


NDSU | EXTENSION

2025 Field to Fork





www.ag.ndsu.edu/food

NDSU EXTENSION

EXTENDING KNOWLEDGE » CHANGING LIVES

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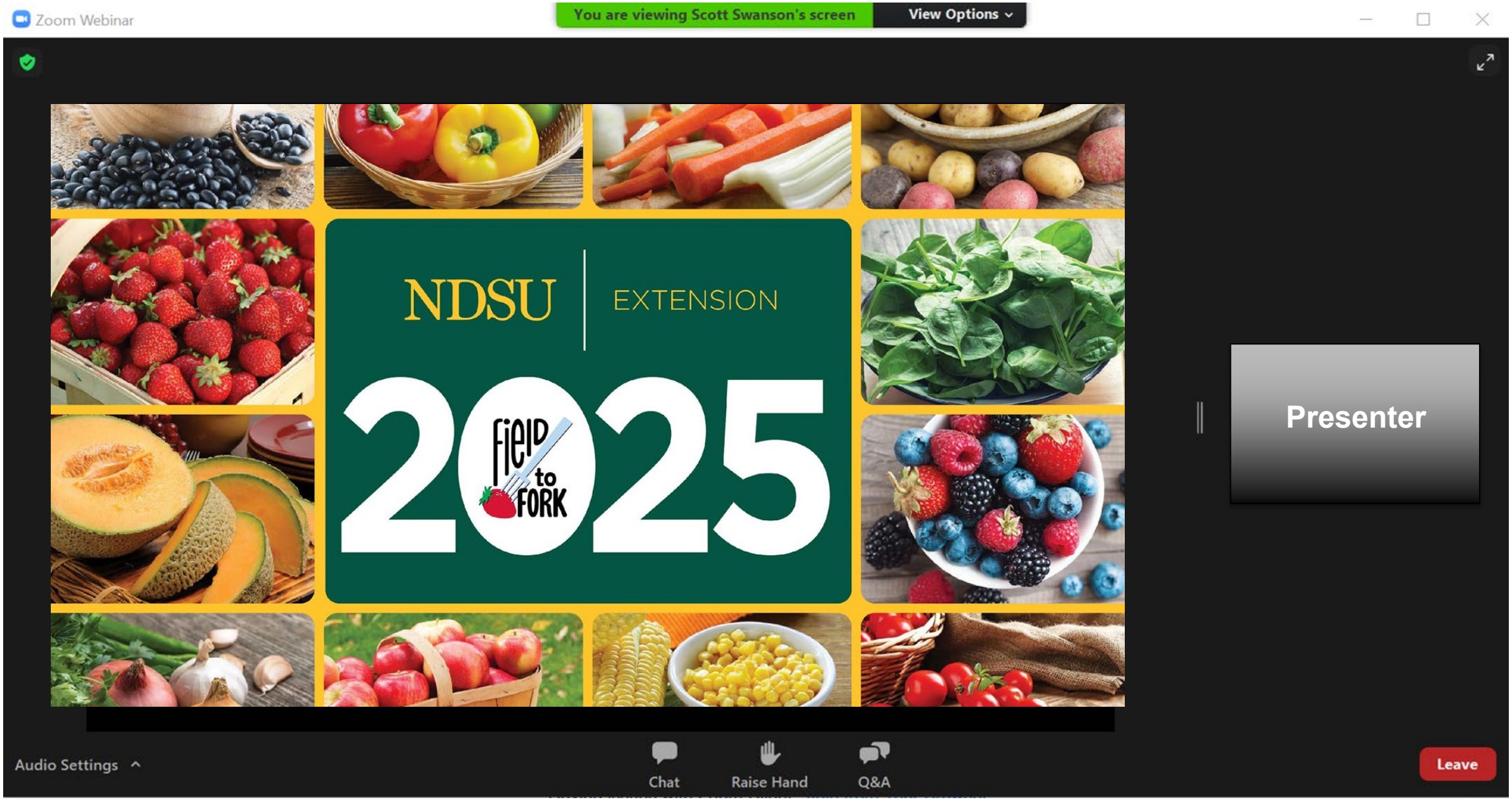
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Acknowledgement: This project was supported by the U.S. Department of Agriculture's (USDA) Agricultural Marketing Service through SCBG24-246. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

May 7

Healthy Soil, Healthy Food

Carlos Pires, NDSU Extension soil health specialist and assistant professor

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SOIL HEALTH

SCHOOL OF NATURAL RESOURCE SCIENCES

PIRES LAB

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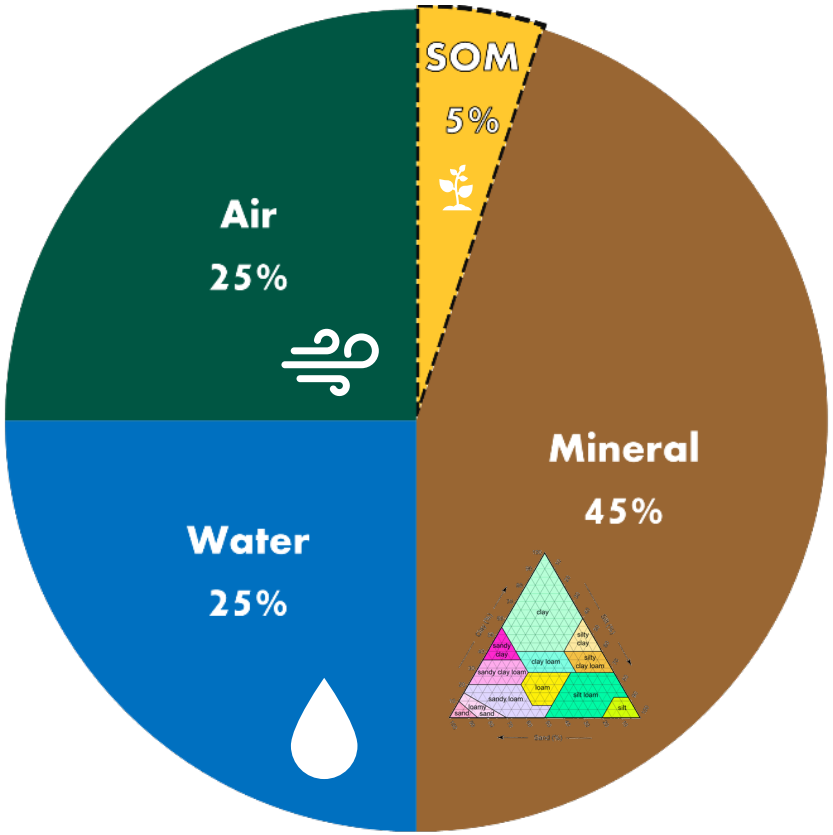
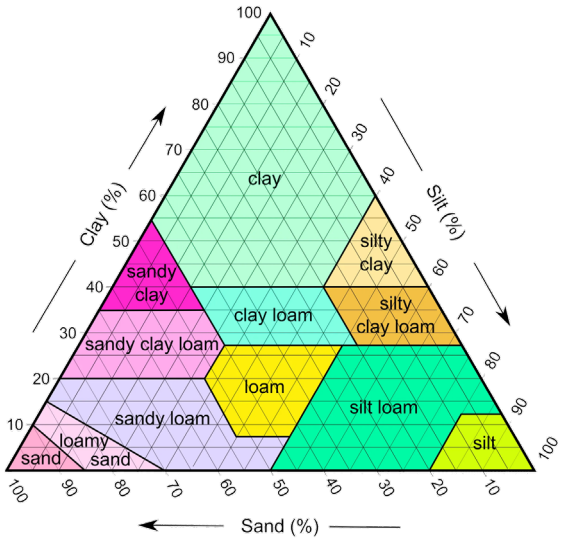
SOIL COMPOSITION



Ideal soil composition

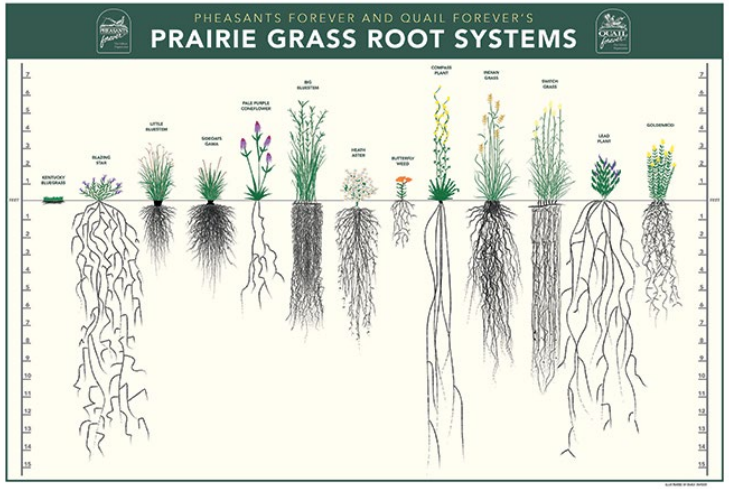
What happens if we…

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

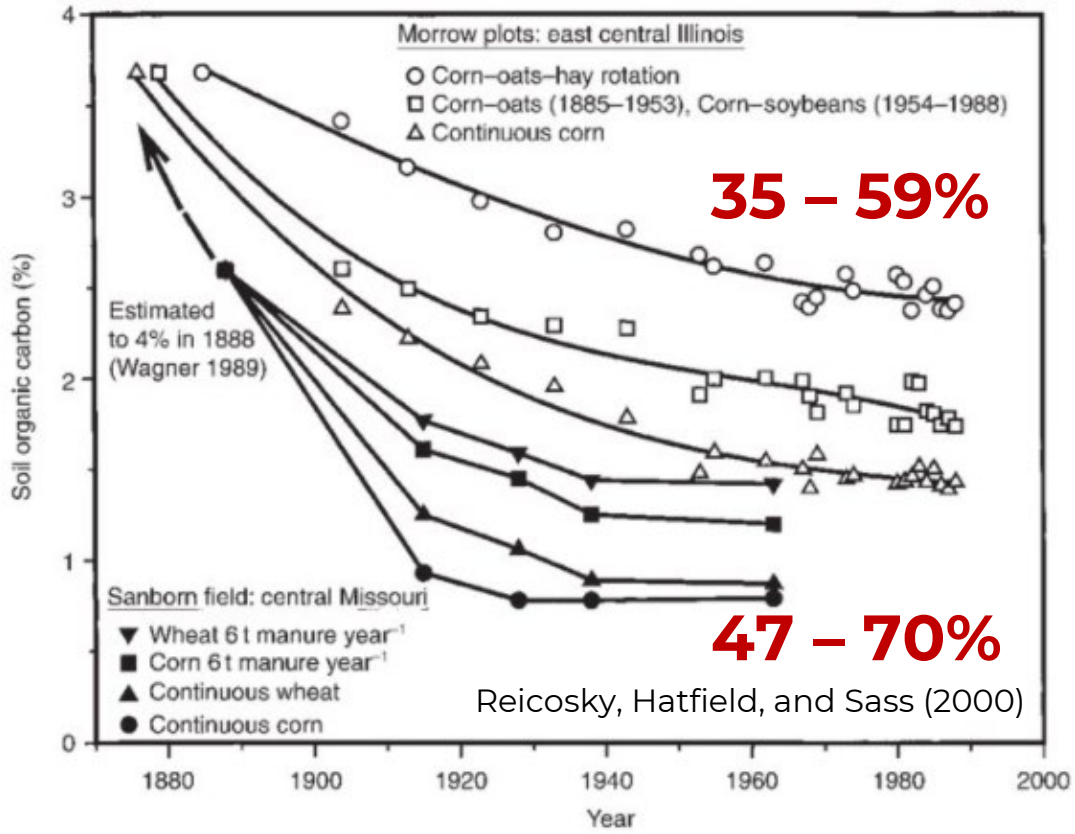


WHY ARE THE UPPER MIDWEST SOILS SO RICH IN ORGANIC MATTER (OR USED TO BE)?

