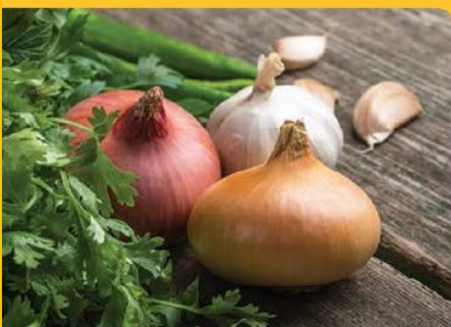




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# 2025

field to fork



# Upcoming Webinars

**See you in 2026!**





Presenter

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Chat



Raise Hand



Q&A

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- **Please complete the short online survey** that will be emailed to you after today's webinar. It will take just a couple minutes!
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***Acknowledgement: This project was supported by the U.S. Department of Agriculture's (USDA) Agricultural Marketing Service through SCBG24-246. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.***





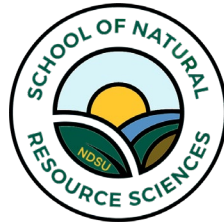
May 7

# Healthy Soil, Healthy Food

Carlos Pires, NDSU Extension soil health specialist and assistant professor

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**mail:**  
U.S. Department of Agriculture  
Office of the Assistant Secretary for Civil Rights  
1400 Independence Avenue, SW  
Washington, D.C. 20250-9410; or

**fax:**  
(833) 256-1665 or (202) 690-7442;

**email:**  
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**correo postal:**  
U.S. Department of Agriculture  
Office of the Assistant Secretary for Civil Rights  
1400 Independence Avenue, SW  
Washington, D.C. 20250-9410; o

**fax:**  
(833) 256-1665 o (202) 690-7442;

**correo electrónico:**  
program.intake@usda.gov.

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Form AD-3027-A—Revised/Printed/Revised: July 2019 Nelle compilazioni al Formulario AD-3027-A/Revised: July 2019

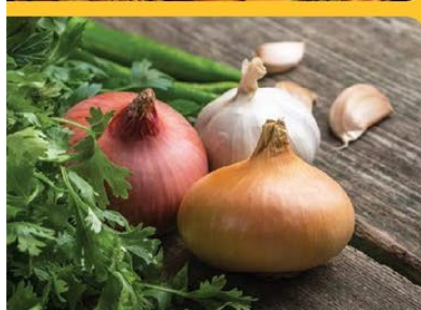




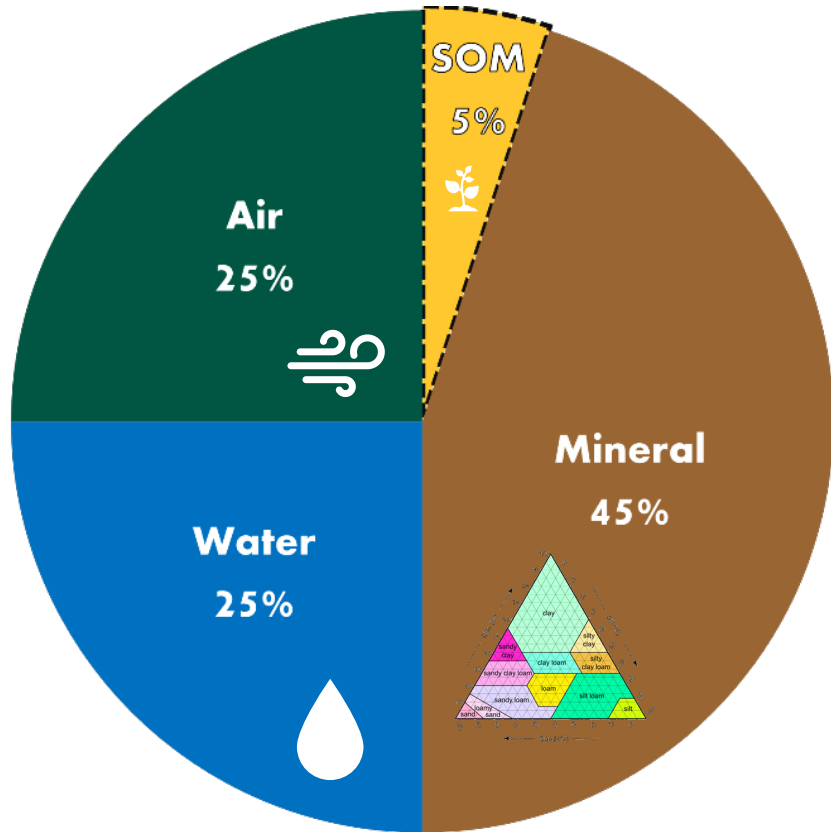
NDSU | EXTENSION

# 2025

field to fork



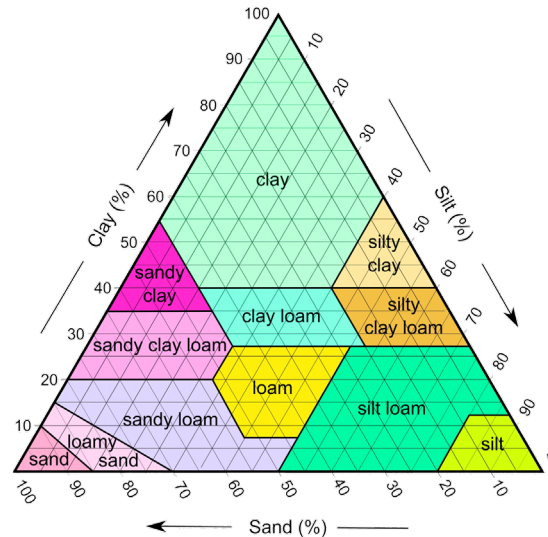
# SOIL COMPOSITION



Ideal soil composition

What happens if we...

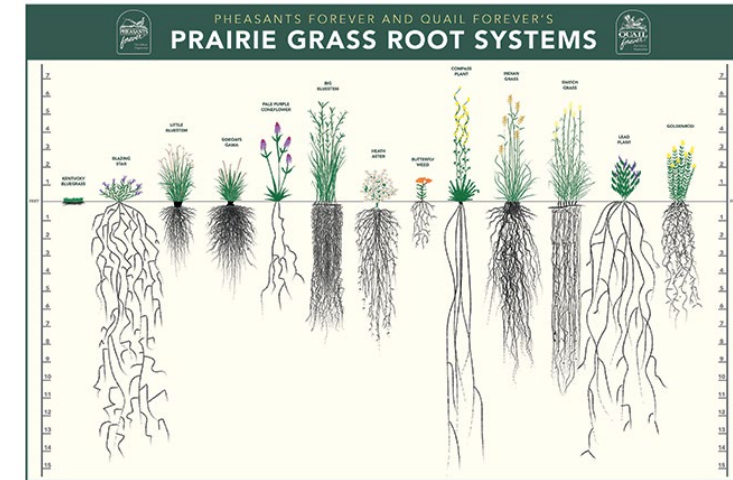
- Increase the water fraction?
- Increase the mineral fraction?
- Change the mineral fraction?



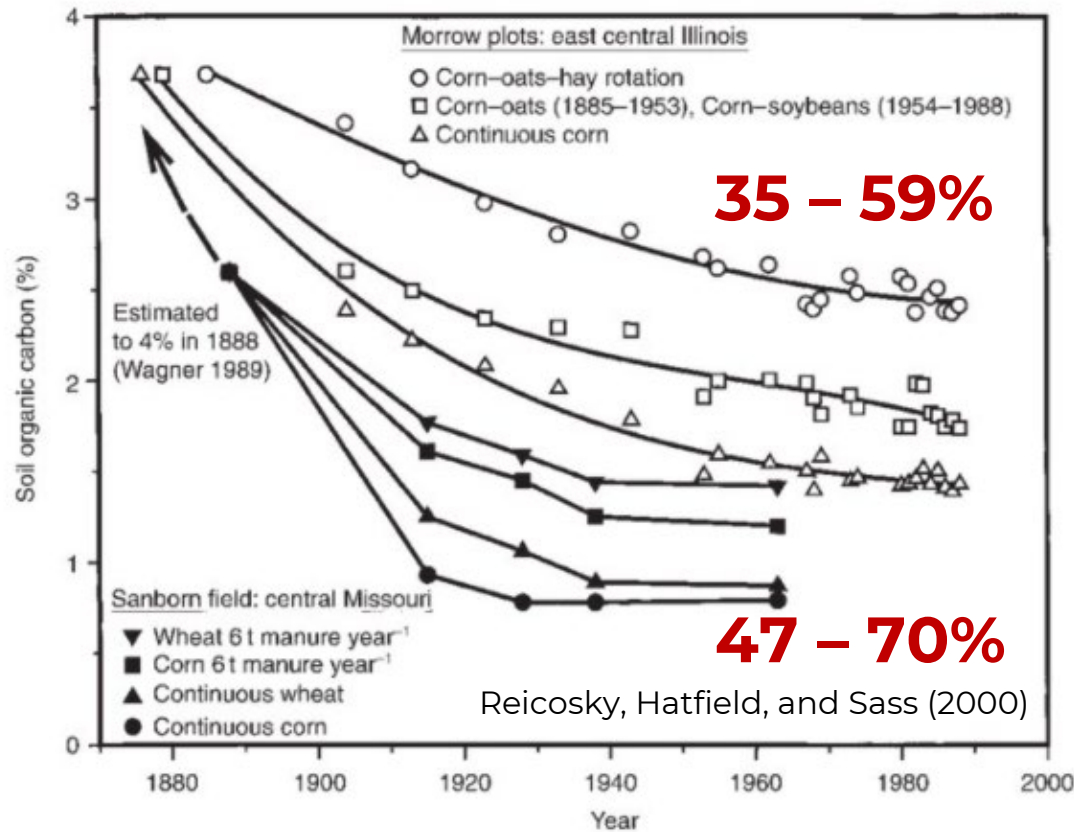


# WHY ARE THE UPPER MIDWEST SOILS SO RICH IN ORGANIC MATTER (OR USED TO BE)?

- 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



# Soil functions

Soils deliver ecosystem services that enable life on Earth

2015  
International  
Year of Soils  
[fao.org/soils-2015](http://fao.org/soils-2015)



Food and Agriculture  
Organization of the  
United Nations

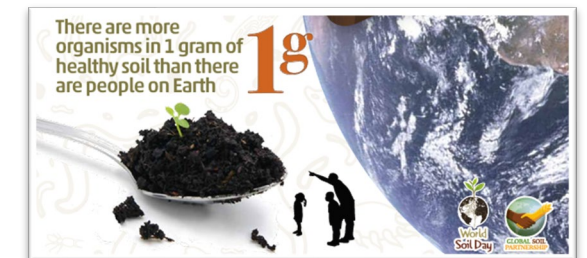
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Federal Department of Economic Affairs,  
Education and Research EAER  
Federal Office for Agriculture FOAG

