USDA

United States Department of Agriculture

Soil Health 101

Soil School

April 15, 2023

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(971) 273-4814

Natural Resources Conservation Service

nrcs.usda.gov/

Objectives

- Why incorporate Soil Health Principles
- How Soil Health Principles impact management decisions
- How to implement Soil Health Principles

Soil Health Principles To Support High Functioning Soils

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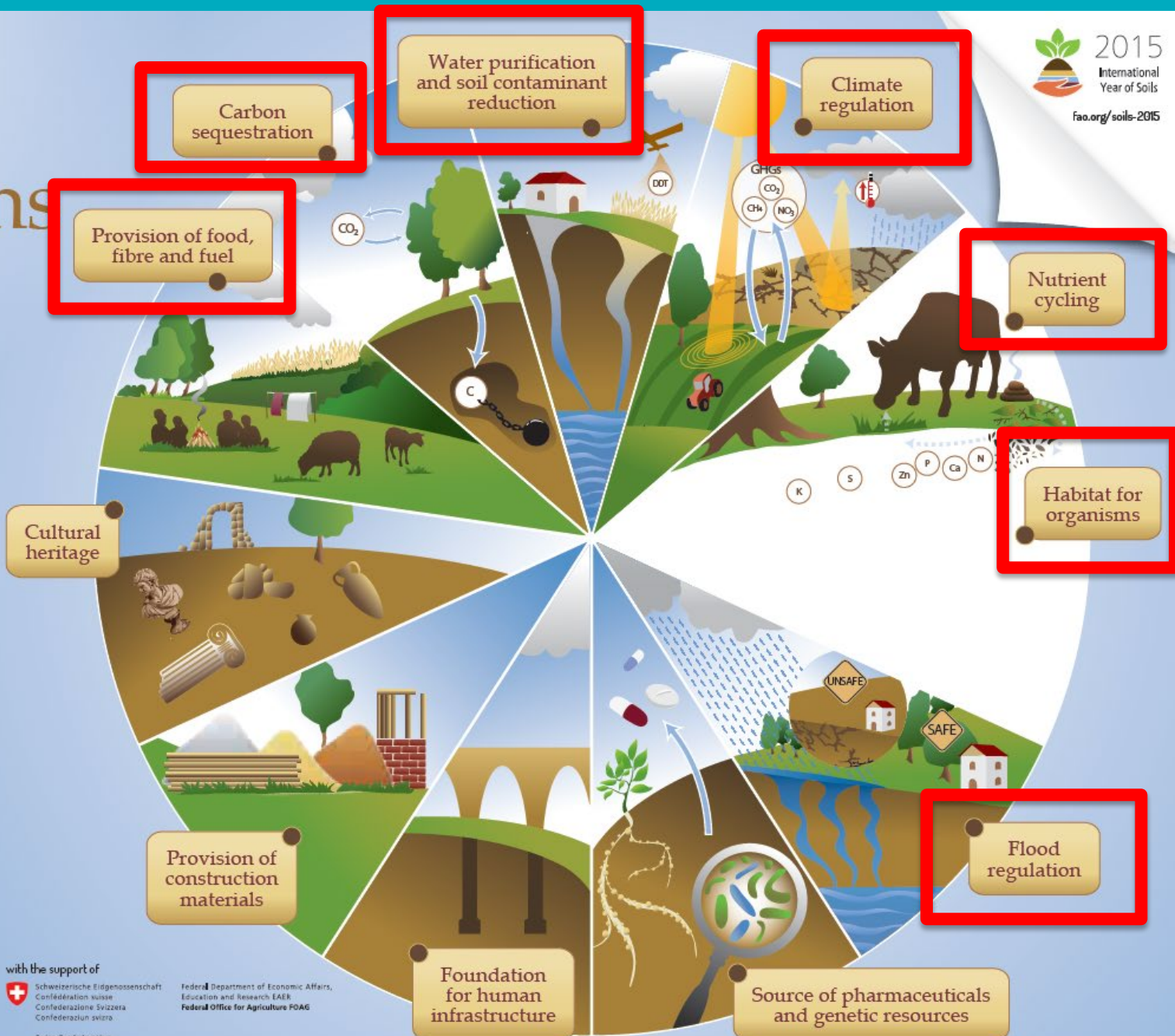
Soil functions