- 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.



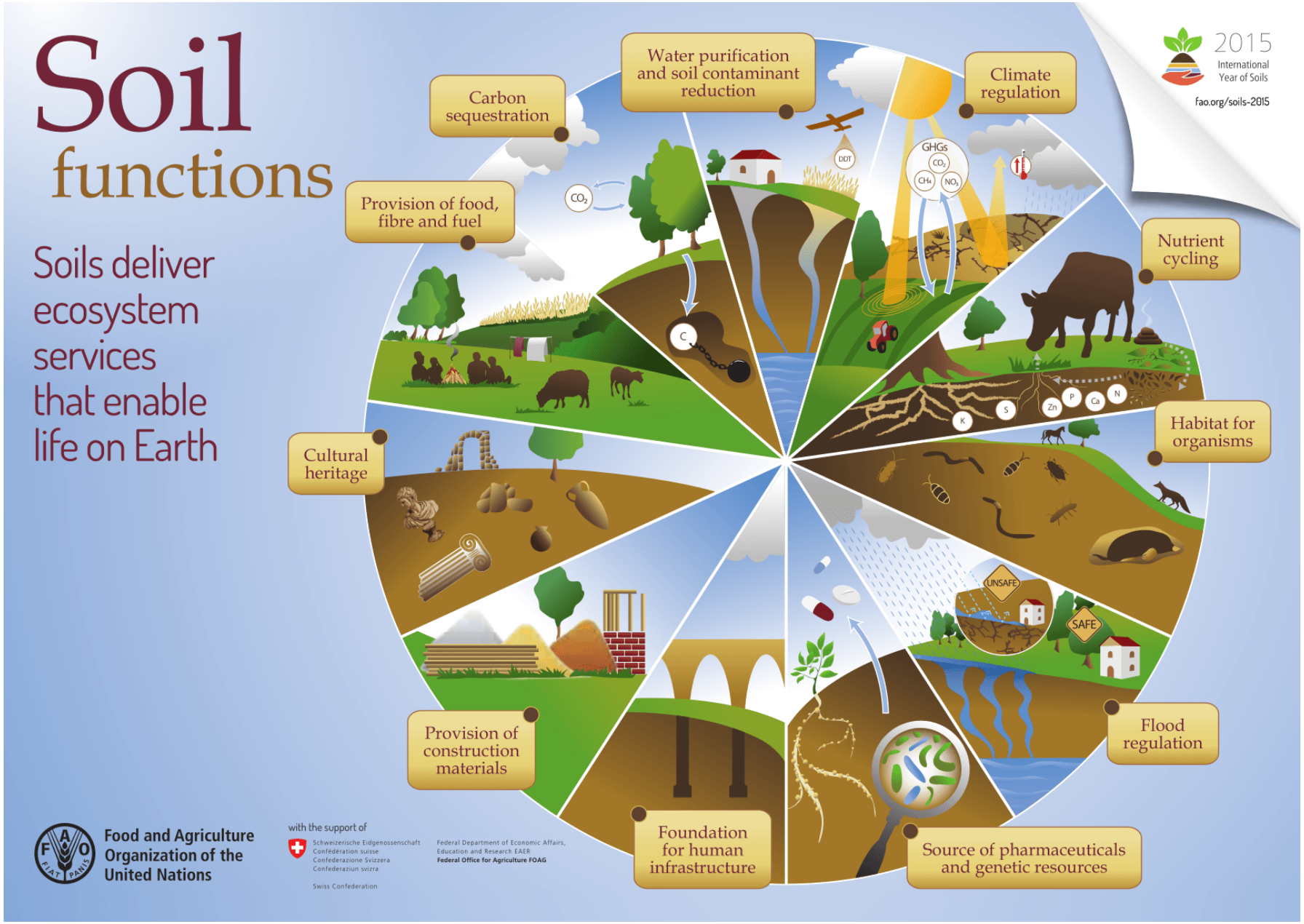
WHY “USED TO BE”?



Reicosky, Hatfield, and Sass (2000)

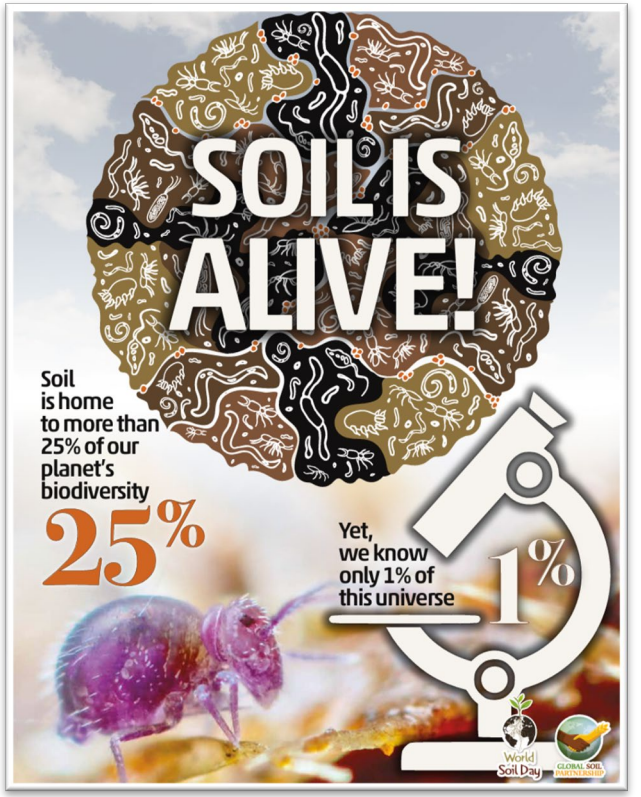
Long-term effect of tillage and crop rotations on soil carbon in Midwest USA

- 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


Soil functions
Soils deliver ecosystem services that enable life on Earth
2015 International Year of Soils
fao.org/soils-2015
Water purification and soil contaminant reduction
Carbon sequestration
Climate regulation
Provision of food, fibre and fuel
Nutrient cycling
Cultural heritage
Habitat for organisms
Provision of construction materials
Flood regulation
Foundation for human infrastructure
Source of pharmaceuticals and genetic resources
GHGs
UNSAFE
SAFE
Food and Agriculture Organization of the United Nations
with the support of
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.



FAO

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.

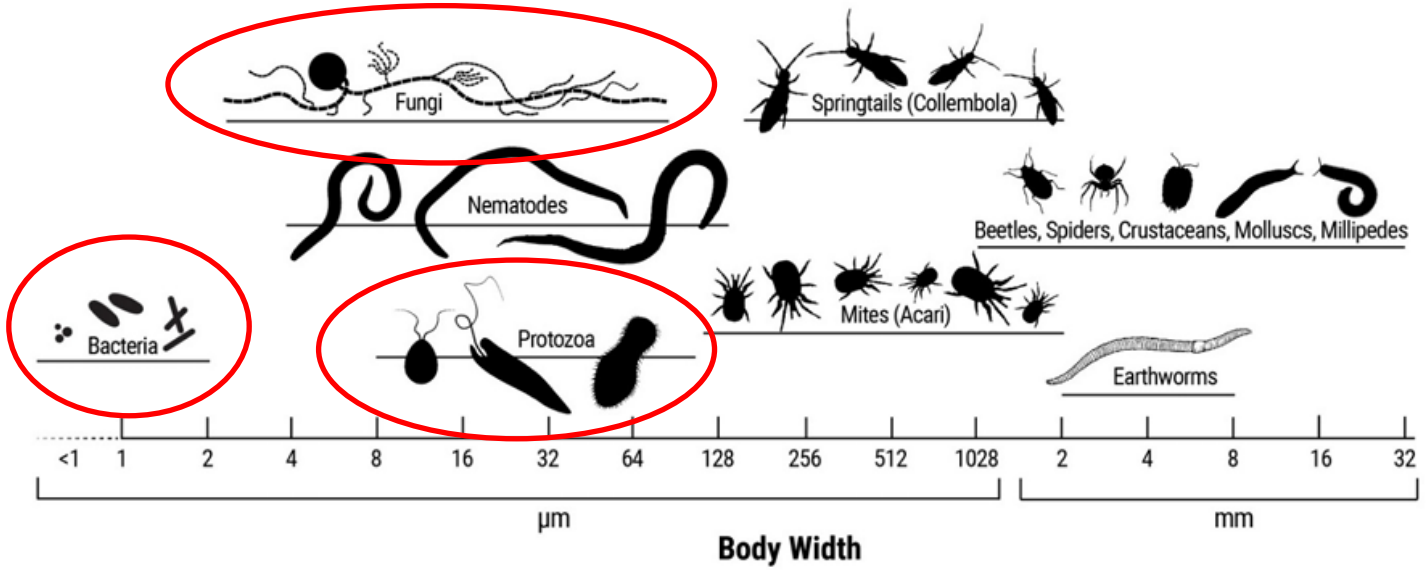


Fig. 1—Soil organisms grouped by class, showing the size of body width. Bacteria in the diagram represent all prokaryotes, bacteria and Archaea.

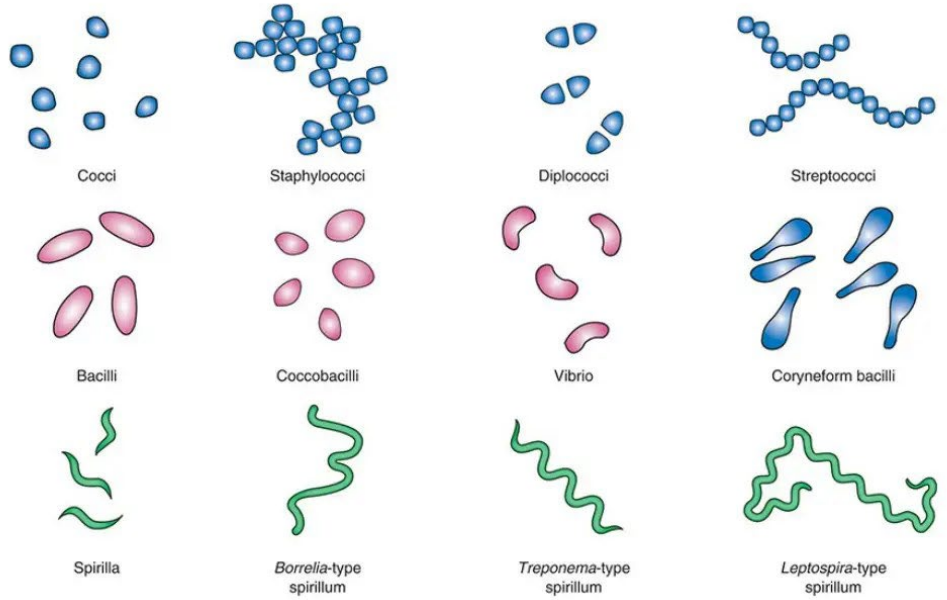
Brackin et al. (2017)

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

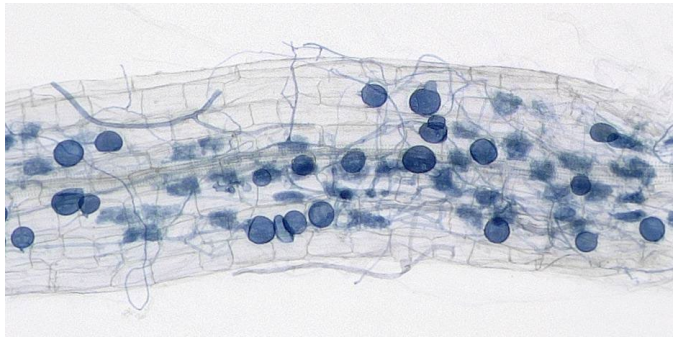
Shapes



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.

