



UNIVERSITY OF SASKATCHEWAN
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and Bioresources
DEPARTMENT OF SOIL SCIENCE
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Soil microorganisms

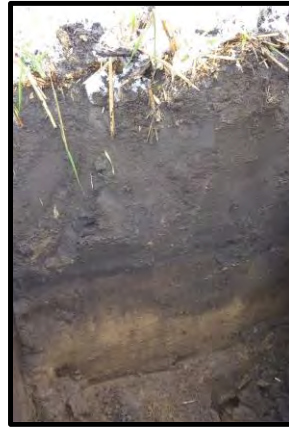
Working with the invisible warriors that bolster agroecosystem resilience



Bobbi Helgason, Ph.D.

Pathways to Sustainability Seminar
April 8, 2025

What is soil health?



“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)

USDA, 2016



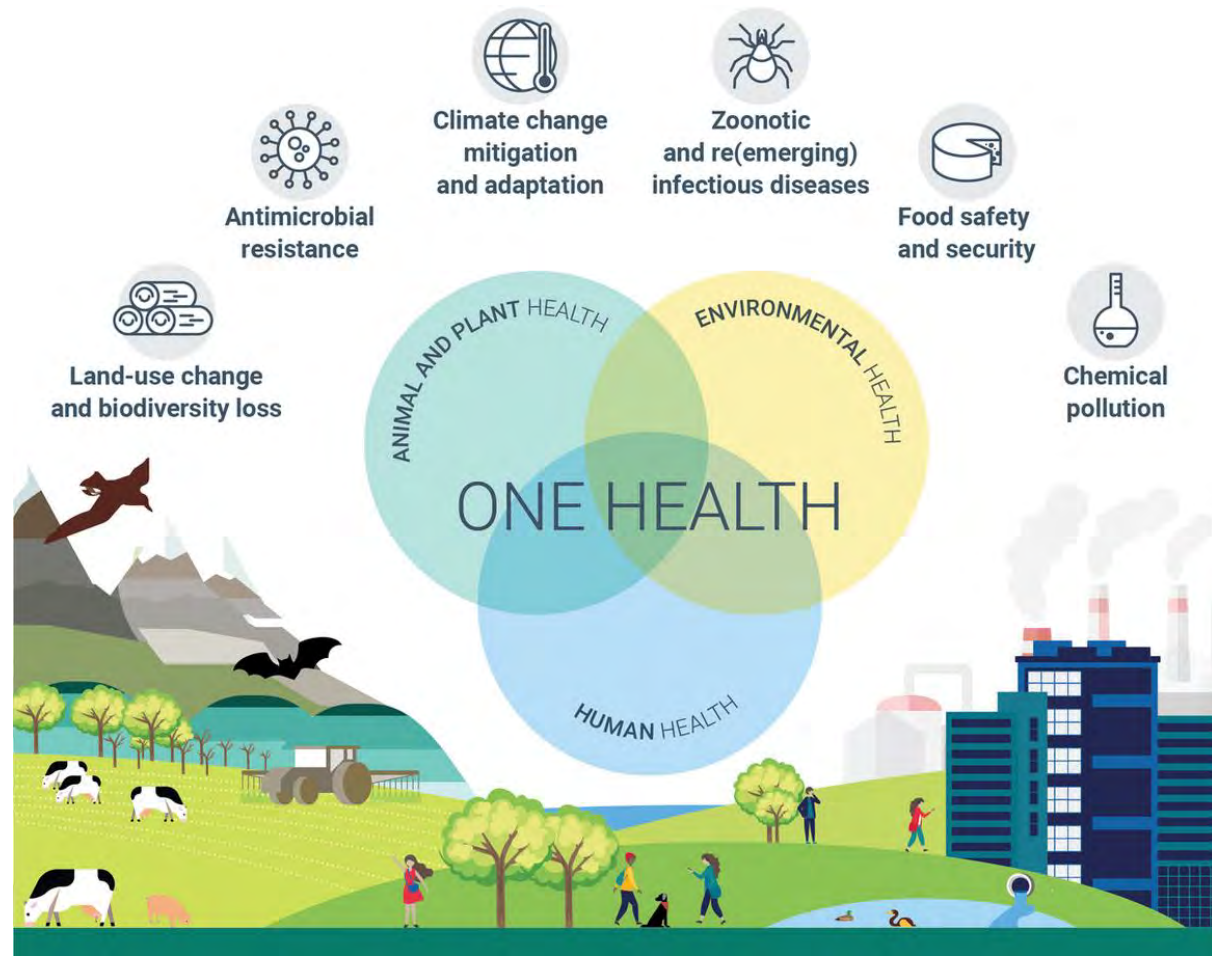
Soil biota provide critical ecosystem services

- **Decomposition & cycling of organic matter**
- **Soil carbon storage and gas exchange**
- **Regulation of nutrient availability**
- **Suppression of pests & disease**
- **Soil detoxification**
- **Plant growth control**



One Health

Human health is inextricably and interdependently linked to broader ecosystem health (e.g., animal and environmental health)



<https://www.ecdc.europa.eu/en/one-health>

Soil biota provide critical ecosystem services



➤ Dairy cattle consume up to 350 kg (!) of soil per year

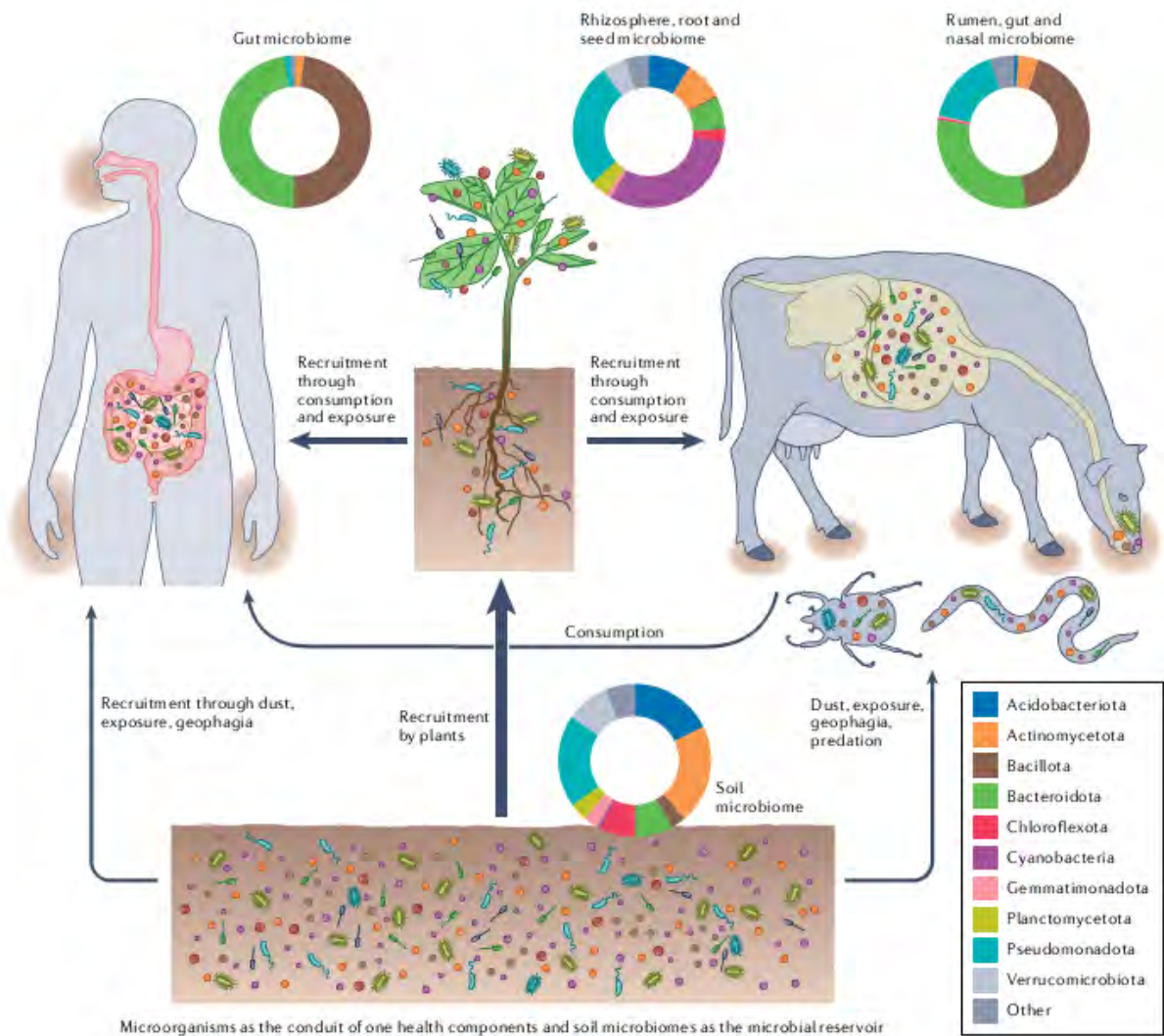
Banerjee and van der Heidjen 2023 Nature Reviews
<https://doi.org/10.1038/s41579-022-00779-w>



Photo source: Dairy Farmers of Canada
<https://dairyfarmersofcanada.ca/en/dairy-in-canada/dairy-excellence/canadian-dairy-cow-diet>

