



NDSU | EXTENSION



2026



**See you in 2027.**

**Thank you for participating!**



**EXTENSION**

**NDSU**

**NDSU** | EXTENSION

**2026** FIELD to FORK

[www.ag.ndsu.edu/food](http://www.ag.ndsu.edu/food)    NDSU EXTENSION    EXTENDING KNOWLEDGE >> CHANGING LIVES

Presenter

Audio Settings ^



Chat



Raise Hand

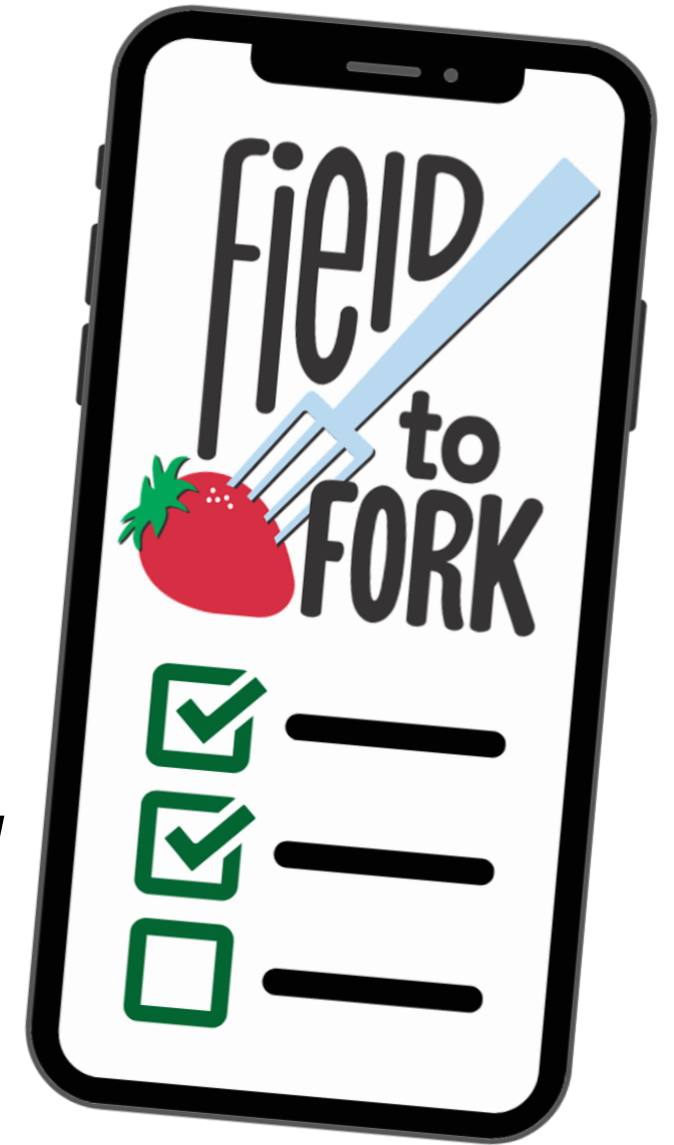


Q&A

Leave

- **Please complete the short online survey** that will be emailed to you after today's webinar. It will take just a couple minutes!
- Be sure to sign up for an opportunity to win a prize in the drawing. After submitting the survey, a form to fill out with your name/address will appear.

***Acknowledgement: This project was made possible with funding from the North Dakota Department of Agriculture through the U.S. Department of Agriculture's Specialty Crop Block Grant program. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.***



April 15

# Does soil health make a difference in producing healthy food?

Carlos Pires, NDSU Extension soil health specialist and assistant professor

NDSU

EXTENSION



NDSU

EXTENSION





**NDSU** | EXTENSION



**2026**

**field to fork**



[www.ag.ndsu.edu/food](http://www.ag.ndsu.edu/food)

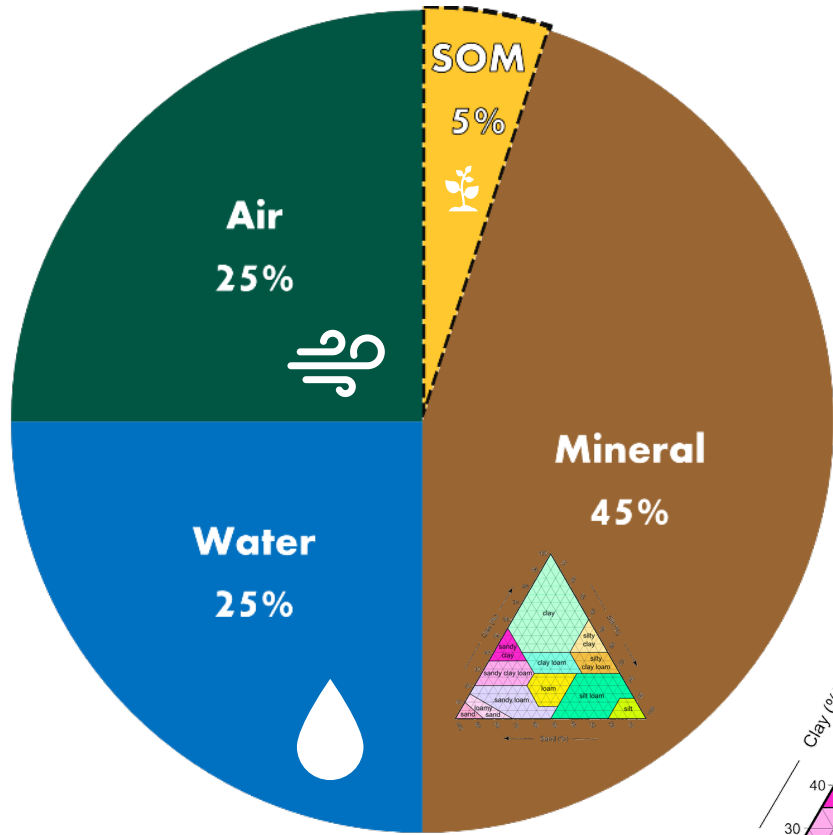
NDSU EXTENSION

EXTENDING KNOWLEDGE >> CHANGING LIVES

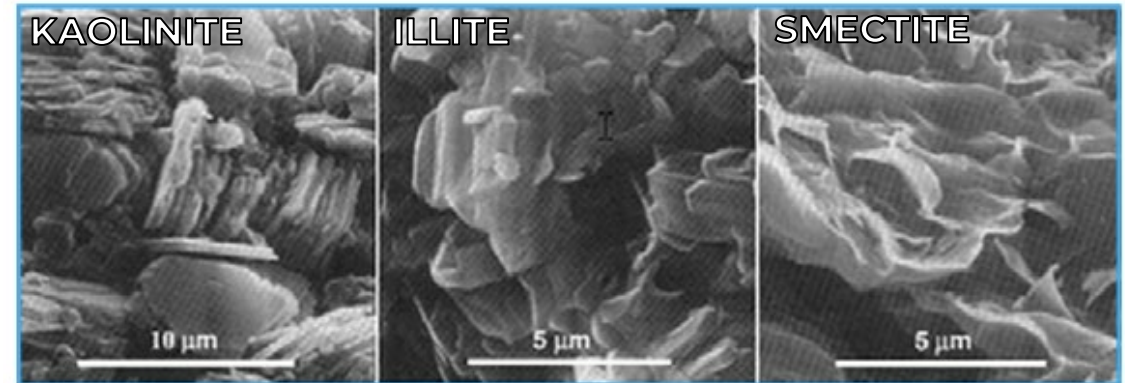
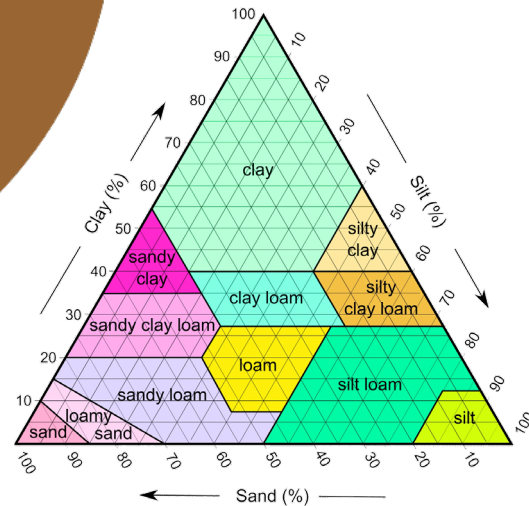
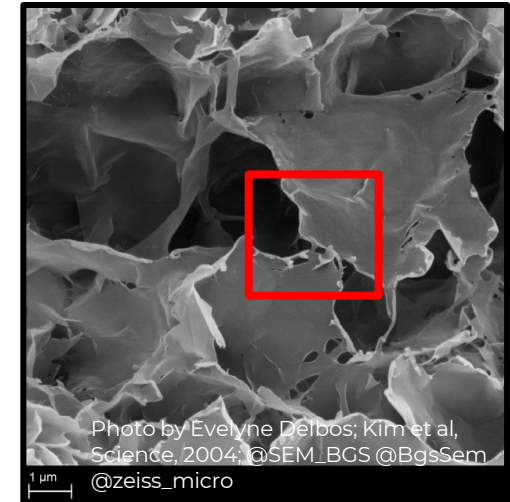
**NDSU**

EXTENSION

# SOIL COMPOSITION

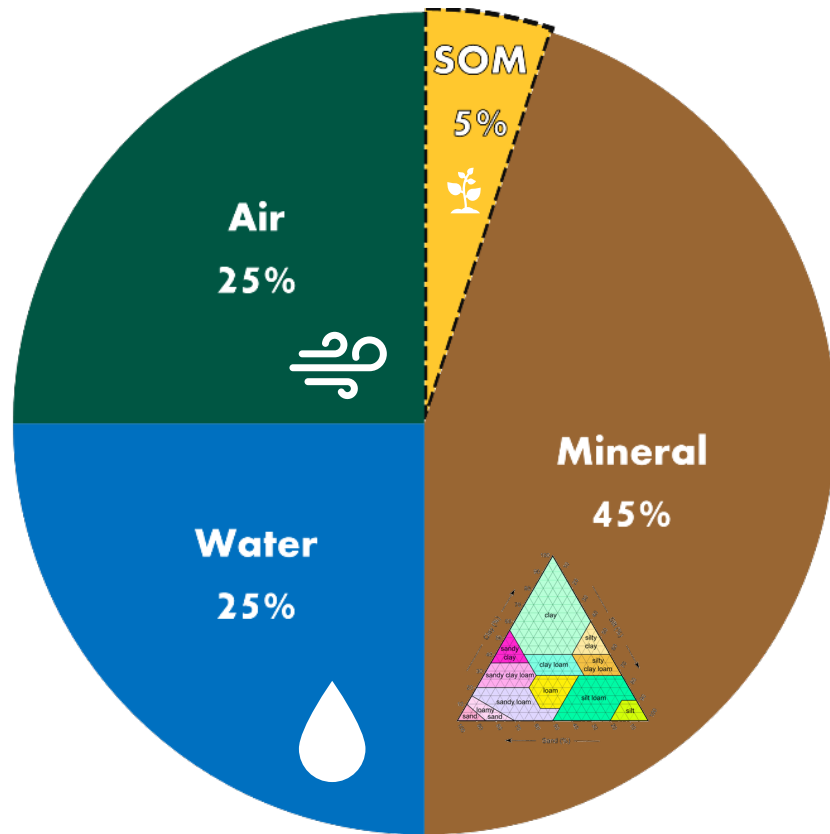


Ideal soil composition



Tovey (1971)

# SOIL COMPOSITION



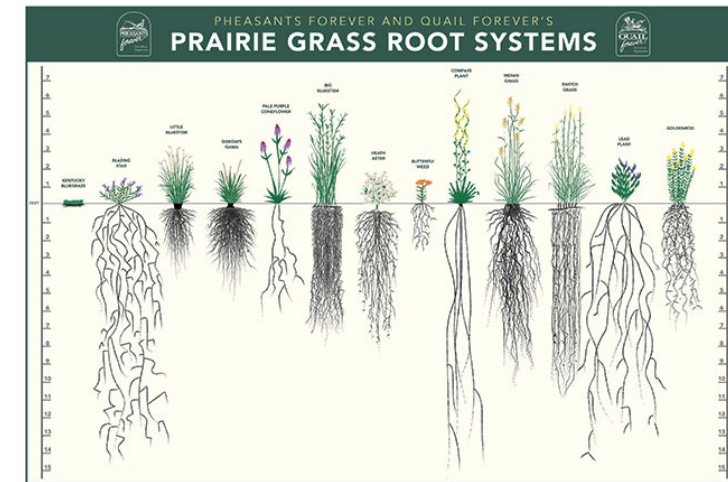
Ideal soil composition

What happens if we...