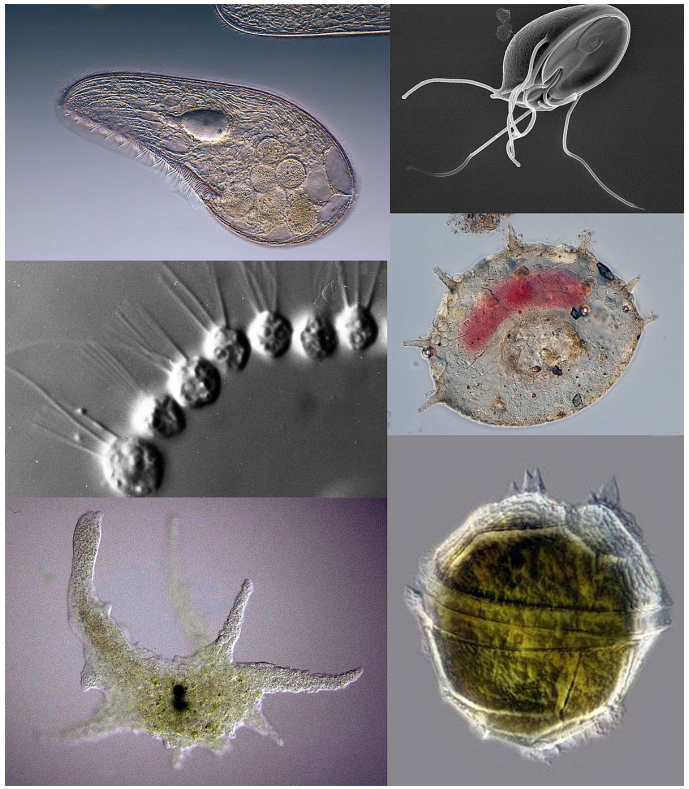
- Examples
  - Penicillium - known for producing the antibiotic penicillin
  - Trichoderma – biological control of insects
  - Arbuscular Mycorrhizal fungi
  - Fusarium – plant pathogen



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 -)	• Decompose N rich materials (low C:N ratio) • Nutrient cycling • Release nutrients that other organisms could not access (usable form) • Help to bind soil particles into aggregates (polysaccharides)
Fungi	• Improve soil aggregation • Decomposers (high C:N ratio – lignin) • Break down nutrients that other organisms cannot
Arbuscular Mycorrhizal Fungi	• Enhance plant nutrient uptake (P, NH_4) • Improve soil aggregation • Forms fungal links between roots of neighboring plants
Protozoa	• Decomposers • Regulate microbial populations (consume bacteria) • Nutrient cycling

ENZYMES

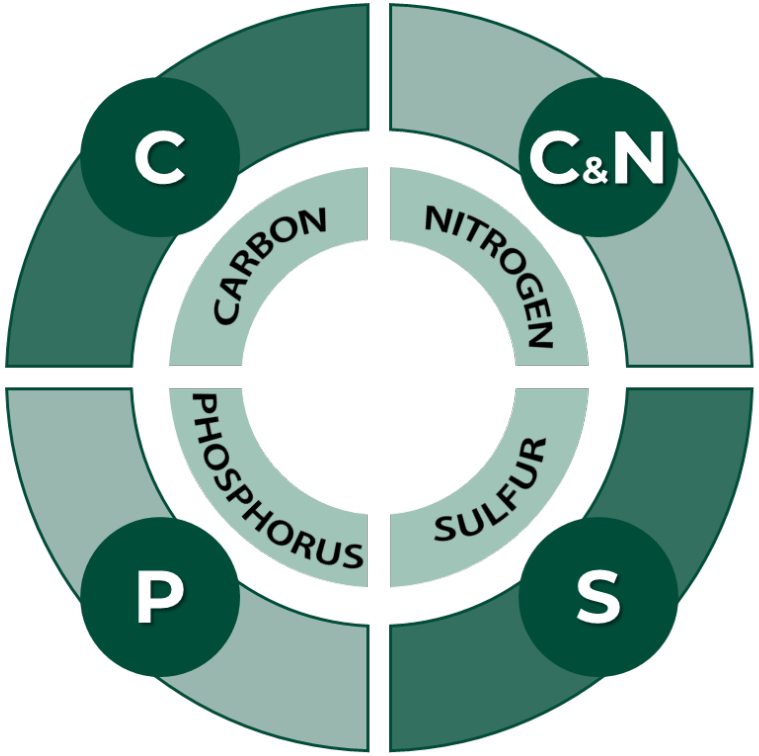
- Soil enzymes are proteins produced by soil organisms and plants
- Accelerate biochemical reactions such as residue (carbon & nitrogen) decomposition
- Essential for nutrient cycling

β-glucosidase (βG)

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-β-glucosaminidase (NAG)

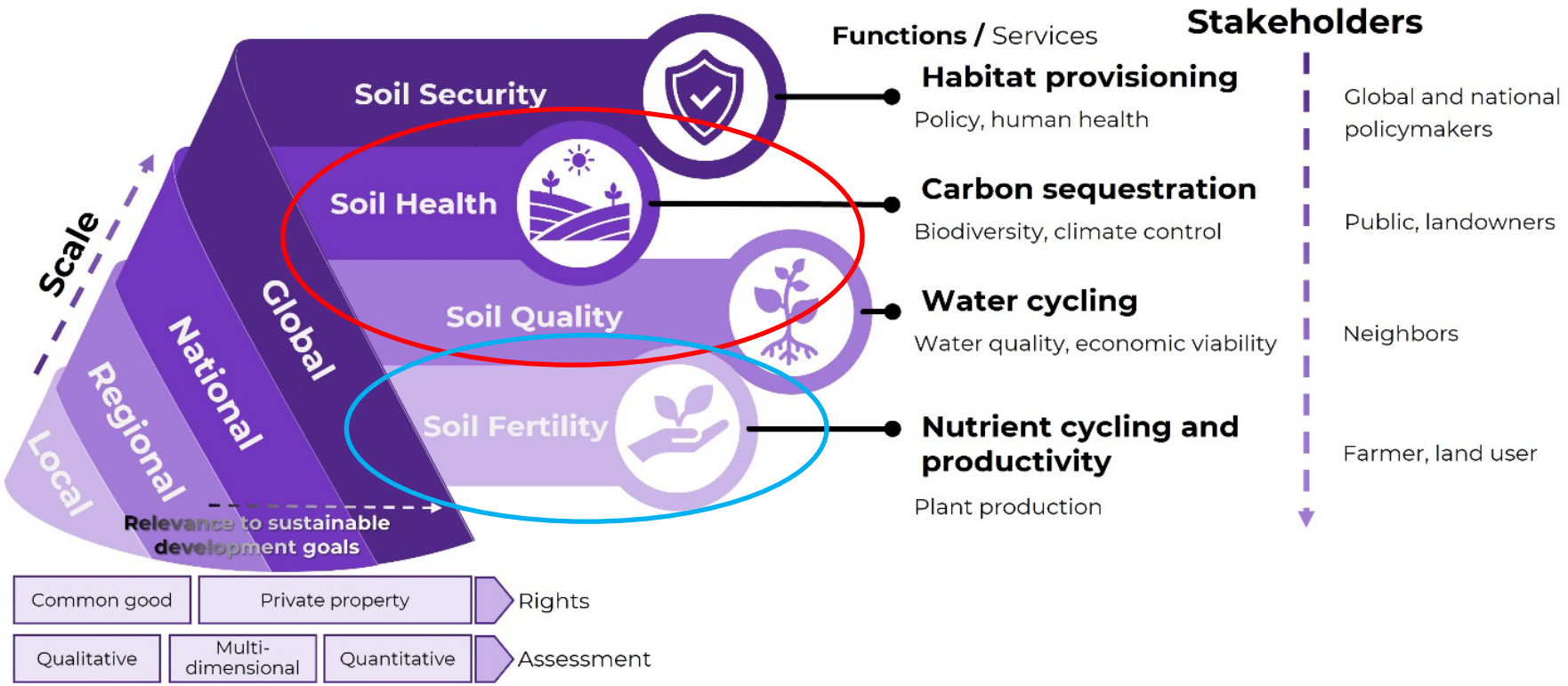
Carbon and nitrogen cycling enzyme that degrades chitin, an N-rich substance present in plants, fungi, bacteria, invertebrates, and animals.

Arylsulfatase (ArylS)

Sulfur cycling enzyme that controls the acquisition of organic sulfur. It allows microorganisms to satisfy their sulfur requirements.

