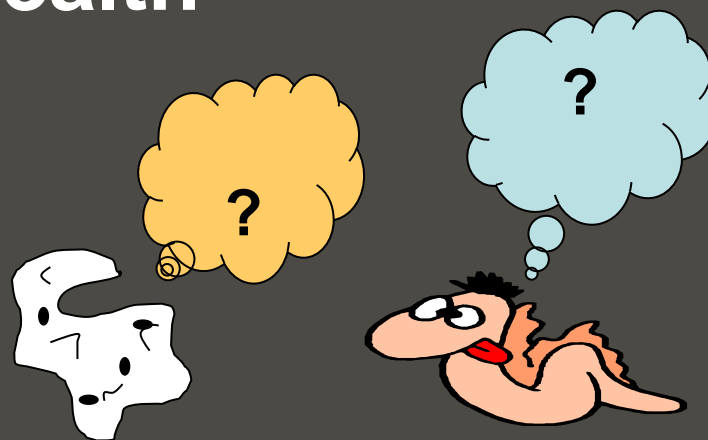


# Biological Considerations of Soil Health



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Department of Soil Science

Presentation to OMAFRA Soil Health Forum  
November 28, 2016 – Guelph, ON



UNIVERSITY  
OF MANITOBA

# Soil Quality vs. Health?

## *Soil Quality*

“Capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health” (Doran & Parkin, 1994)

## *Soil Health*

“The continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal and human health” (Doran & Safley, 1997)