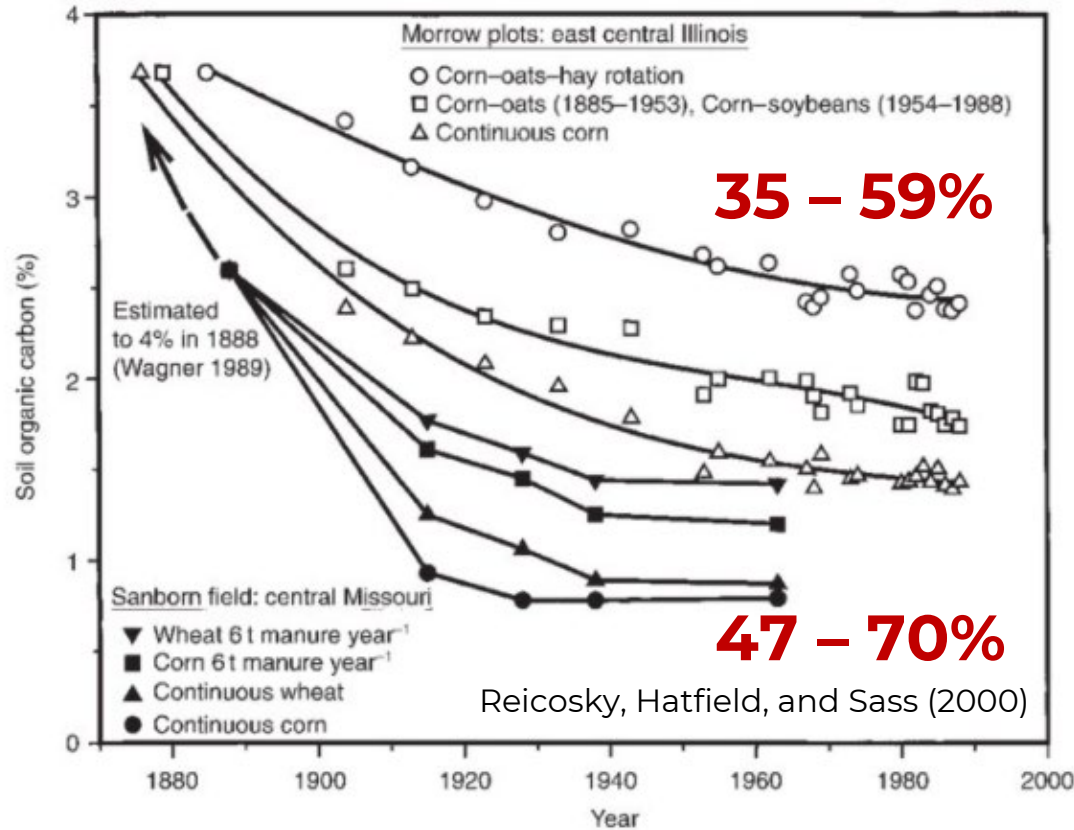
- Increase the water fraction?
- Increase the mineral fraction?
- Change the mineral fraction?

# WHY ARE THE UPPER MIDWEST SOILS SO RICH IN ORGANIC MATTER (OR USED TO BE)?

- Glacial activity
  - Young soils. Because glaciers covered the soil, these soils have not had as much exposure to wind and water.
- Native Vegetation
  - Prairie vegetation occupied much of this area until ~150 years ago. Deep root system.
- Climate
  - Short growing seasons and hard winters prevent SOM degradation.



# WHY “USED TO BE”?



REMOVED ORGANIC MATTER THROUGH TILLAGE



MONOCULTURE AND CROPPING PRACTICES THAT LIMITS CARBON RETURN



INCREASED EROSION RATES AND SOIL DEGRADATION

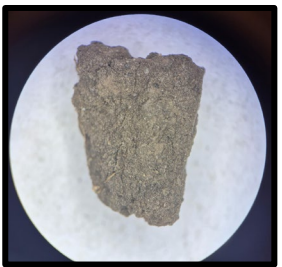
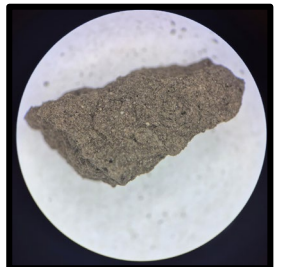
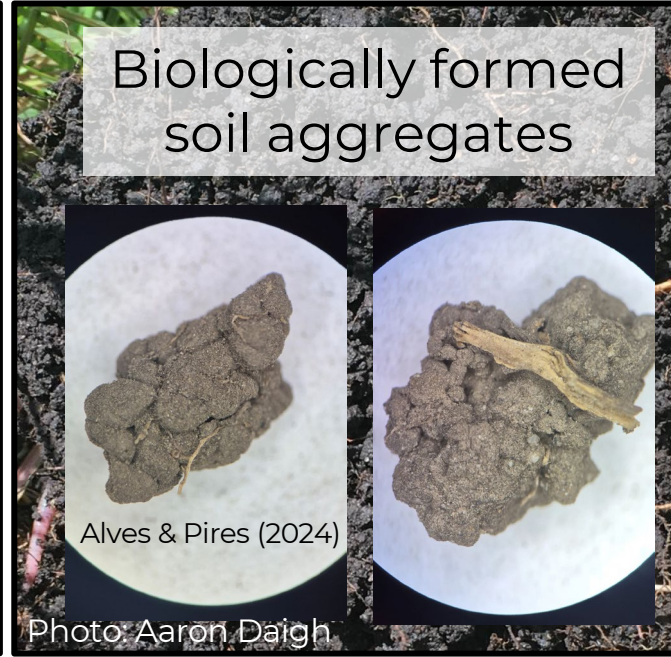
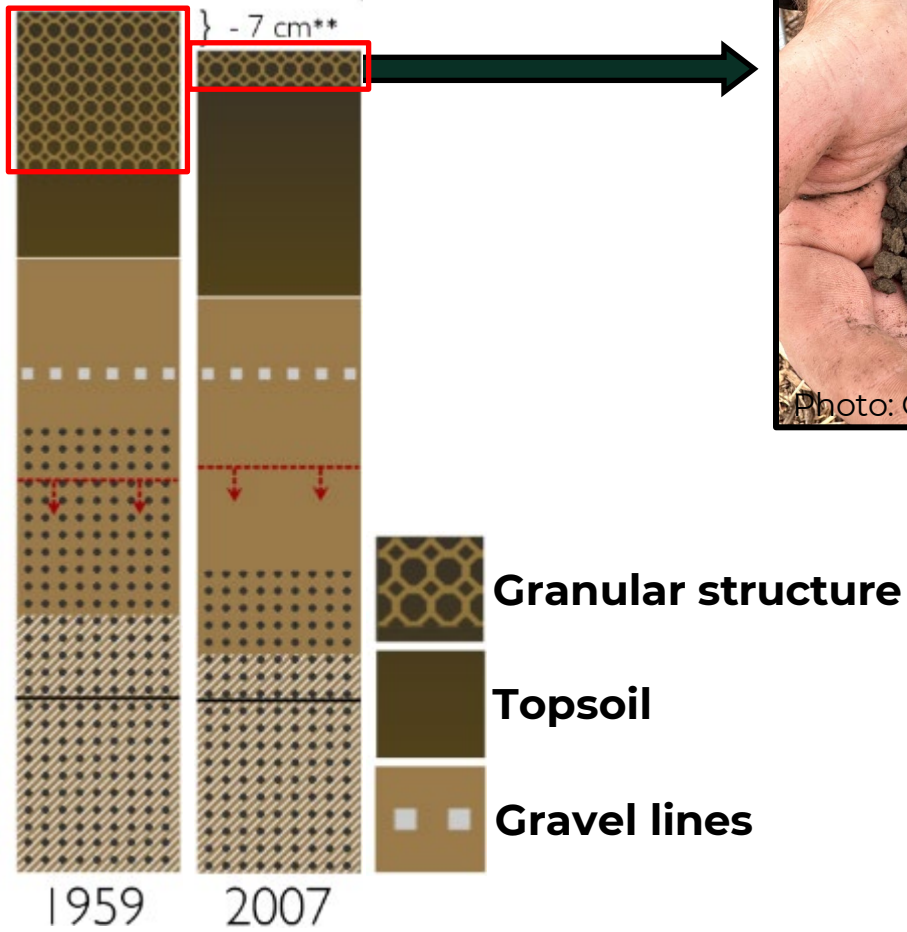