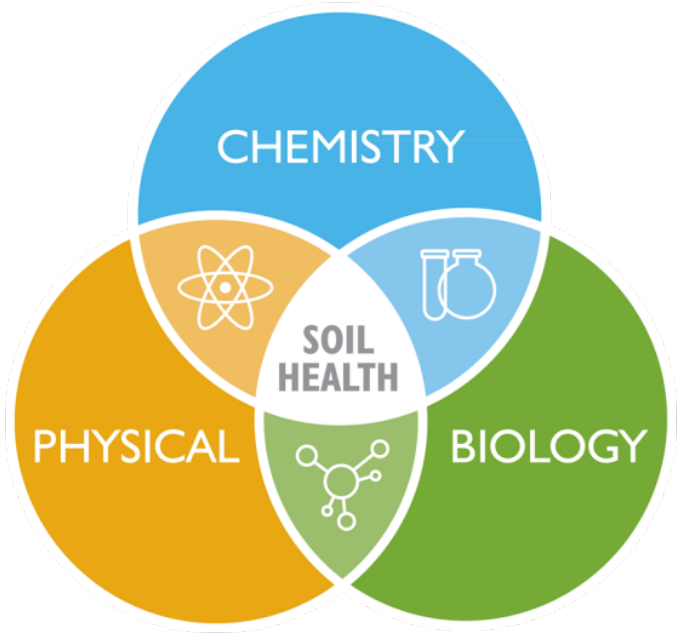
SOIL HEALTH

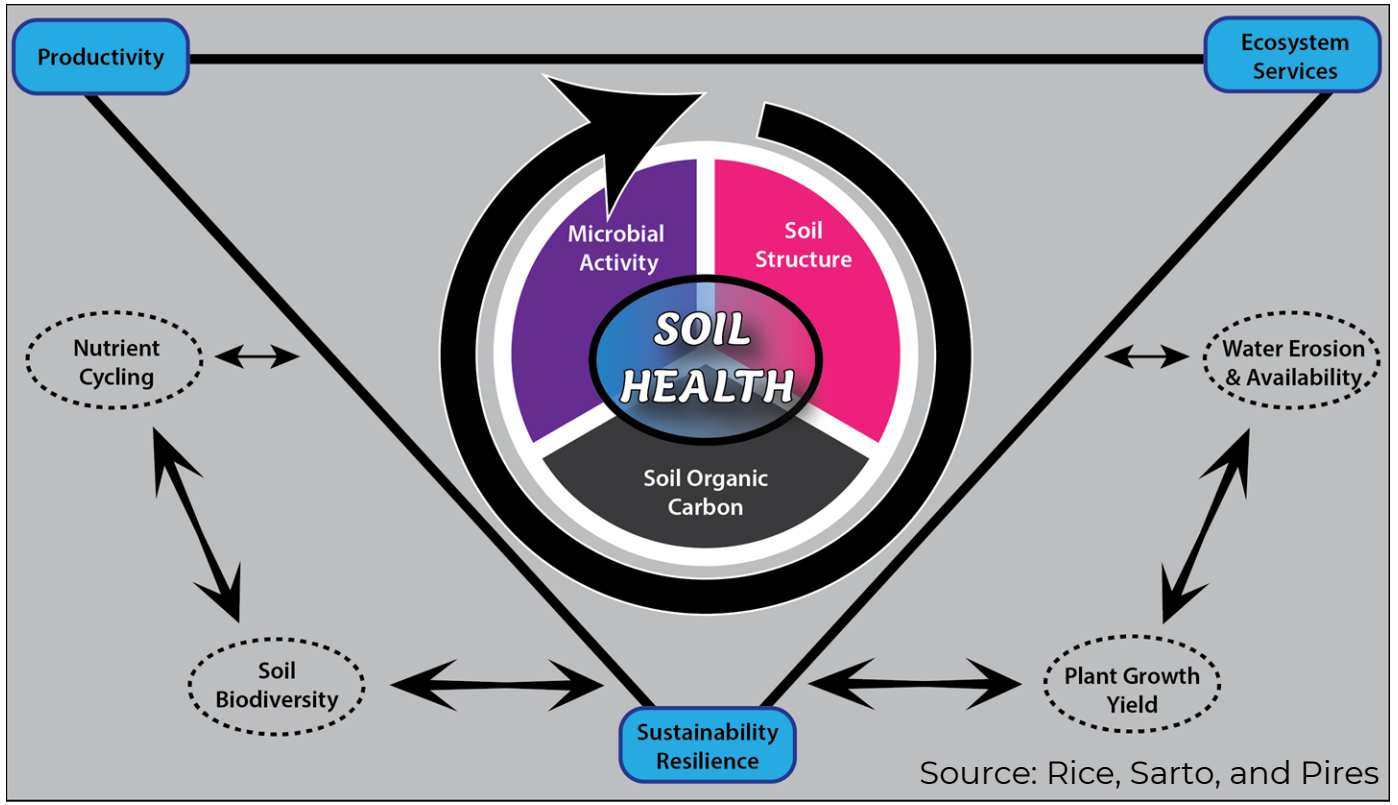
- The capacity of the soil to function as a living ecosystem and sustain plants, animals, and humans.



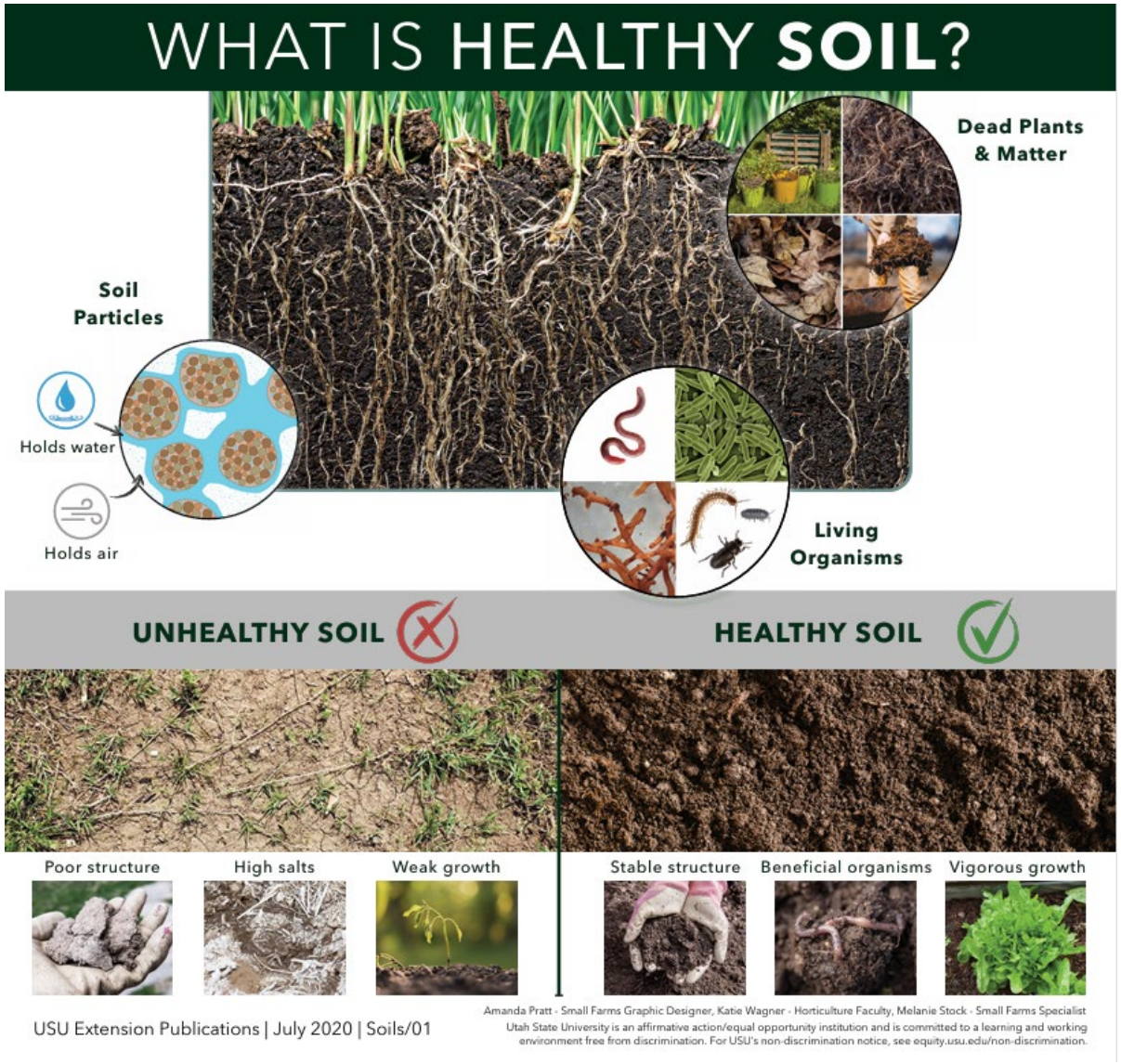
Relevant spatial scales, functions, ecosystem services, and stakeholders of soil security, health, quality, and fertility. The concepts also differ in the view of soil rights and assessments. Source: Adapted from Lehman et al. (2020).

SOIL HEALTH


CHEMISTRY
SOIL HEALTH
PHYSICAL
BIOLOGY


Productivity
Ecosystem Services
Microbial Activity
Soil Structure
SOIL HEALTH
Soil Organic Carbon
Nutrient Cycling
Water Erosion & Availability
Soil Biodiversity
Plant Growth Yield
Sustainability Resilience
Source: Rice, Sarto, and Pires

SOIL HEALTH



FAO

SOIL HEALTH PRINCIPLES

MINIMIZE DISTURBANCE

No-tillage, minimum tillage, strip tillage.

MAXIMIZE SOIL COVER

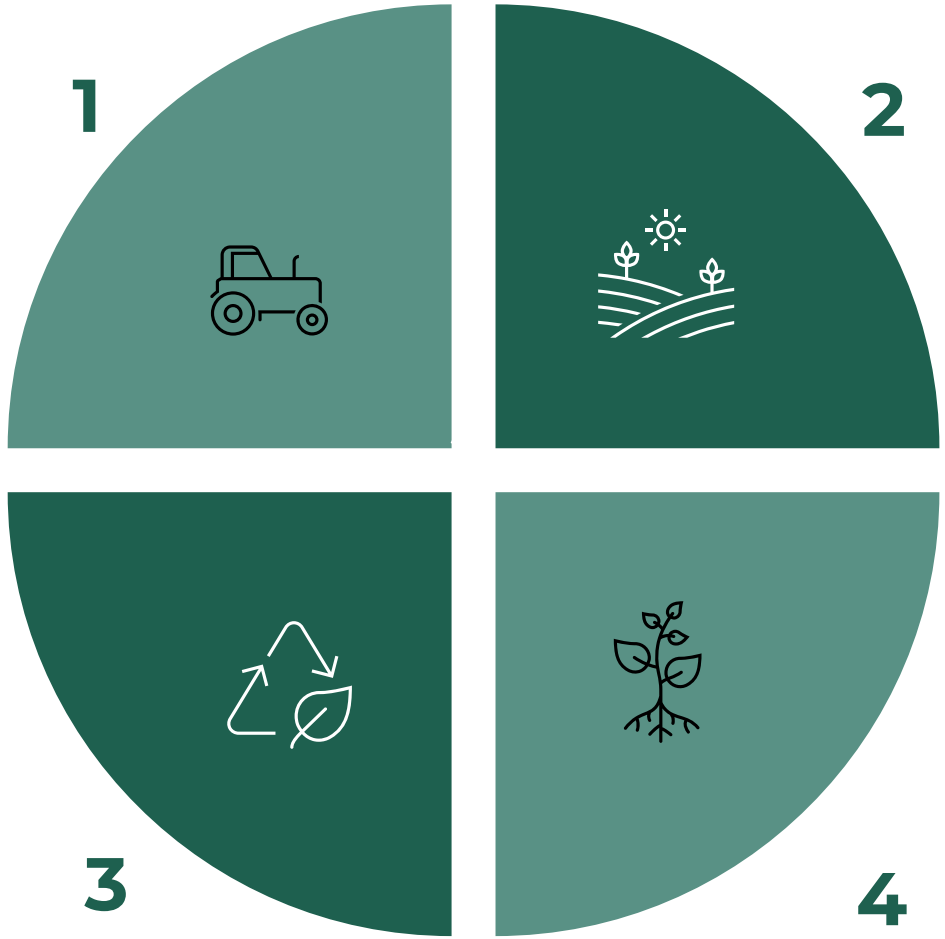
Cover crops, residue management, cropping system, perennials