Soils deliver ecosystem services that enable life on Earth



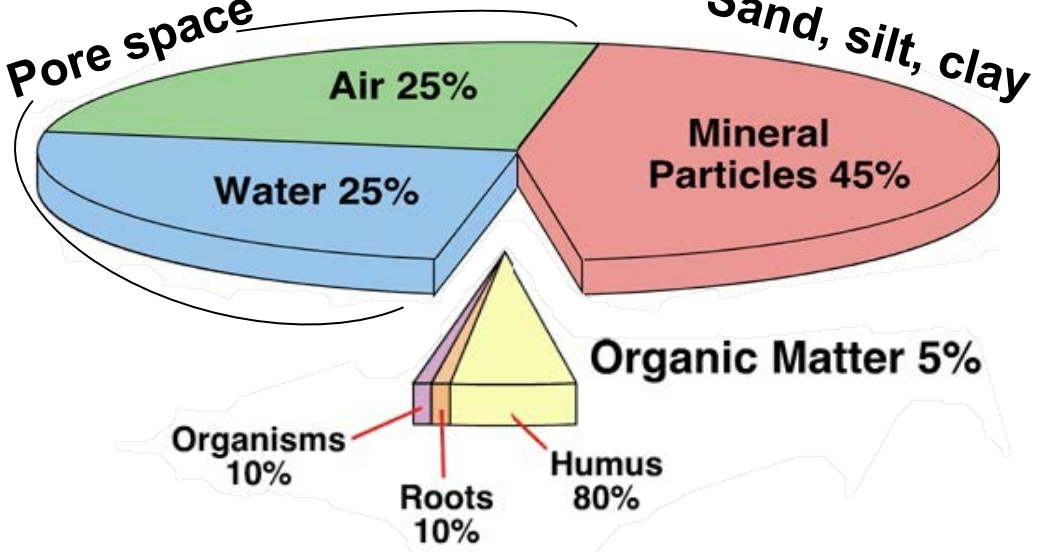
2015 International Year of Soils
fao.org/soils-2015

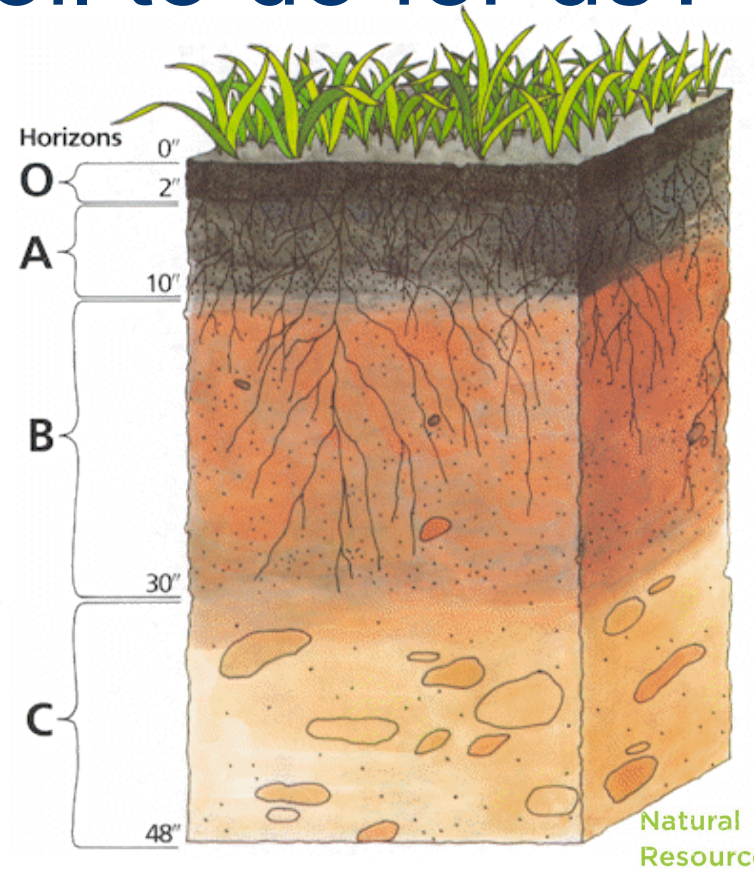
Food and Agriculture Organization of the United Nations

with the support of
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Federal Department of Economic Affairs, Education and Research EAER
Federal Office for Agriculture FOAG

Soil Function

What do we want soil to do for us?