**Soil is a
reservoir that
inoculates
other higher
organisms**



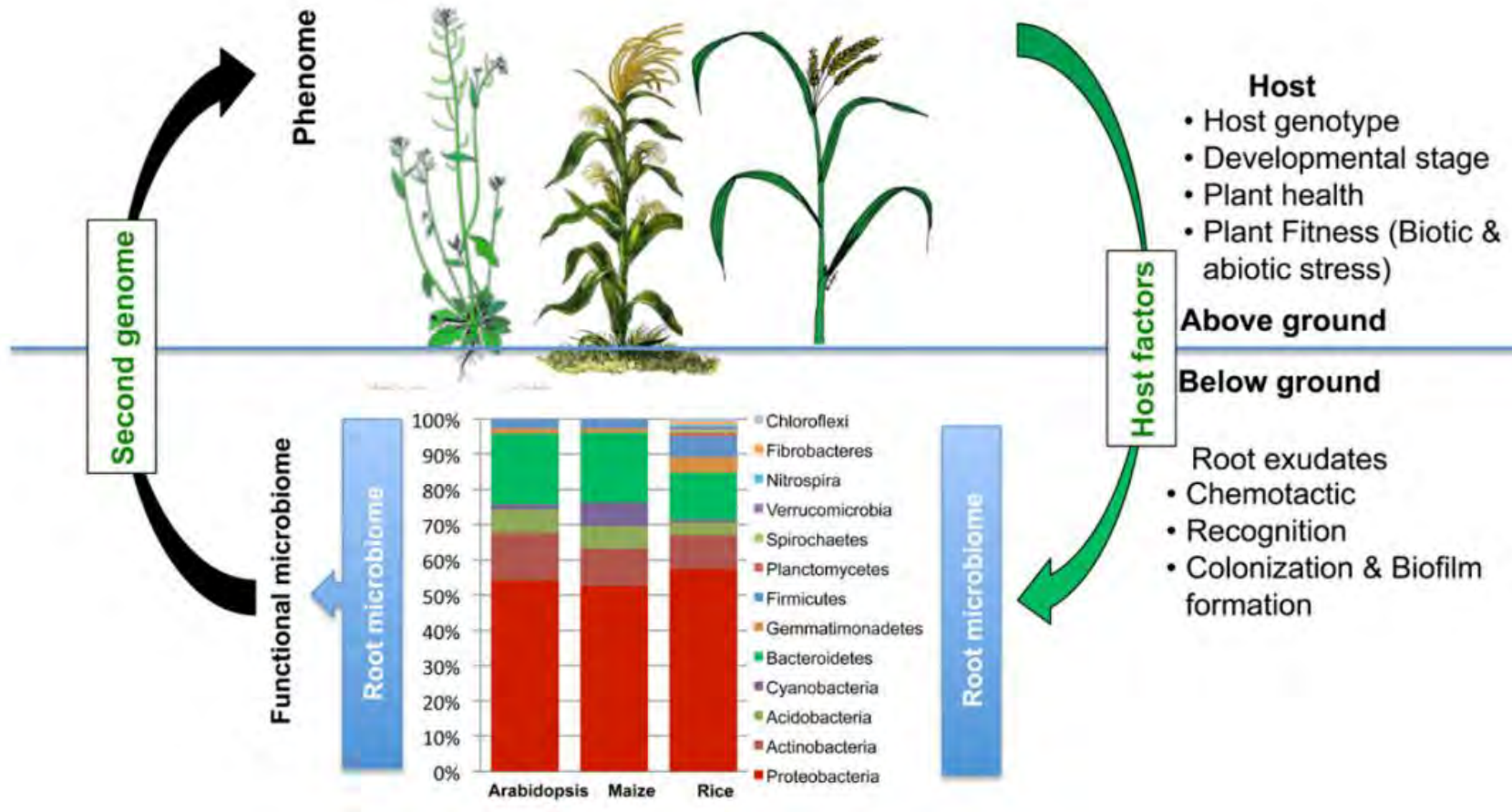


Soil is a reservoir that inoculates other higher organisms



Banerjee and van der Heidjen 2023
Soil microbiomes and One Health
Nature Reviews

<https://doi.org/10.1038/s41579-022-00779-w>



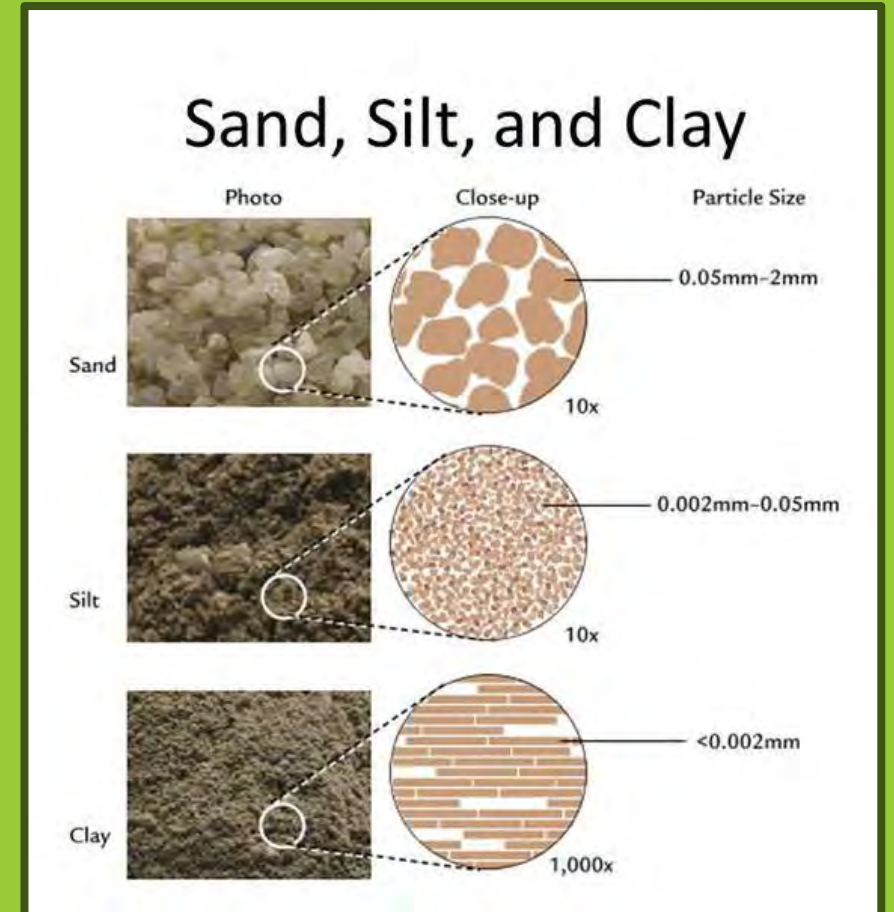
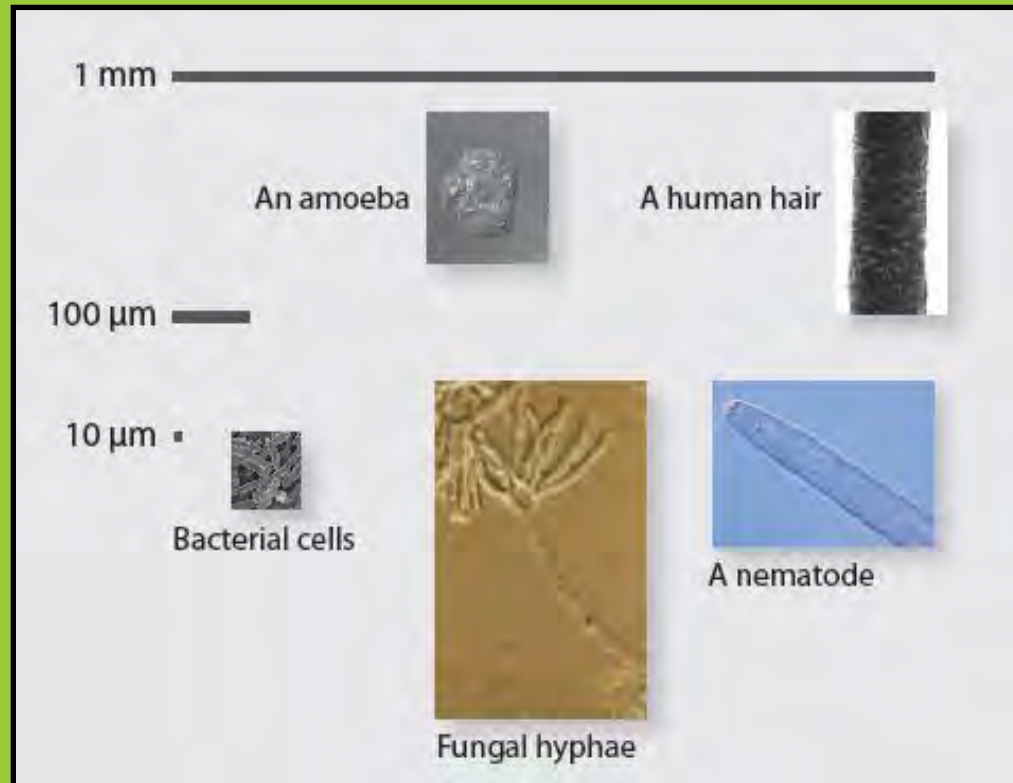
Soil is teeming with life