MAXIMISE BIODIVERSITY

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

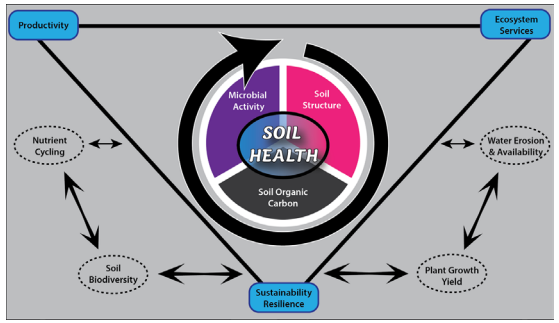
MAXIMIZE CONTINOUS LIVING ROOTS

Cove crops, reduce fallow



"Make the most efficient use of external inputs"

SOIL HEALTH JOURNEY



VISIBLE OUTCOMES

IMPROVED WATER AVAILABILITY AND DRAINAGE

IMPROVED SOIL STRUCTURE

IMPROVED NUTRIENT CYCLING

ORGANIC MATTER TURNOVER

BIOLOGICAL ACTIVITY

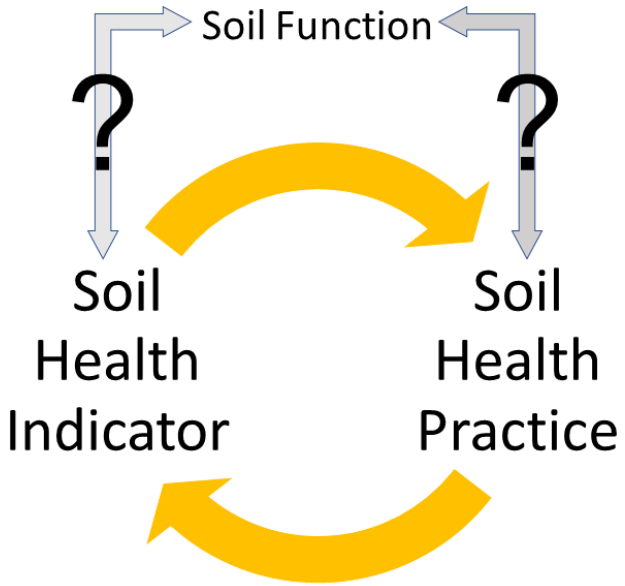
INVISIBLE OUTCOMES

Hatfield et al. 2017. Advances in Agronomy

MEASURING SOIL HEALTH

Soil Health Indicators are NOT an end to themselves

Management



Outcomes

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

Source: Andrew McGuire

Slide courtesy: Dr. Krupek, Ohio State University

SOIL HEALTH ASSESSMENT: COMMON INDICATORS

Soil Biology

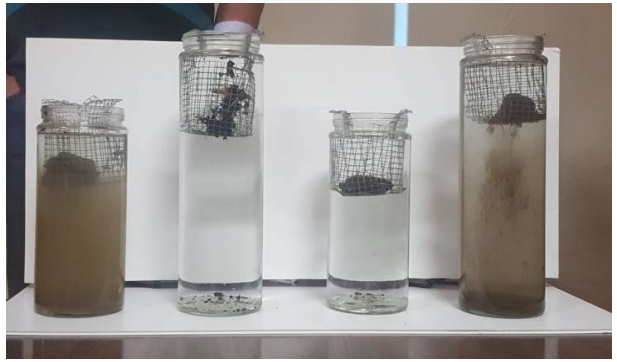
- Respiration potentials
- Number and diversity of mycorrhiza, and earthworms
- Diversity of macro and microorganisms
- Microbial profiling, Enzymatic activity
- Soil proteins