REDUCED SOIL BIODIVERSITY AND FUNCTIONALITY AND INCREASED USE OF EXTERNAL INPUTS

Long-term effect of tillage and crop rotations on soil carbon in Midwest USA

# WHY "USED TO BE"?

- Soil structure

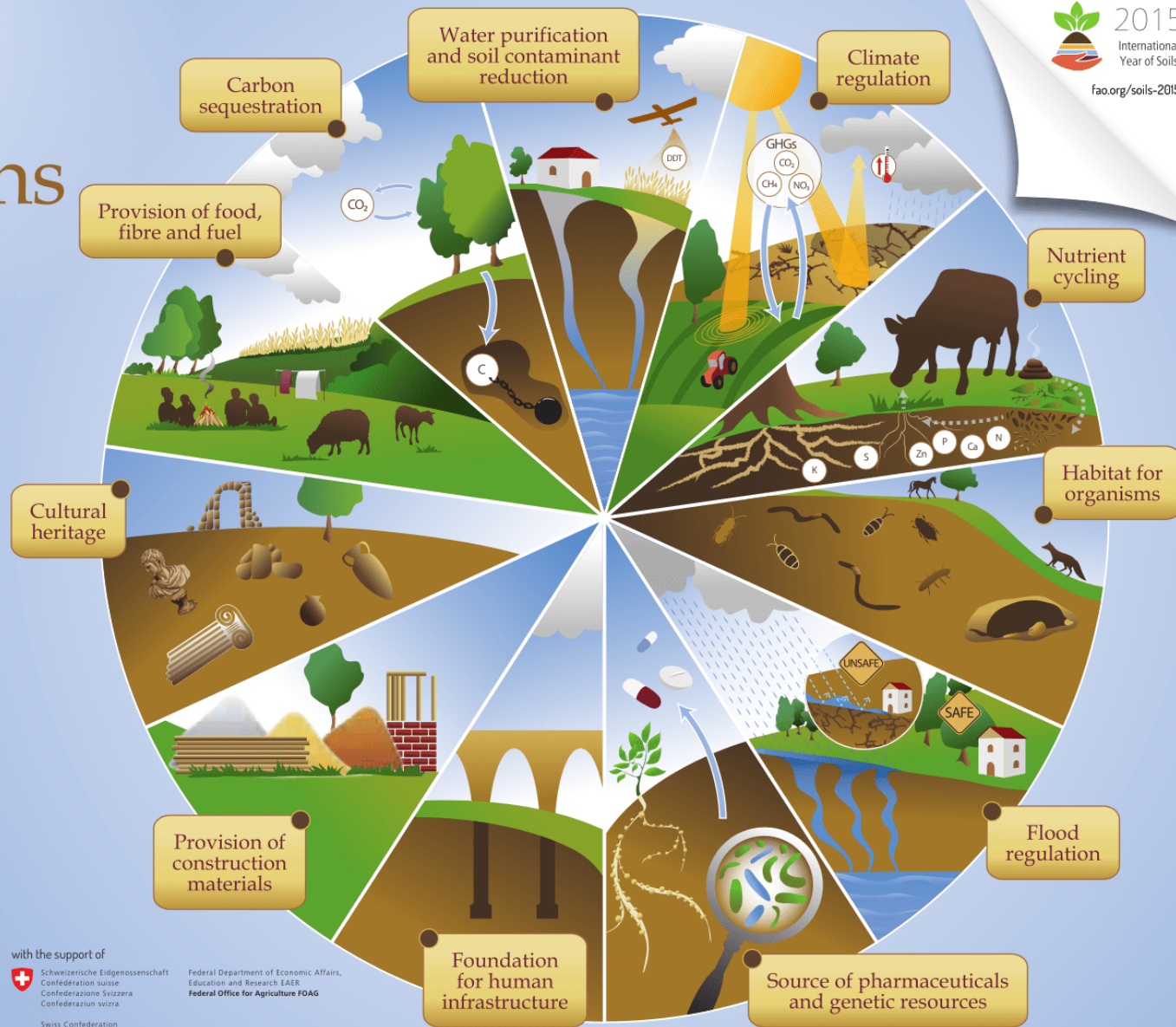



Veenstra and Burras. 2016. SSSAJ. Work from Iowa State University

# Soil functions

Soils deliver ecosystem services that enable life on Earth

2015  
International Year of Soils  
fao.org/soils-2015



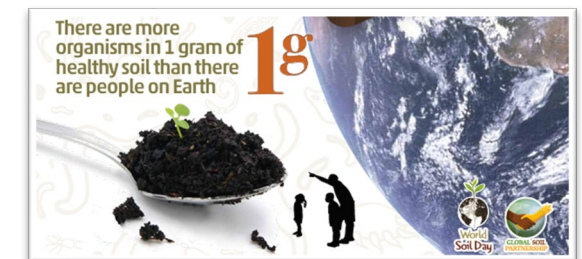
 Food and Agriculture Organization of the United Nations

with the support of  
 Schweizerische Eidgenossenschaft  
 Confédération suisse  
 Confederazione Svizzera  
 Confederaziun svizra  
 Swiss Confederation

Federal Department of Economic Affairs,  
 Education and Research EAER  
 Federal Office for Agriculture FOAG

# WHAT DO WE KNOW ABOUT SOIL BIODIVERSITY?

- Soil biodiversity is the variety of life belowground.
- Soil is home to more than 25% of our planet's biodiversity.
- More than 40% of living organisms in terrestrial ecosystems are associated during their life cycle directly with soils.
- Soils contain arguably the most diverse terrestrial communities on the planet.



## WHAT ARE SOIL MICROBES

- Soil microbes are the incredibly diverse and abundant microscopic organisms, including bacteria, fungi, archaea, and other protists, that live in the soil and play a crucial role in soil health and ecosystem processes.

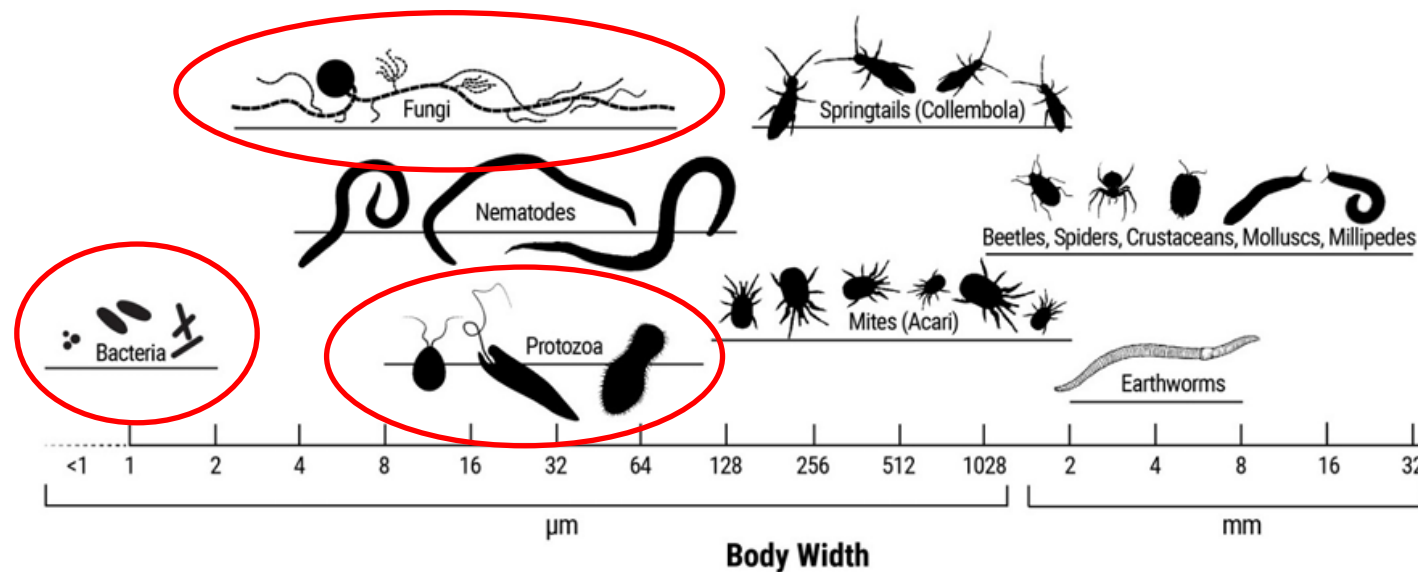
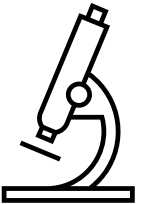


Fig. 1—Soil organisms grouped by class, showing the size of body width. Bacteria in the diagram represent all prokaryotes, bacteria and Archaea.

Brackin et al. (2017)



# THE ROLE OF SOIL MICROBES

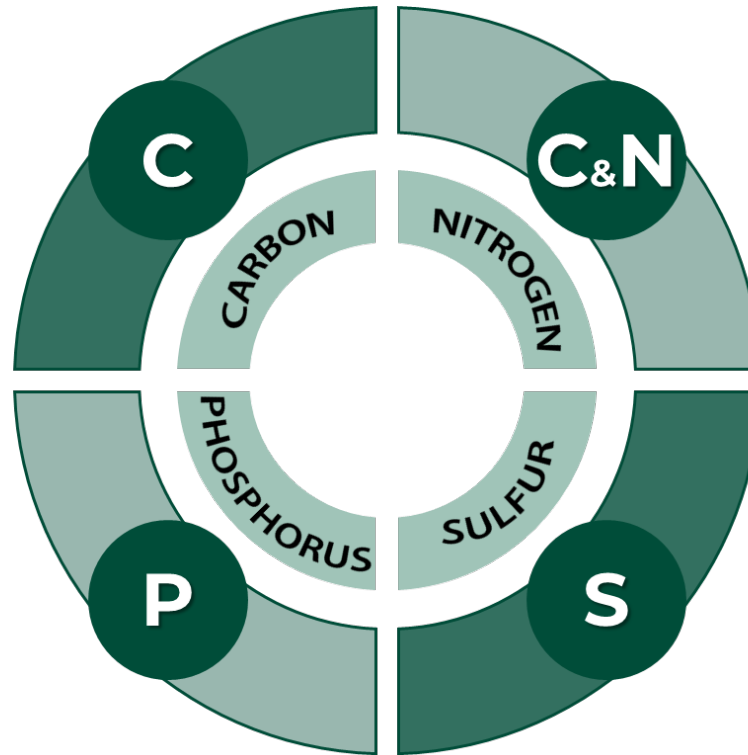
Microbial Group	Microbes' roles
Bacteria (Gram + & Gram -)	<ul style="list-style-type: none"><li>• Decompose N rich materials (low C:N ratio)</li><li>• Nutrient cycling</li><li>• Release nutrients that other organisms could not access (usable form)</li><li>• Help to bind soil particles into aggregates (polysaccharides)</li></ul>
Fungi	<ul style="list-style-type: none"><li>• Improve soil aggregation</li><li>• Decomposers (high C:N ratio – lignin)</li><li>• Break down nutrients that other organisms cannot</li></ul>
Arbuscular Mycorrhizal Fungi	<ul style="list-style-type: none"><li>• Enhance plant nutrient uptake (P, NH<sub>4</sub>)</li><li>• Improve soil aggregation</li><li>• Forms fungal links between roots of neighboring plants</li></ul>
Protozoa	<ul style="list-style-type: none"><li>• Decomposers</li><li>• Regulate microbial populations (consume bacteria)</li><li>• Nutrient cycling</li></ul>

# ENZYMES

- Soil enzymes are proteins produced by soil organisms and plants
- Accelerate biochemical reactions such as residue (carbon & nitrogen) decomposition
- Essential for nutrient cycling

**$\beta$ -glucosidase ( $\beta$ G)**  
Carbon cycling enzyme that facilitates the degradation of plant material to generate sugars that microbes use as a source of energy.

**Acid Phosphatase (AcidP)**  
Phosphorus cycling enzyme that converts organic phosphorus to mineral phosphorus. Acid phosphatases predominate in soil with a pH between 4-6 while alkaline phosphatase predominates in soils with pH between 9-11.