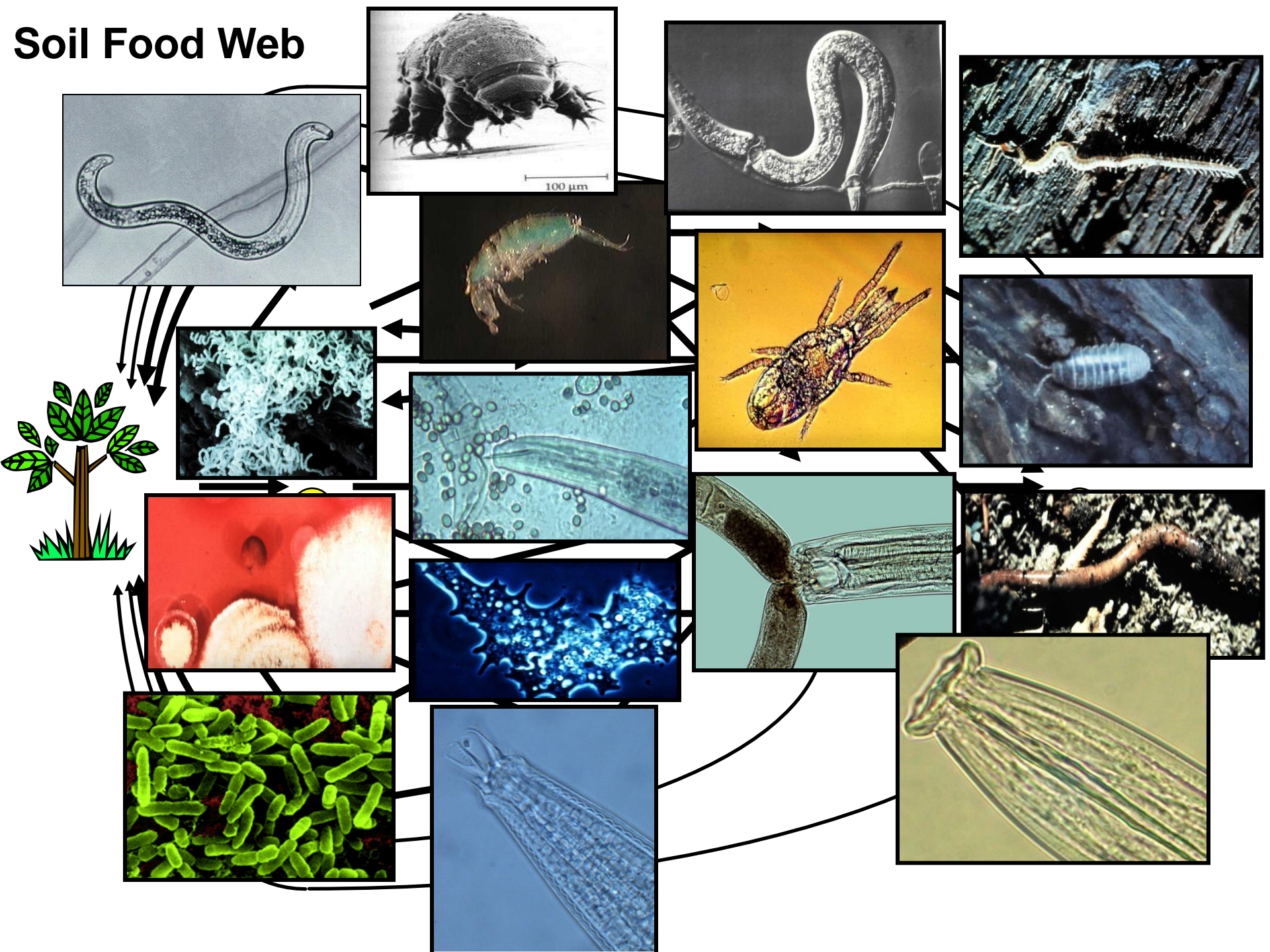
## **Reference State**

Natural system, Soil of desired characters, Benchmark in Time

# Services of Soil Health: Biological

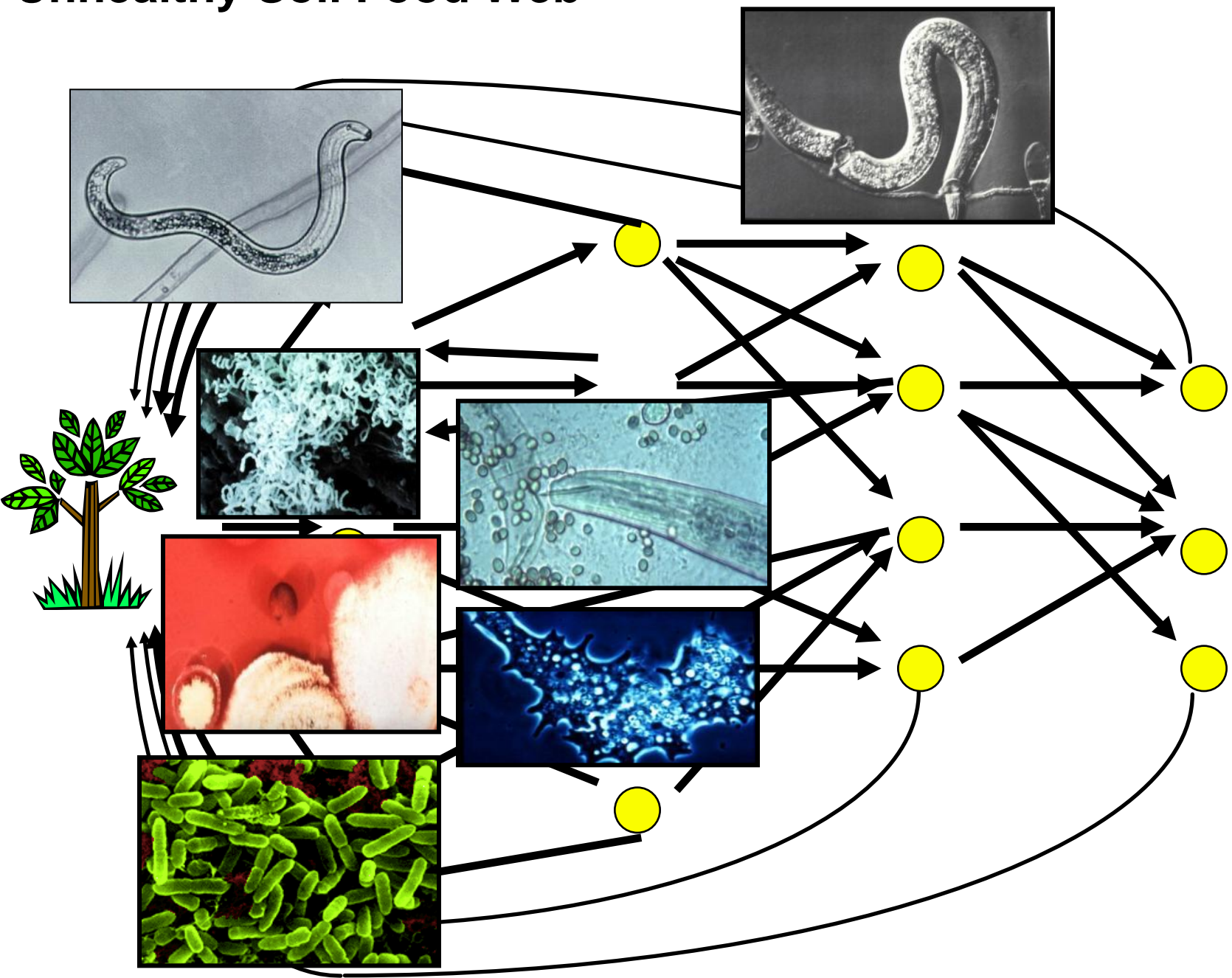
- Nutrient cycling
- Disease/Pest management
- Decomposition
- Soil Structure
- Detoxification
- Growth Promotion
- C sequestration
- Nitrous oxide consumption