# 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.

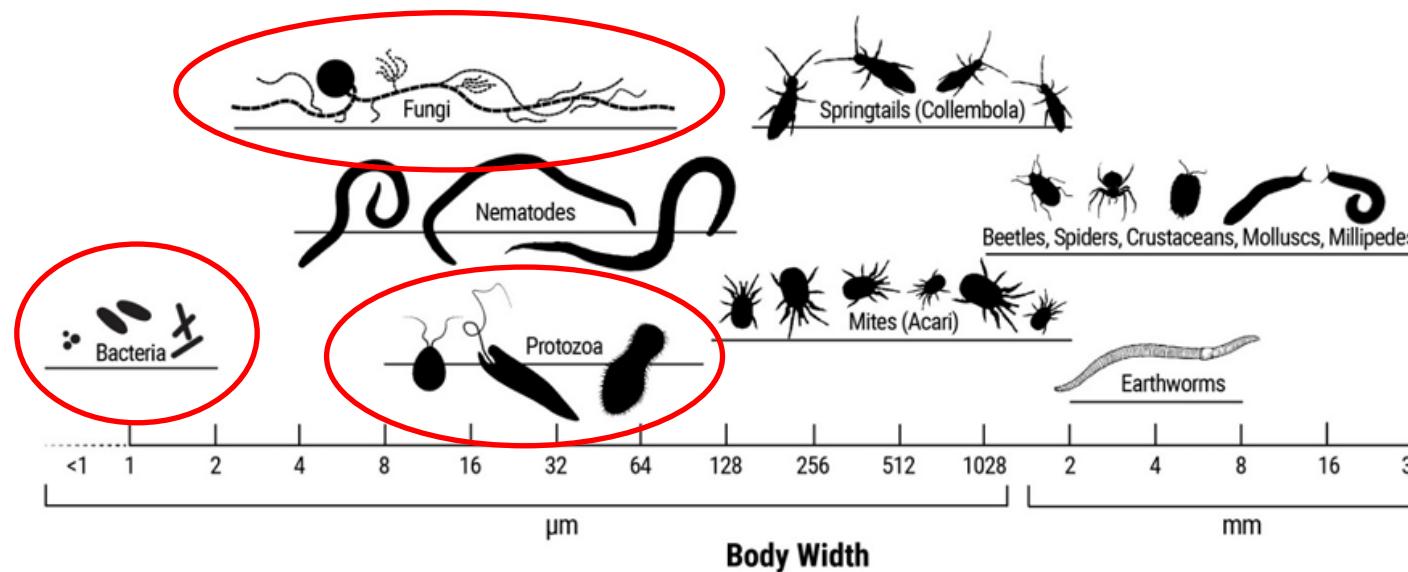
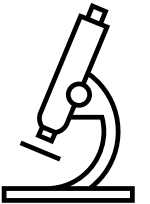


Fig. 1—Soil organisms grouped by class, showing the size of body width. Bacteria in the diagram represent all prokaryotes, bacteria and Archaea.

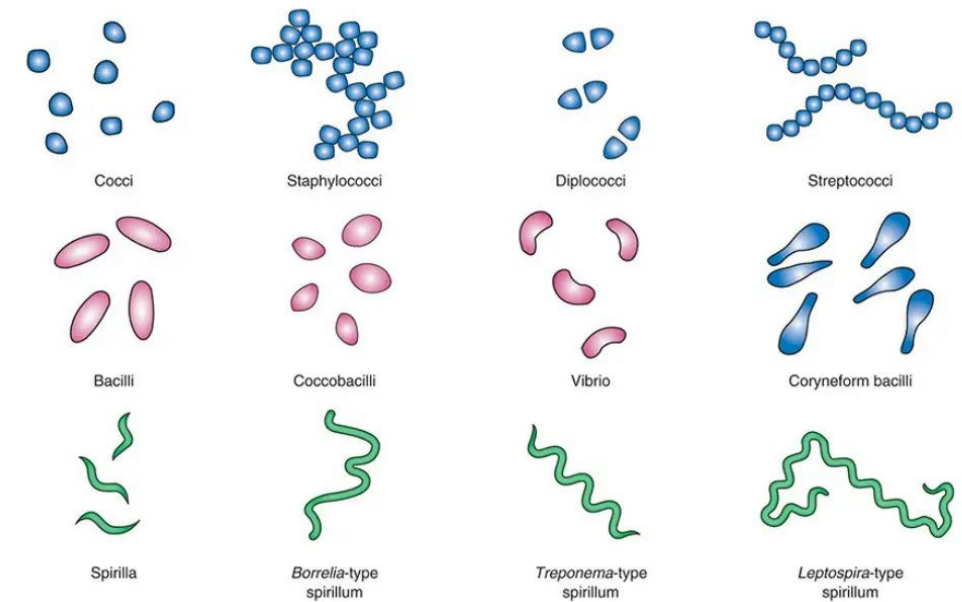
Brackin et al. (2017)



# BACTERIA

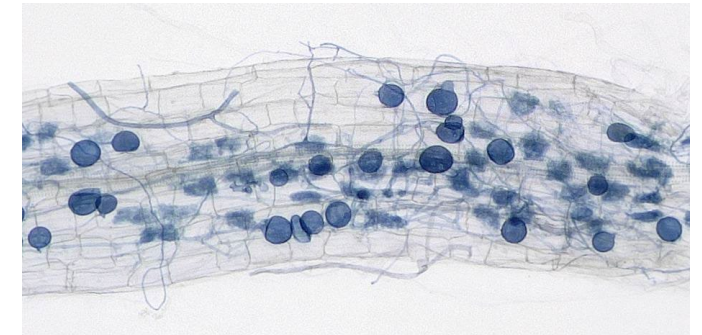
- Bacteria are simple, single-celled microorganisms
  - Fast growing
  - High energy requirements
  - High activity in tilled soils
  - Gram+ are water stress resistant
  - Gram- are not.
- Examples
    - Escherichia coli (E. coli)
    - Rhizobium – N fixation
    - Nitrobacter and Nitrosomonas – Nitrification
    - Azospirillum – Root growth

## Shapes



# FUNGI

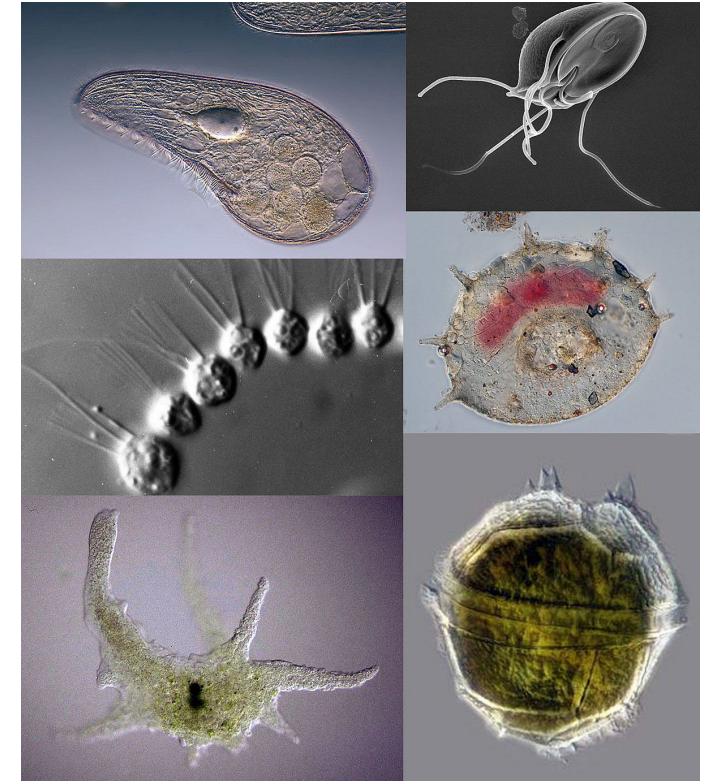
- Fungi are multi-cellular organisms.
  - The best-known fungi are mushrooms, molds, and yeast.
  - Fungi grow as long strands called hyphae (up to several yards long)
    - Mycelium is a network (bunch) of hyphae
  - Can be grouped as decomposers, mutualists, or pathogens.
- 
- Examples
    - Penicillium - known for producing the antibiotic penicillin
    - Trichoderma – biological control of insects
    - Arbuscular Mycorrhizal fungi
    - Fusarium – plant pathogen