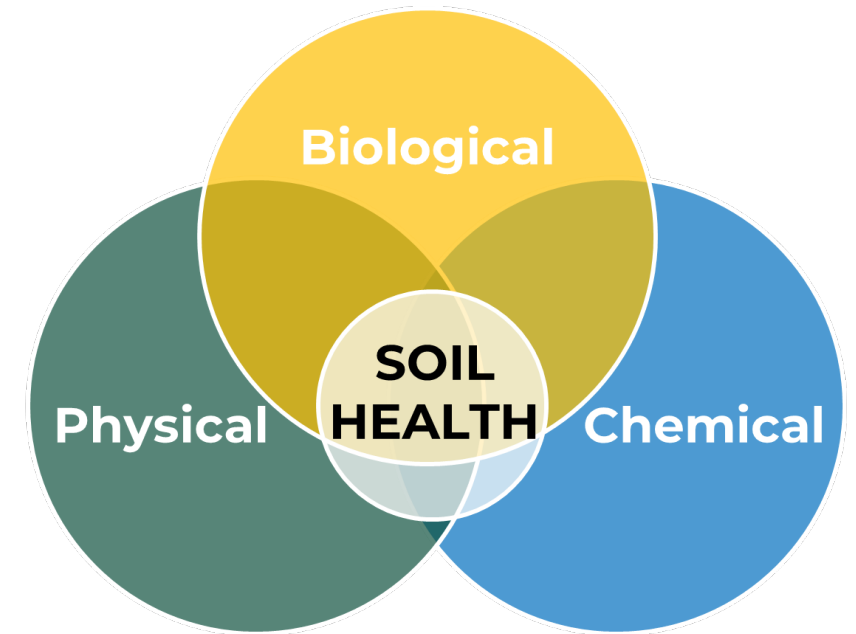
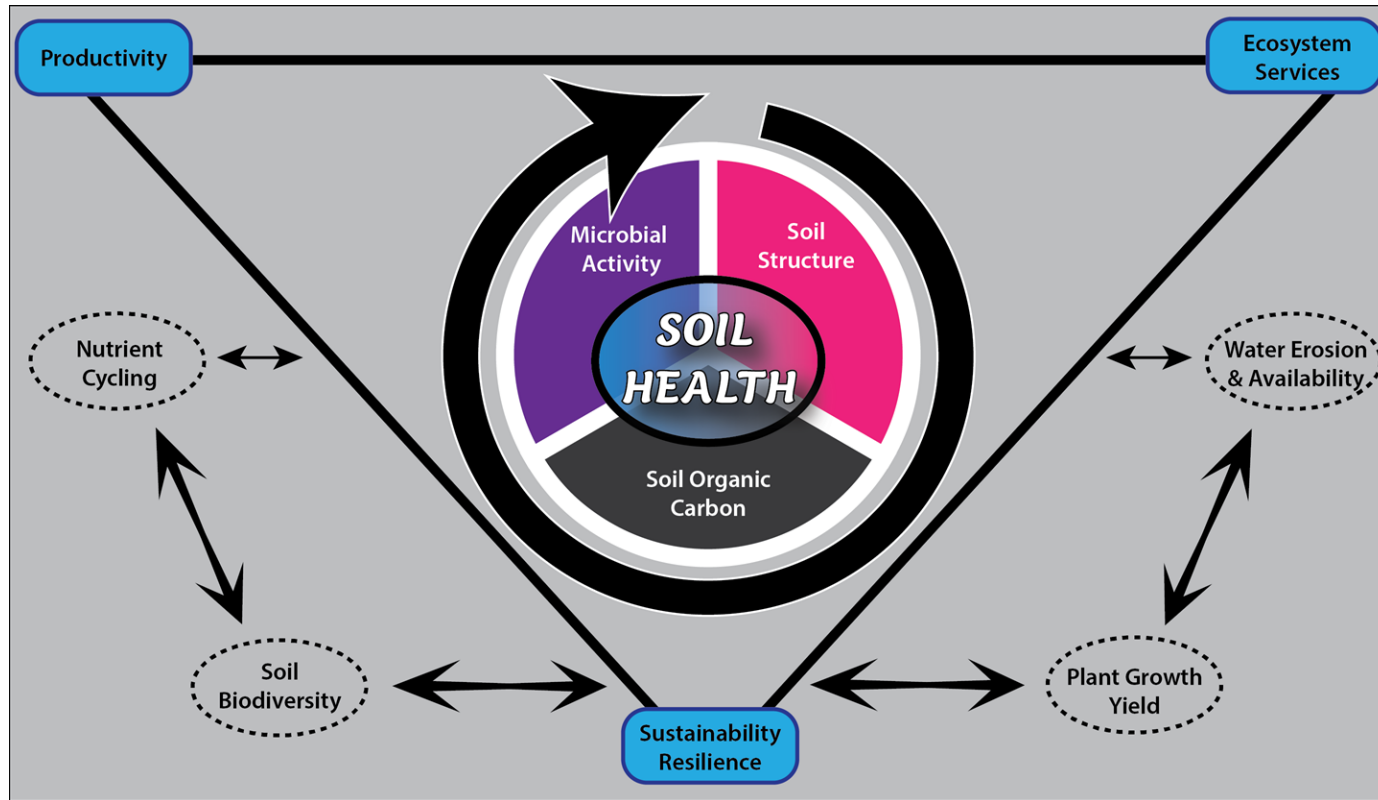


**N-acetyl- $\beta$ -glucosaminidase (NAG)**  
Carbon and nitrogen cycling enzyme that degrades chitin, an N-rich substance present in plants, fungi, bacteria, invertebrates, and animals.

**Arylsulfatase (AryIS)**  
Sulfur cycling enzyme that controls the acquisition of organic sulfur. It allows microorganisms to satisfy their sulfur requirements.

# SOIL HEALTH

- The capacity of the soil to function as a living ecosystem and sustain plants, animals, and humans.

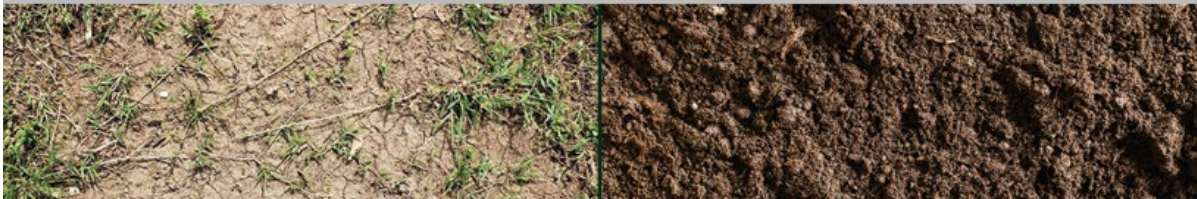


# SOIL HEALTH

## WHAT IS HEALTHY SOIL?



**UNHEALTHY SOIL** ❌ **HEALTHY SOIL** ✅



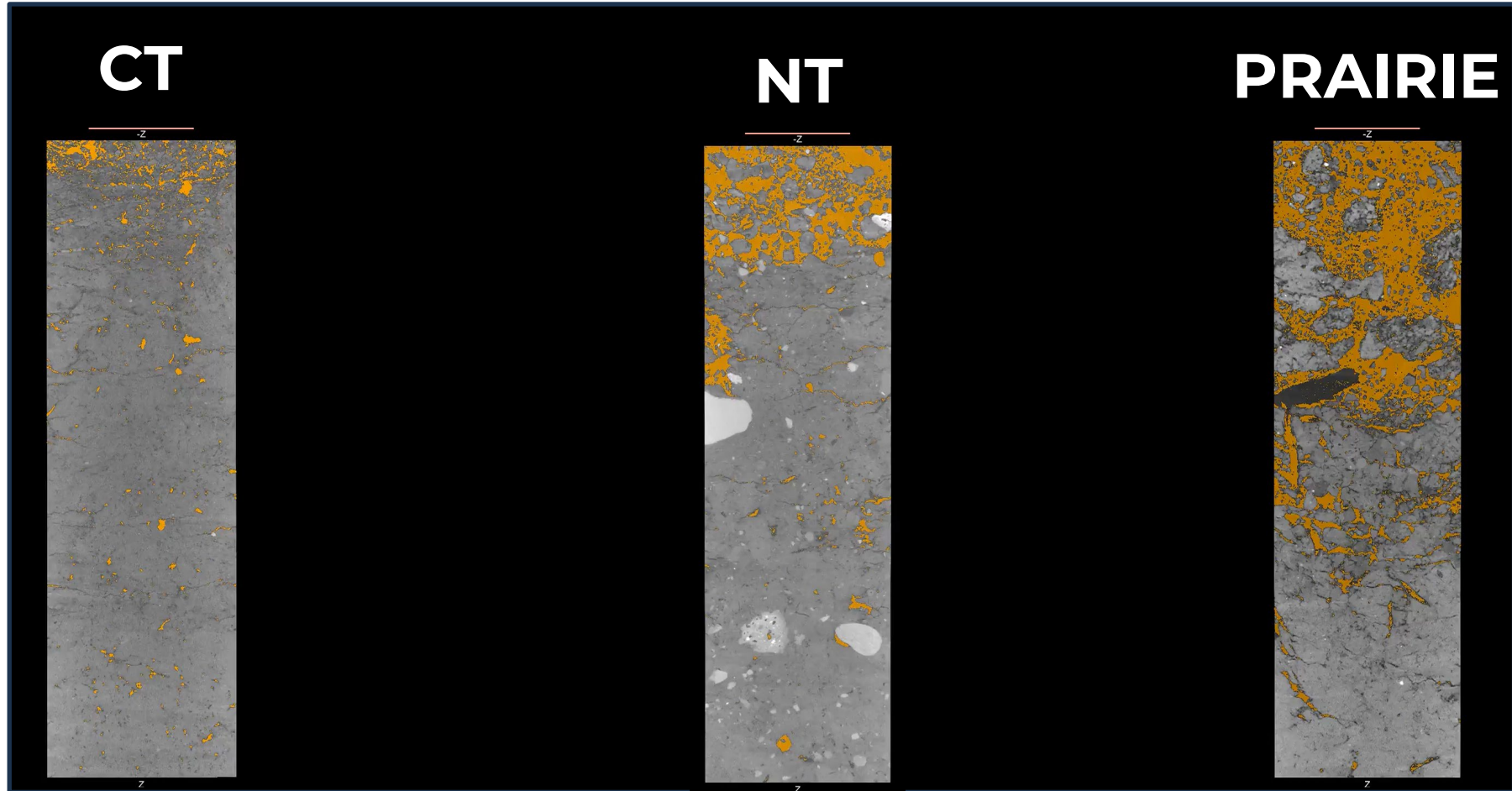
USU Extension Publications | July 2020 | Soils/01

Amanda Pratt - Small Farms Graphic Designer, Katie Wagner - Horticulture Faculty, Melanie Stock - Small Farms Specialist  
 Utah State University is an affirmative action/equal opportunity institution and is committed to a learning and working environment free from discrimination. For USU's non-discrimination notice, see [equity.usu.edu/non-discrimination](http://equity.usu.edu/non-discrimination).