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

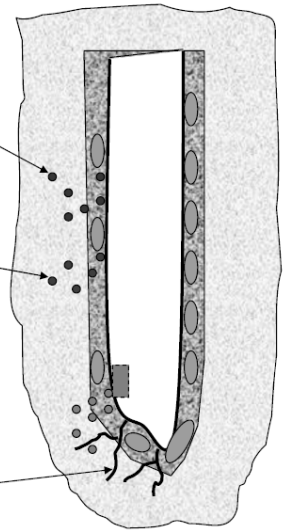
MANAGING SOIL MICROBES

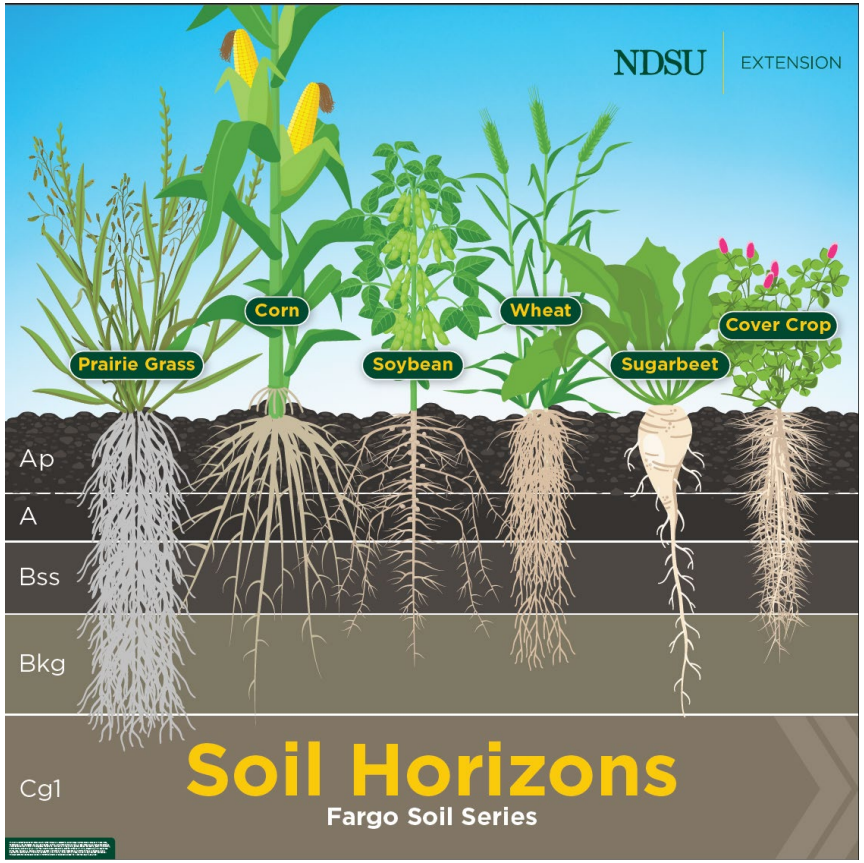
Management

- 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 polysacchrides





MANAGING SOIL MICROBES

- Soil health principles

Management

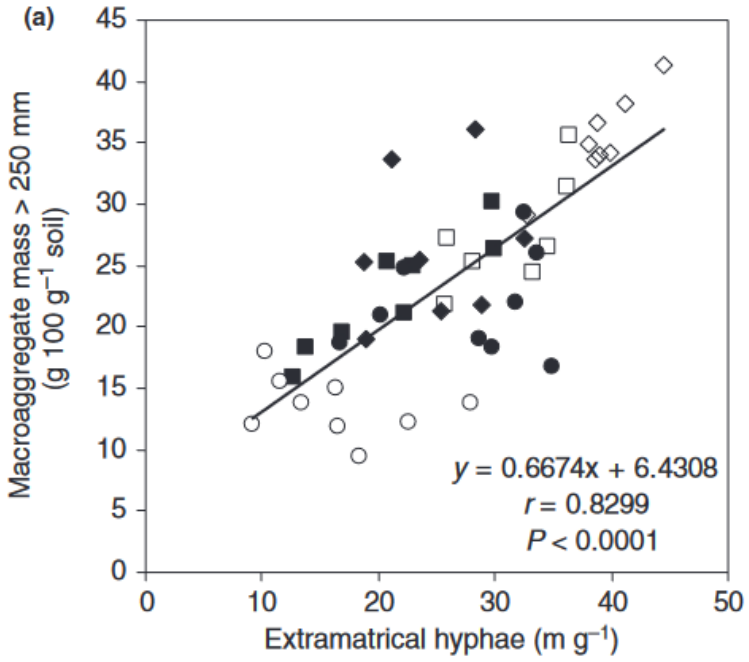
Cover crops

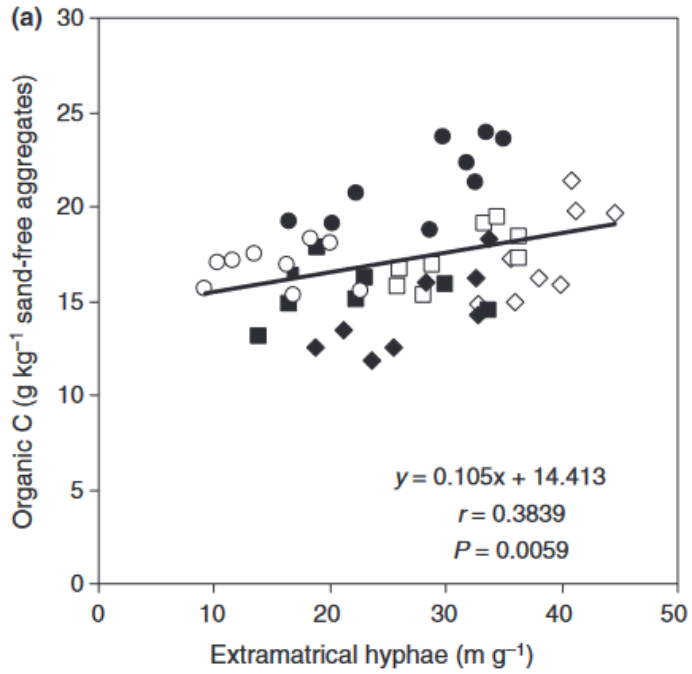
MANAGING SOIL MICROBES

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

Indicators

Aggregates
Fungi
Carbon