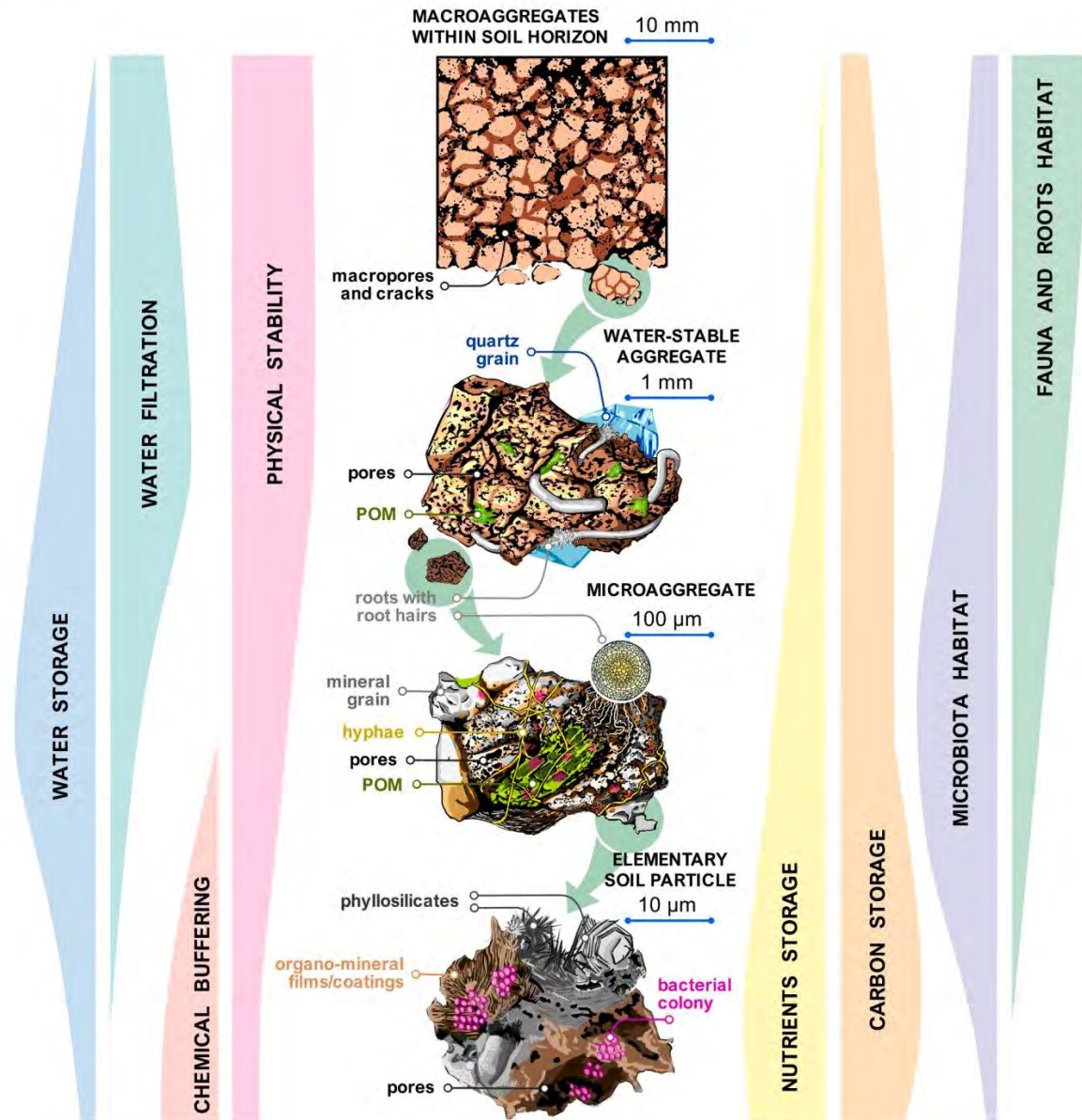
Lakshmanan et al. 2014. Functional soil microbiome: belowground solutions to an aboveground problem. Plant Physiol 166:689-700.



Microbes: how small are they?

Where do they live?

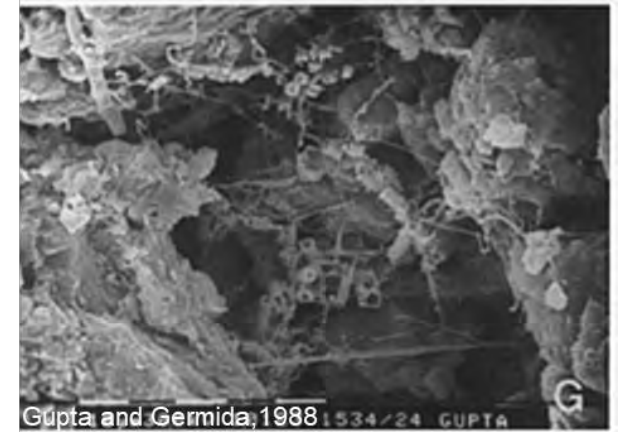




Soil: a microbial habitat



Soil: a microbial habitat



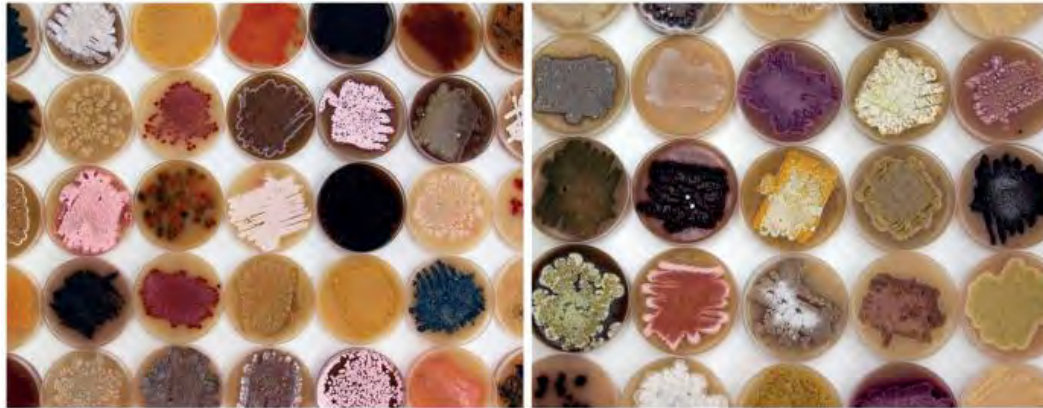
Soil: a microbial habitat

- soil is comprised of solid, liquid and gaseous phases
- competition exists among an enormous variety of organisms (including plants!) for nutrients, space and moisture



<https://www.llnl.gov/news/researchers-dish-dirt-soil-microbes>
<https://www.victorleshyk.com/>





⚡ Different species of Actinobacteria can be identified by growing them on artificial substrates made with jelly-like substances and nutrients such as oatmeal (see pages 64-65). Different colours and shapes allow the distinction of different species. (PT/FIIRV)

Source: Global Atlas of Soil Biodiversity

Soil harbors incredible microbial abundance & diversity

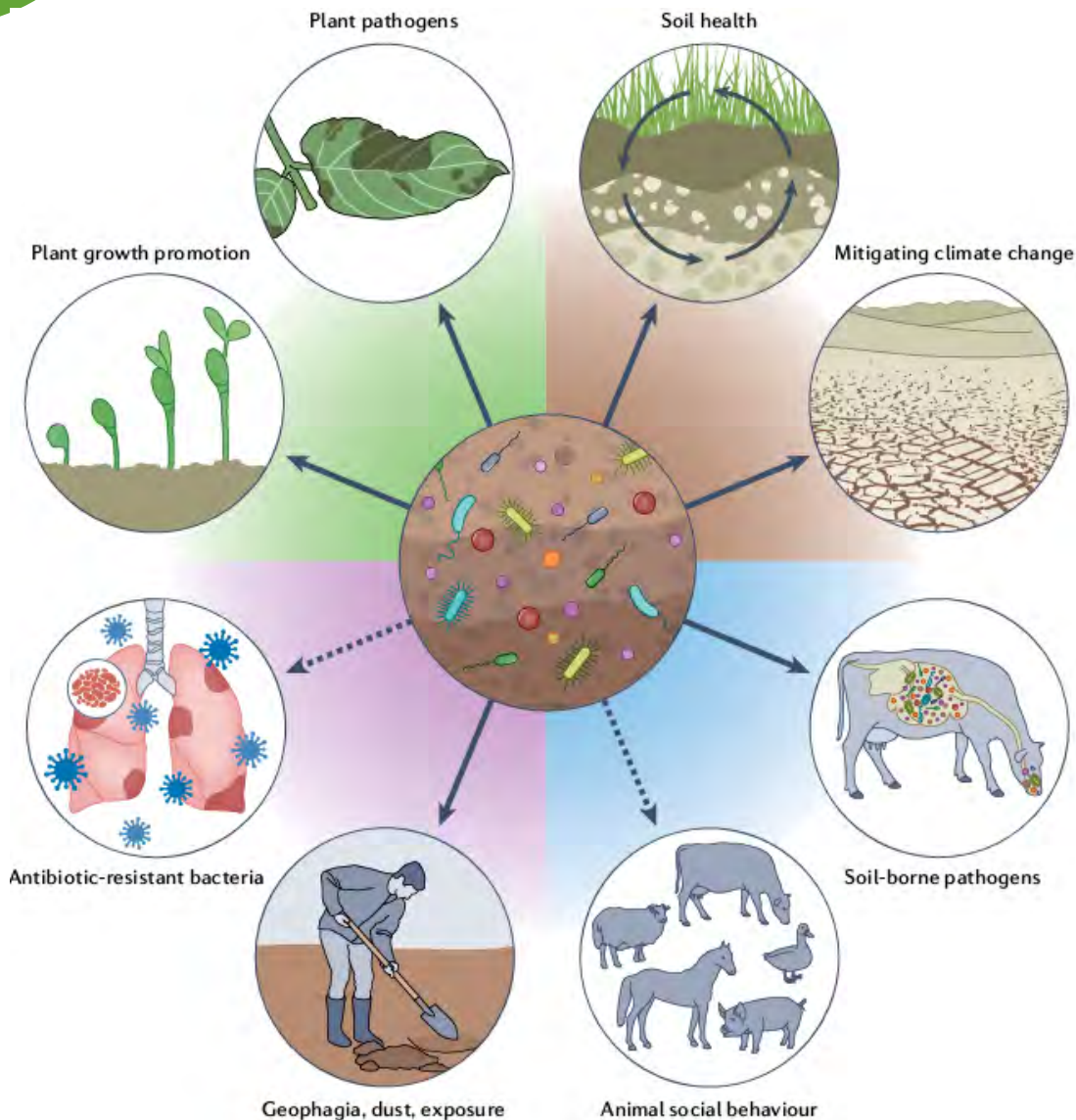
Mass
(Gt C = 10^{15} g C)

Fungi	12
Bacteria	7
Protists	1.5
Arthropods	0.2
Annelids	0.2
Nematodes	0.01

Source: Encyclopedia of Soil

[https://www.encyclopedie-environnement.org/en/zoom/soil-biomass/#:~:text=Of%20the%20%E2%89%88%20Gt,Gt%20C\)%%20%5B4%5D.](https://www.encyclopedie-environnement.org/en/zoom/soil-biomass/#:~:text=Of%20the%20%E2%89%88%20Gt,Gt%20C)%%20%5B4%5D.)



