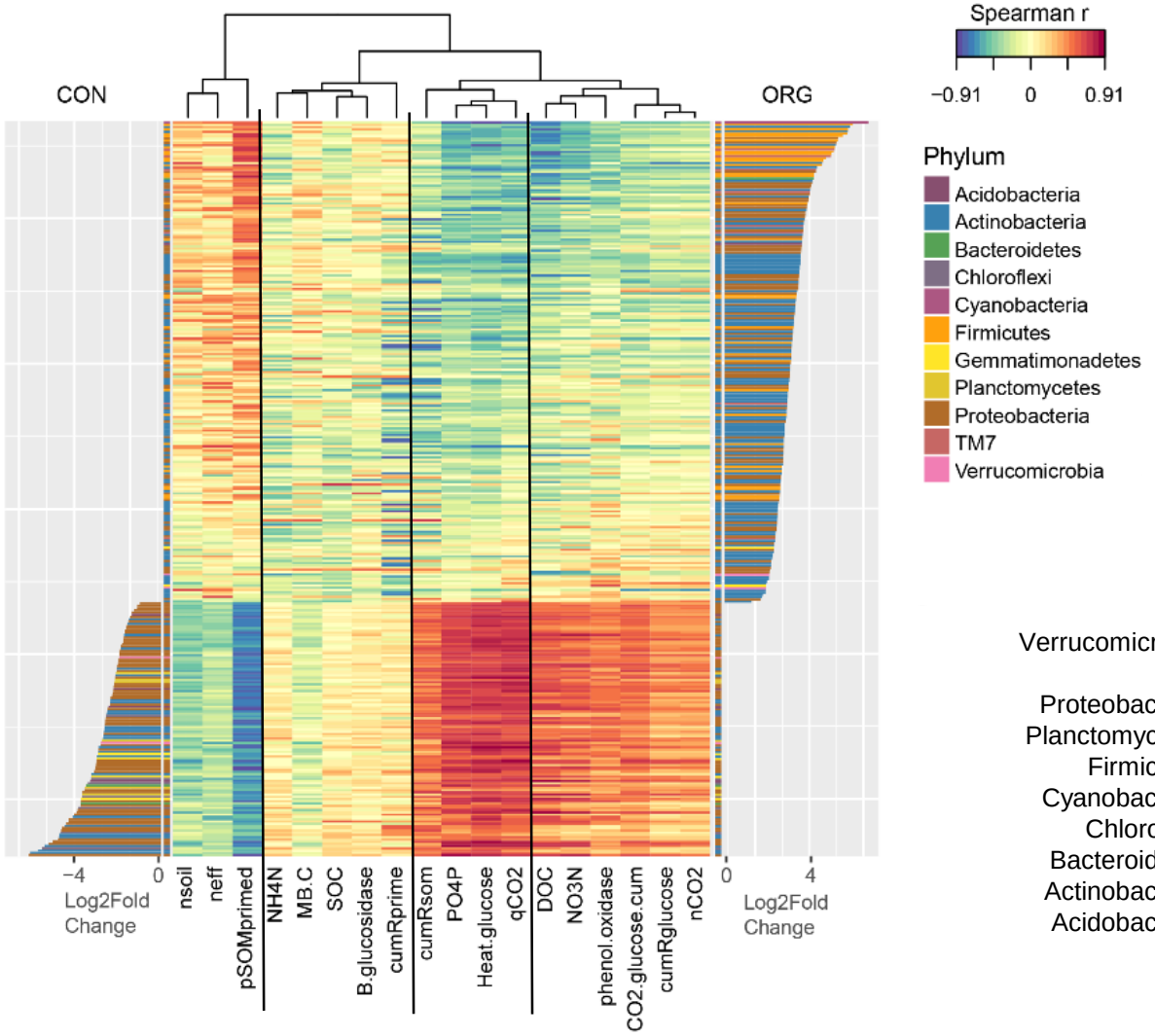


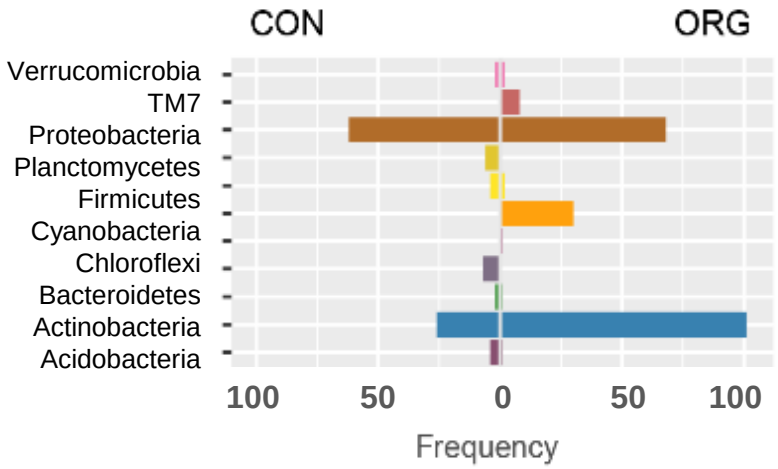


Long-term Organic vs. Conventional

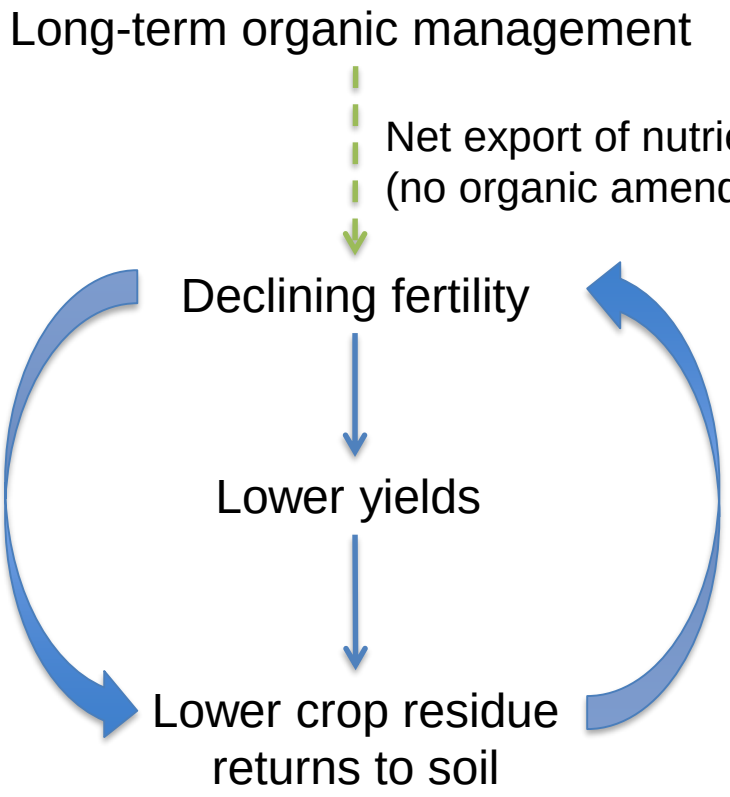
^{13}C assimilators differ in identity and function



^{13}C heavy DNA fraction ORG vs CON



Can we use compost to restore fertility?



Carbon is energy for the microbes!

Compost provides nutrients *and carbon*

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Organic amendment application
*enhanced plant-microbe interactions