# SOIL HEALTH

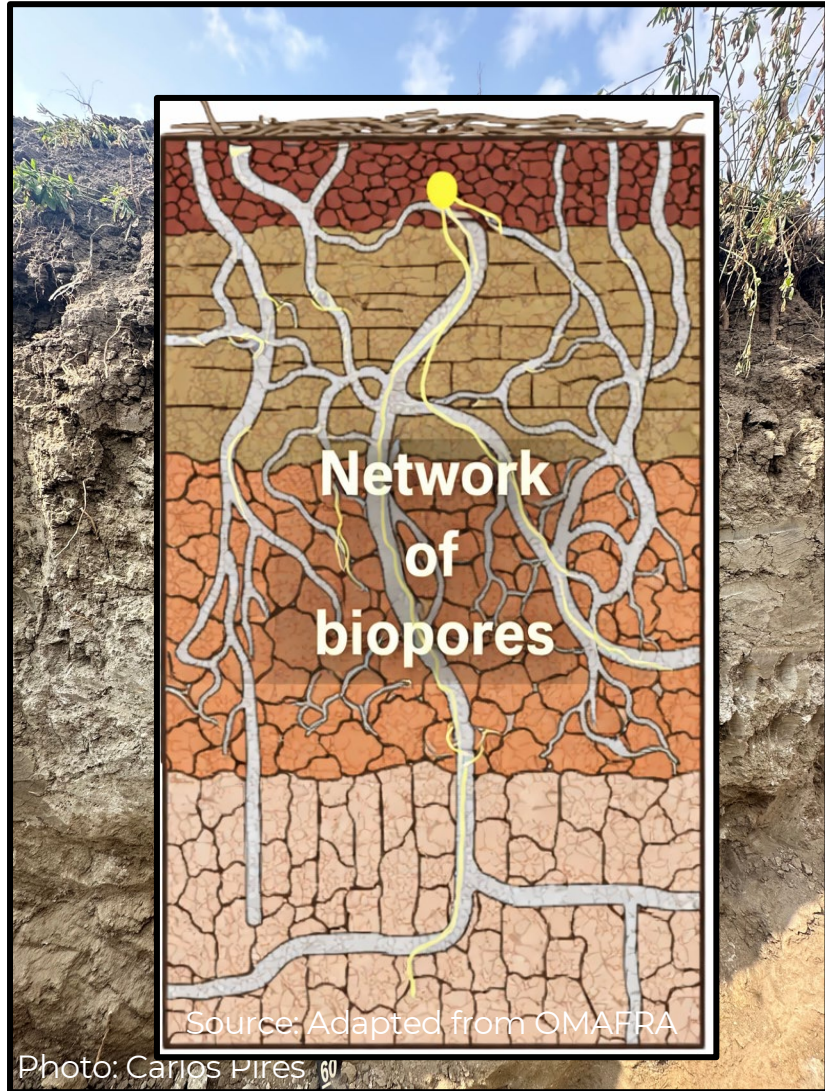


Photos: Carlos Pires

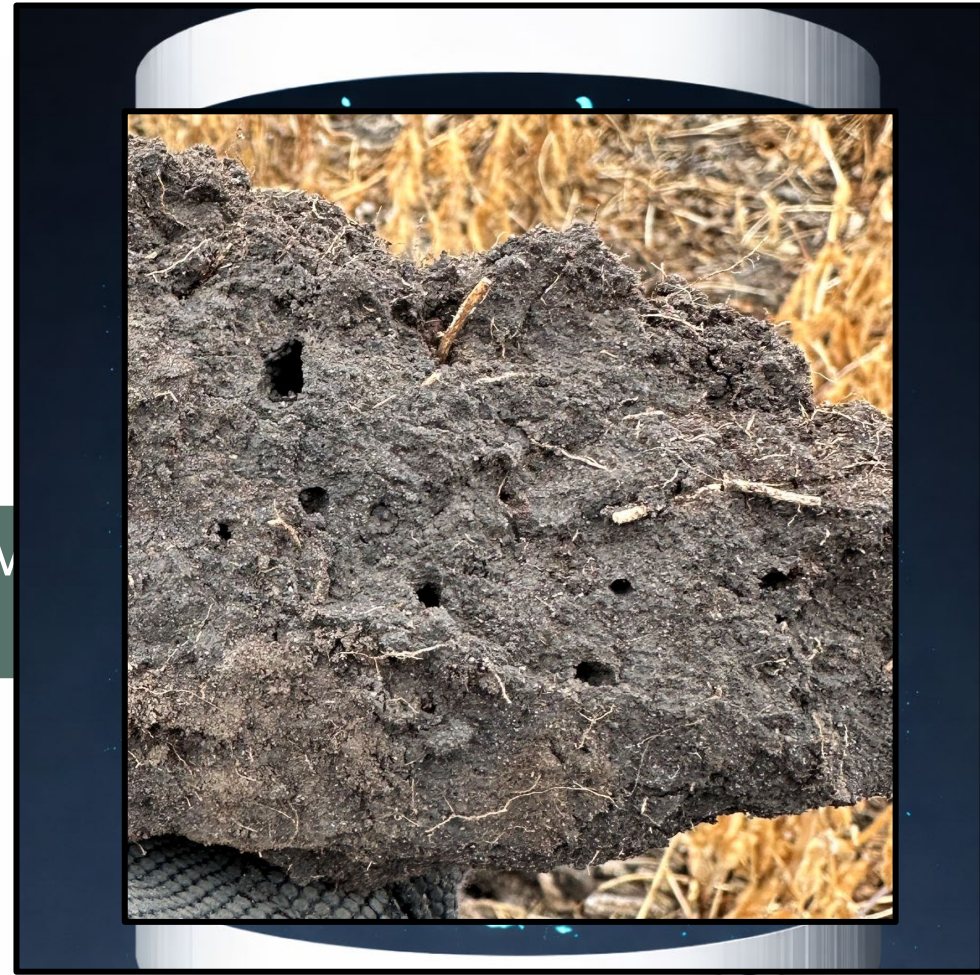


Source: Duncan, Pires, Rice, et al. (2022)

# SOIL HEALTH



# MACROPORES



Macropores typically represent **< 1%** of all soil pores  
U.S. Interstates: 48,605 miles  
All other roads: 4,148,891 miles  
Contribute **up to 70%** to moving water via infiltration  
Source: FHWA 2012

Source: Schjøning et al. 2016 Soil Research; Hirmas et al. 2018 Nature

# SOIL HEALTH PRINCIPLES



## MINIMIZE DISTURBANCE

No-tillage, minimum tillage, strip tillage.



## MAXIMIZE SOIL COVER

Cover crops, residue management, cropping system, perennials



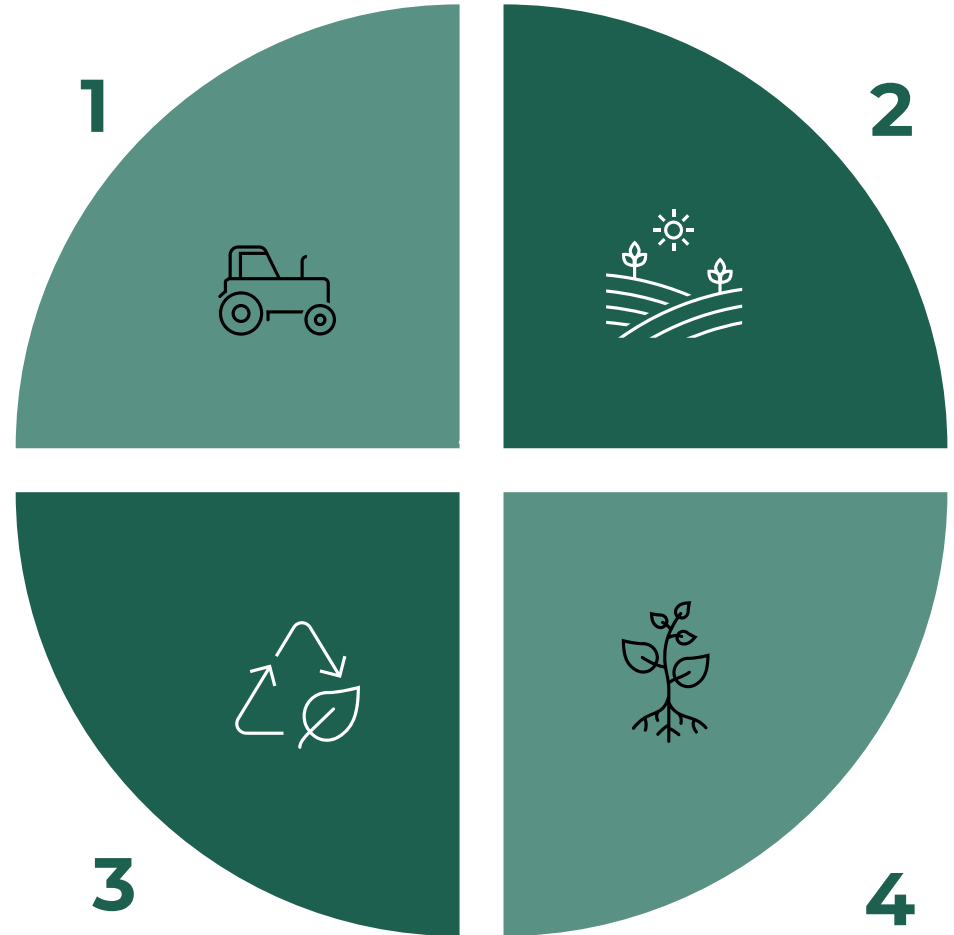
## MAXIMISE BIODIVERSITY

Plant diversity (cash and cover crop), integrated crop-livestock system



## MAXIMIZE CONTINUOUS LIVING ROOTS

Cove crops, reduce fallow



***“Make the most efficient use of external inputs”***

# Soil health and the C cycle: It is all connected!



Photo: Karen Kawakami

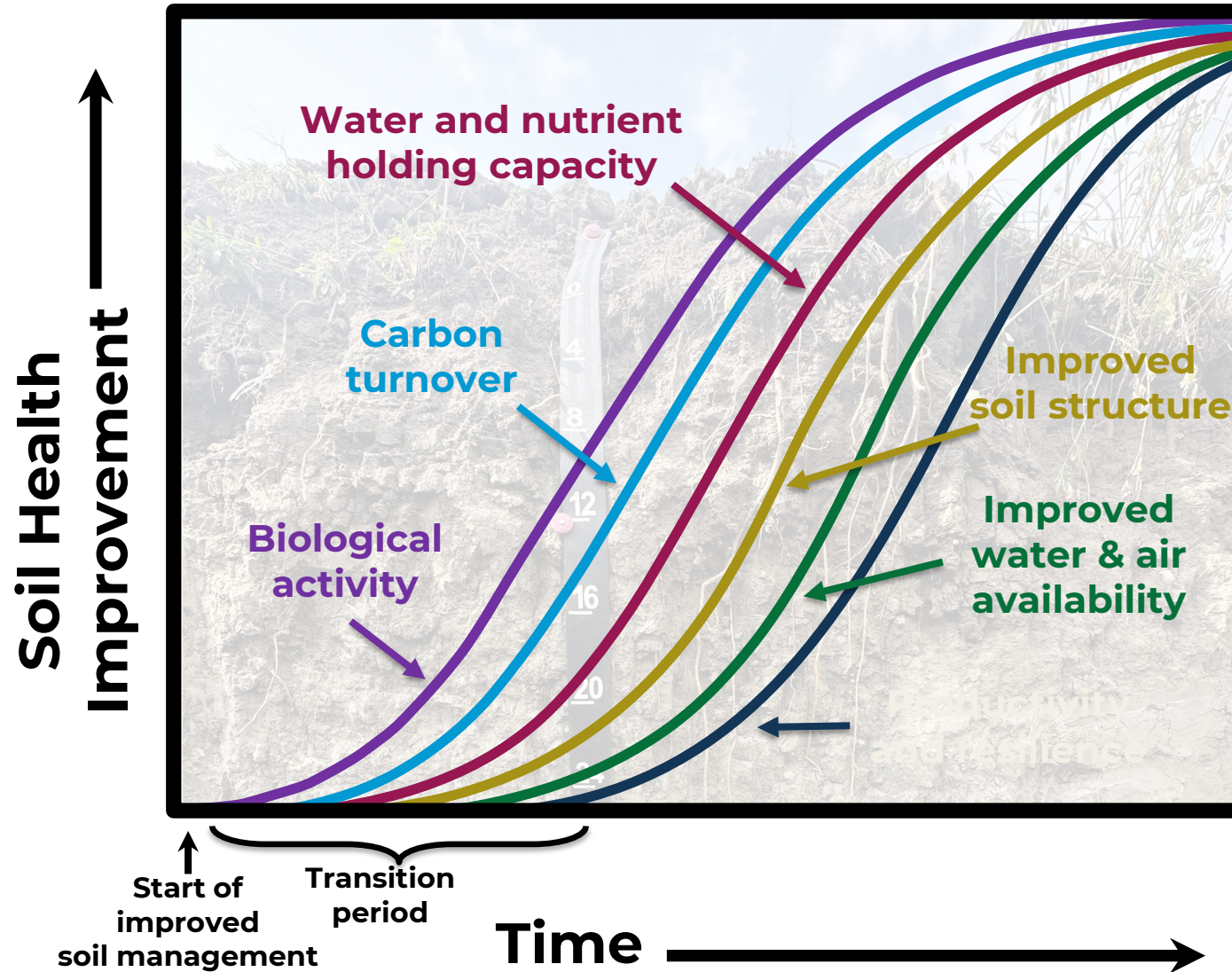
- Cover
- Crop rotation
- No soil disturbance
- Organic material
- Diversity