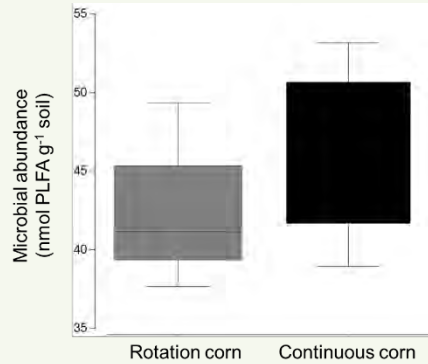


Soil Health and One Health

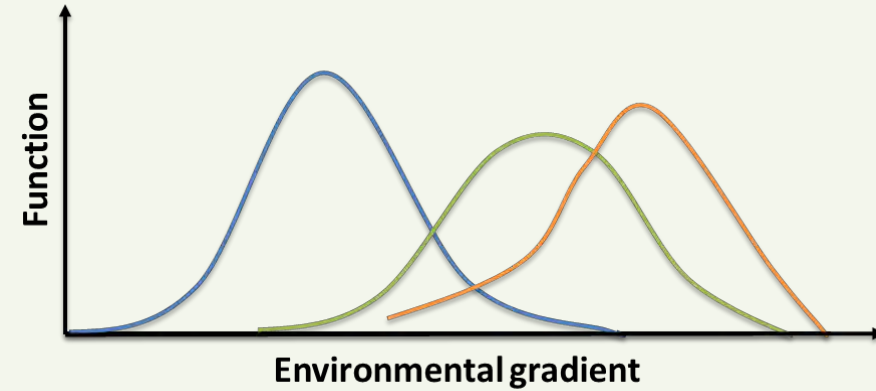


Working with the invisible warriors

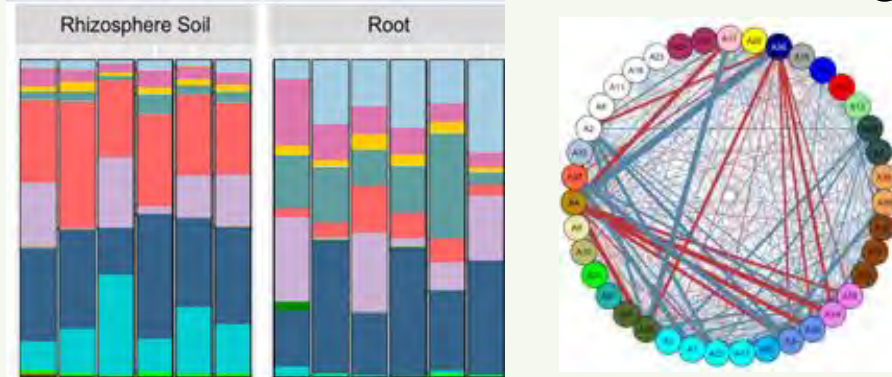
Microbial Abundance = capacity



Microbial diversity = insurance



Microbial Composition = ecology



Cropping system management practice

*Continuous cropping

Reduced physical disturbance

Diverse cropping rotations

Balanced nutrient management

Organic amendment application

Cover cropping

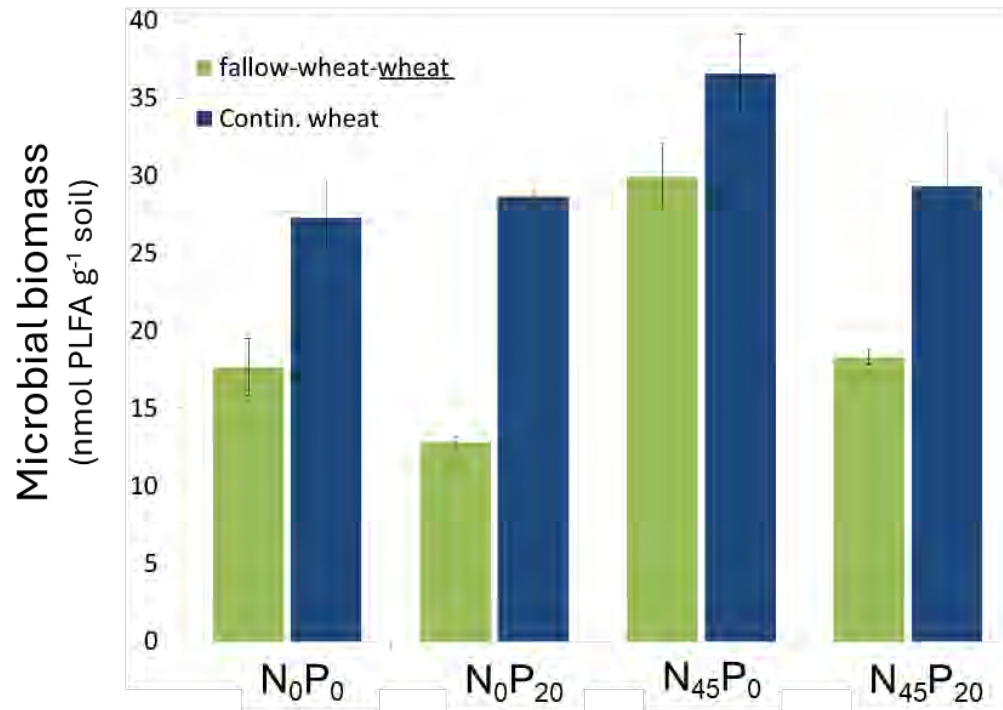
Use of inoculants

Soil is a reservoir that inoculates other higher organisms



AAFC Lethbridge Historical Rotation Plots

22 -123% increase (p<0.05)



1967: 45 kg ha⁻¹ N
1972: 20 kg ha⁻¹ P

Management to support soil microorganisms



Continuous Cropping



Cropping system management practice

Continuous cropping

***Reduced physical disturbance**

Diverse cropping rotations

Balanced nutrient management

Organic amendment application

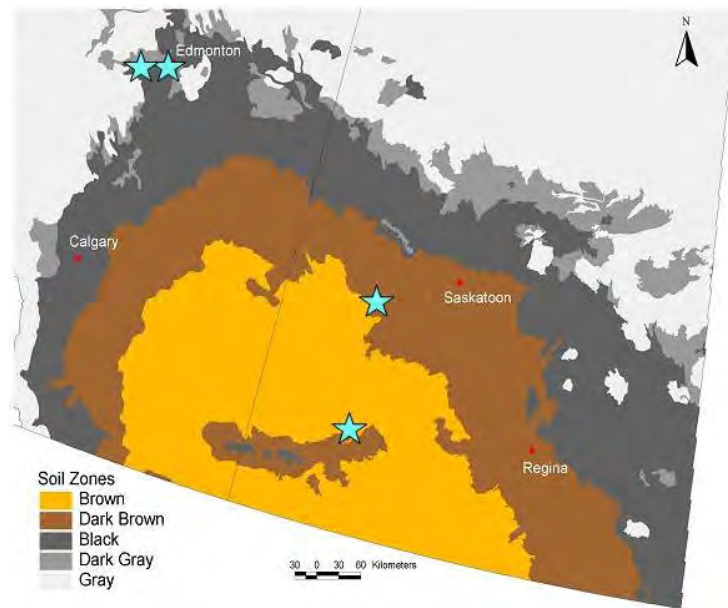
Cover cropping

Use of inoculants

Soil is a reservoir that inoculates other higher organisms



Reduced physical disturbance



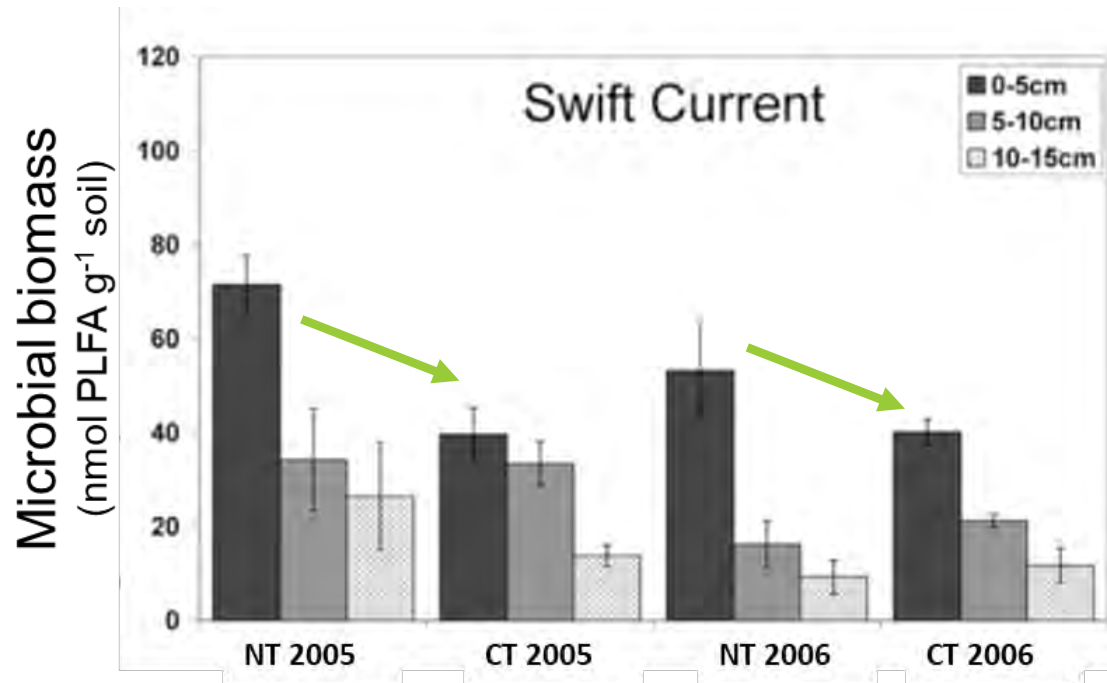
NT vs CT
Long term sites (~25yr)
4 locations
2 years