# Soil Food Web





# Unhealthy Soil Food Web



# Nematode Mouth Form = Function

Plant  
Feeder

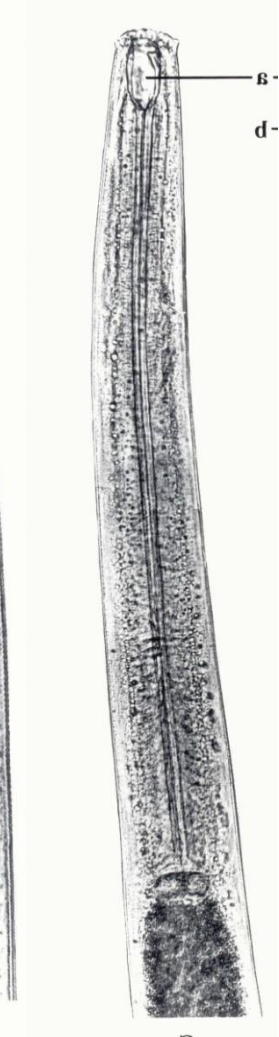
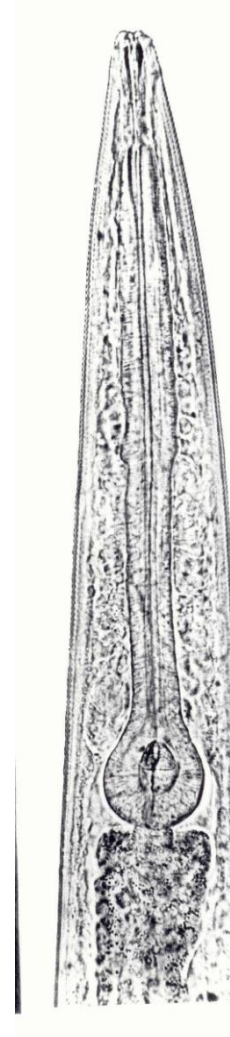
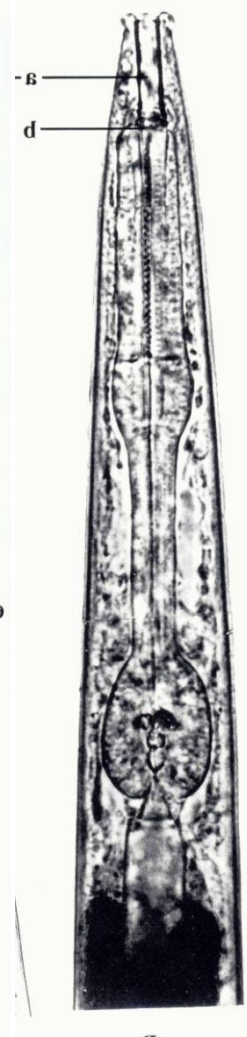
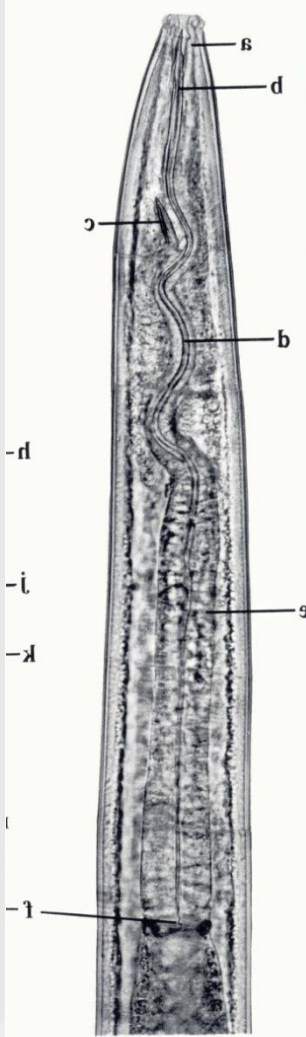
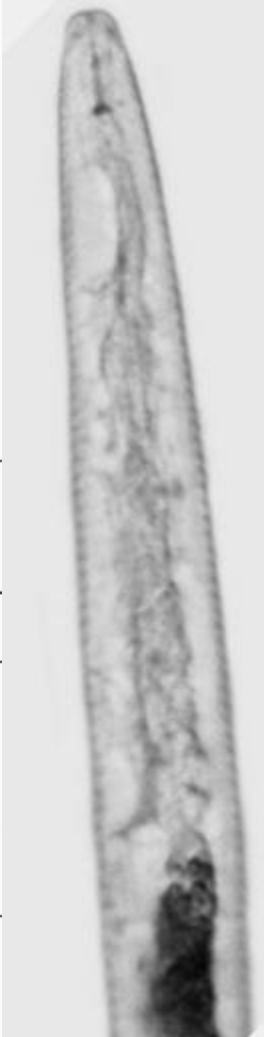
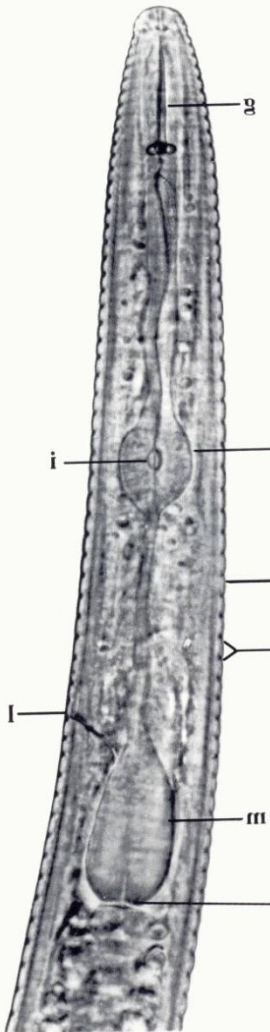
Fungal  
Feeder