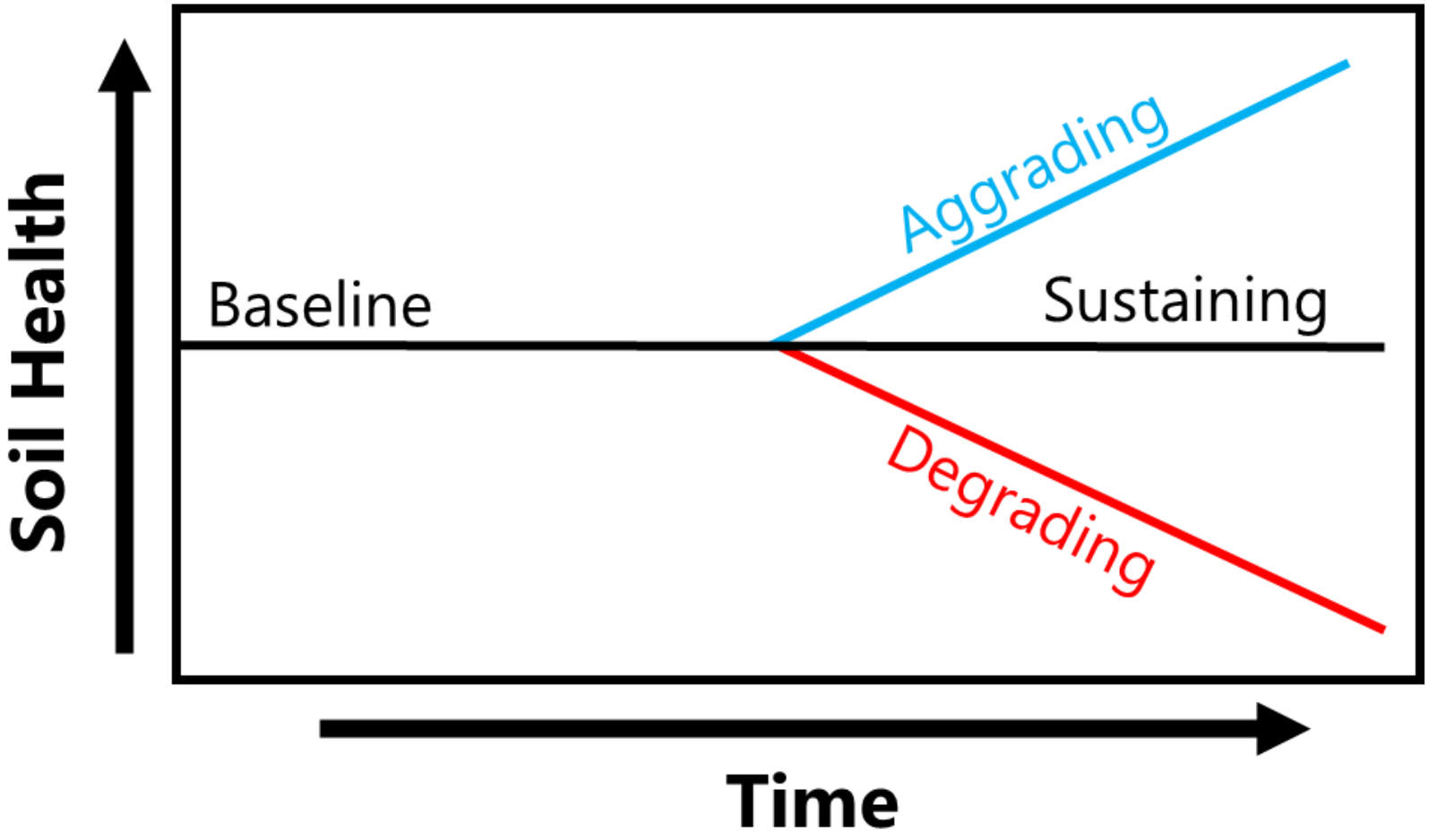




Outcome

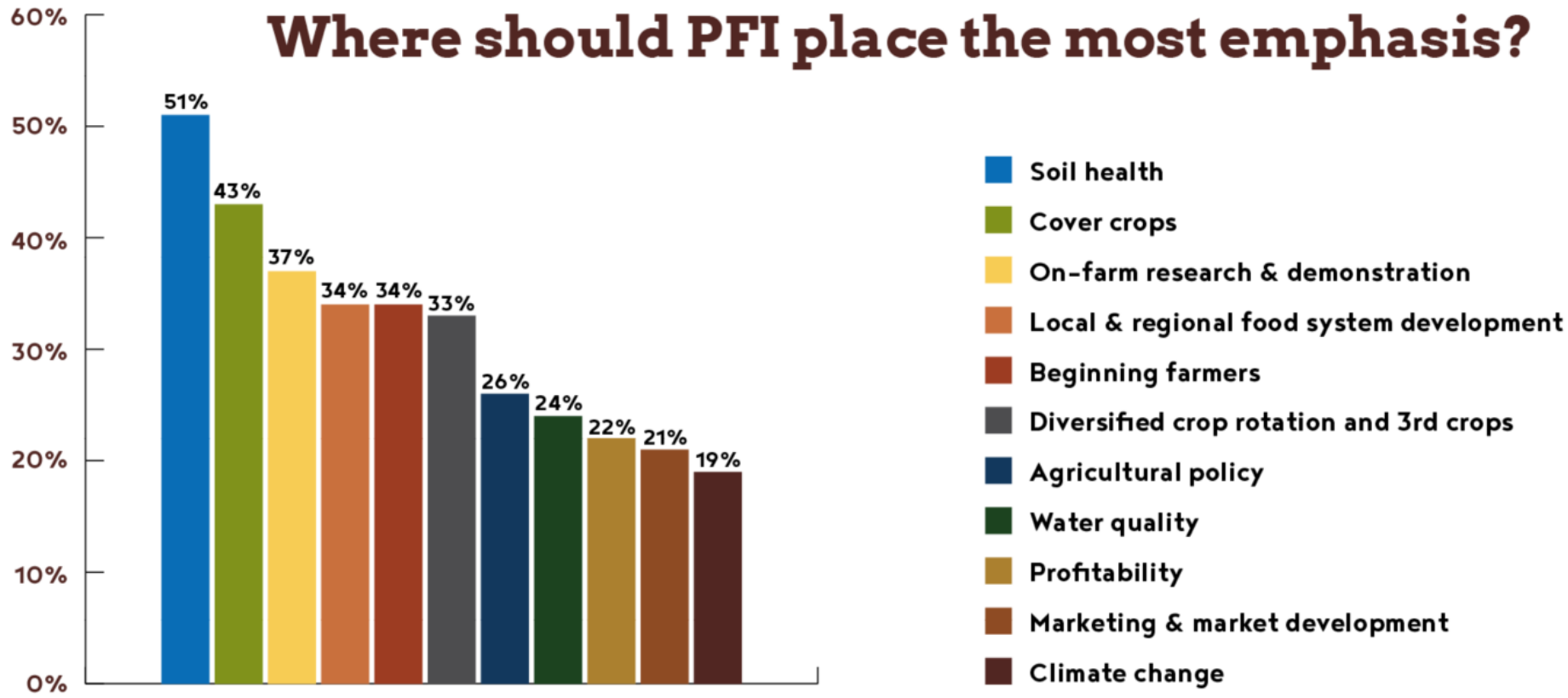
Higher SOM
Increased biodiversity

MONITORING SOIL HEALTH



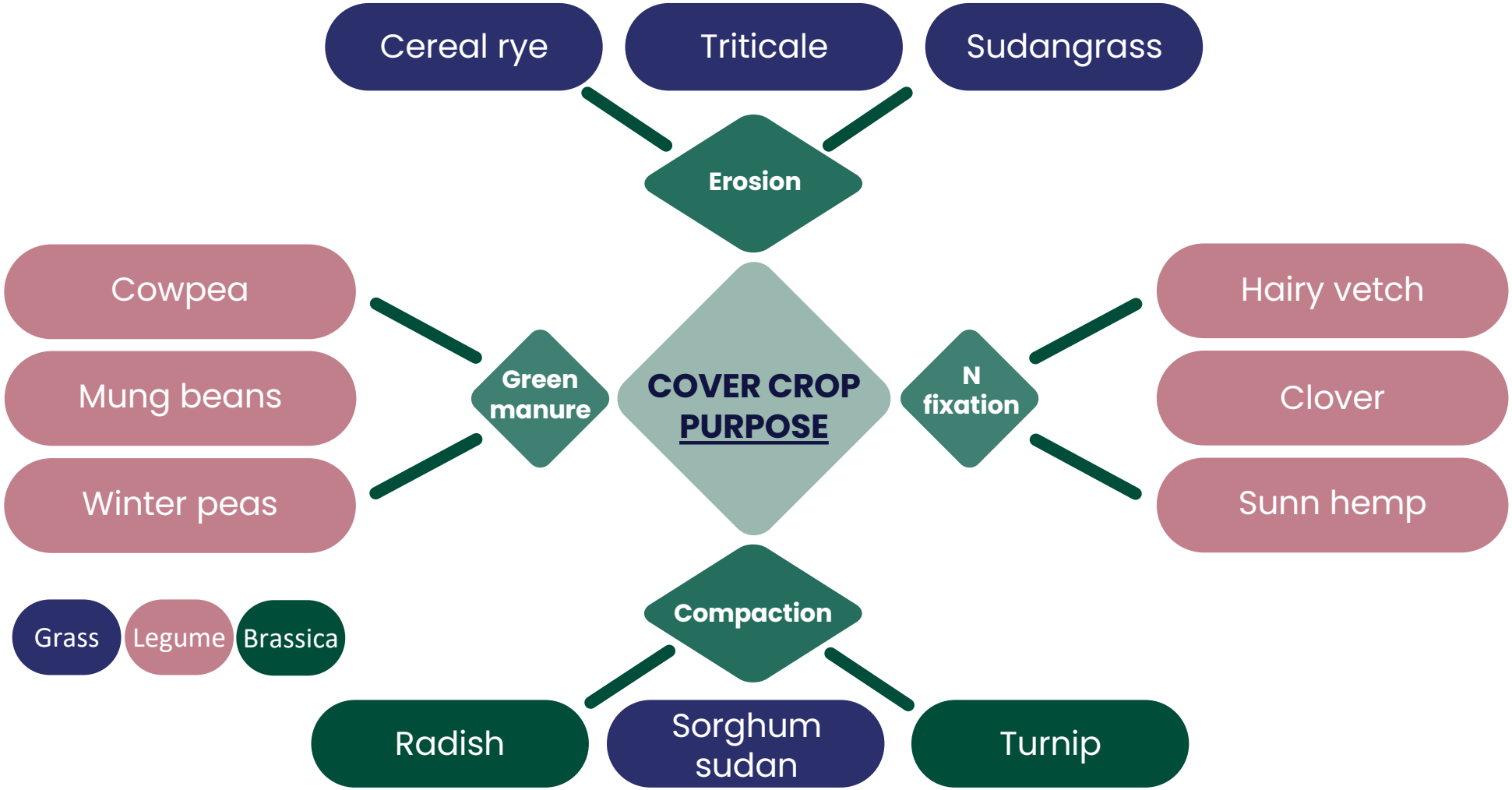
SOIL HEALTH AND COVER CROPS

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



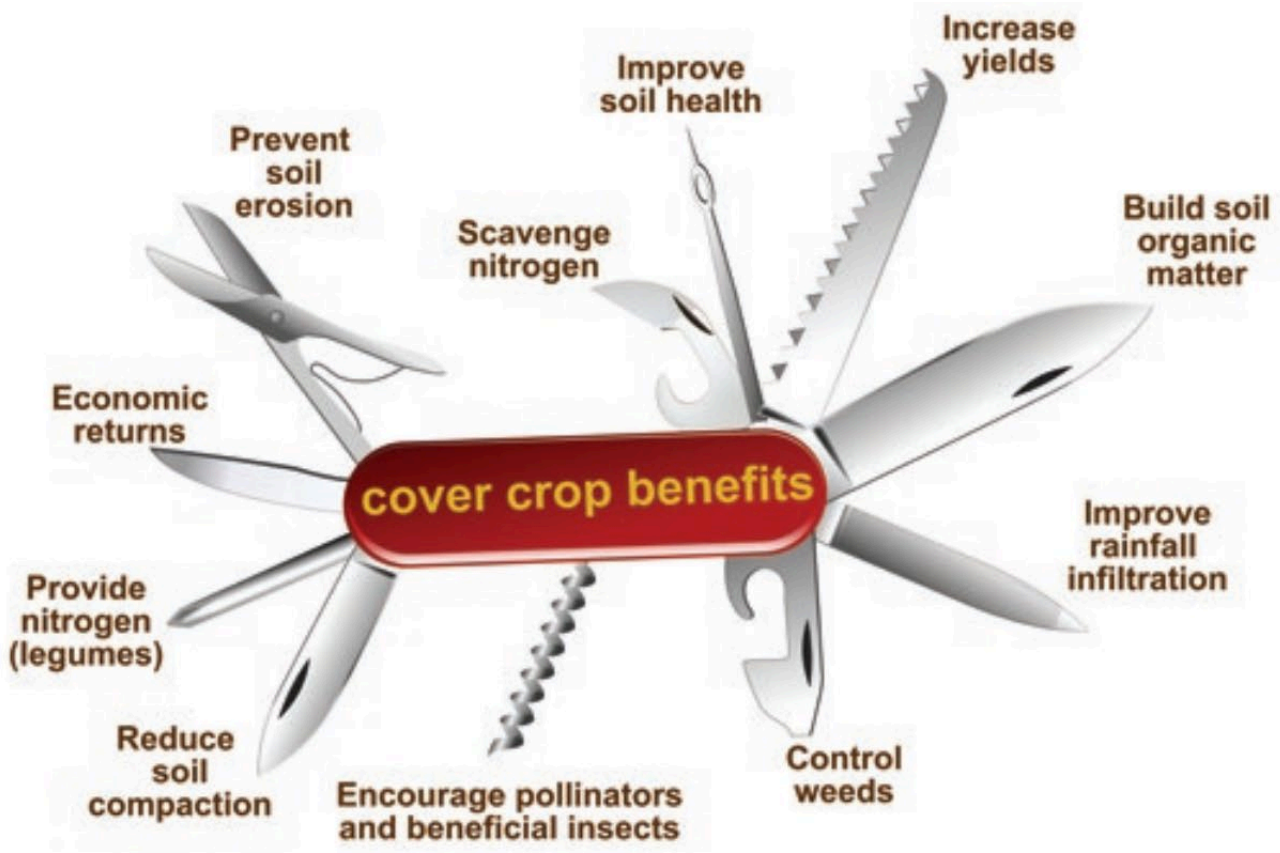
Source: Practical Farmers of Iowa Survey Results. https://practicalfarmers.org/2024/01/a-birds-eye-view/

SOIL HEALTH AND COVER CROPS



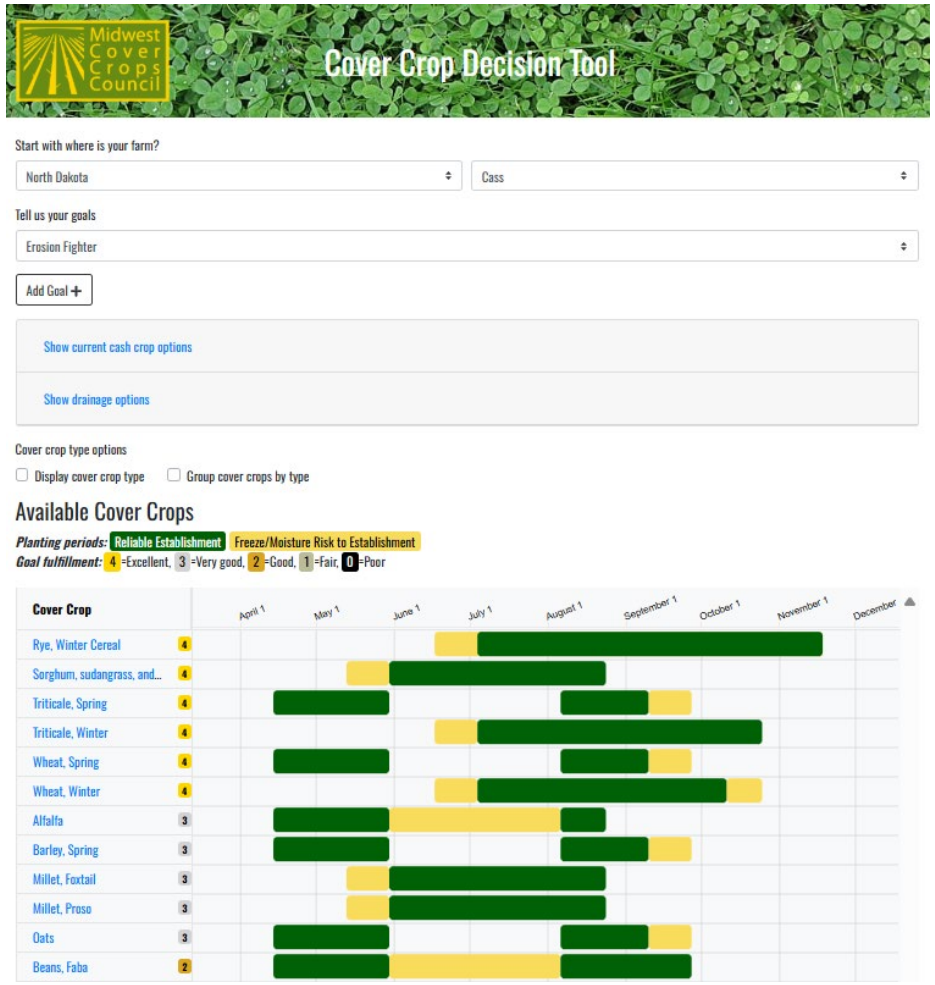
SERVICE PLANTS!