Breton, AB
Spring, pre-seeding



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



Helgason et al. 2009 SSSAJ

Management to support soil microorganisms



Reduced Physical Disturbance



Cropping system management practice

*Continuous cropping

*Reduced physical disturbance

*Diverse cropping rotations

*Balanced nutrient management

Organic amendment application

Cover cropping

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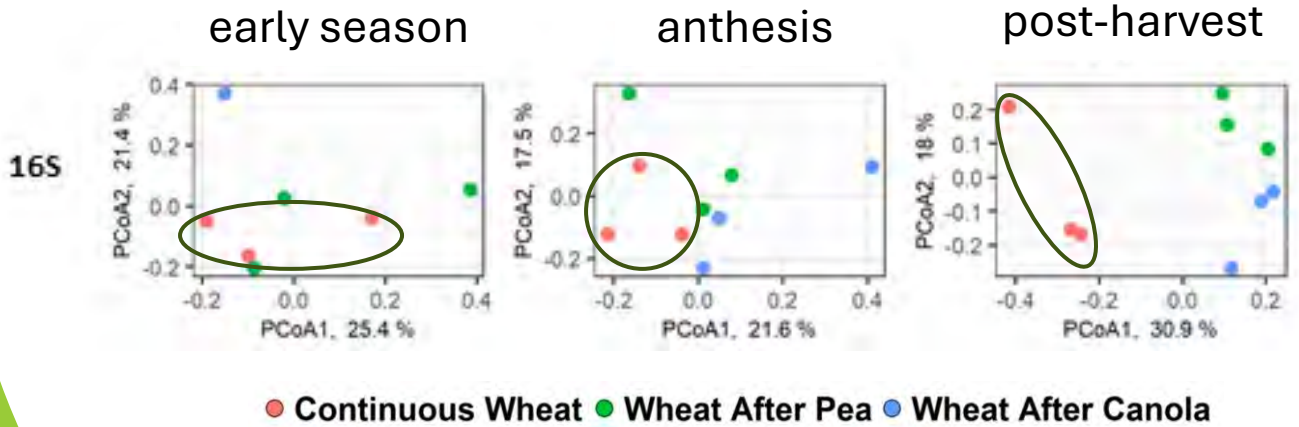


AAFC New Rotation Experiment (Swift Current est. 1987; 29 yrs)

continuous wheat vs. wheat-canola-wheat-pea (n=3)



Soil bacterial Community Structure

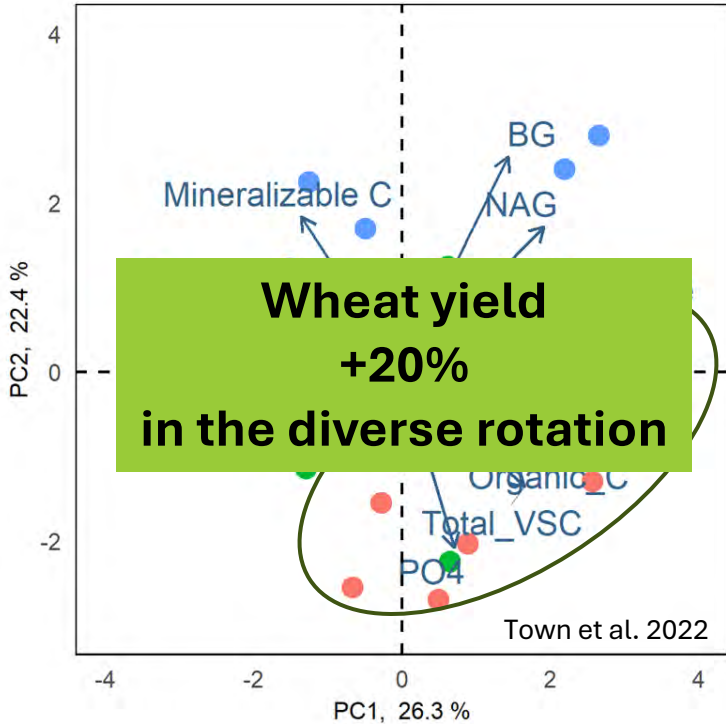


Management to support soil microorganisms



AAFC New Rotation Experiment (Swift Current est. 1987; 29 yrs)

continuous wheat vs. wheat-canola-wheat-pea (n=3)



Management to support soil microorganisms



- Continuous Cropping
- Reduced physical disturbance
- Diverse Crop Rotations
- Balanced nutrient management

Cropping system management practice

*Continuous cropping

*Reduced physical disturbance

*Diverse cropping rotations

*Balanced nutrient management

Organic amendment application

Cover cropping

Use of inoculants

Soil is a reservoir that inoculates other higher organisms



Soil organic matter provides resilience to stress



Soil organic matter

Promotes:

- good soil structure
- aggregate formation and stability

Regulates:

- soil moisture & nutrient cycling
- climate (C storage and GHG)

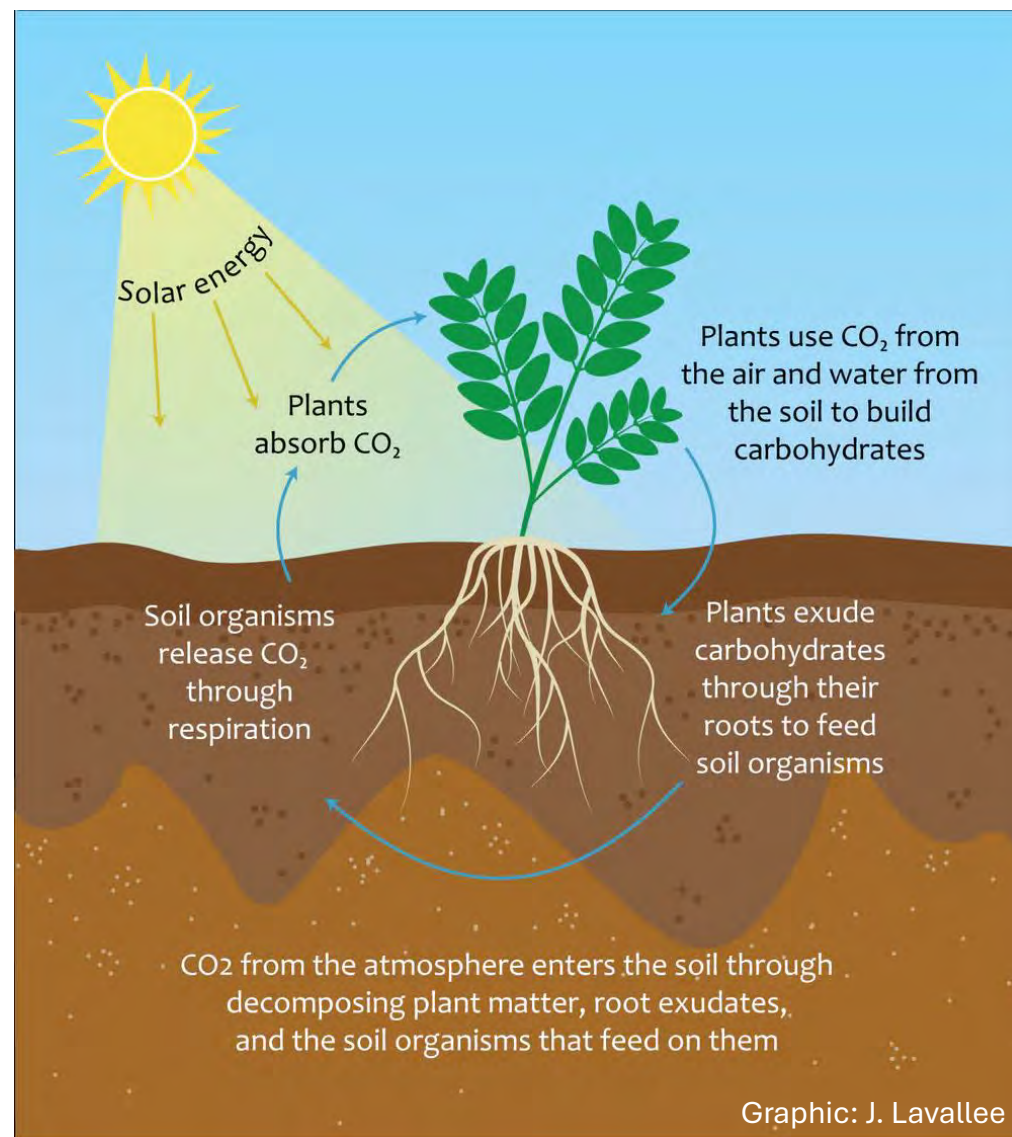
Is a source of:

- nutrients for plants and microbes
- energy (food) for microorganisms



Where does soil organic matter come from?