Omnivore

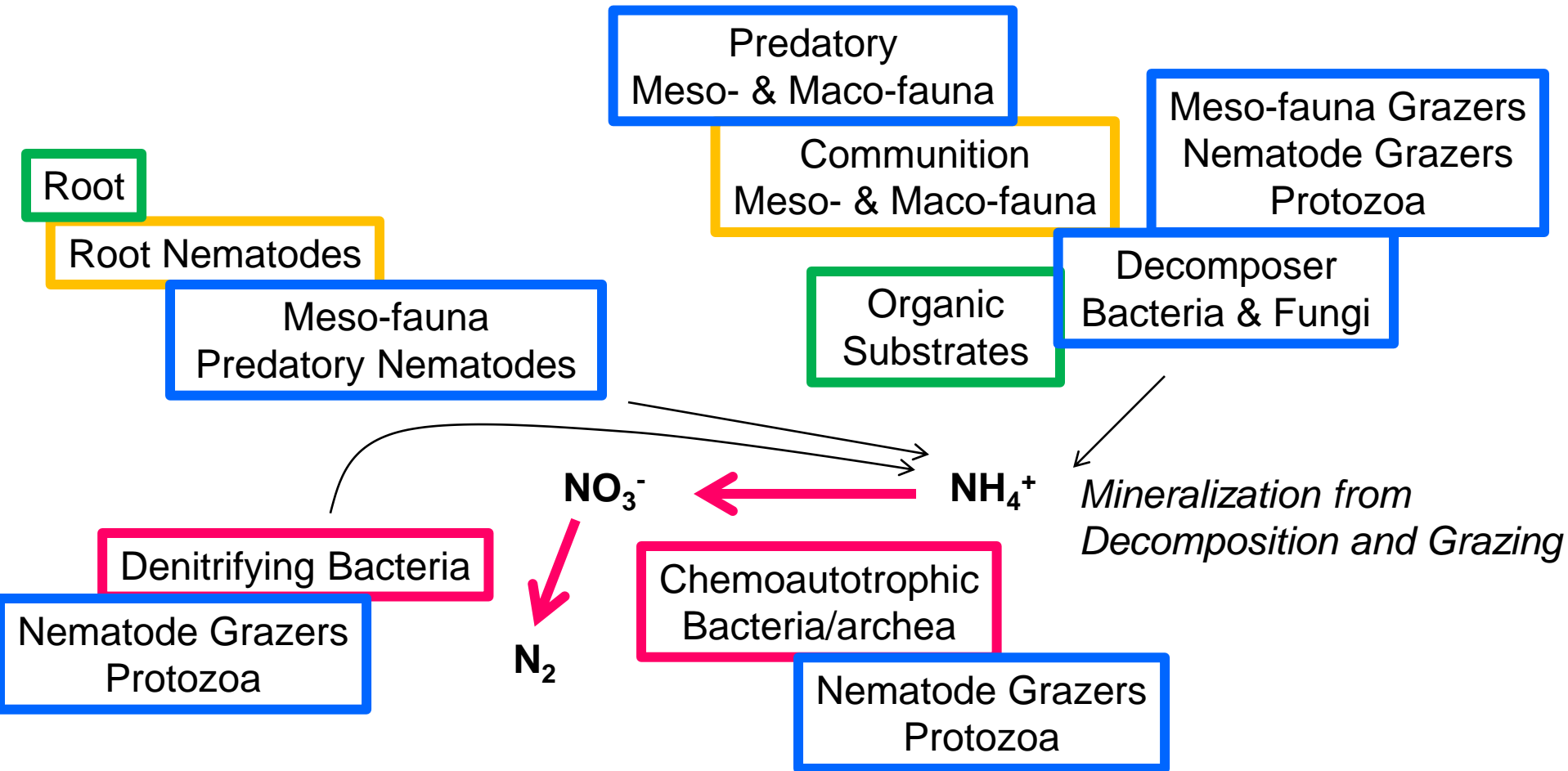
Rhabditid  
Bacterial  
Feeder

Bacterial  
Feeder

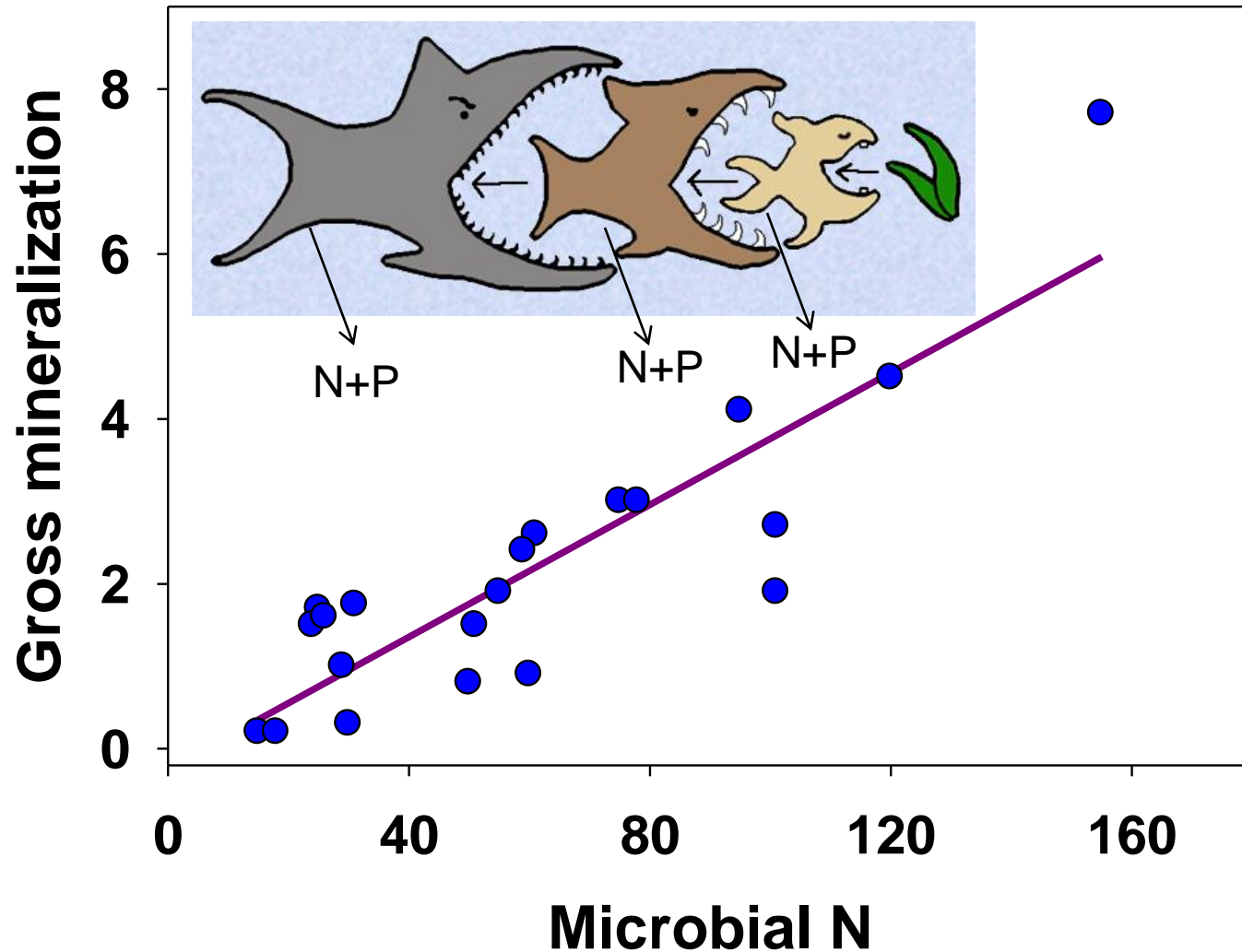
Predator



# Soil Health of Nitrogen



# Microbial Nitrogen is Released From Bacteria and Fungi to Plants



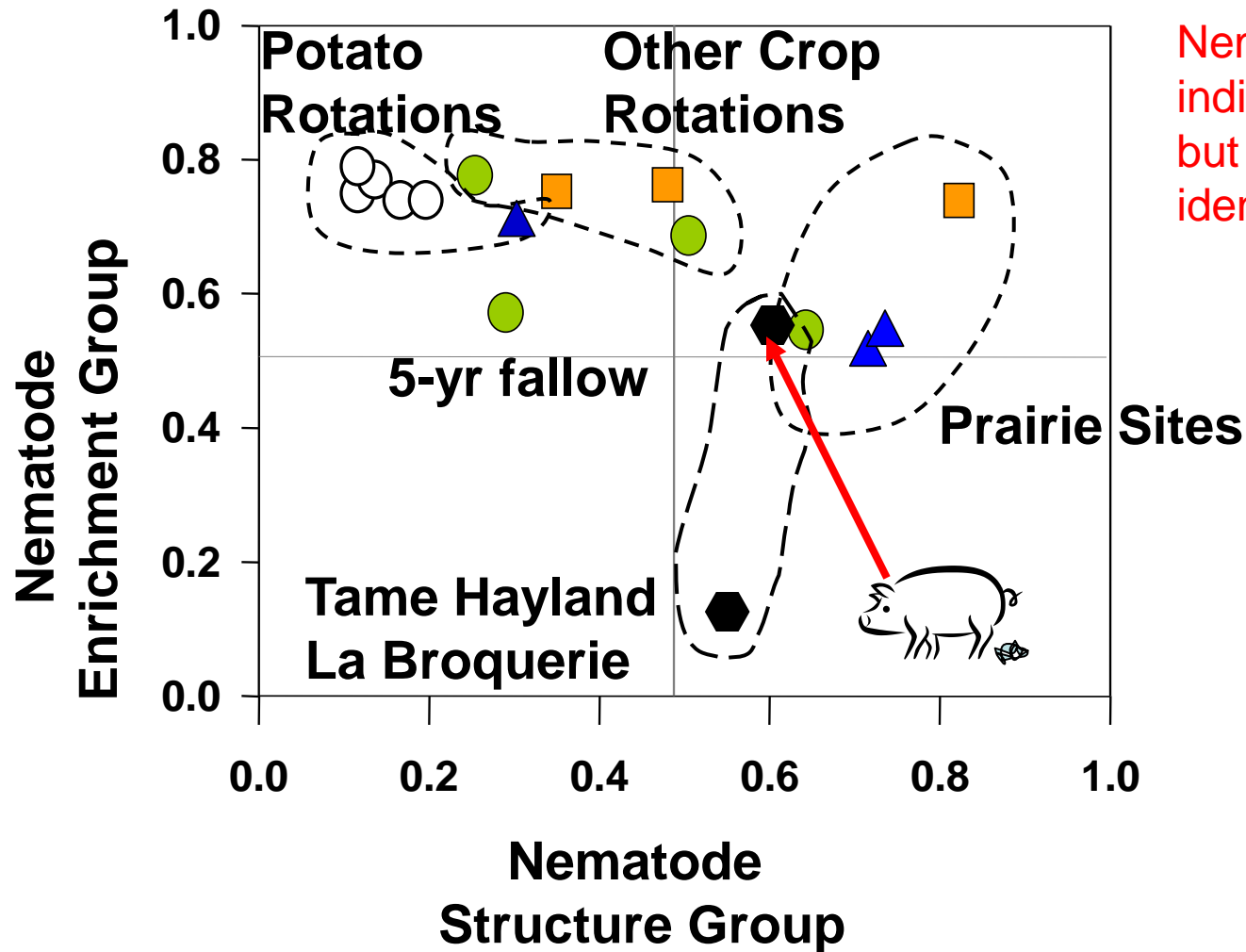
Soil organisms pooh too!



Mineralization in intact cores by N isotopic dilution  
(Murphy, Sparling, Fillery, unpublished)