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Important Soil Functions

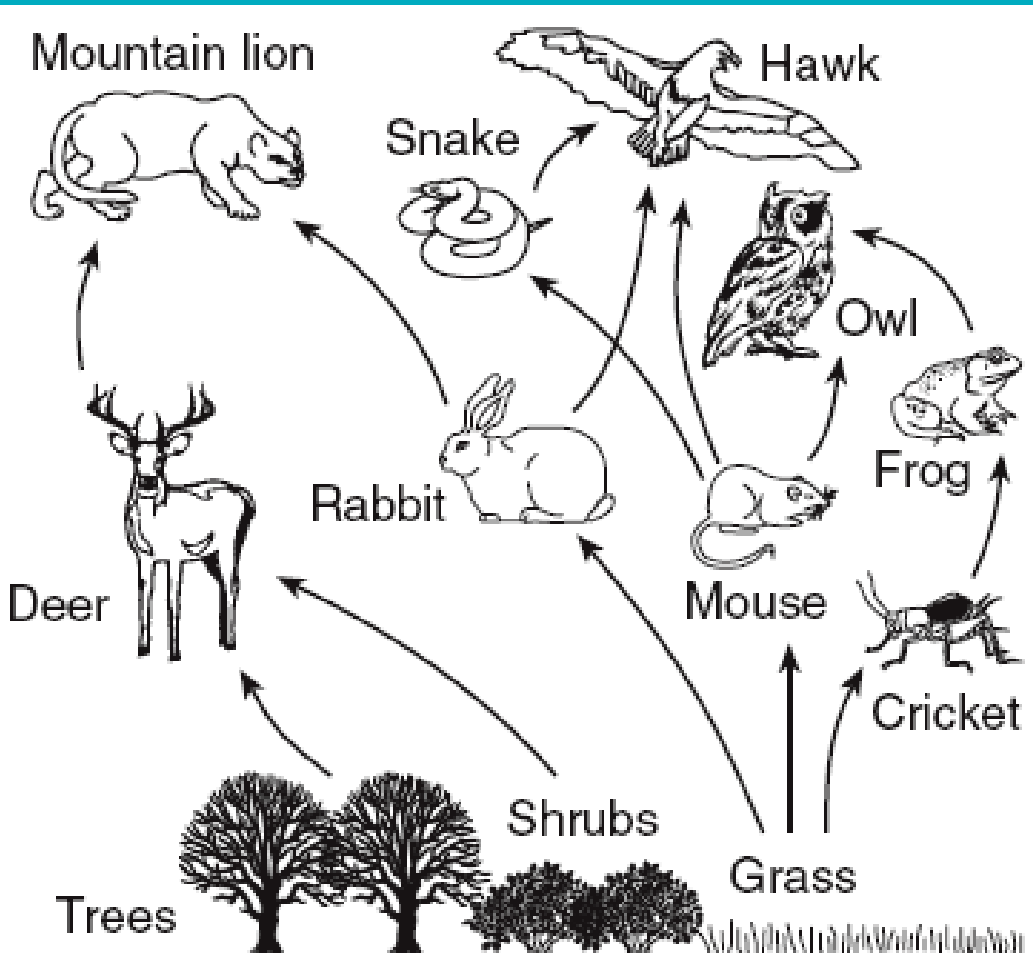
- Support productive plants
- Be stable and resist erosion
- Efficient at cycling nutrients internally
- Allow H_2O to enter quickly
- Drain well to avoid drowning plant roots
- Store H_2O for future plant use
- Resist pests, pathogens, and disease
- Help plants grow during 'stressful' events