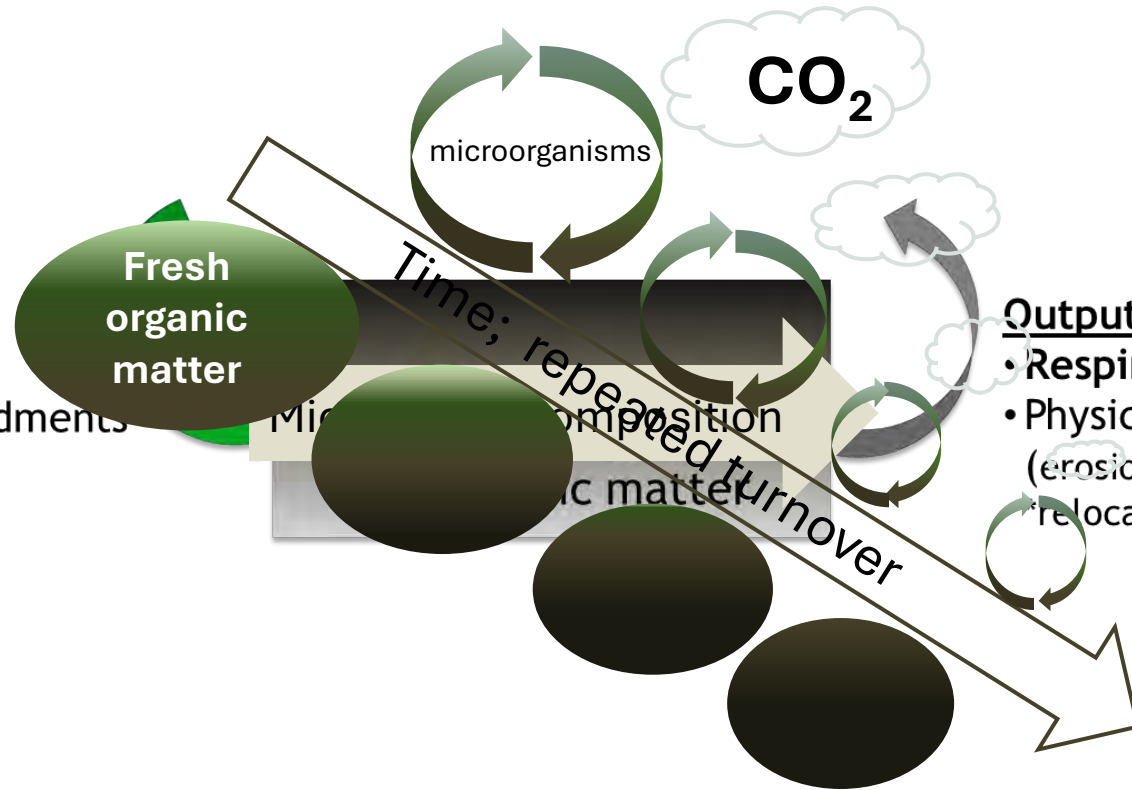
- In agroecosystems most new C comes from plants (and organic amendments)
- Energy held by organic matter *fuels* other important processes (e.g., nitrogen cycling)



Microbial transformations drive soil C cycling

Inputs

- Plant C
- Soil amendments

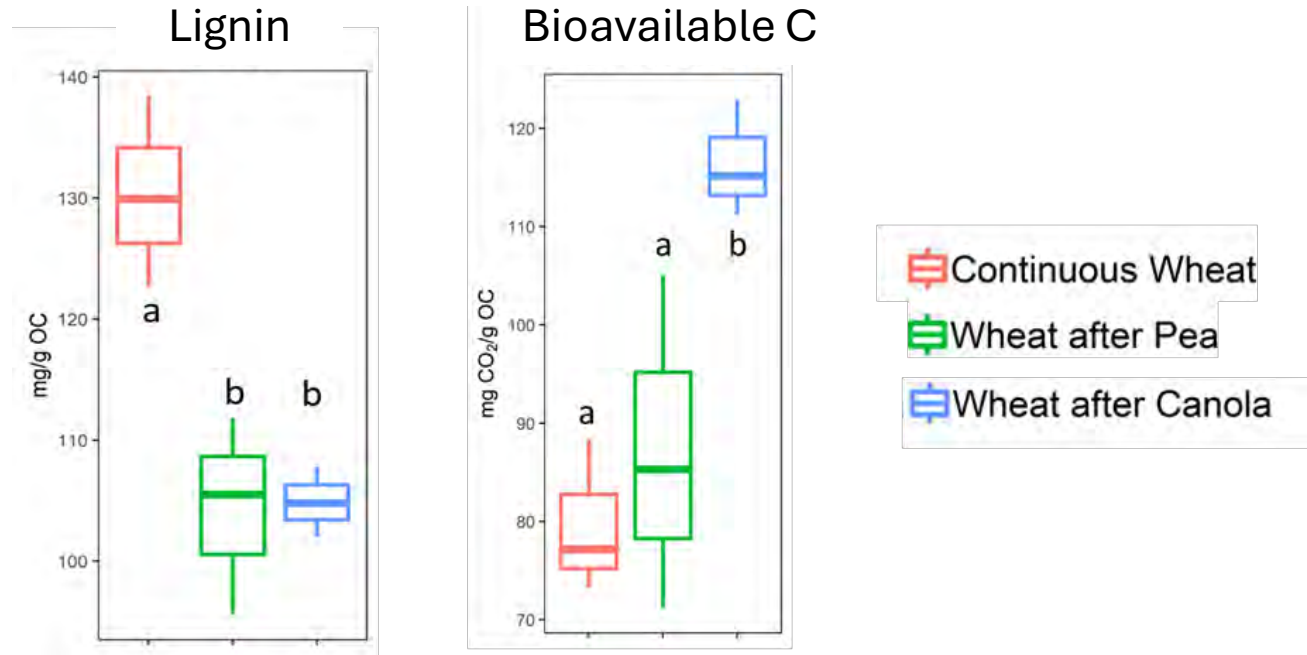


Outputs

- Respiration (CO_2 & CH_4)
- Physical transport (erosion, leaching) & relocation



Not all soil organic matter is created equally



AAFC New Rotation Experiment (Swift Current est. 1987; 29 yrs)
continuous wheat vs. wheat-canola-wheat-pea (n=3)



Not all soil organic matter is created equally

Carbon and nitrogen cycling are intimately coupled in soil

*There is a **nitrogen investment** needed to build soil organic matter (and thus to store carbon)*

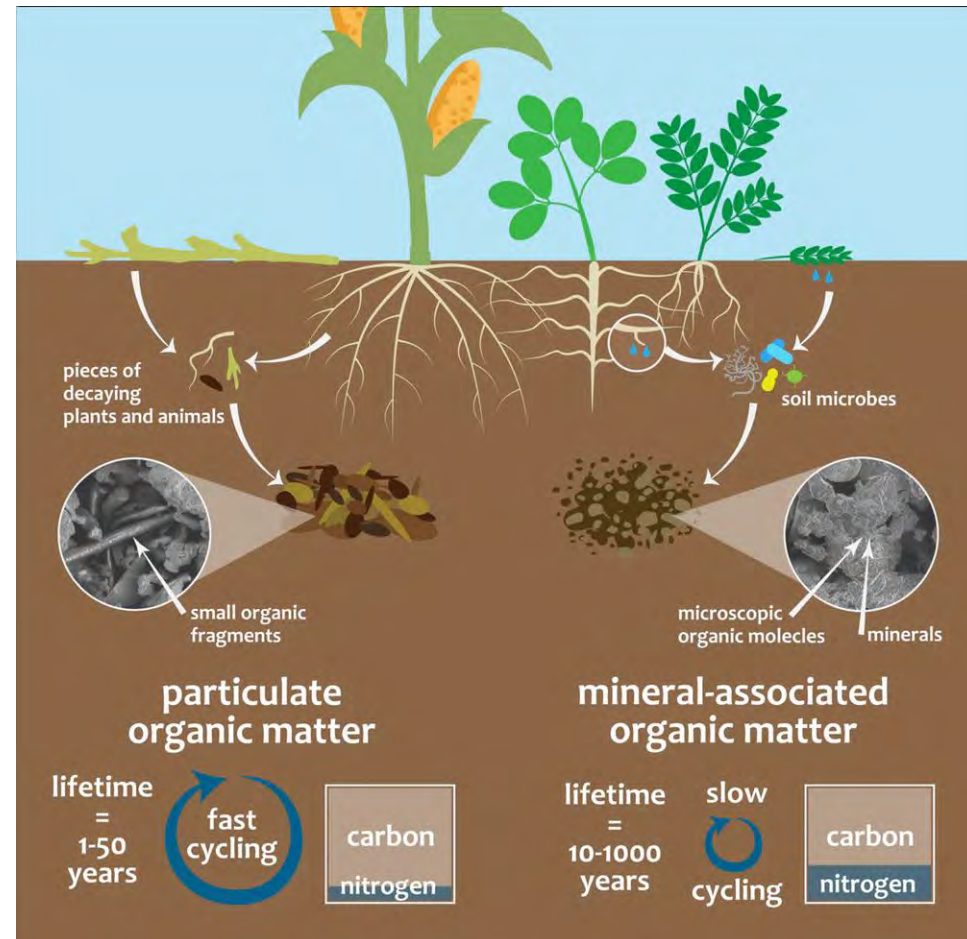
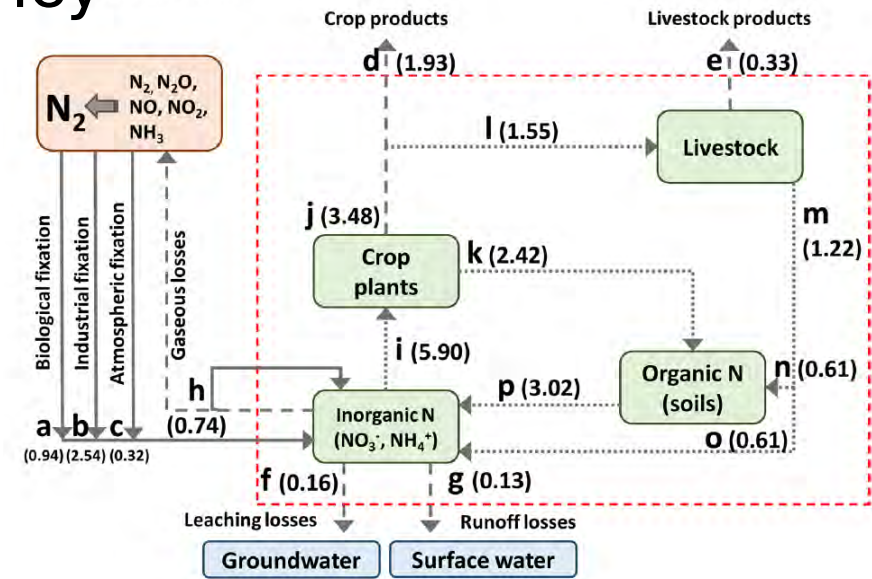
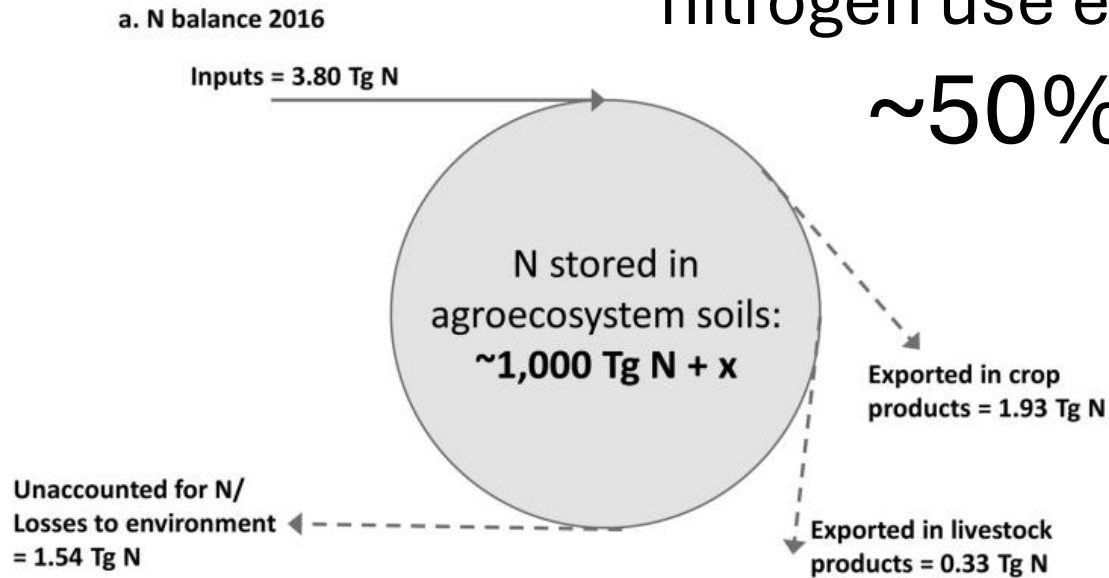