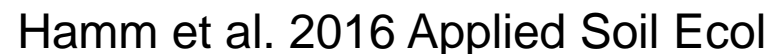


# Summary Nematode Analysis Of Manitoba Agricultural Soils

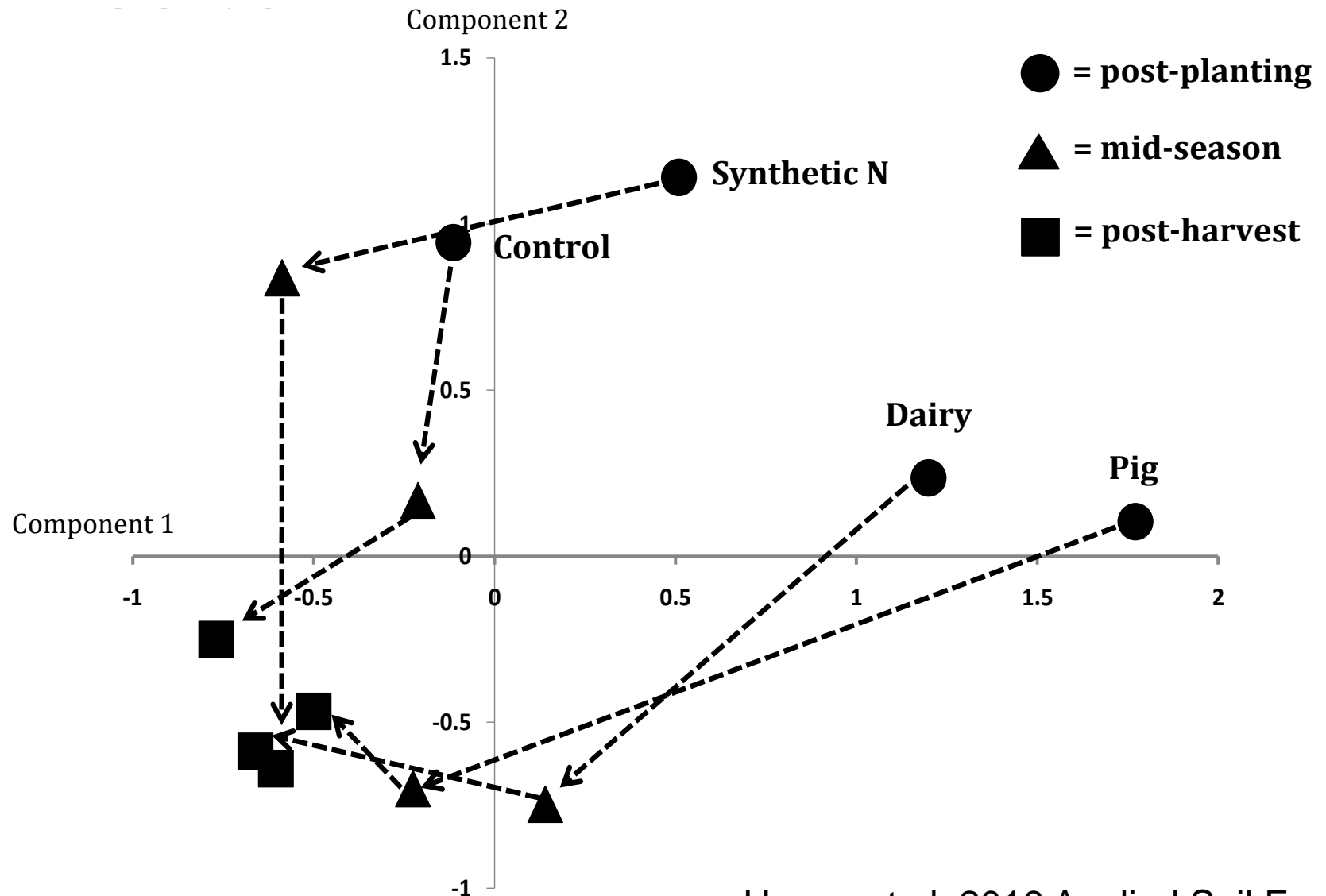


Nematodes are great indicators of healthy soil – but they need to be identified

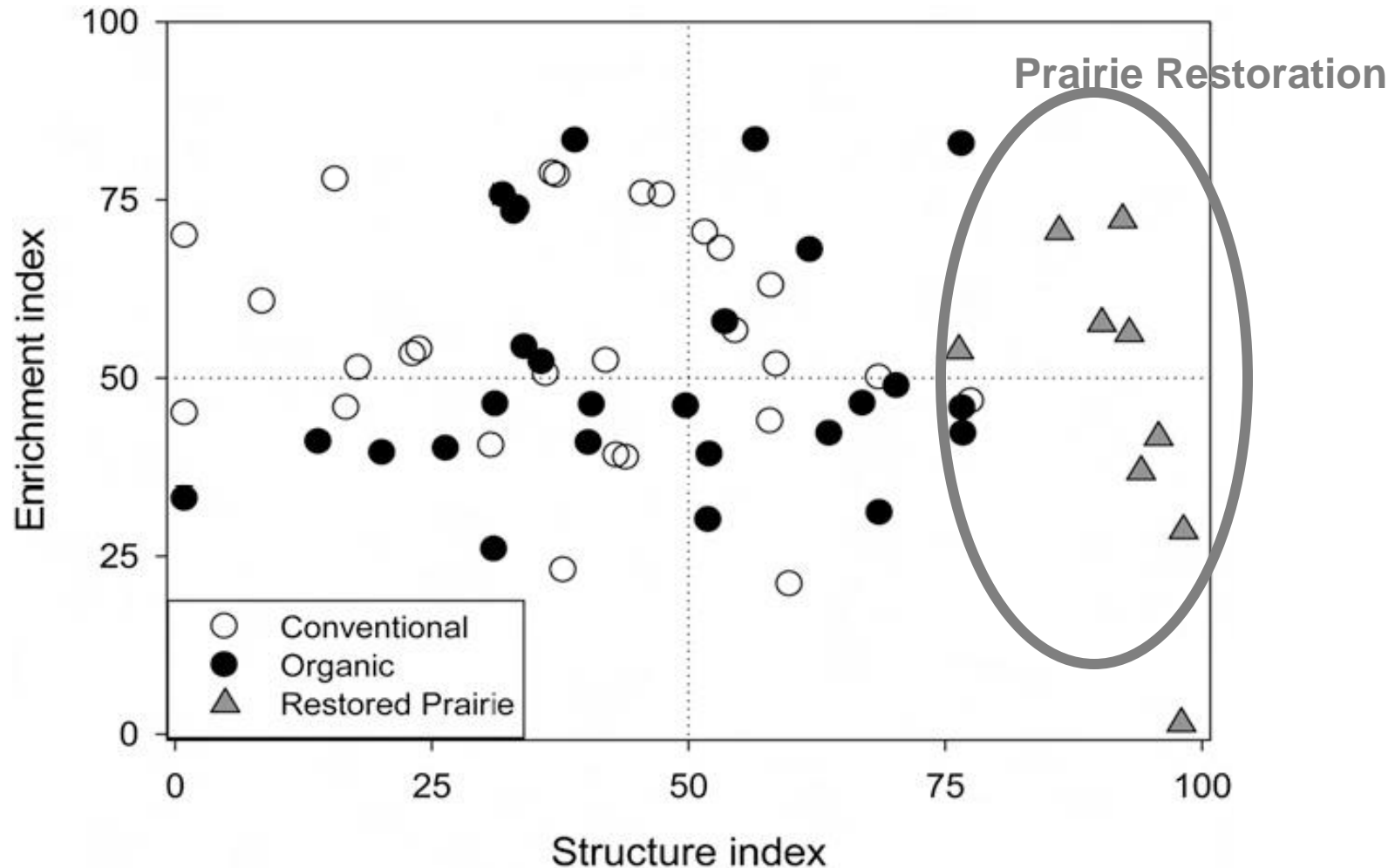
## Solid Dairy Manure



# Over a Growing Season Diversity Changes



# Nematodes Respond to Management



Comparison of nematode food web enrichment and structure conditions in conventional and organic managements, and restored prairie treatment. Data points represent enrichment and structure index scores for all three sampling times.

Briar et al. 2012, J Nematol



# Mycorrhizal Fungi After 13 Years of Organic Management

Rotation	Management	Arb Col (%)	Total Col (%)
Grain-Only	Conventional	23 (11) <sup>1</sup>	32 (14)
Grain-Only	Organic	35 (4) ←	50 (4) ←
Forage-Grain	Conventional	16 (6)	28 (15)
Forage-Grain	Organic	35 (8) ←	45 (7) ←
Forage-Grain Compost	Conventional	14 (4)	30 (8)
Forage-Grain Compost	Organic	25 (8) ←	36 (8) ←

## ANOVA tests

	Management	**	*
Management and Rotation	Rotation	n.s.	n.s.
	Interaction	n.s.	n.s.