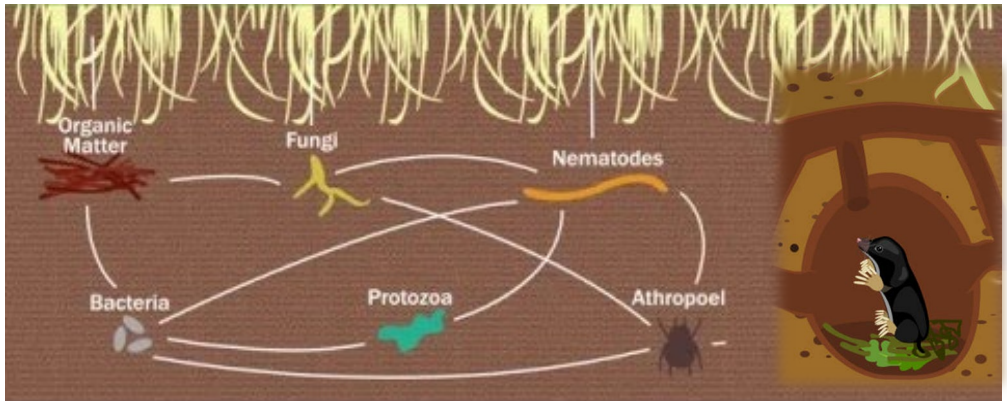
Important Soil Functions

- Support productive plants and livestock
- Be stable and resist erosion
- Efficient at cycling nutrients internally
- Allow H_2O to enter quickly
- Drain well to avoid drowning plant roots
- Store H_2O for future plant use
- Resist pests, pathogens, and disease
- Help plants grow during 'stressful' events