Increased microbial abundance and diversity

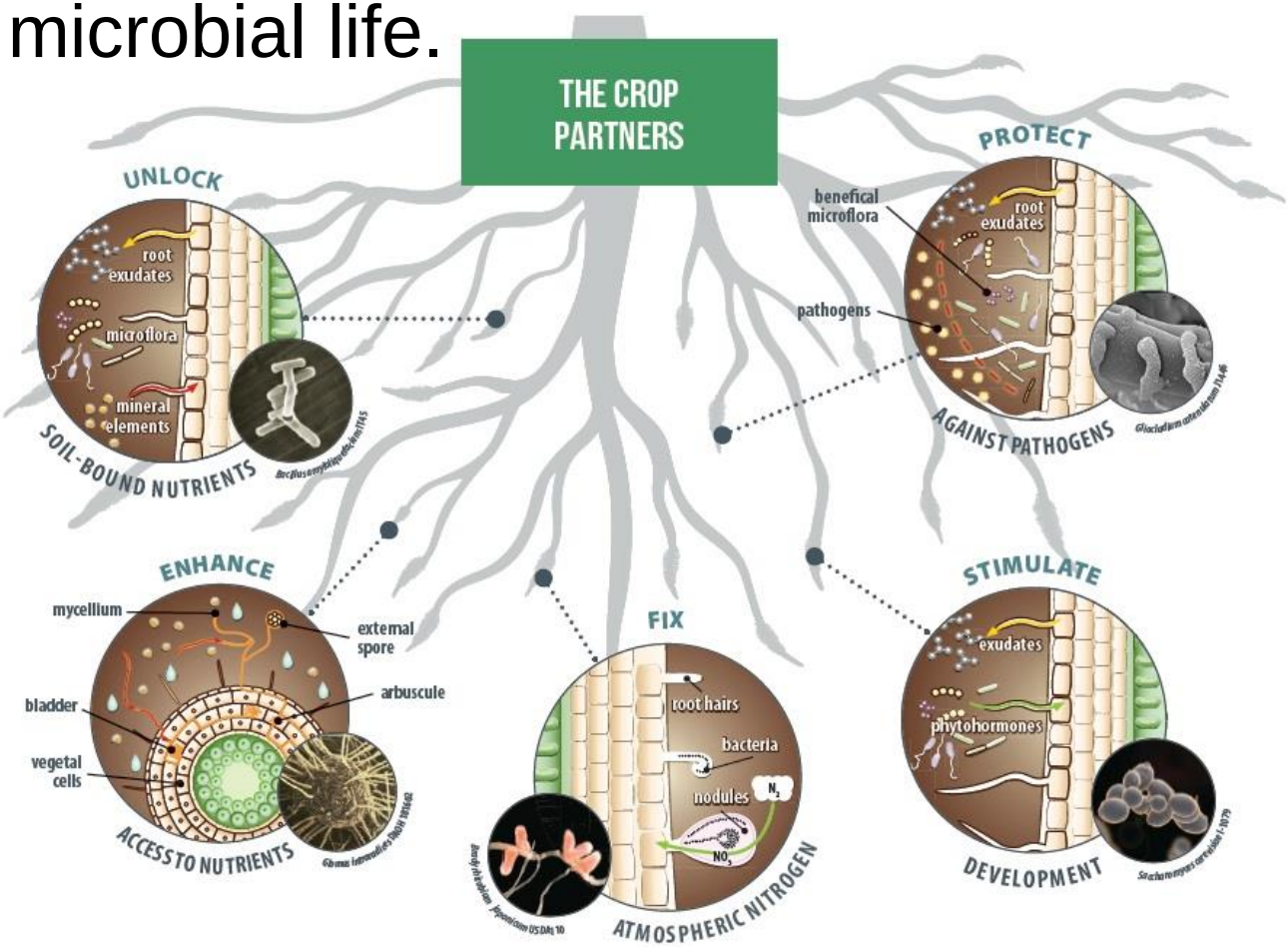
Improved soil functioning

=

healthy soil!

Root-microbe-soil interactions

Every time we plant a crop, we are putting seed into a soil teeming with microbial life.



http://www.lallemandplantcare.com/en/our-solutions/rhizosphere-inoculants/

Acknowledgements

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Agriculture et Agroalimentaire Canada

Colleagues and predecessors who envisioned and maintained AAFC's rich resource of long-term experiments.

Ed Gregorich, Henry Janzen and Ben Ellert

Melissa Arcand, Sarah Kuzmicz

UNIVERSITY OF SASKATCHEWAN
College of Agriculture and Bioresources
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AGBIO.USASK.CA

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Canada

Thank you!

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Soils and Crops 2018 Agronomy Workshop
March 7, 2018