Welsh et al. in preparation

# Impact of Perennials in Rotation on Soil Organic Matter

Rotation	Management	Organic Matter %
Grain-only	Conventional	7.2 (0.2)
Grain-only	Organic	6.7 (0.5)
Forage-grain	Conventional	7.9 (0.5)
Forage-grain	Organic	7.9 (0.8)
Forage-grain compost	Conventional	8.1 (0.1)
Forage-grain compost	Organic	8.1 (0.4)
Planted Prairie	Prairie	8.0 (0.9)

High productivity  
High root mass  
Lack of soil disturbance



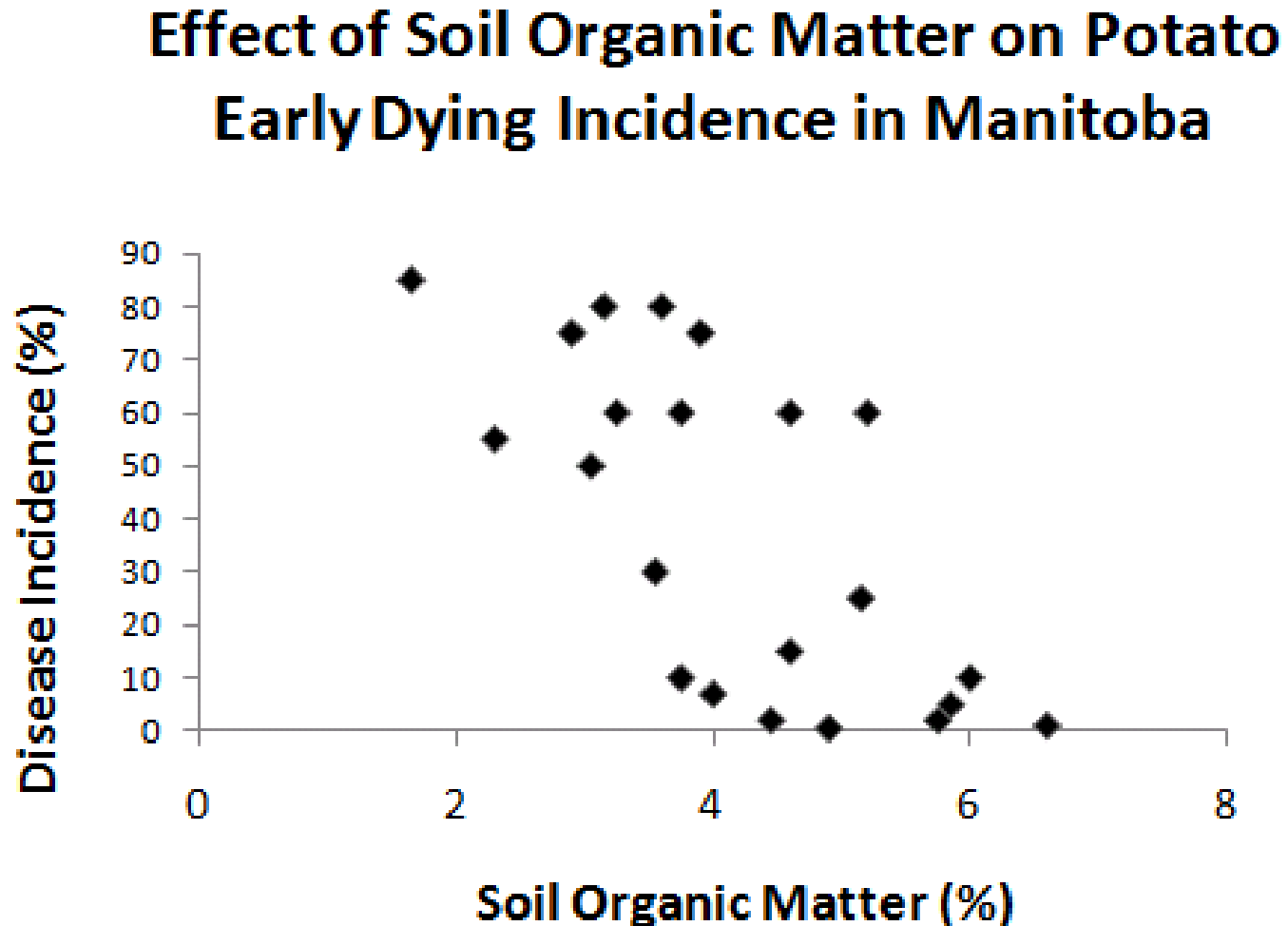
Promote soil organic  
matter buildup

# Addition of Soil Organic Matter Improves Potato Yield

Treatment	Marketable yield (metric ton ha <sup>-1</sup> ) <sup>v</sup>			
	Regular	Bonus	Overweight	Total
Wheat	11.0±0.9 <sup>w</sup>	16.1±1.1 ab <sup>y</sup>	3.7±1.3 ab	30.8±1.6b
Compost	10.5±0.9	19.5±2.1 a	8.7±1.8 a	38.7±1.3 a
Mustard meal	8.9±0.4	14.0±1.3 ab	4.3±0.6 ab	27.2±1.8b
Vapam	13.3±1.0	16.6±1.1 ab	3.2±1.0 ab	33.1±1.6ab
Oat/pea	9.5±0.8	16.9±0.8 ab	5.9±1.4 ab	32.3±1.2ab
Canada milk vetch	10.9±0.3	15.2±0.9 ab	6.0±1.4 ab	32.0±0.3ab
Sorghum-Sudangrass (2 years)	11.7±0.3	11.4±1.2 b	2.9±1.6 b	26.0±1.6b
Sorghum-Sudangrass (1 year)	11.1±1.3	14.8±1.2 ab	4.9±0.4 ab	30.8±2.3b
Fall Rye	11.0±0.9	14.5±1.6 ab	5.6±1.7 ab	31.2±2.6ab
Oriental mustard	11.7±1.4	15.5±1.5 ab	3.5±1.0 ab	30.6±1.4b
Yellow mustard	11.7±0.8	15.4±1.1 ab	5.4±0.9 ab	32.6±1.7ab
Alfalfa (2years)	10.1±0.4	15.4±0.9 ab	7.2±0.9 ab	32.6±1.2ab