# PROTOZOA

- Single-celled organisms
- Primarily eat bacteria
- The bacteria contain more N than the protozoa can utilize and some ammonium is released to plants.
- Examples
  - Amoeba
  - Giardia
  - Toxoplasma



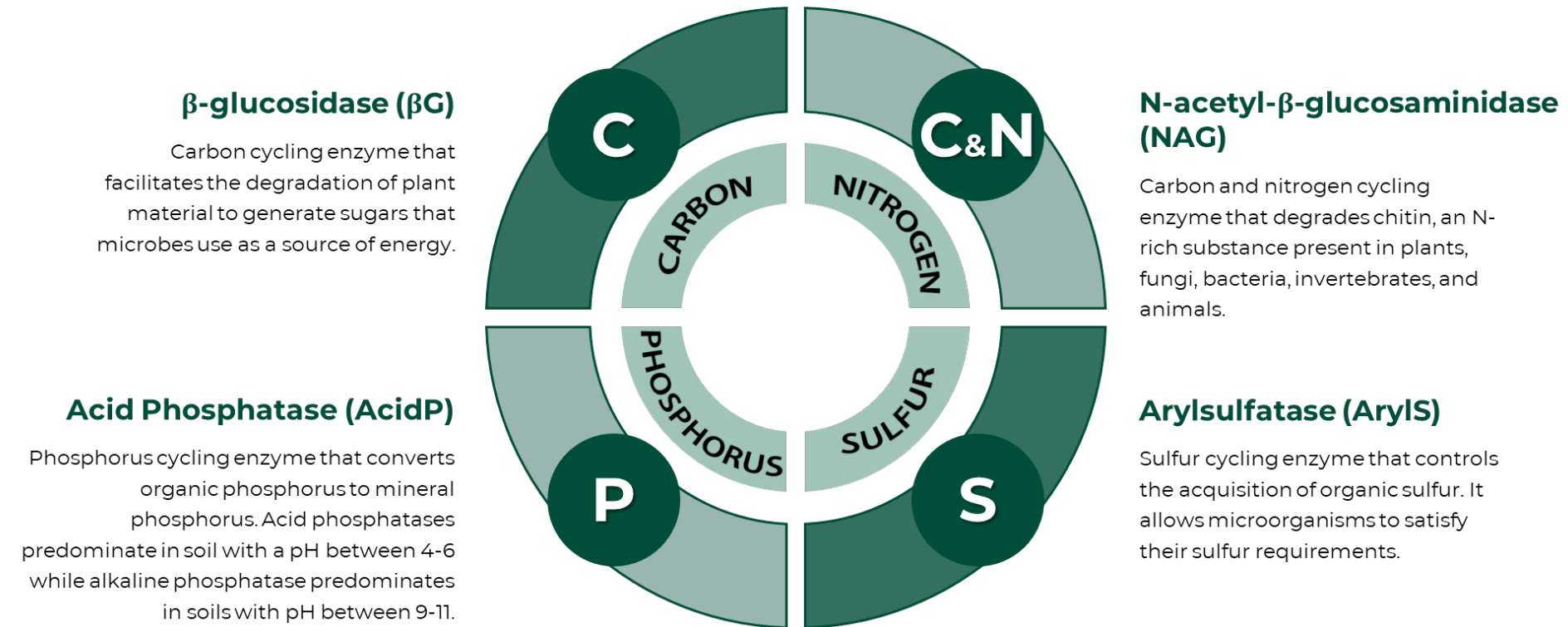
# THE ROLE OF SOIL MICROBES

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>



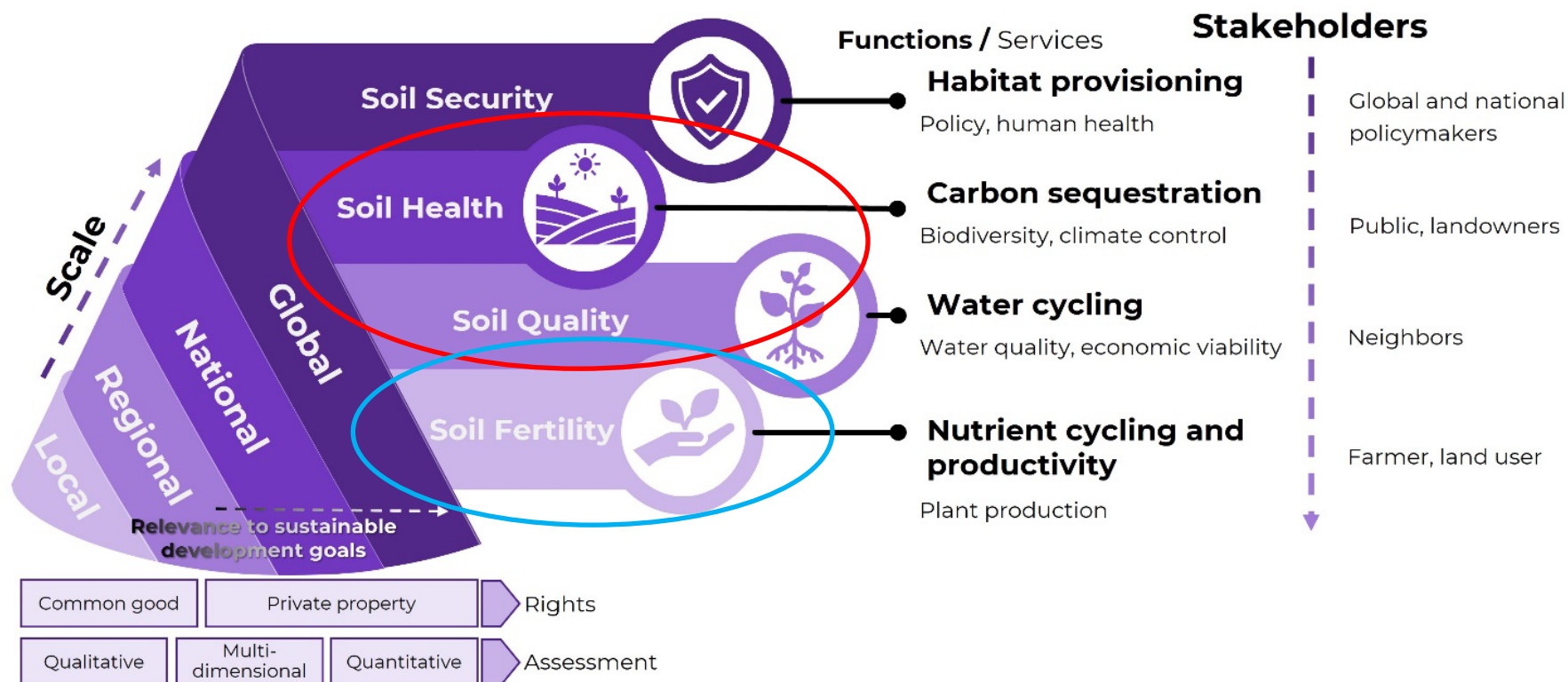
# ENZYMES

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



# SOIL HEALTH

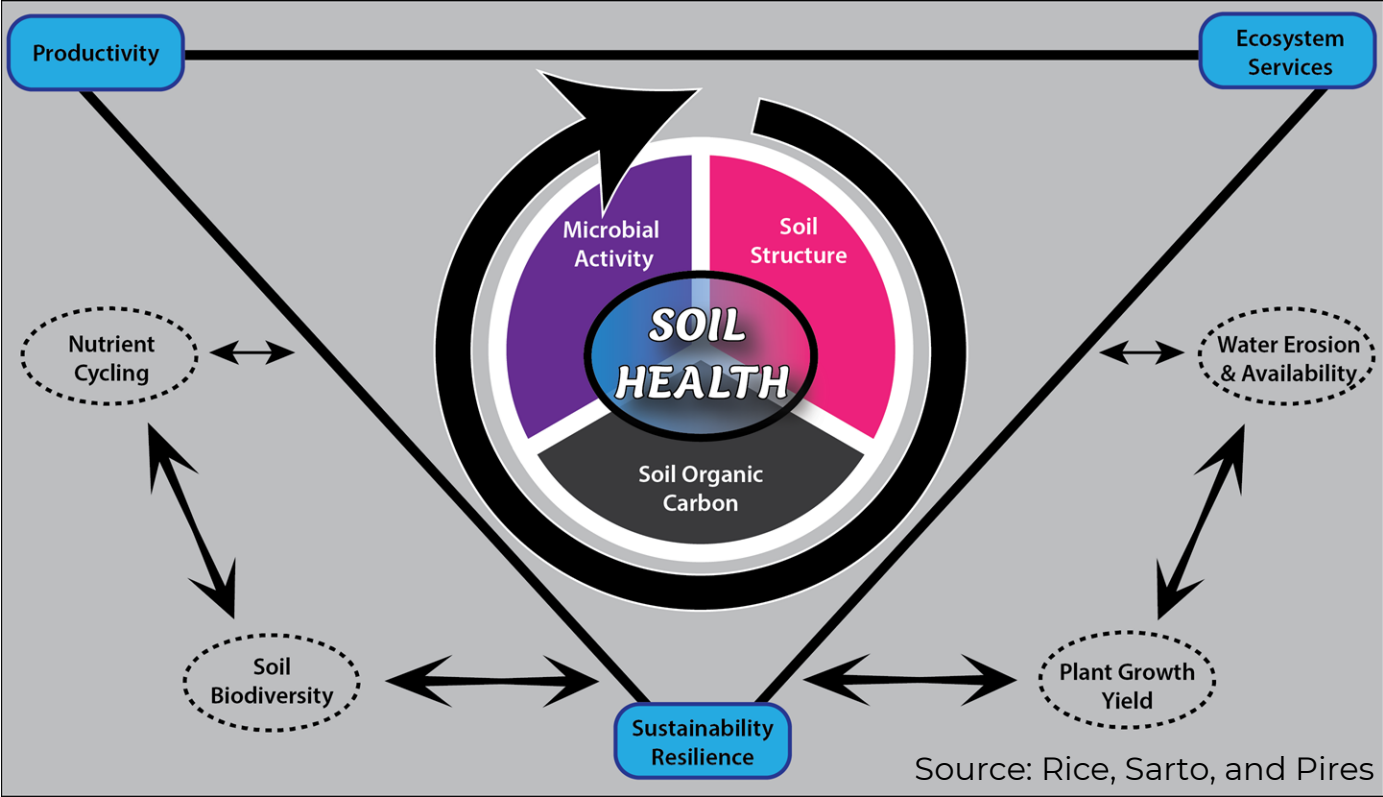
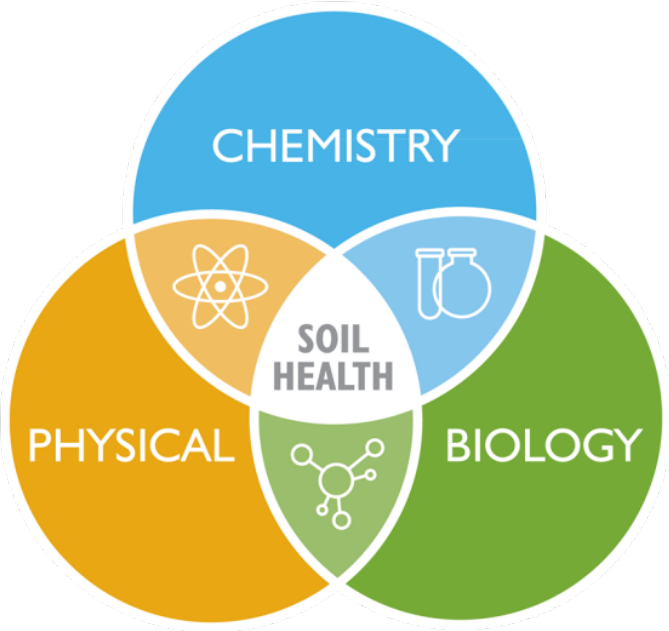
- The capacity of the soil to function as a living ecosystem and sustain plants, animals, and humans.



Relevant spatial scales, functions, ecosystem services, and stakeholders of soil security, health, quality, and fertility. The concepts also differ in the view of soil rights and assessments. Source: Adapted from Lehman et al. (2020).