Figure: Jocelyn Lavallee

Nitrogen use efficiency improvements needed

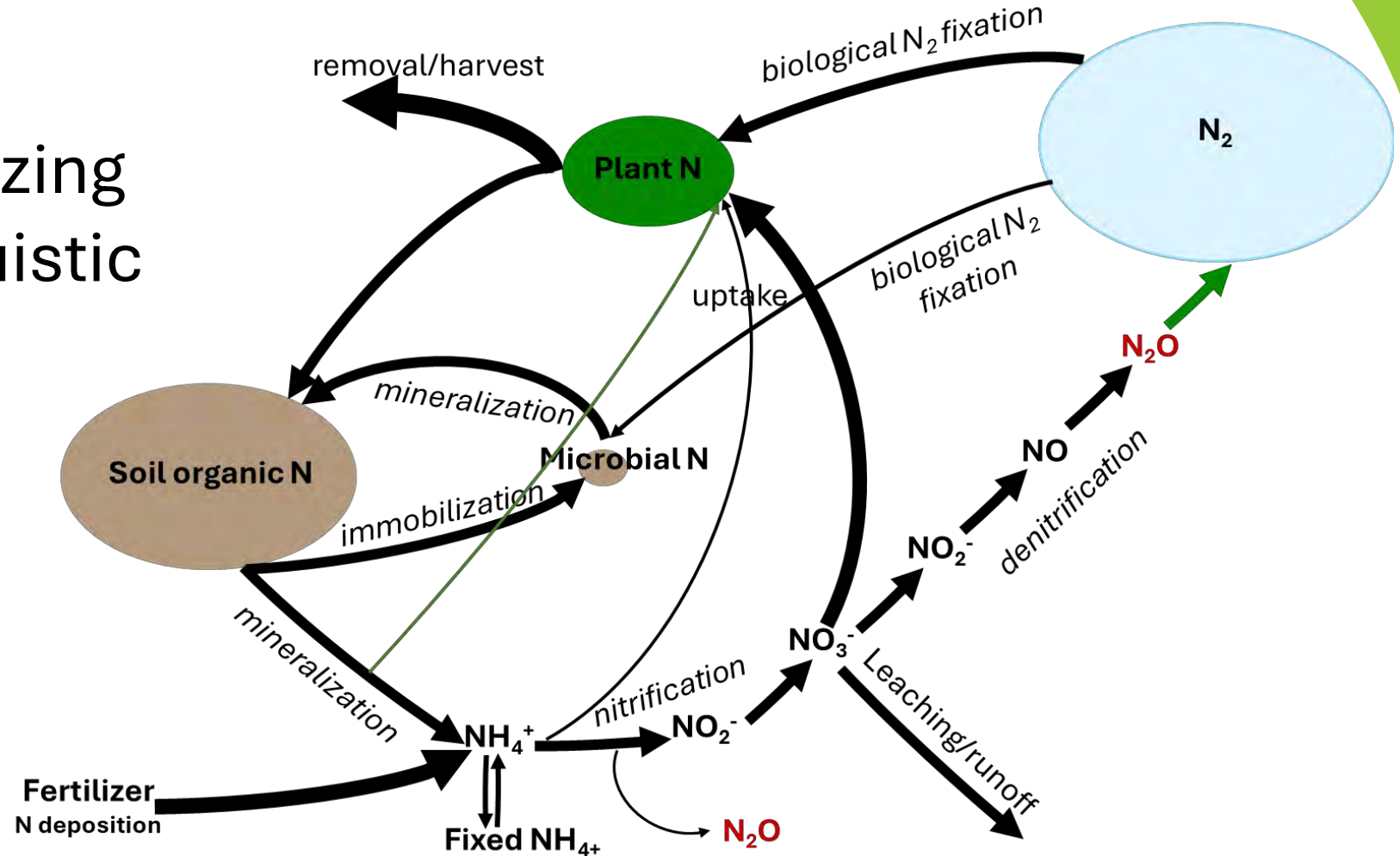
Estimated Canadian crop
nitrogen use efficiency

~50%

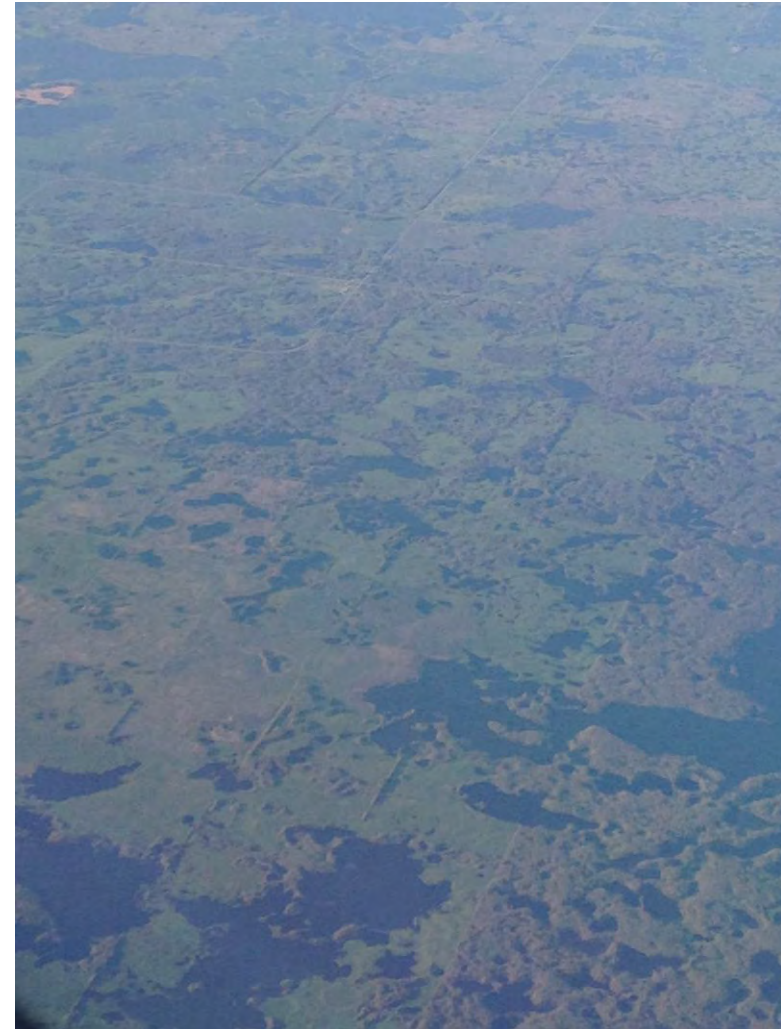
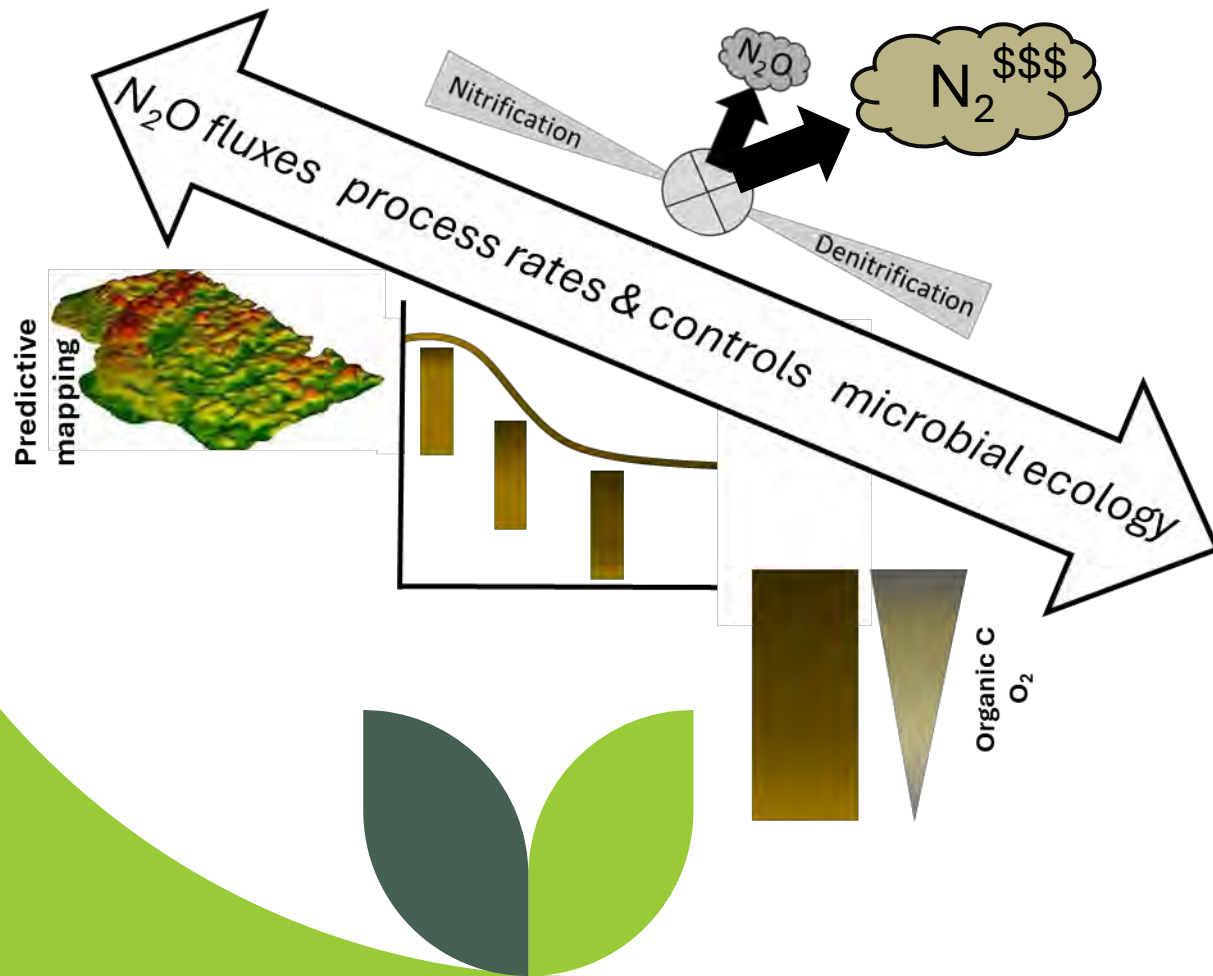