=



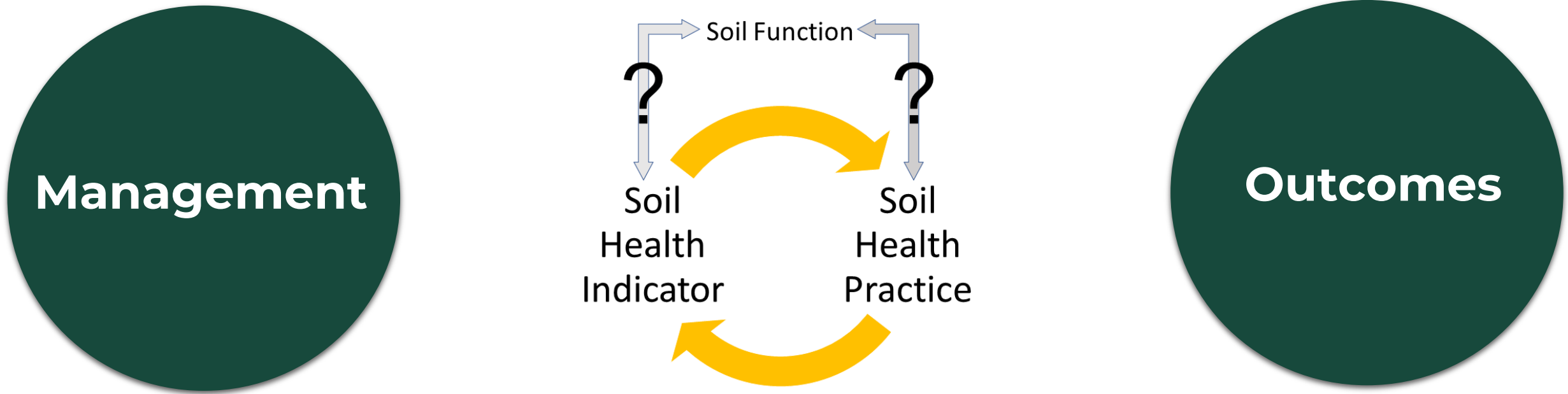
Carbon

# Soil health does not happen overnight!!



# MEASURING SOIL HEALTH

Soil Health Indicators are **NOT** an end to themselves



Soil health indicators are **tools** that help translate **management** practices into our desired **outcomes**

# SOIL HEALTH ASSESSMENT: COMMON INDICATORS

## Soil Biology

- Respiration potentials
- Number and diversity of mycorrhiza, and earthworms
- Diversity of macro and microorganisms
- Microbial profiling, Enzymatic activity
- Soil proteins

## Soil Chemistry

- Soil organic matter content
- Total C and N content, Active C
- Inorganic N
- pH, Salinity content
- Heavy metals: lead, copper, nickel, zinc
- Electrical conductivity, CEC
- Macro & micronutrients

## Soil Physical

- Bulk density
- Aggregate stability
- Available water capacity
- Water-filled pore space



Time

Source: Nunes et al. (2021)

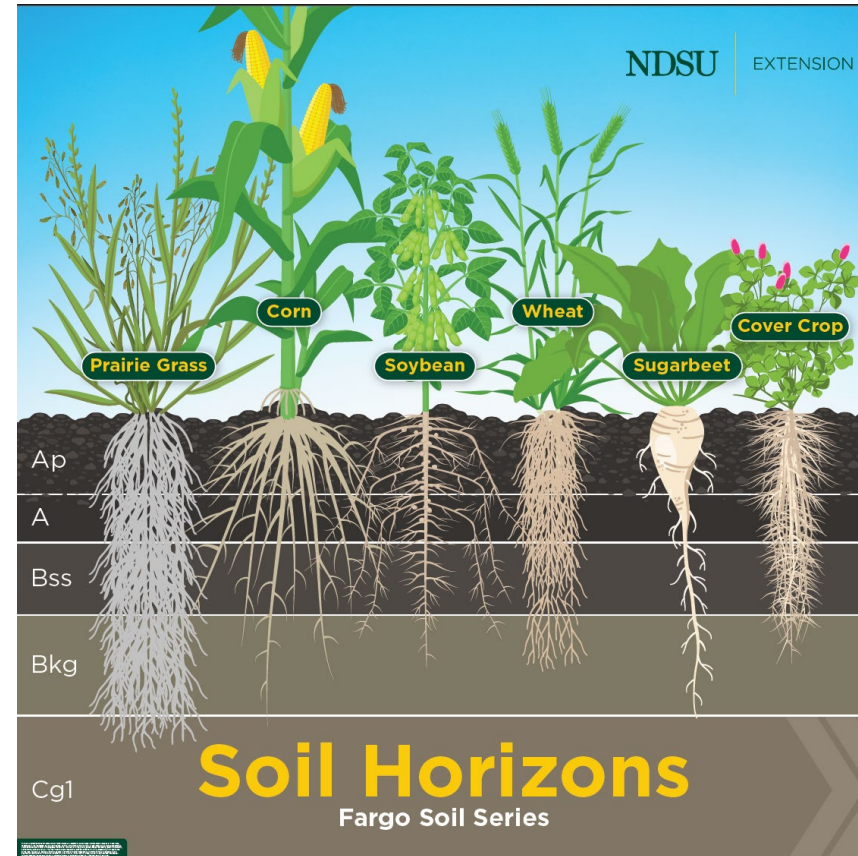
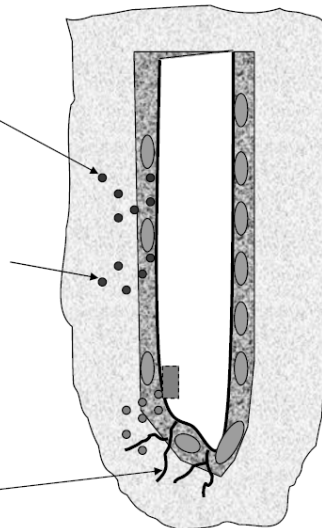
Slide courtesy: Dr. Krupek, Ohio State University

# MANAGING SOIL MICROBES

- Most microbes are found in the rhizosphere.
- Rhizosphere is the area surrounding plant roots.

## Plant derived organic materials in the rhizosphere

- Exudates
  - low molecular weight compounds released from plant cells in a non-metabolic manner (leakage)
- Secretions
  - compounds metabolically released from plant cells
- Lysates
  - compounds released from moribund cells during autolysis
- Plant mucilage
  - plant polysacchrides



# MANAGING SOIL MICROBES

- Soil health principles

Management

Cover crops

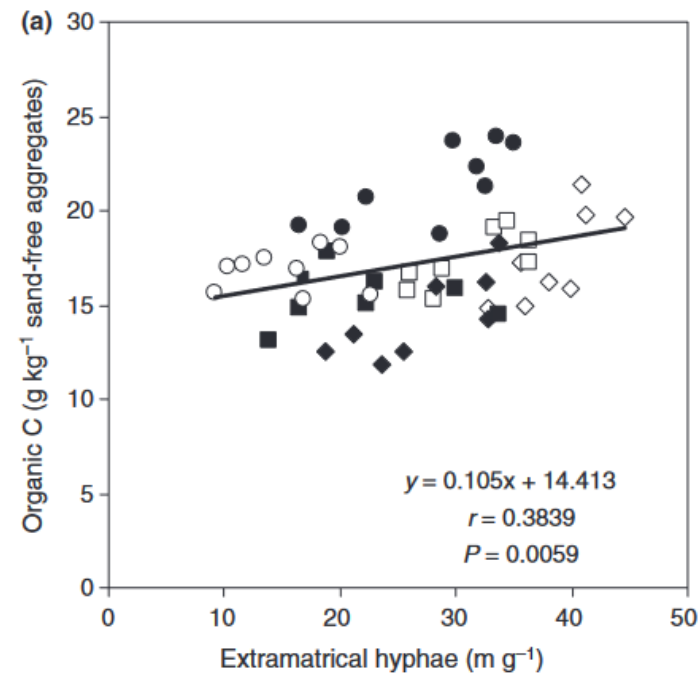
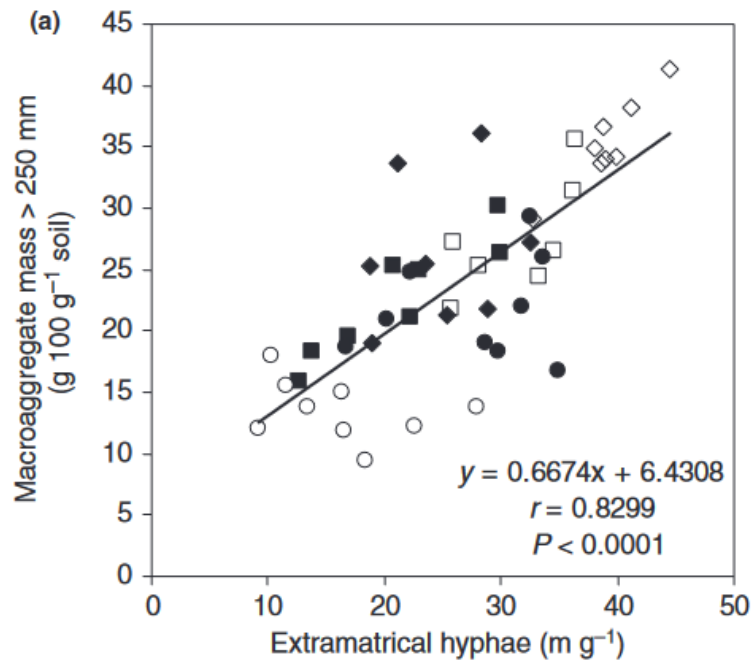