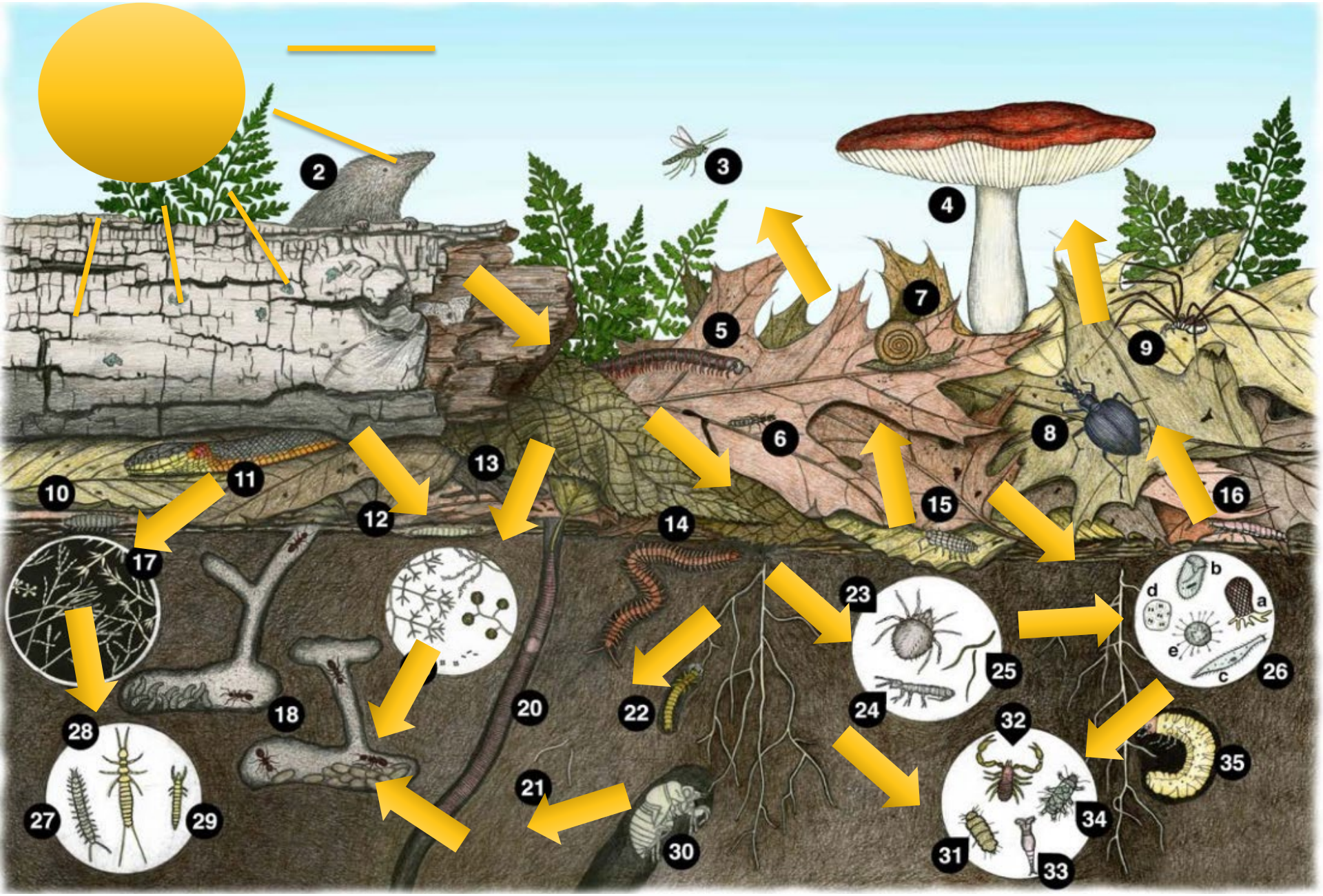
BIOLOGY

Food Web


Mountain lion
Hawk
Snake
Owl
Frog
Rabbit
Deer
Mouse
Cricket
Shrubs
Grass
Trees

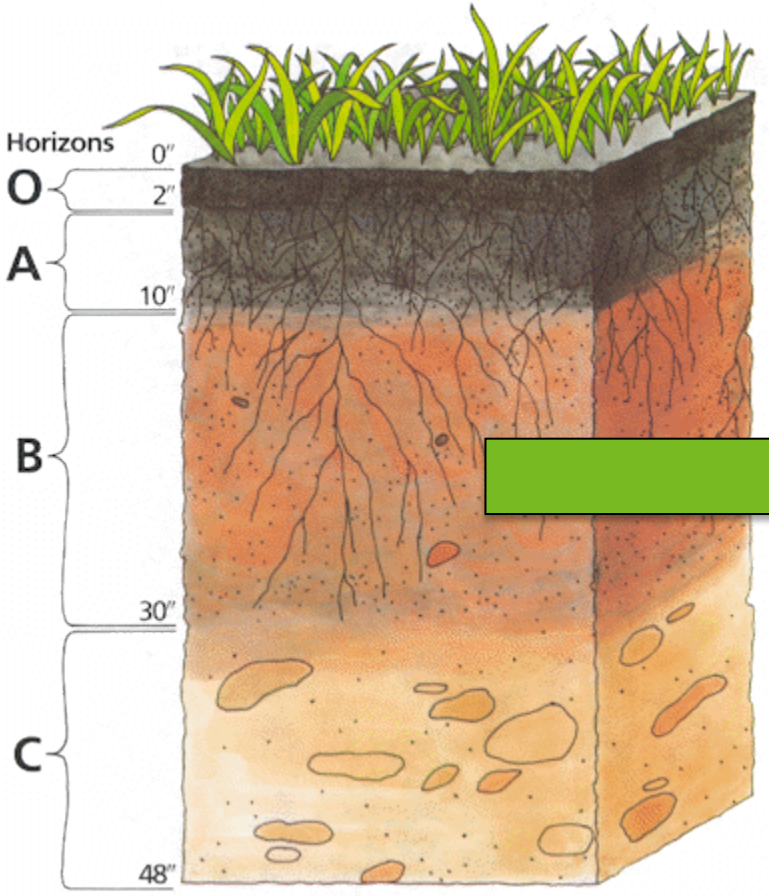

Organic Matter
Fungi
Nematodes
Bacteria
Protozoa
Athropoel

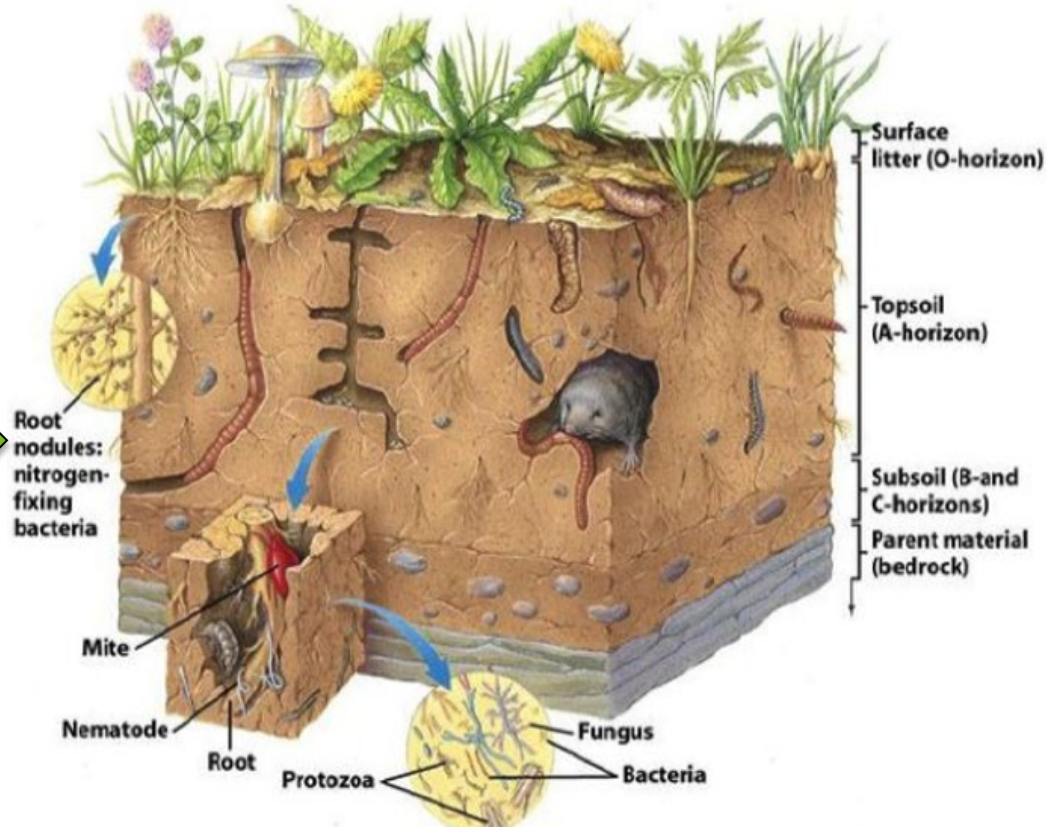