# SOIL HEALTH



# SOIL HEALTH

## WHAT IS HEALTHY SOIL?

**Soil Particles**

Holds water

Holds air

**Dead Plants & Matter**

**Living Organisms**

### UNHEALTHY SOIL ❌

Poor structure

High salts

Weak growth

### HEALTHY SOIL ✅

Stable structure

Beneficial organisms

Vigorous growth

USU Extension Publications | July 2020 | Soils/01

Amanda Pratt - Small Farms Graphic Designer, Katie Wagner - Horticulture Faculty, Melanie Stock - Small Farms Specialist  
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# SOIL HEALTH PRINCIPLES



## MINIMIZE DISTURBANCE

No-tillage, minimum tillage, strip tillage.



## MAXIMIZE SOIL COVER

Cover crops, residue management, cropping system, perennials



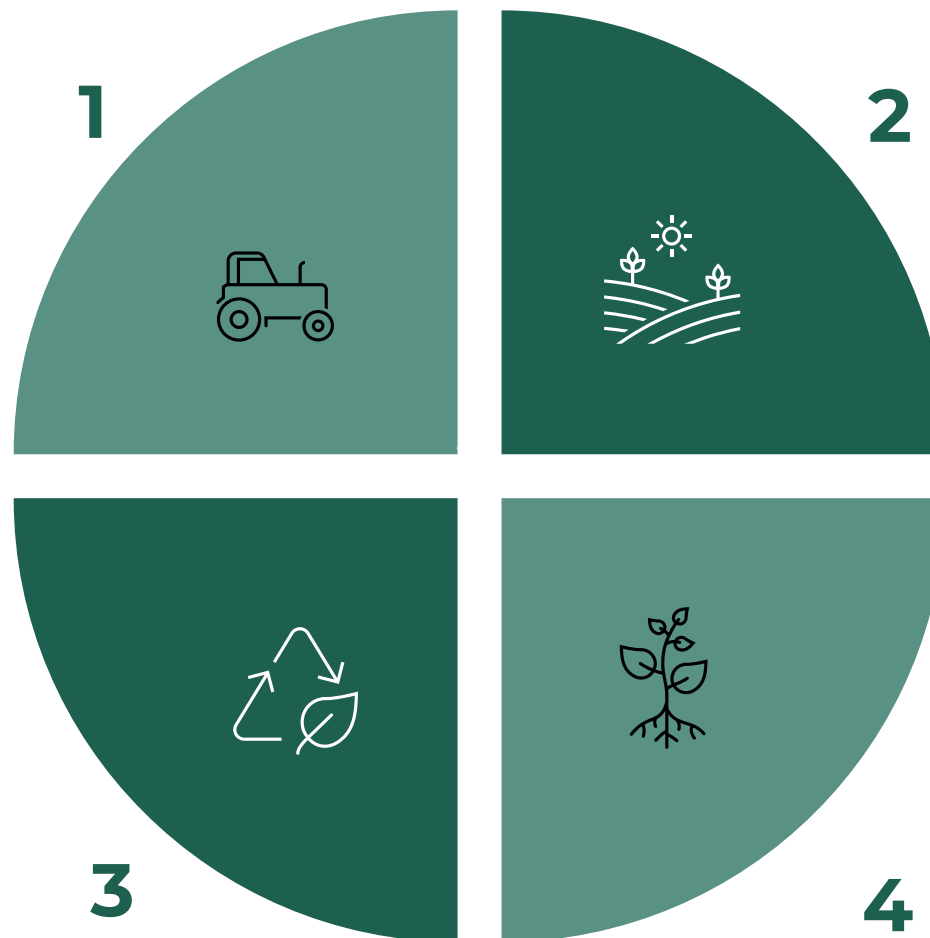
## MAXIMISE BIODIVERSITY

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



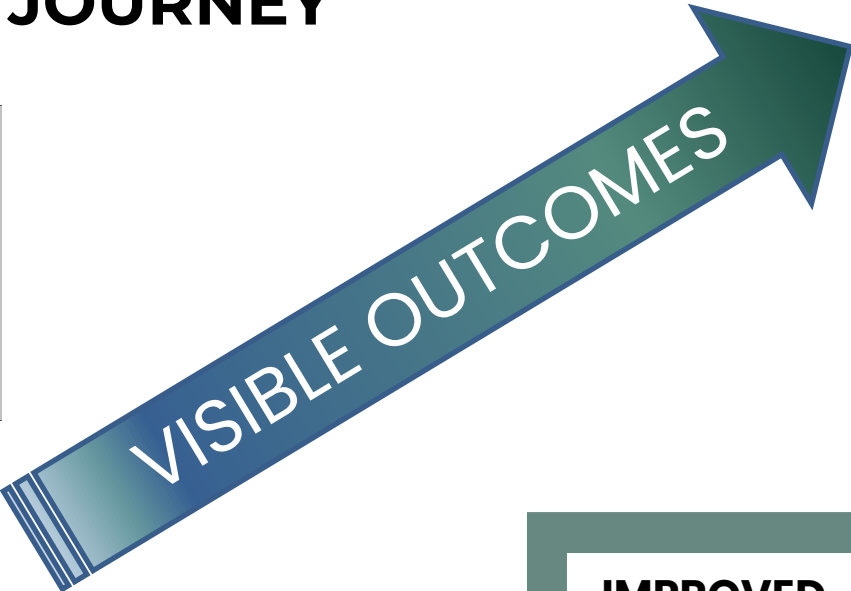
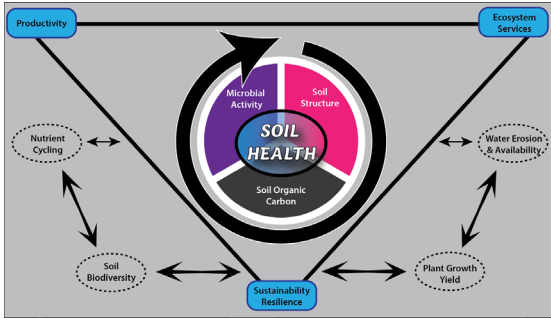
## MAXIMIZE CONTINUOUS LIVING ROOTS