# Soil Organic Matter Decreases Some Diseases

Tenuta et al. unpublished





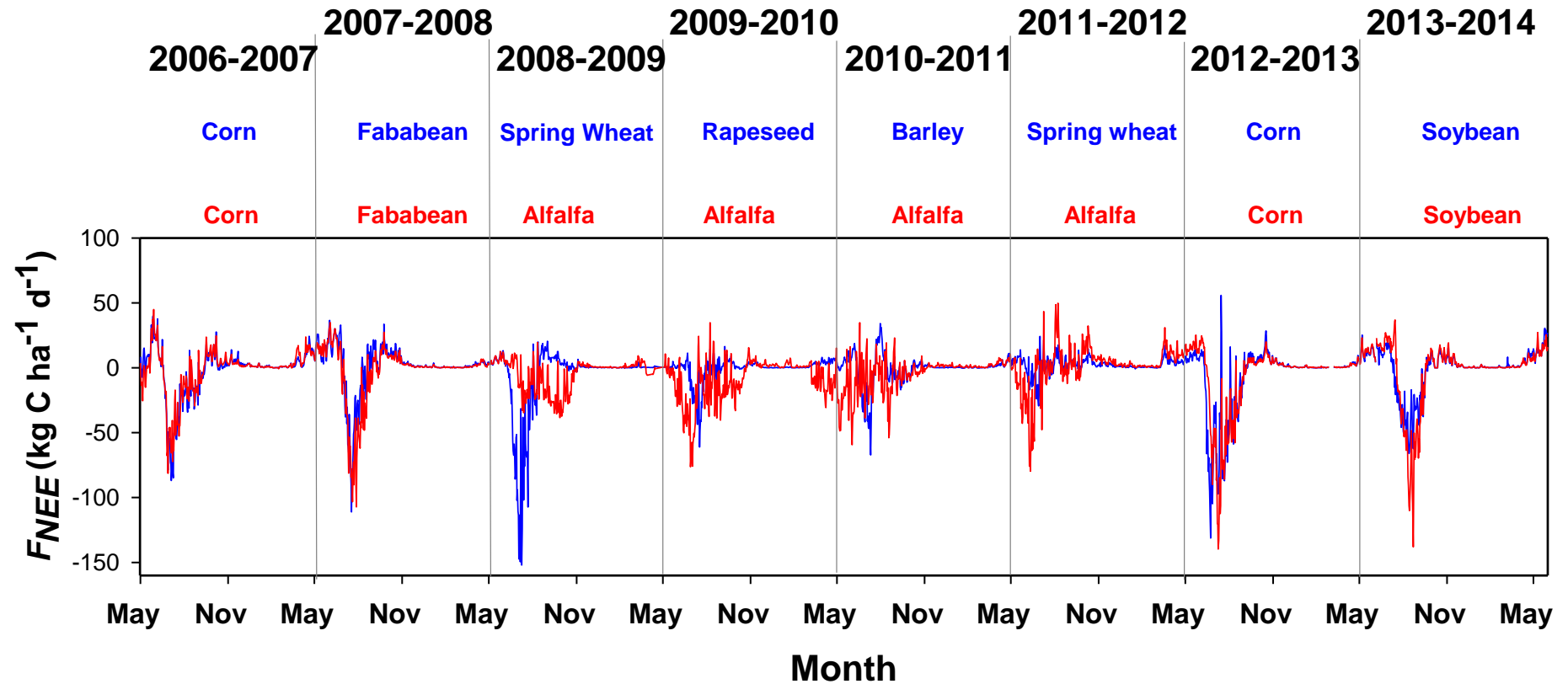
# What Does Organic Matter Do?

- Slowly available food source
- Reservoir of nutrients
- Habitable space for microorganisms
- Provides aeration
- Holds water
- Improves aggregation
- Improves root penetration
- Improve movement of meso- and macro-fauna
- C sequestration
- Buffers pH
- Warms soil
- Growth promotion substances

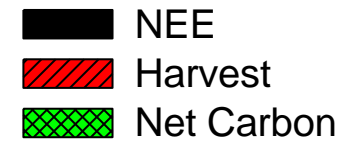
# Greenhouse Gases?

- Going to be a major driver of the “new agriculture”
- C sequestration
- N<sub>2</sub>O emissions
- Soil health concept will grow to encompass these (partly political driven)

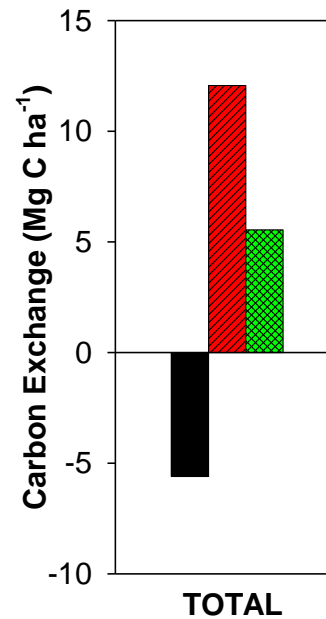
# Net Daily CO<sub>2</sub> Emissions at TGAS-MAN Site



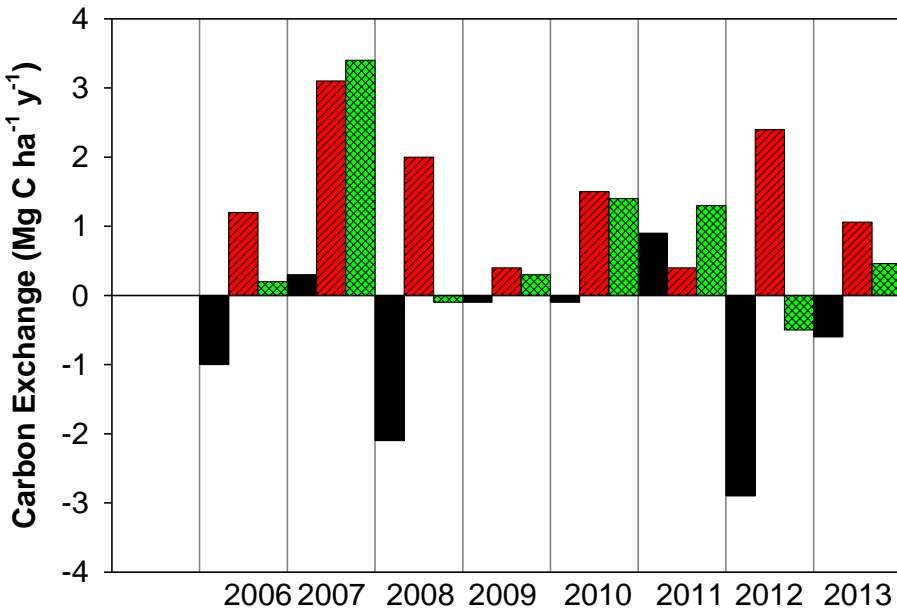
# C Budget (Mg ha<sup>-1</sup>)