Soils are host to ~25% of Earth's Biodiversity



Farming with Soil Life: A Handbook for Supporting Soil Invertebrates and Soil Health on Farms – Xerces Society

Soil is ALIVE!





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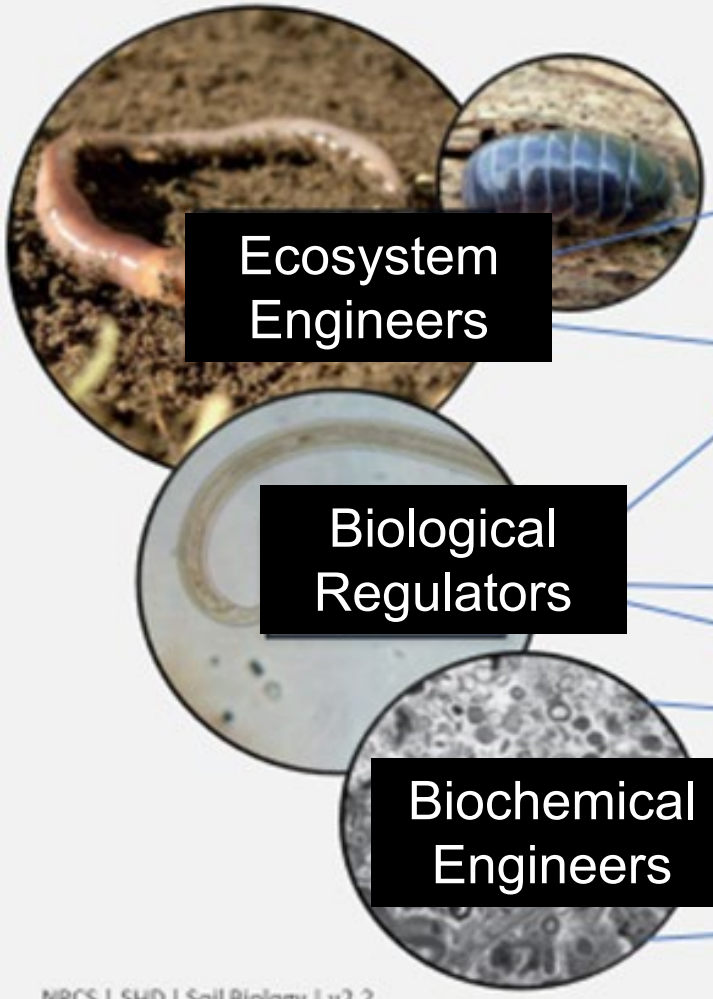
Soil Organisms
3 Functional Groups