Microbial transformations drive soil N cycling

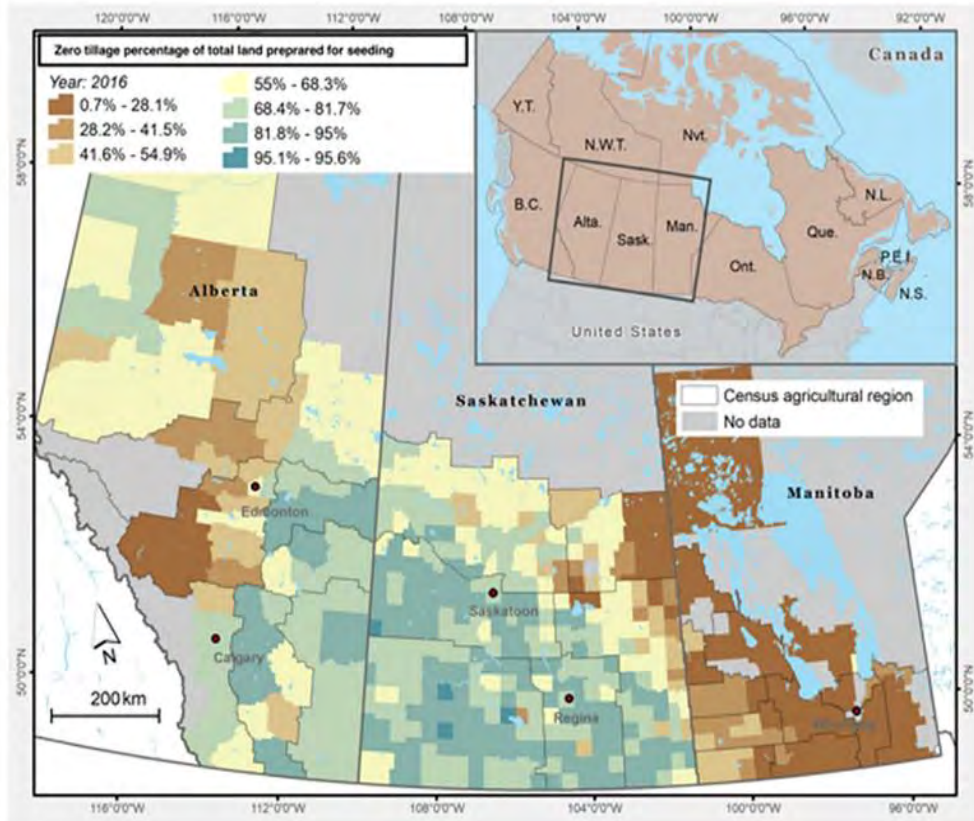
Soil microbes are amazing
...but they are not altruistic



Fine-tune N management to reduce microbially-driven N losses



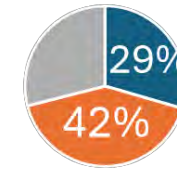
Successful adoption of conservation tillage



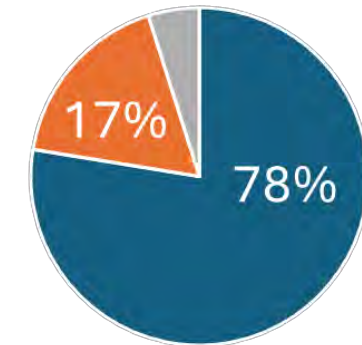
Map: Awada et al. 2021 PLOS One



Manitoba
4.3 M ha

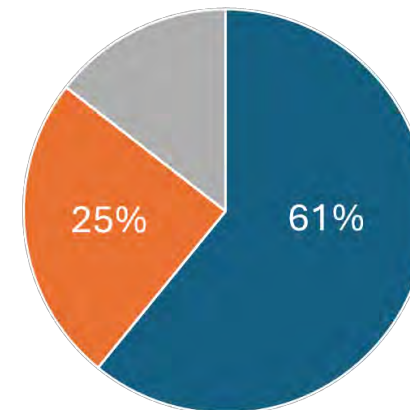


Saskatchewan
15.56 M ha



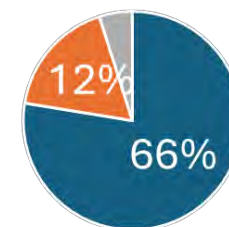
95%

Canada
33.9 M ha



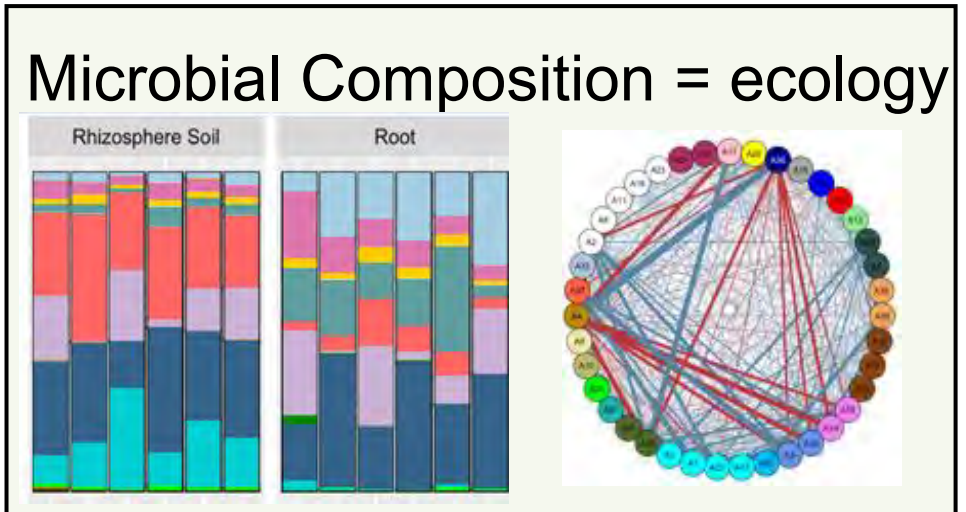
- No-till seeding or zero-till seeding
- Tillage retaining most crop residue on the surface
- Tillage incorporating most crop residue into soil

Alberta
9.2 M ha



“Because soil forms from the interaction of climate ... and living organisms (especially native vegetation) as influenced by topography ... and type of parent material ... over time, soil is the most complex and variable of all microbial habitats”

Peter Hartel. In Sylvia, D.M. et al. (Eds) Principles and Applications of Soil Microbiology. 2nd Edition. p.26



The vast metabolic capacity of soil’s unseen soil microbial communities sustains ecosystem health and provides resilience to natural and anthropogenic perturbations.



Acknowledgements



Bobbi Helgason
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A huge thanks to our Soil Microbiology team: current and alumni!

Soil Microbial Ecology Program

Soil carbon stabilization/
destabilization

Nutrient cycling and
prevention of losses
(improved efficiency)

Plant-microbe
interactions

microorganisms