# MANAGING SOIL MICROBES

- Relationship between **fungi**, **aggregate stability**, and **carbon**

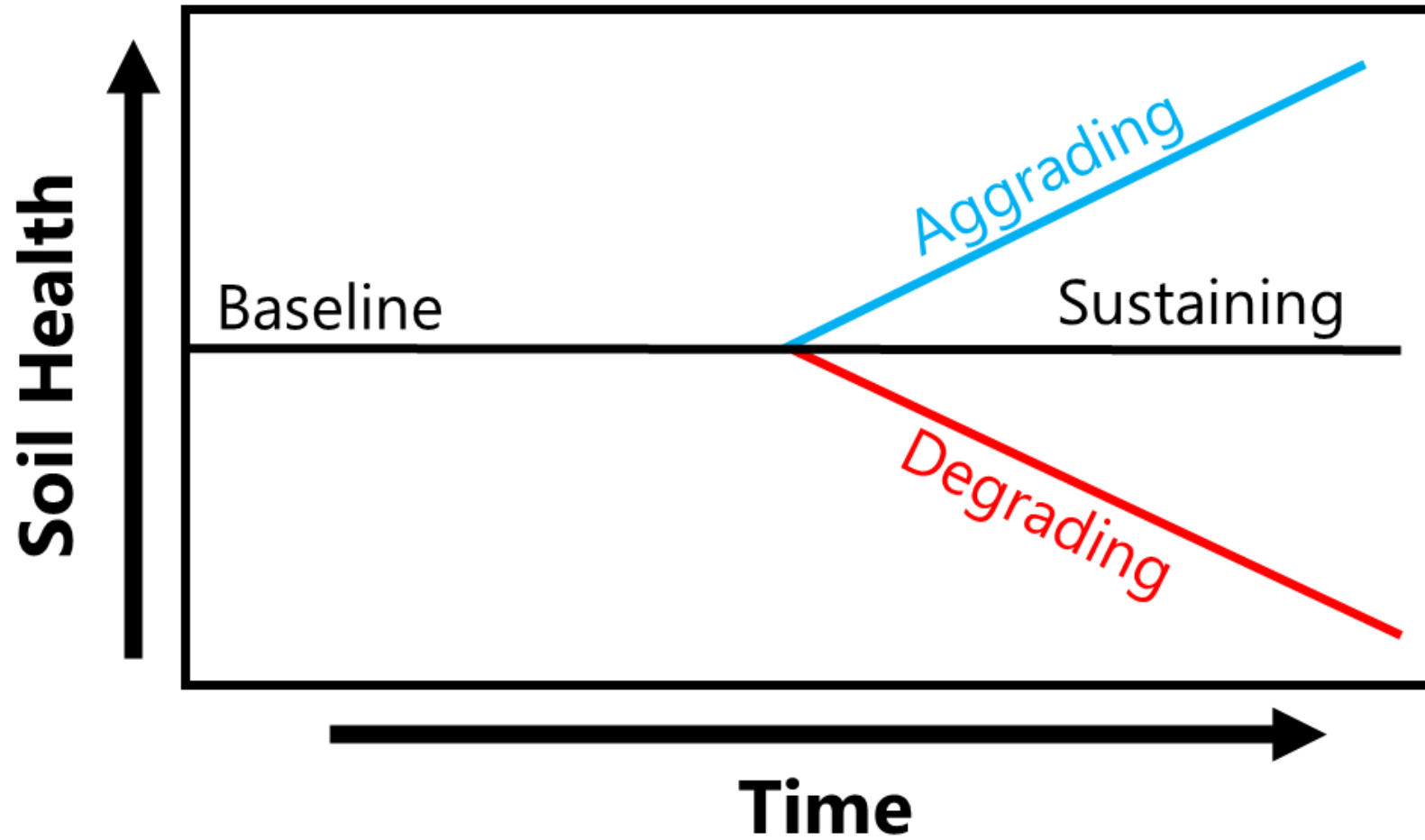


Aggregates  
Fungi  
Carbon



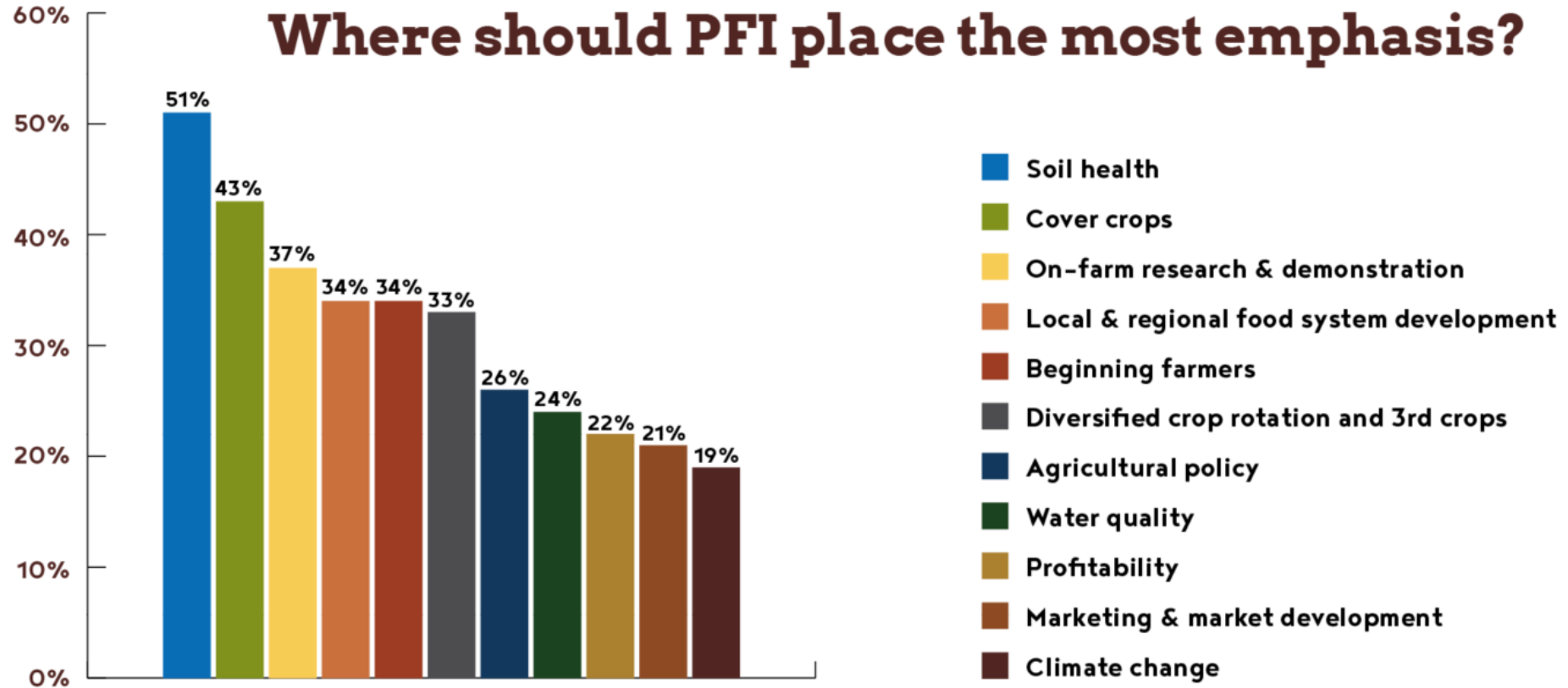
Higher SOM  
Increased  
biodiversity

# MONITORING SOIL HEALTH



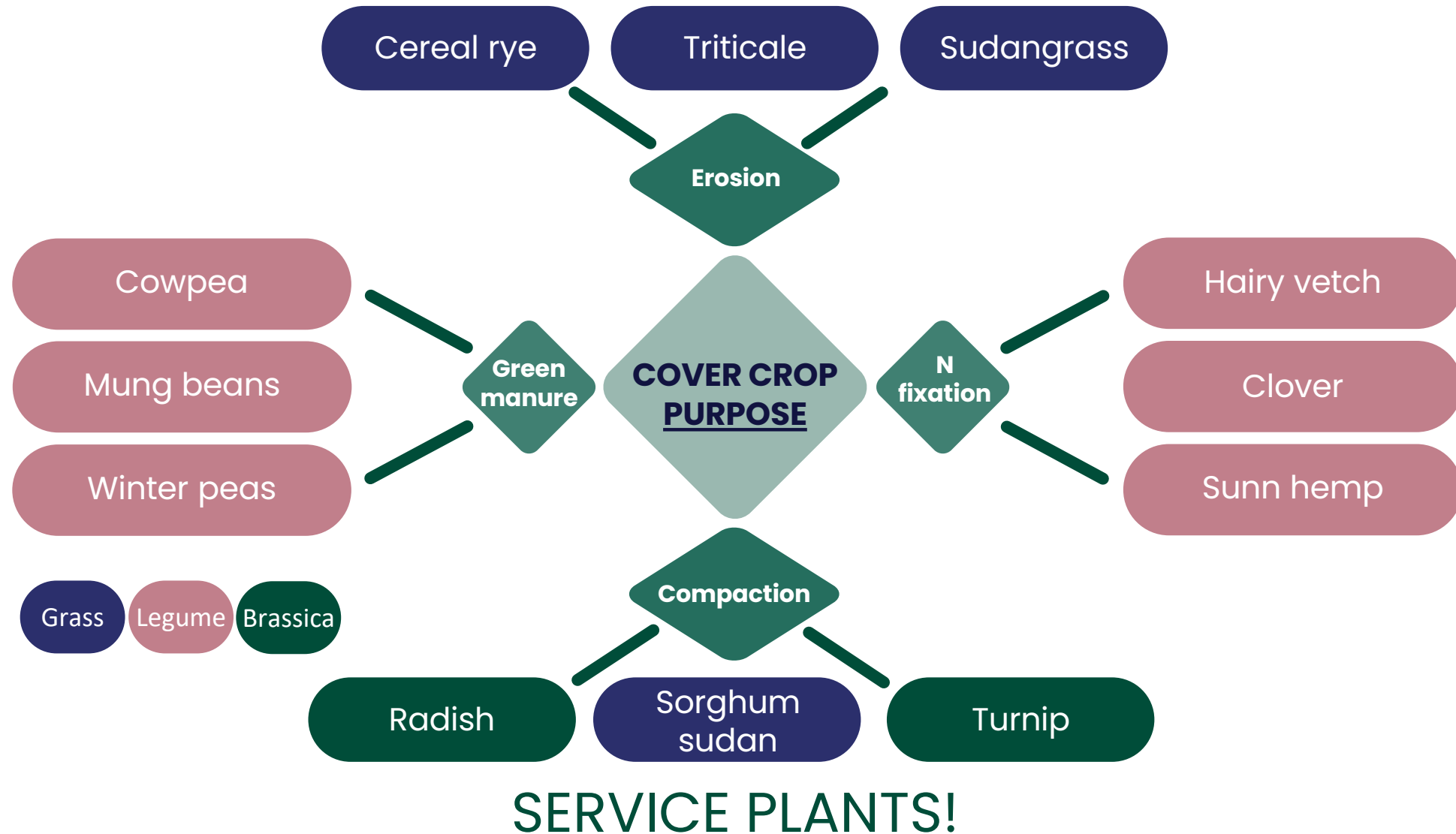
# SOIL HEALTH AND COVER CROPS

Soil Health and Cover Crops: A Topic Of Interest Across Farmers, Growers and Producers



Source: Practical Farmers of Iowa Survey Results. <https://practicalfarmers.org/2024/01/a-birds-eye-view/>

# SOIL HEALTH AND COVER CROPS



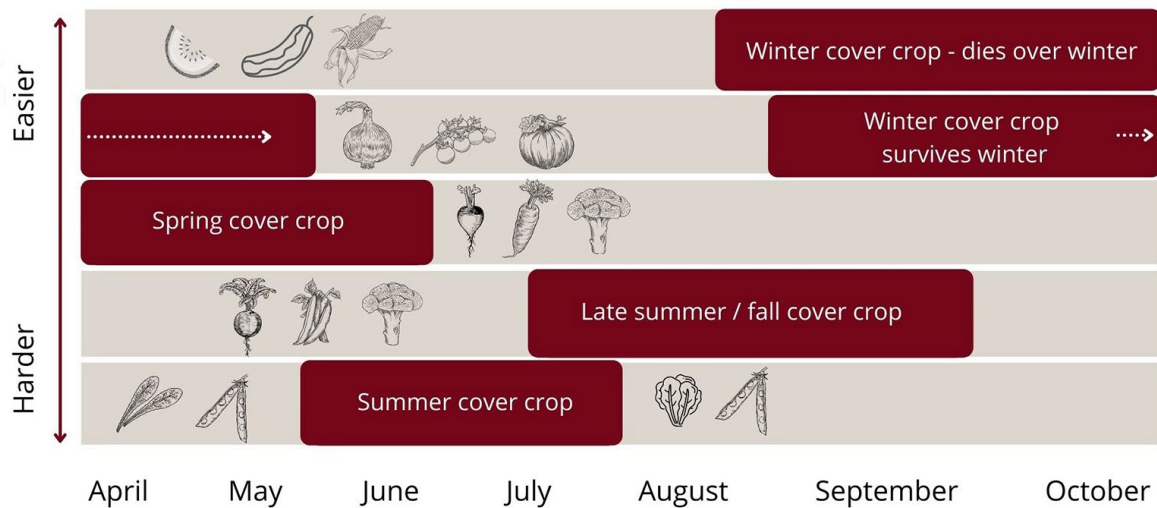
# SOIL HEALTH AND COVER CROPS



# SOIL HEALTH AND COVER CROPS

- Consider a “target cash crop”
  - Early spring crops, warm season crops, and fall cash crops
  - Manage your space in blocks based on harvest times

Cover Crop Timing Options for Minnesota Vegetable Growers



Source: University of Minnesota Extension



## Cover Crop Chart

GROWTH CYCLE	PLANT ARCHITECTURE	RELATIVE WATER USE
A = Annual	Υ = Upright	● = Low
B = Biennial	* = Upright-Spreading	●● = Medium
P = Perennial	≡ = Prostrate	●●● = High