Key Ecosystem Functions



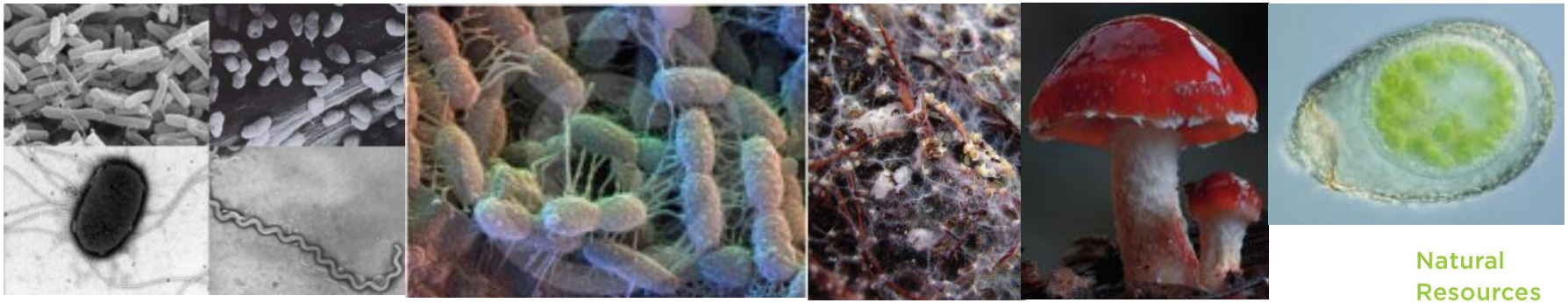
- Decomposition & C Cycling
- Ecosystem Resiliency
- Building soil, creating aggregates & pores
- Population Regulation
- Nutrient Cycling
- Plant Productivity

Turbe et al., 2010;
Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.

Soil Organisms Functional Group:

Biochemical Engineers

Functional group	Functions	Representative members
Biochemical Engineers	**Regulate** 90% of energy flow in soil; **Build** soil organic matter and aggregates; **Protection** from and **cause** of plant stress; **Nutrient cyclers**	Soil microbes (bacteria, archaea, fungi, protozoa)



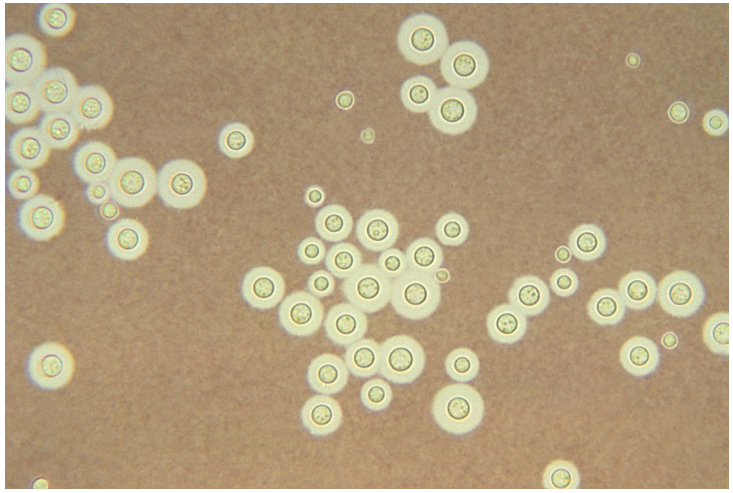
Turbe et al., 2010; Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.

Radiotrophic fungus:

Discover in 1991 in Chernobyl Nuclear Power Plant

Ionizing Radiation Changes the Electronic Properties of Melanin and Enhances the Growth of Melanized Fungi
E. Dadachova et al., 2007

Cladosporium sphaerospermum



Cryptococcus neoformans

Exophiala dermatitidis

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Biology is Resilient

Soil Organisms Functional Group:
Biological Regulators

Functional group	Functions	Representative members
Biological Regulators	**Regulate** populations of other soil organisms; **Mineralize** nutrients	Protozoa and small invertebrates (e.g., nematodes, pot worms, springtails, mites)

Nematodes

Springtails and Mites

Protozoa

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Turbe et al., 2010; Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.