Cove crops, reduce fallow



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

# SOIL HEALTH JOURNEY



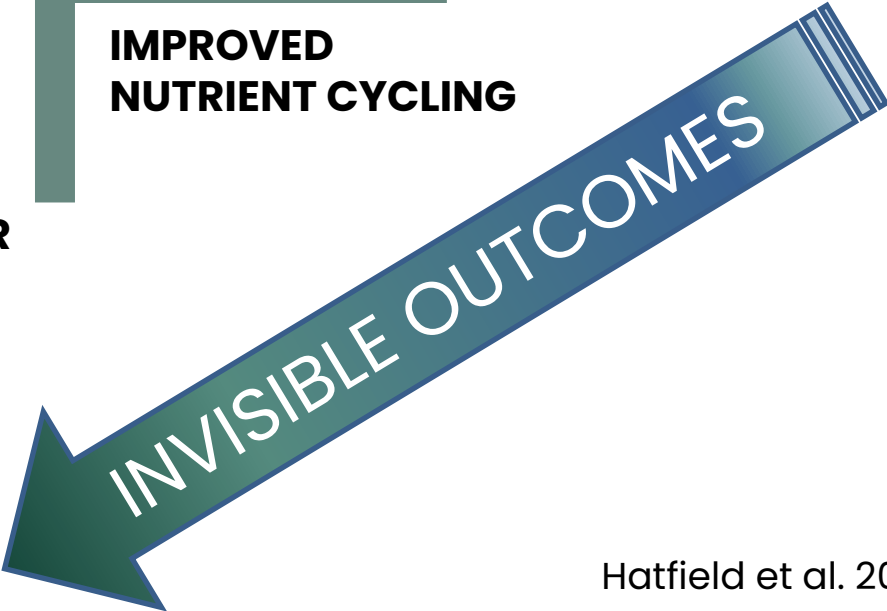
**IMPROVED WATER  
AVAILABILITY AND  
DRAINAGE**

**IMPROVED  
SOIL STRUCTURE**

**IMPROVED  
NUTRIENT CYCLING**

**ORGANIC MATTER  
TURNOVER**

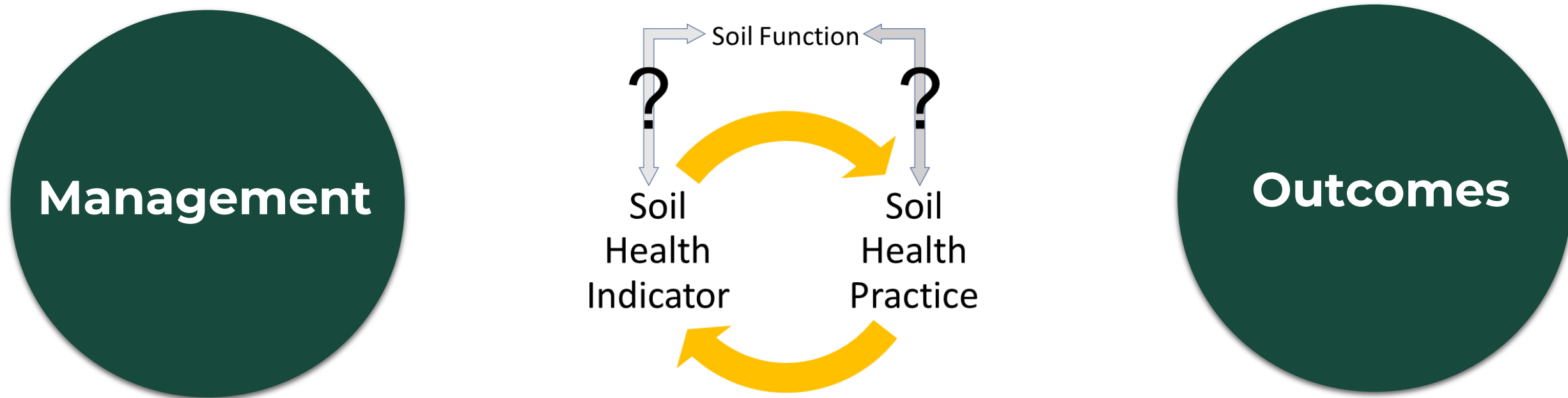
**BIOLOGICAL  
ACTIVITY**



Hatfield et al. 2017. Advances in Agronomy

# 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

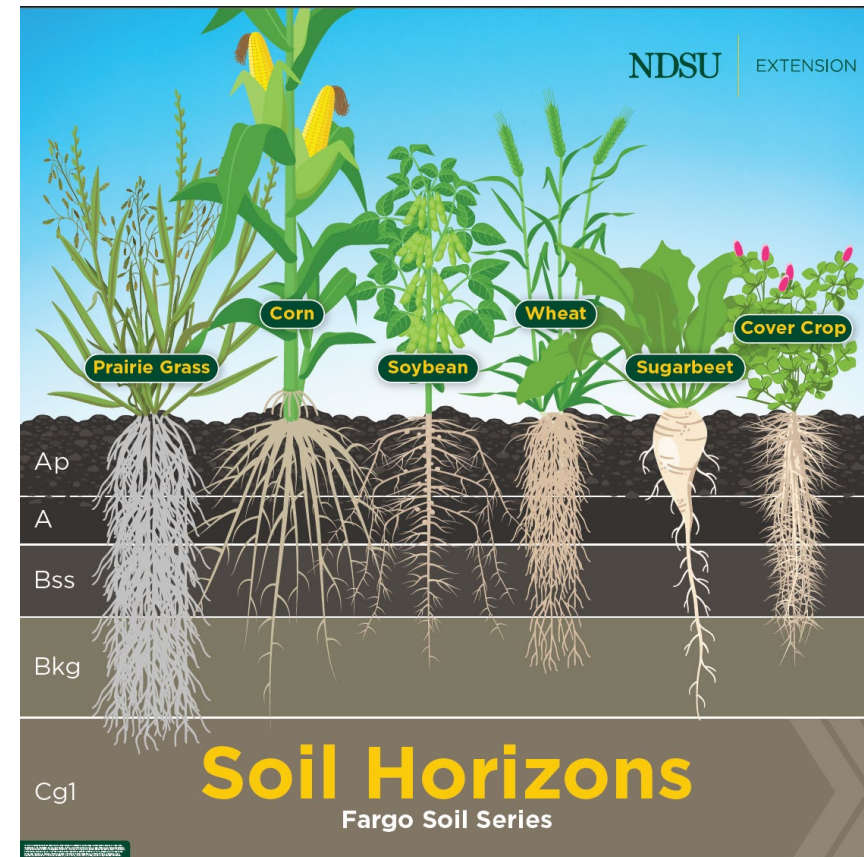
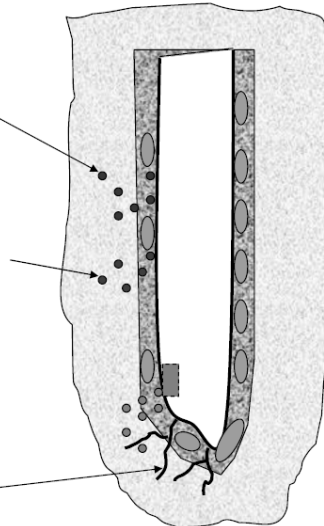
# MANAGING SOIL MICROBES

## Management

- 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 polysaccharides



# MANAGING SOIL MICROBES

- Soil health principles



Management

Cover crops

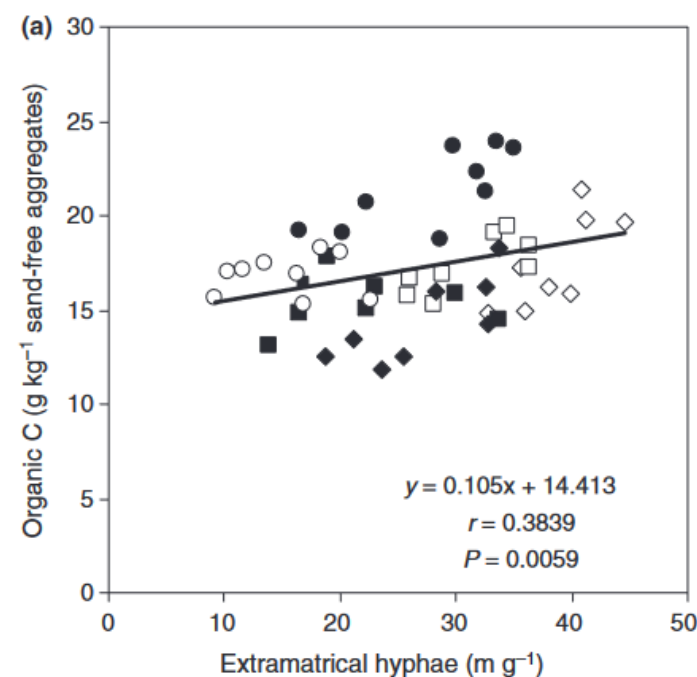
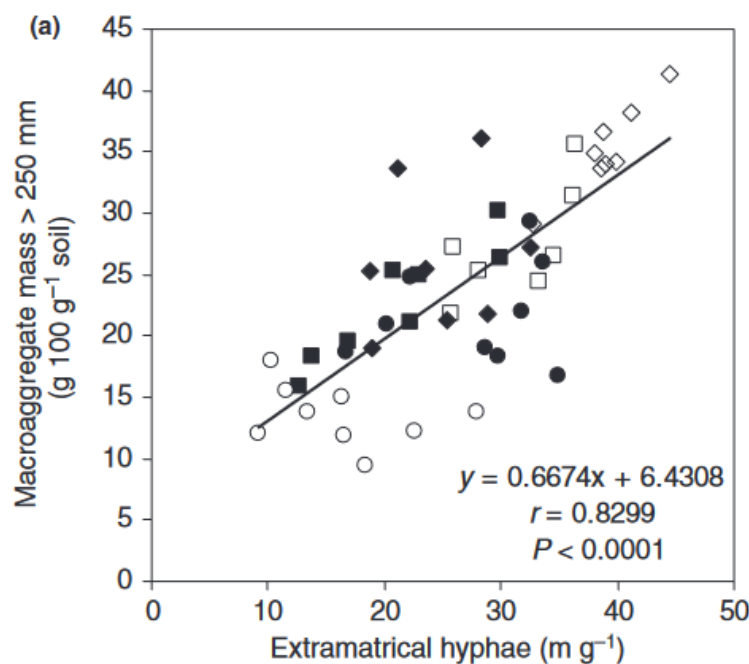