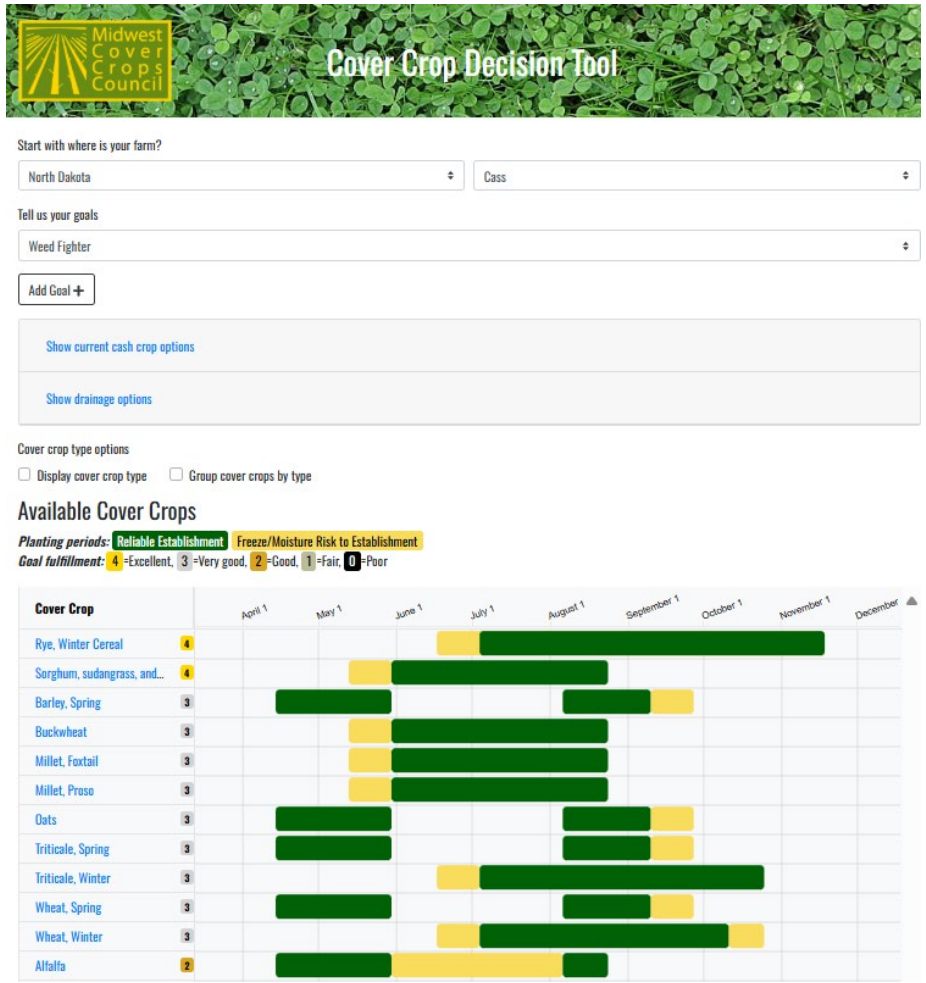
SOIL HEALTH AND COVER CROPS



Slide courtesy: Dr. Krupek, Ohio State University

SOIL HEALTH AND COVER CROPS

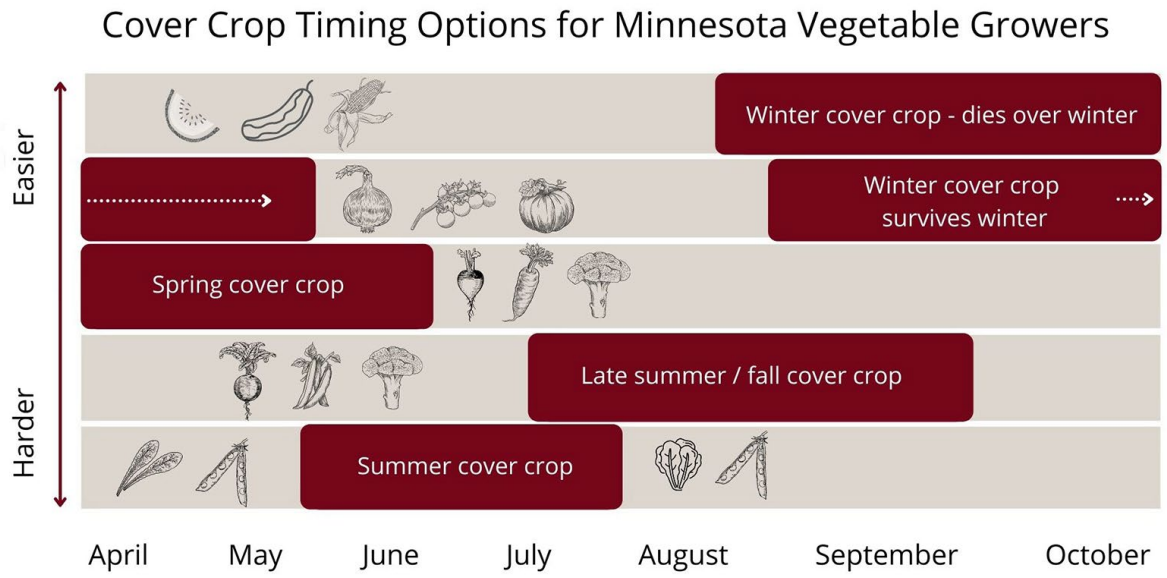




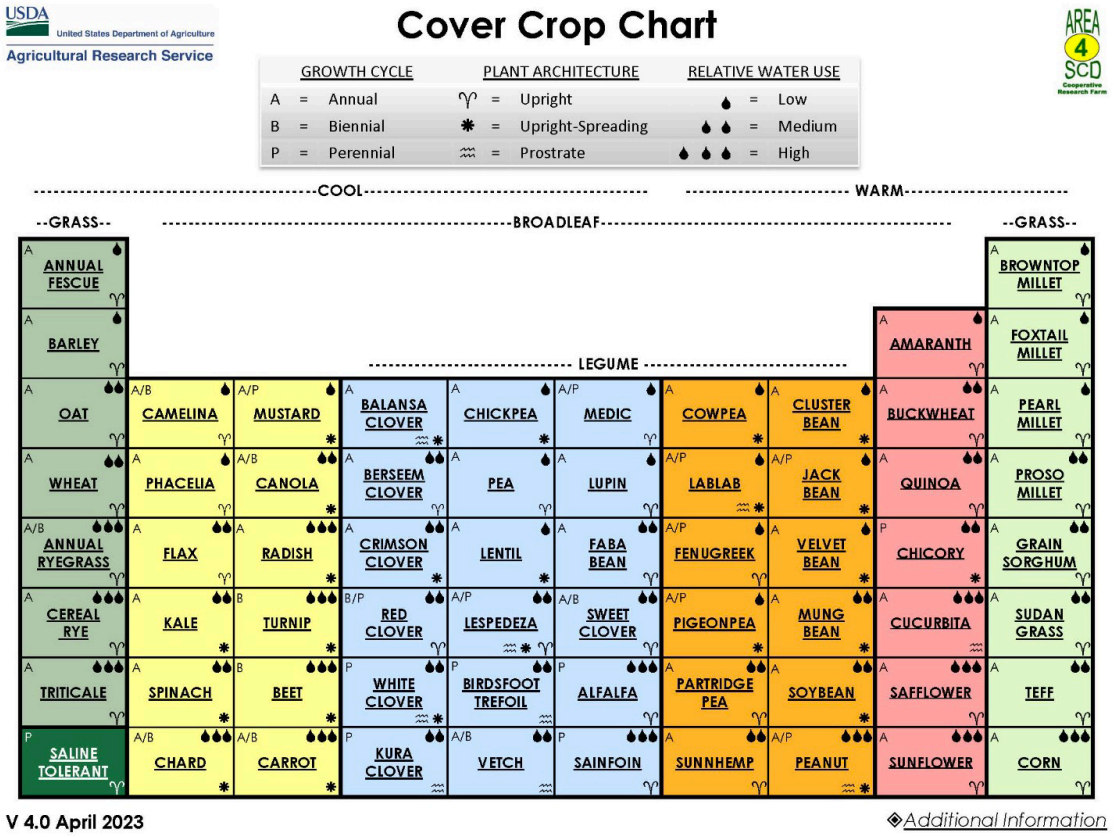
https://www.midwestcovercrops.org/selector-tools/

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



Source: University of Minnesota Extension



Slide courtesy: Dr. Krupek, Ohio State University

SOIL HEALTH AND COVER CROPS: TERMINATION

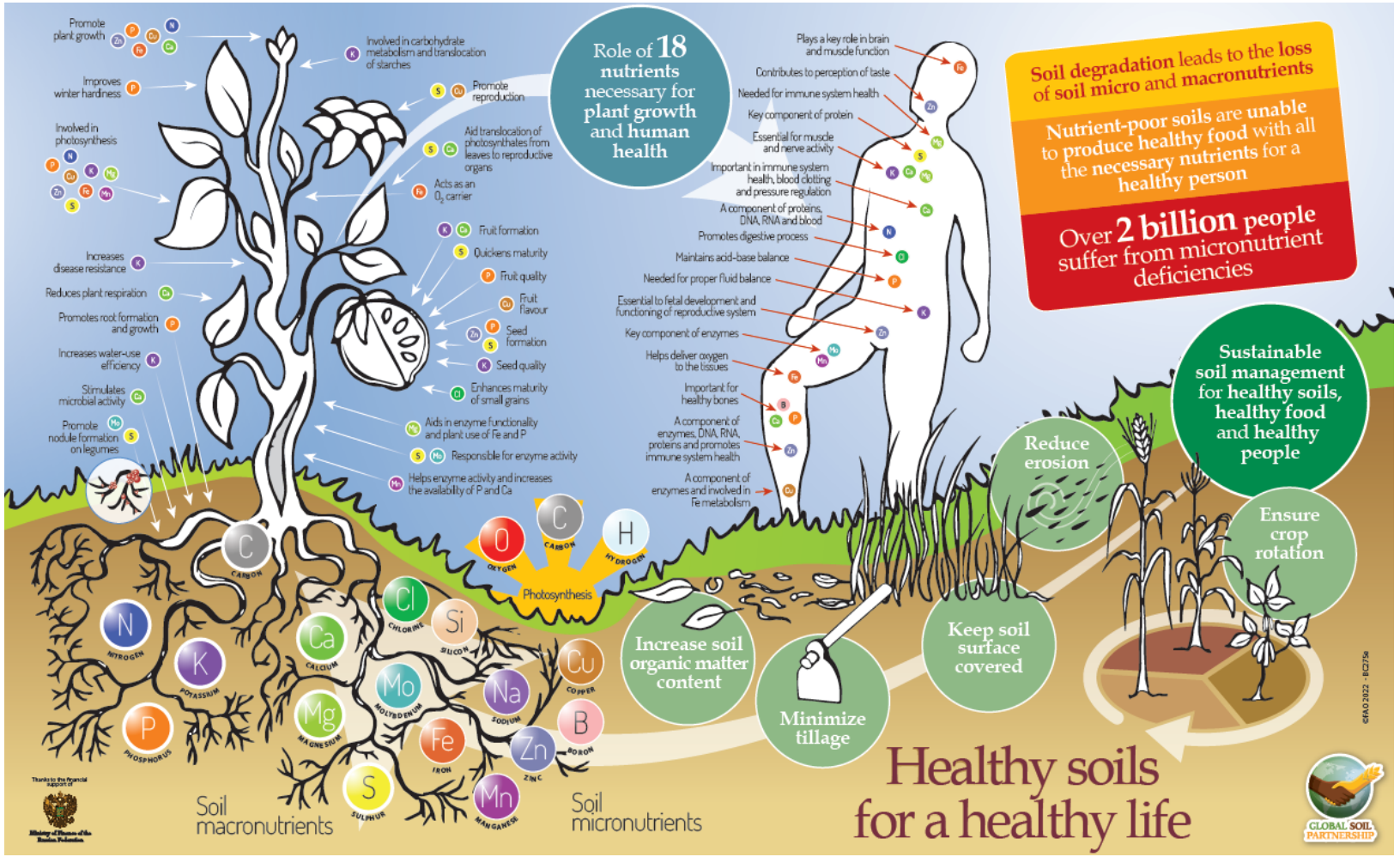
- Cover crop species, growth state, weather, and cover cropping goals should all be considered
- Balance between benefits and potential penalties to the next crop

- **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.

FAO

ONE HEALTH: SOIL, ANIMAL, ENVIRONMENTAL, HUMAN

Healthy soils for healthy plants for healthy humans

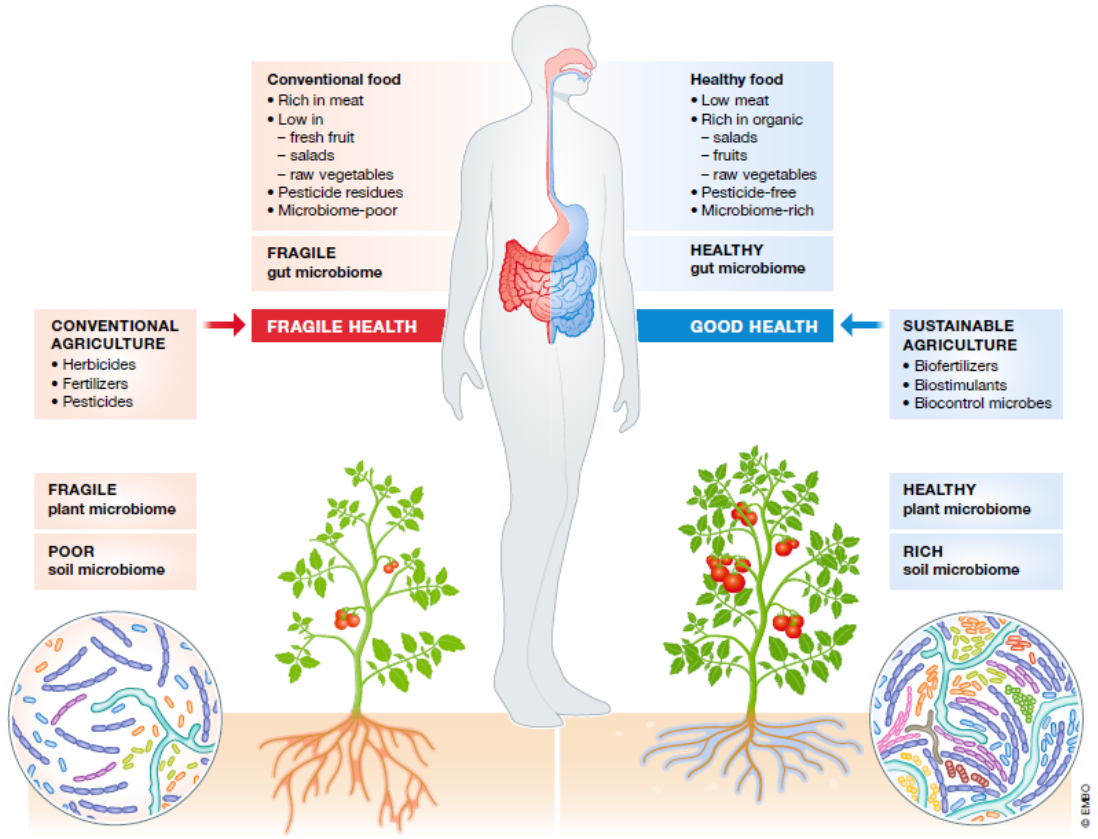
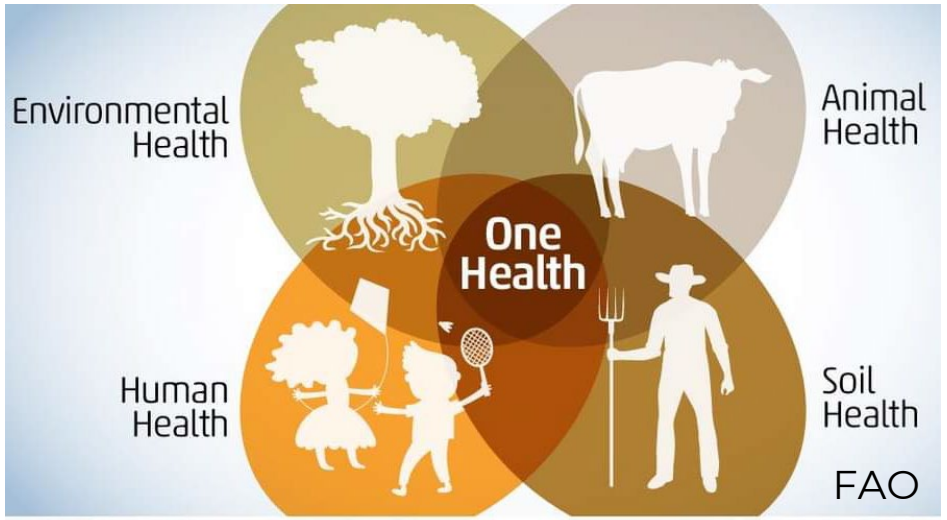


Figure 2. The direct and indirect effects of the plant microbiota on the human gut microbiome.



Source: Heribert Hirt

Thank you!

carlos.pires@ndsu.edu

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

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