--COOL--				--WARM--															
--GRASS--		BROADLEAF				--GRASS--													
A	ANNUAL FESCUE						A	BROWNTOP MILLET											
A	BARLEY						A	AMARANTH											
							A	FOXTAIL MILLET											
A	OAT	A/B	CAMELINA	A/P	MUSTARD	A	BALANSA CLOVER	A	CHICKPEA	A/P	MEDIC	A	COWPEA	A	CLUSTER BEAN	A	BUCKWHEAT	A	PEARL MILLET
A	WHEAT	A	PHACELIA	A/B	CANOLA	A	BERSEEM CLOVER	A	PEA	A	LUPIN	A/P	LABLAB	A/P	JACK BEAN	A	QUINOA	A	PROSO MILLET
A/B	ANNUAL RYEGRASS	A	FLAX	A	RADISH	A	CRIMSON CLOVER	A	LENTIL	A	FABA BEAN	A/P	FENUGREEK	A	VELVET BEAN	A	CHICORY	A	GRAIN SORGHUM
A	CEREAL RYE	A	KALE	A	TURNIP	B/P	RED CLOVER	A/P	LESPEDEZA	A/B	SWEET CLOVER	A/P	PIGEONPEA	A	MUNG BEAN	A	CUCURBITA	A	SUDAN GRASS
A	TRITICALE	A	SPINACH	A	BEET	P	WHITE CLOVER	P	BIRDSFOOT TREFOIL	P	ALFALFA	A	PARTRIDGE PEA	A	SOYBEAN	A	SAFFLOWER	A	TEFF
P	SALINE TOLERANT	A/B	CHARD	A/B	CARROT	P	KURA CLOVER	A/B	VETCH	P	SAINFOIN	A	SUNNHEMP	A/P	PEANUT	A	SUNFLOWER	A	CORN

V 4.0 April 2023

◆ Additional Information

Slide courtesy: Dr. Krupek, Ohio State University

# SOIL HEALTH AND COVER CROPS: TERMINATION

- Cover crop species, growth state, weather, and cover cropping goals should all be considered
- Balance between benefits and potential penalties to the next crop
- **NATURAL TERMINATION:** Winter kill of summer/fall grasses, radish, turnip, peas
- **CHEMICAL TERMINATION:** Herbicides
- **MECHANICAL TERMINATION:** Tarp, roller/crimper, mower, chain. You can be creative!

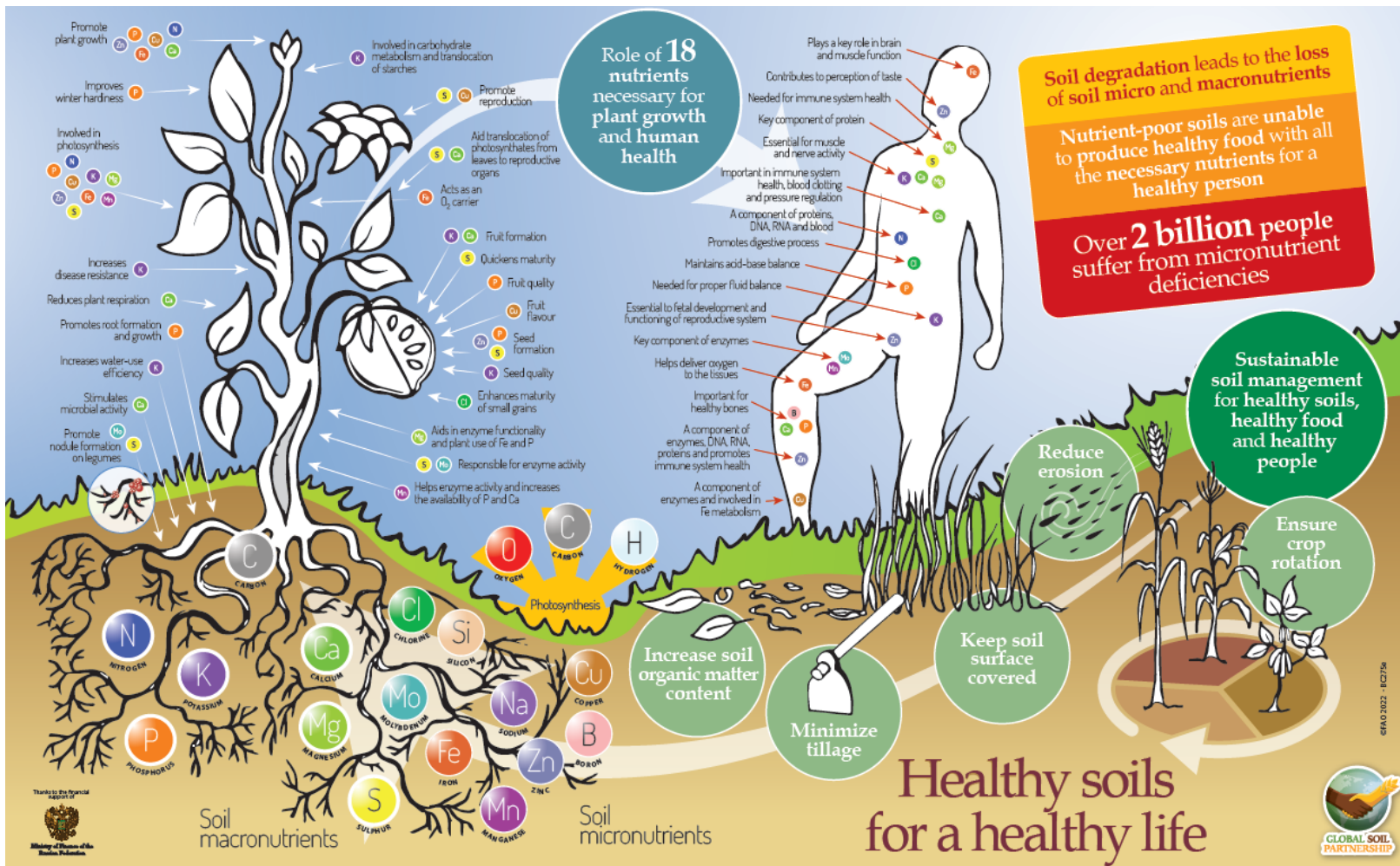


Tarping. Source: University of Wisconsin-Madison Extension



Roller crimper

# SOIL THE FOUNDATION OF NUTRITION



- More than half of the world today suffers from a deficiency of micronutrients despite adequate daily caloric intake
- The first cause of malnutrition is soil deficiency, followed by low food intake.

# ONE HEALTH: SOIL, ANIMAL, ENVIRONMENTAL, HUMAN

Healthy soils for healthy plants for healthy humans

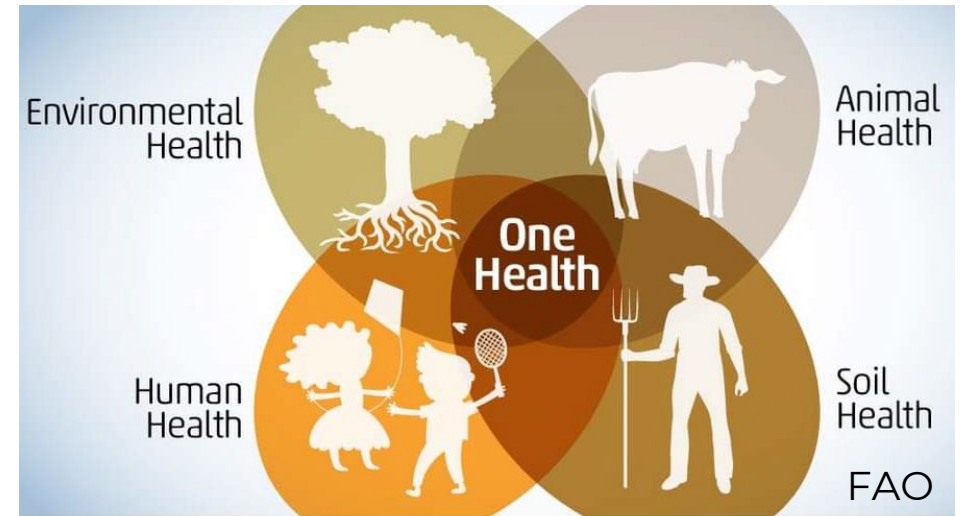
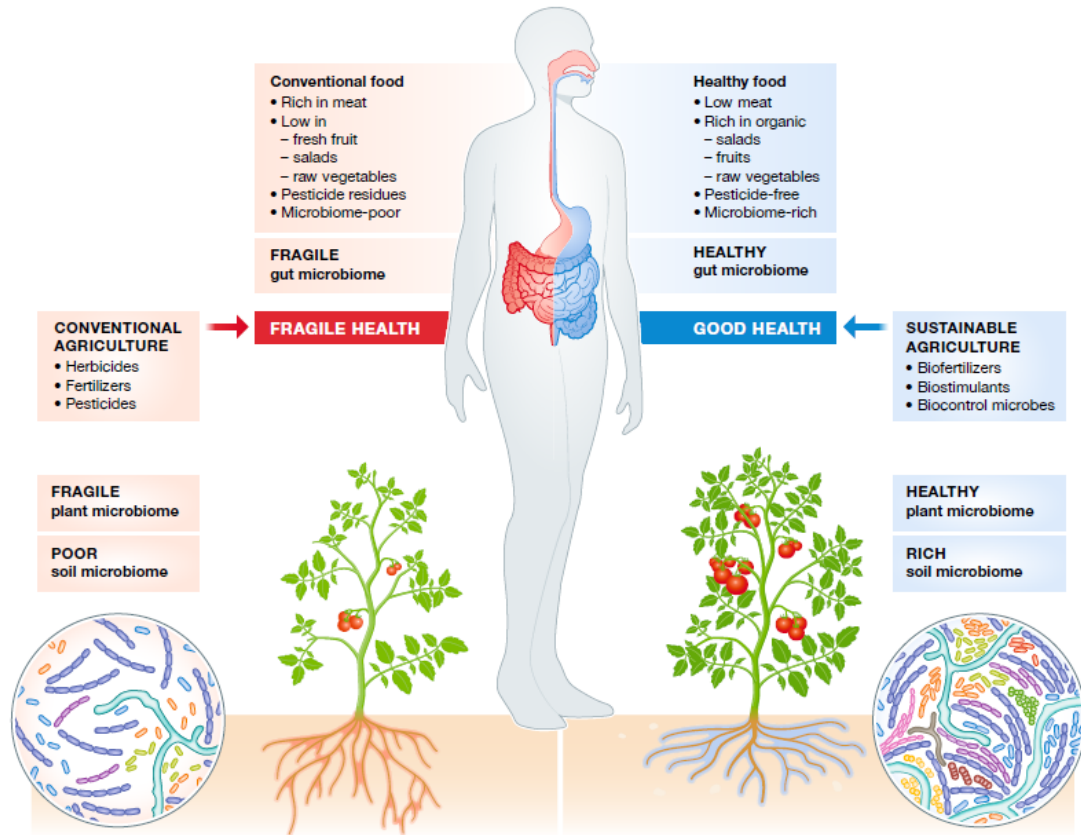
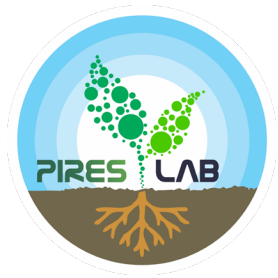


Figure 2. The direct and indirect effects of the plant microbiota on the human gut microbiome.

Source: Heribert Hirt

# Thank you! Questions...

**Carlos Pires, Ph.D.**  
Assistant Professor  
Extension Soil Health Specialist



**NDSU** NORTH DAKOTA  
STATE UNIVERSITY