# MANAGING SOIL MICROBES

- Relationship between fungi, aggregate stability, and carbon

## Indicators

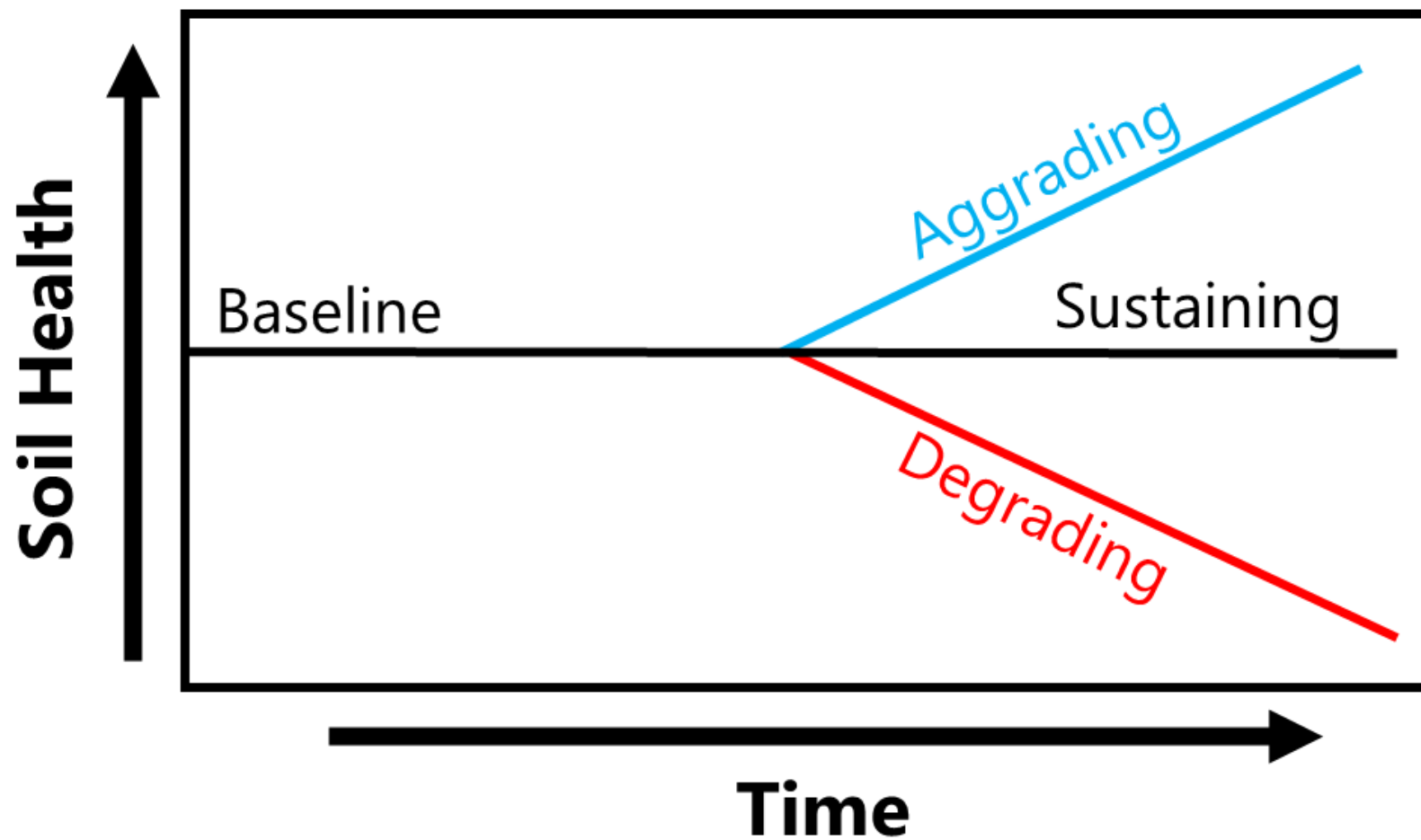
Aggregates  
Fungi  
Carbon



## Outcome

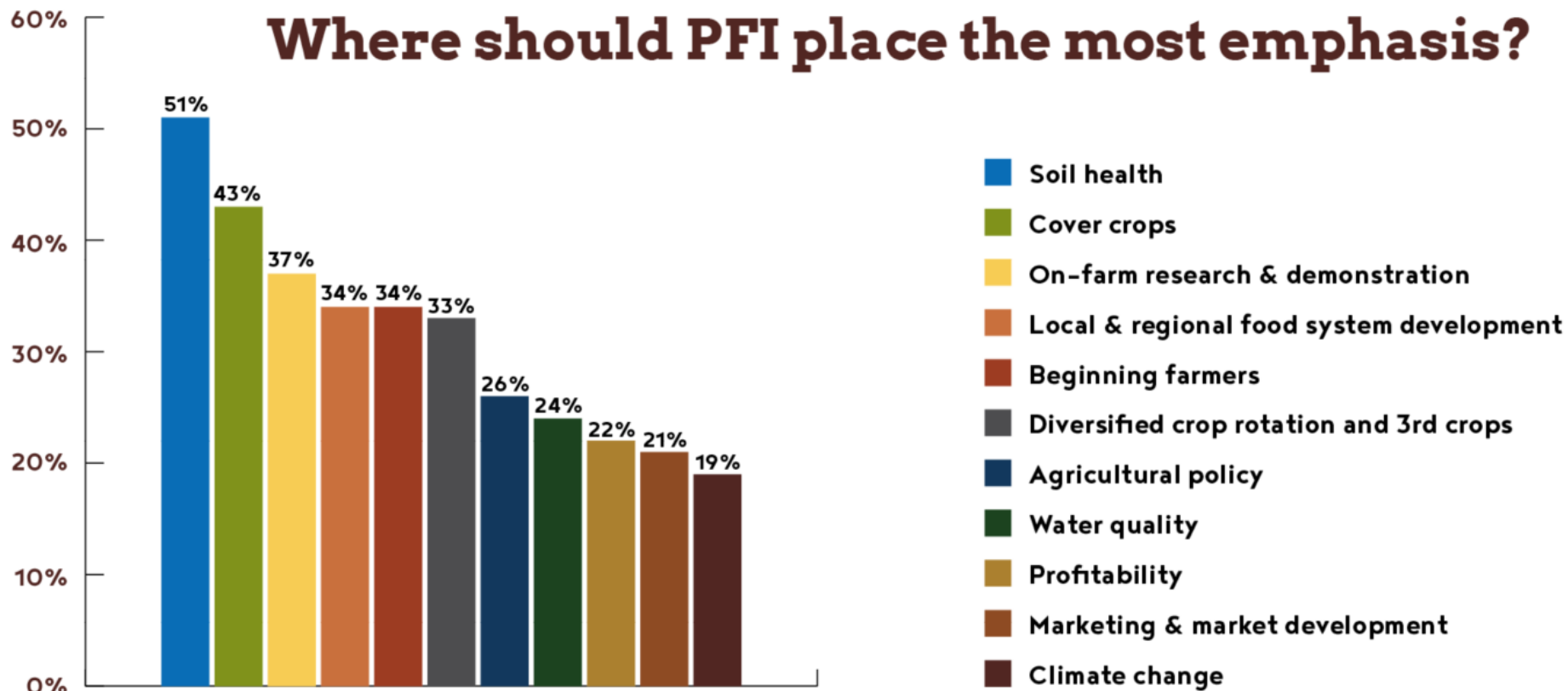
Higher SOM  
Increased  
biodiversity

# MONITORING SOIL HEALTH



# SOIL HEALTH AND COVER CROPS

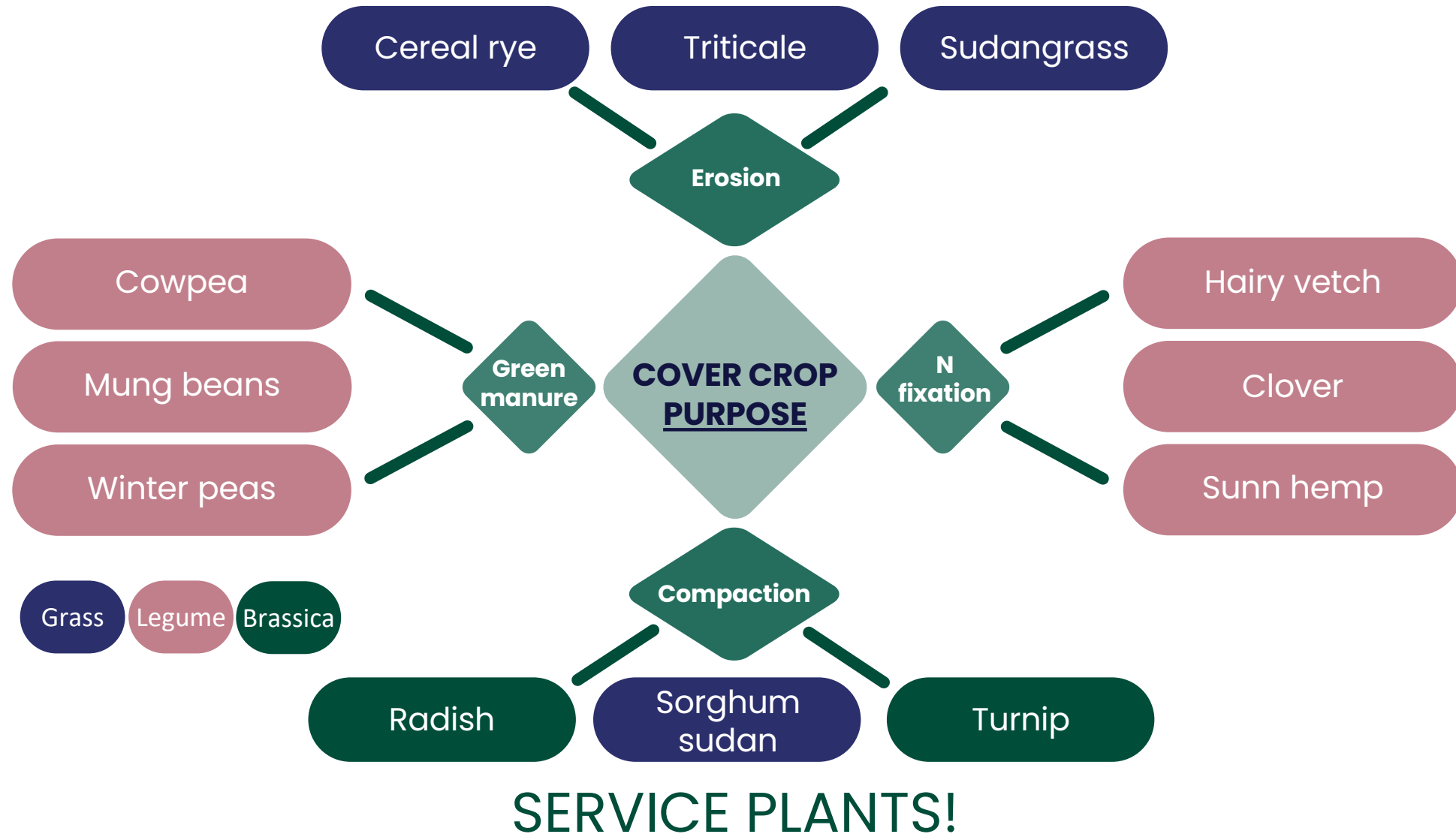
Soil Health and Cover Crops: A Topic Of Interest Across Farmers, Growers and Producers



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



# SOIL HEALTH AND COVER CROPS

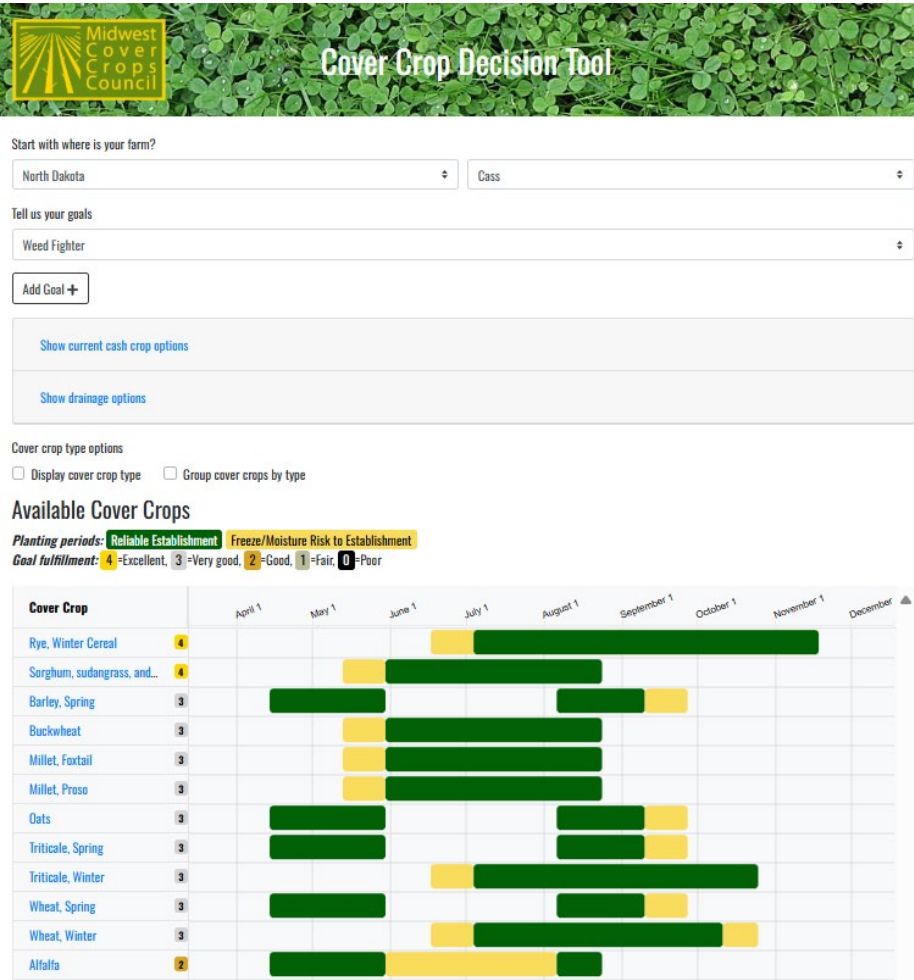