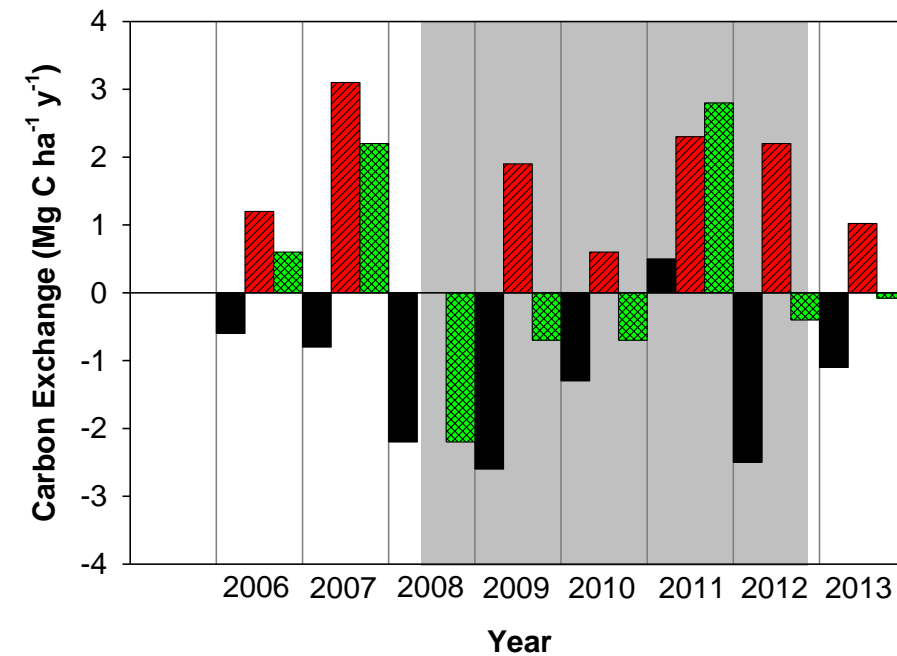
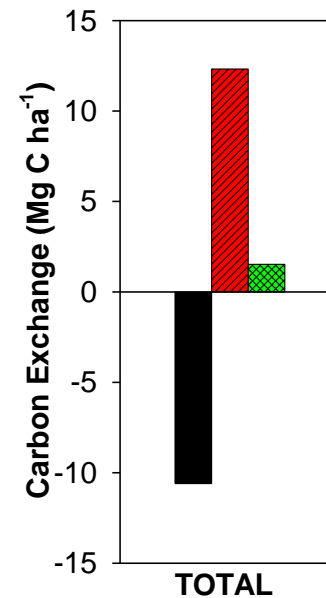
**Continuous  
Annual**



*115.2 Mg C ha<sup>-1</sup> to 30 cm  
4% organic carbon drop of  
Amount at start of study!*

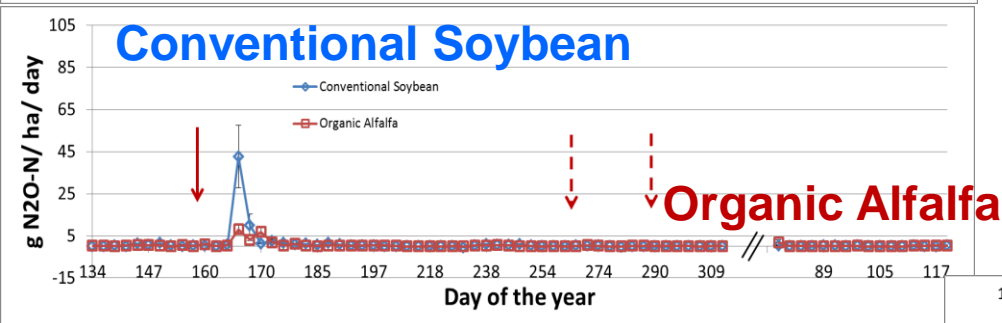
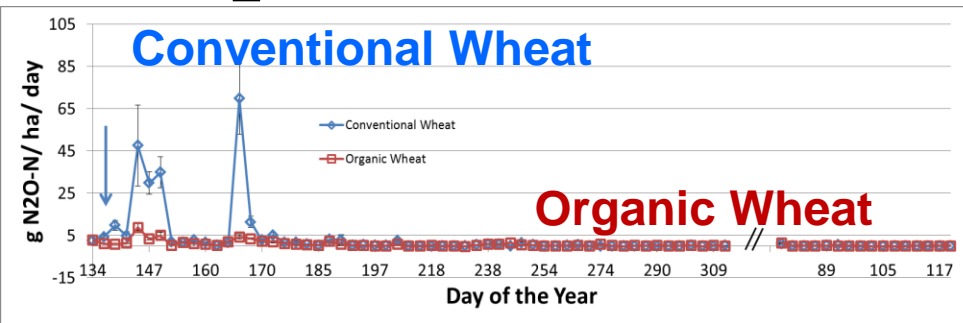


**Annual Perennial**





# N<sub>2</sub>O Emissions Conventional and Organic

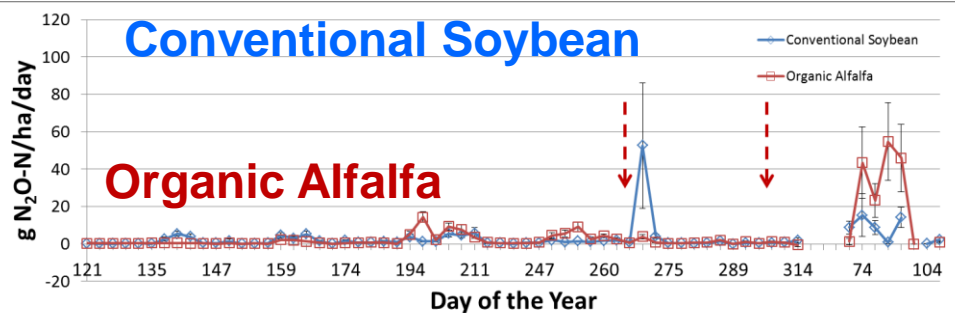
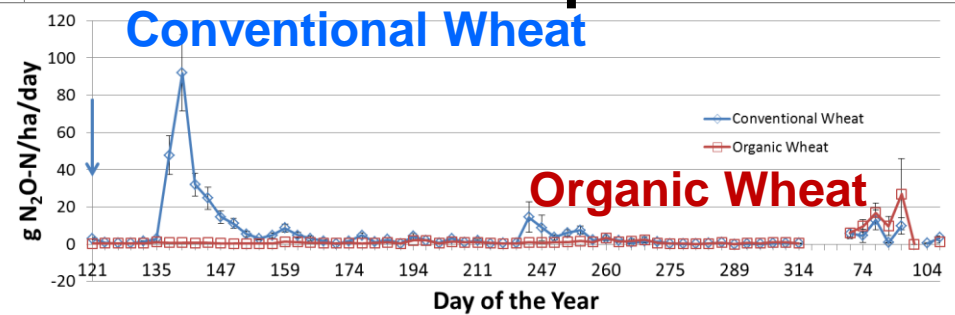


**2014 Crop Year**

*Little N<sub>2</sub>O emissions with legume crops*

*Overall lower N<sub>2</sub>O emission with organic production*

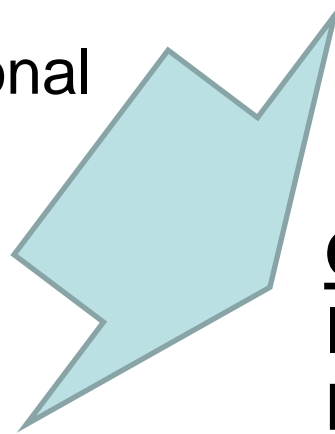
**2015 Crop Year**



# Management and Impact to Soil Biological Health

## **Management Impacts**

Trophic Structure  
Taxonomic and Functional  
Diversity  
Activity



## **Outcomes**

Redundancy  
Functioning  
Services including yield  
Resilience  
Improved input efficiency

# What Can You Do to Improve Soil Health?

- Steadily introduce C (perennials, covers, double cropping, animal manures)
- Limit tillage
- Limit broad spectrum biocides
- Limit compaction
- Insure good fertility
- Introduce biological fixed N
- Decrease disease/pest pressure
- Good cultural practices to limit weeds
- Diversified rotation