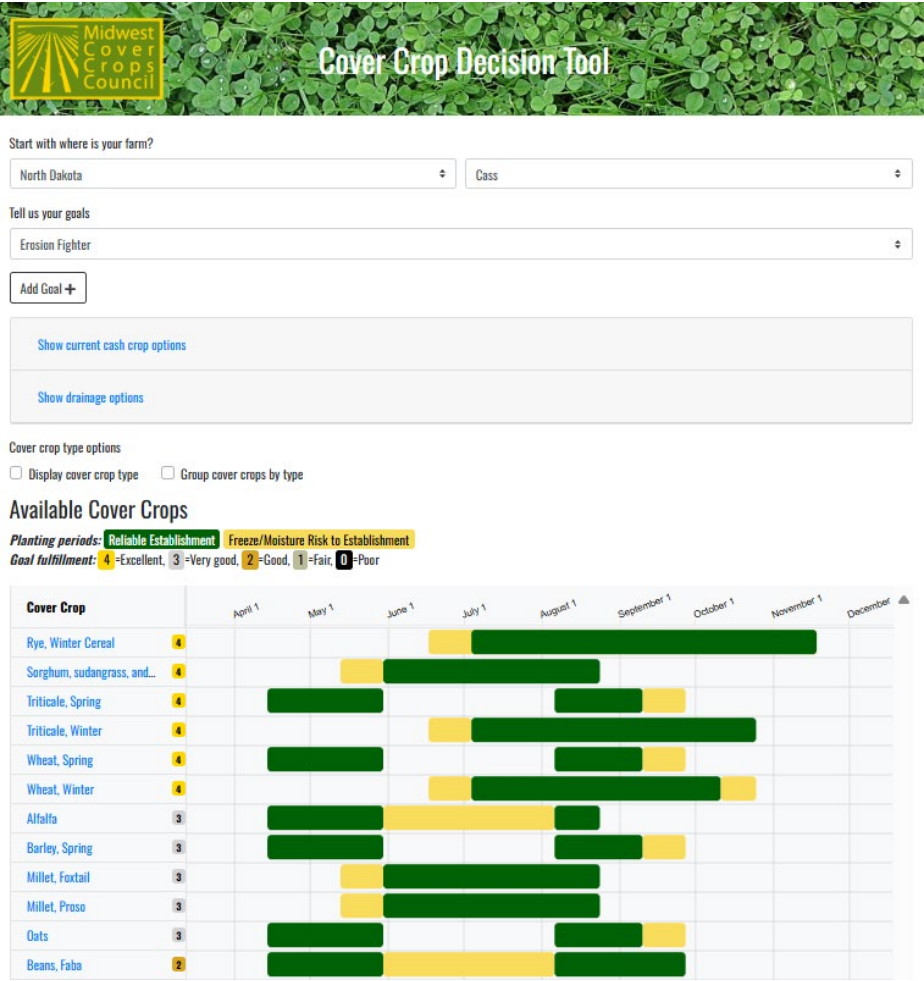


# SOIL HEALTH AND COVER CROPS



Slide courtesy: Dr. Krupek, Ohio State University

# SOIL HEALTH AND COVER CROPS



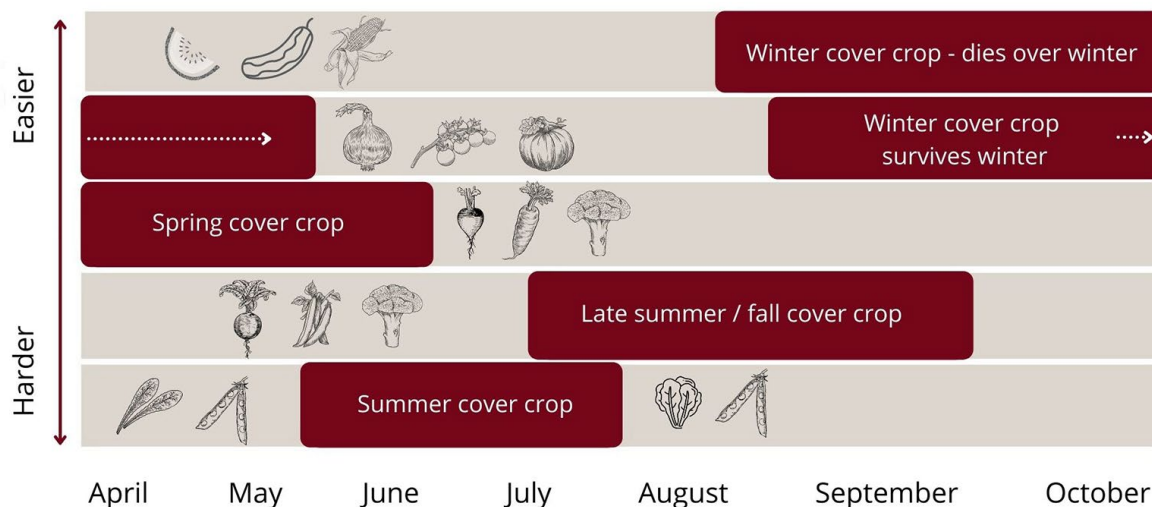
<https://www.midwestcovercrops.org/selector-tools/>



# 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	Y = Upright	● = Low
B = Biennial	* = Upright-Spreading	●● = Medium
P = Perennial	~ = Prostrate	●●● = High



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

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!

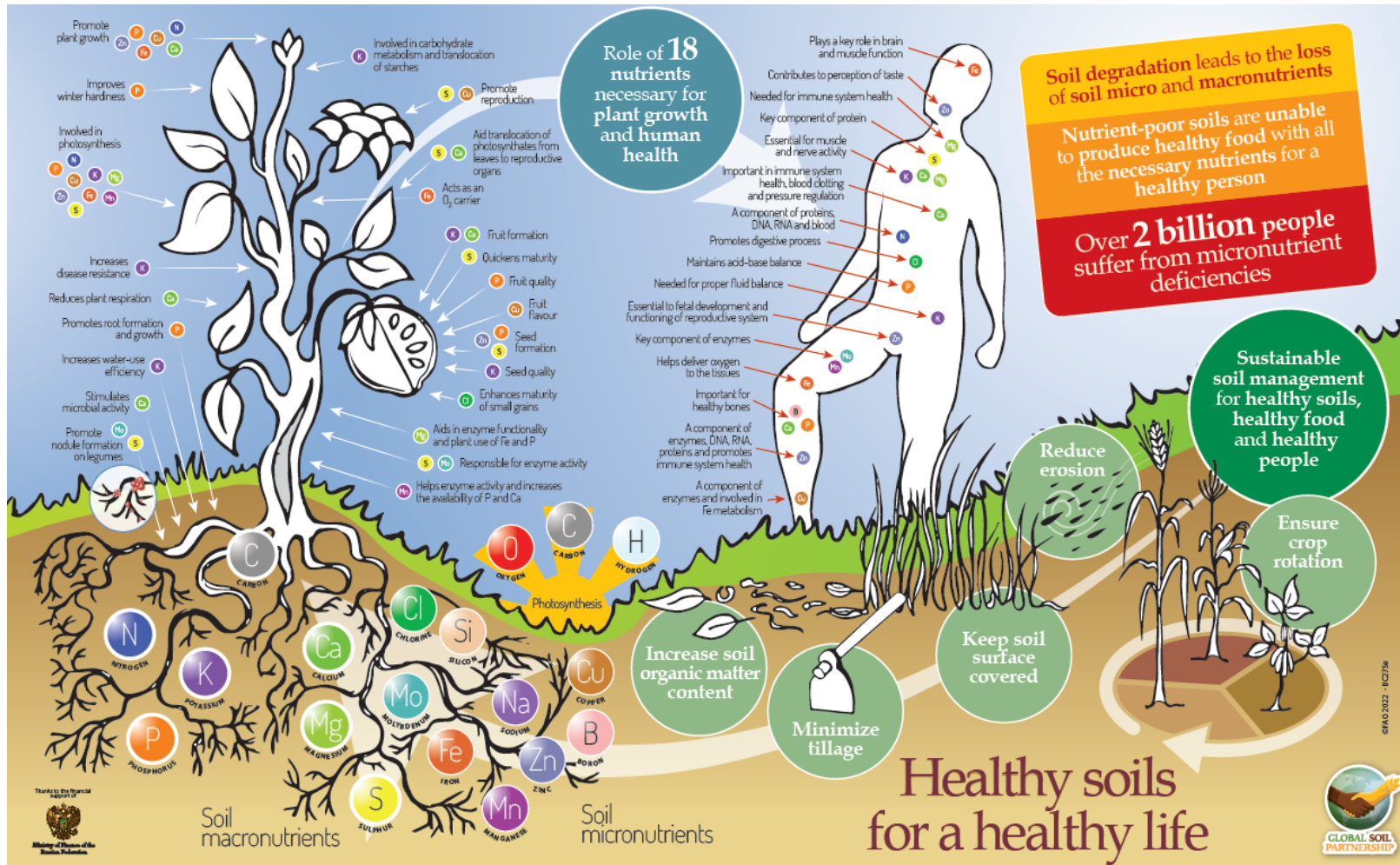


Tarping. Source: University of Wisconsin-Madison Extension



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

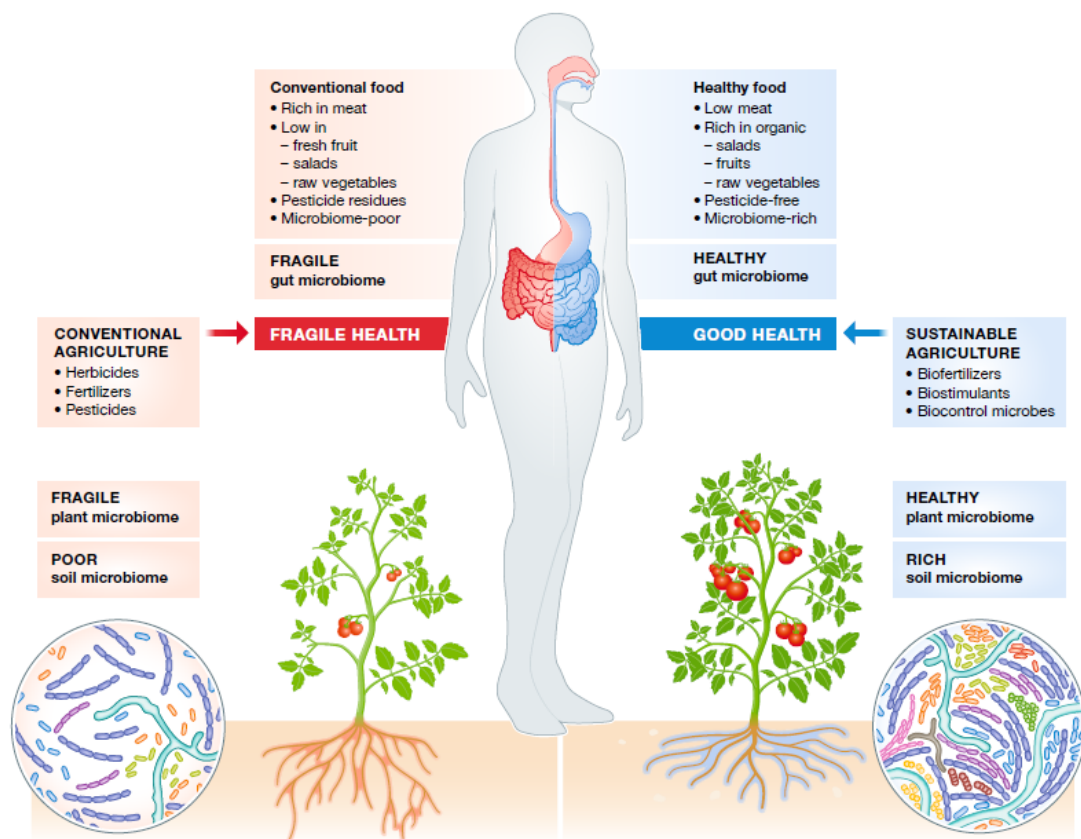
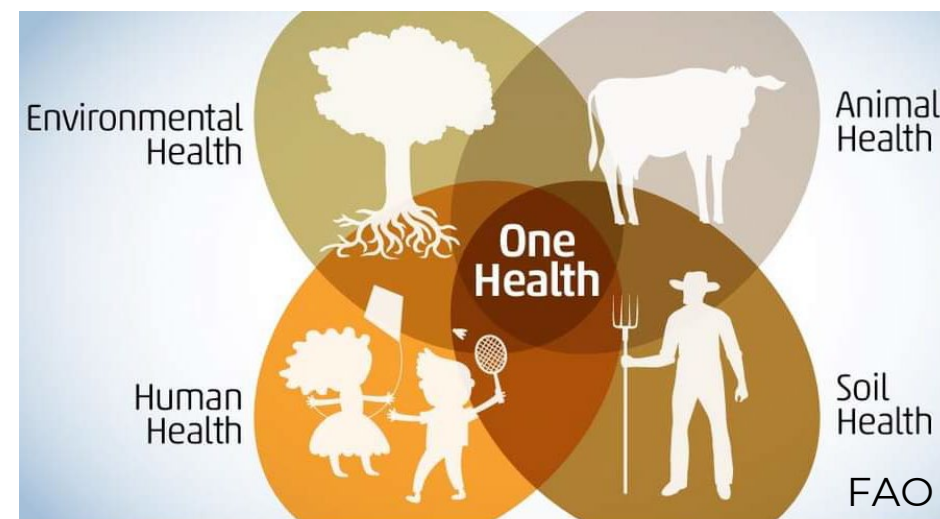


Figure 2. The direct and indirect effects of the plant microbiota on the human gut microbiome.



Source: Heribert Hirt

# Thank you!

*[carlos.pires@ndsu.edu](mailto:carlos.pires@ndsu.edu)*

Dr. Carlos Pires  
Extension Soil Health Specialist  
Assistant Professor of Soil Health  
School of Natural Resource Sciences