Soil Organisms Functional Group:
Ecosystem Engineers

Functional group	Functions	Representative members
Ecosystem Engineers	**Build** pore networks and soil aggregates **Redistribute** soil particles, microbes, & organic matter	Plant roots, earthworms, & other larger invertebrates (millipedes, centipedes, beetles, caterpillars, scorpions, etc.)

Bioturbation video:
https://vimeo.com/222168889

Turbe et al., 2010;
Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.

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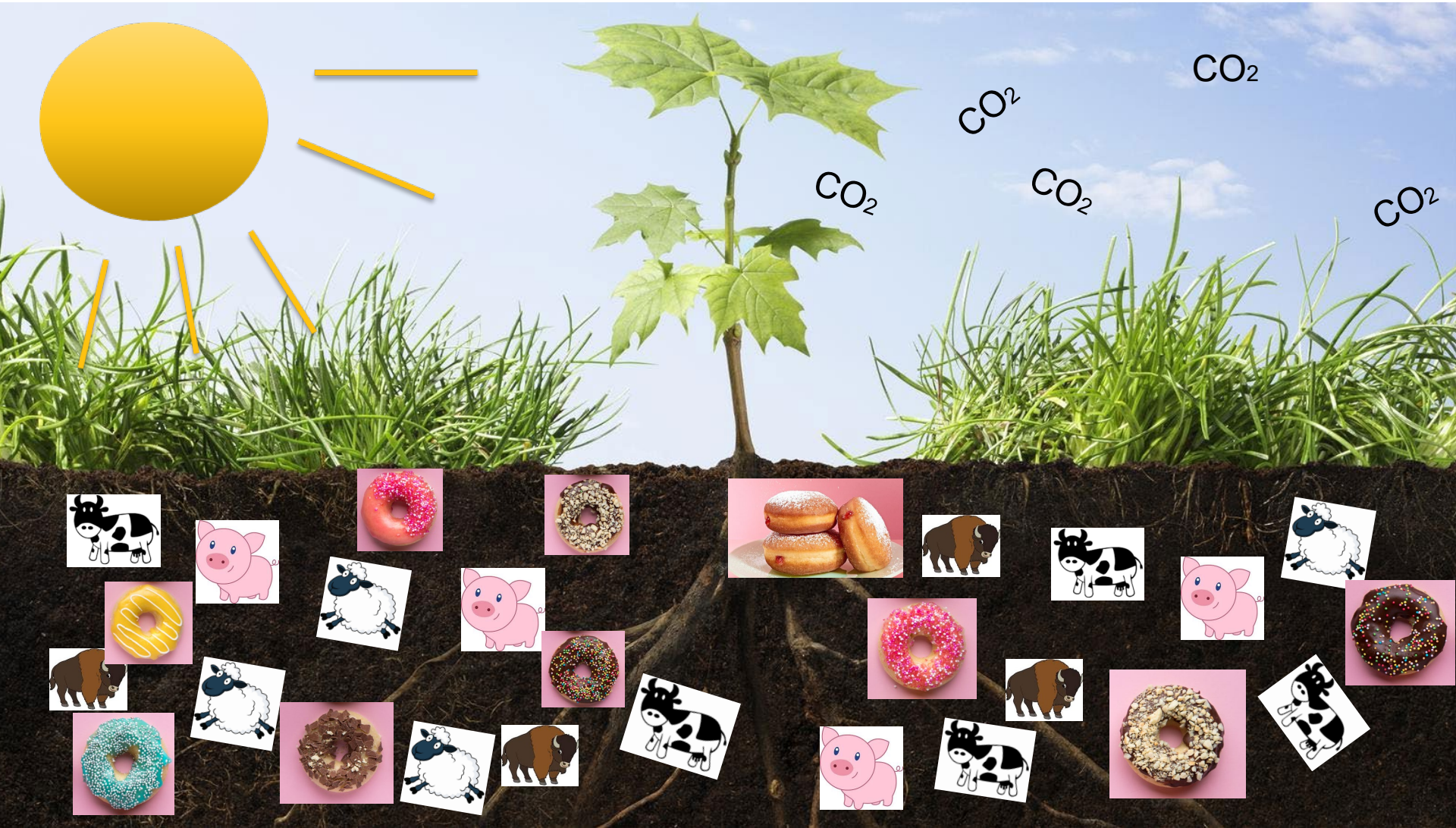
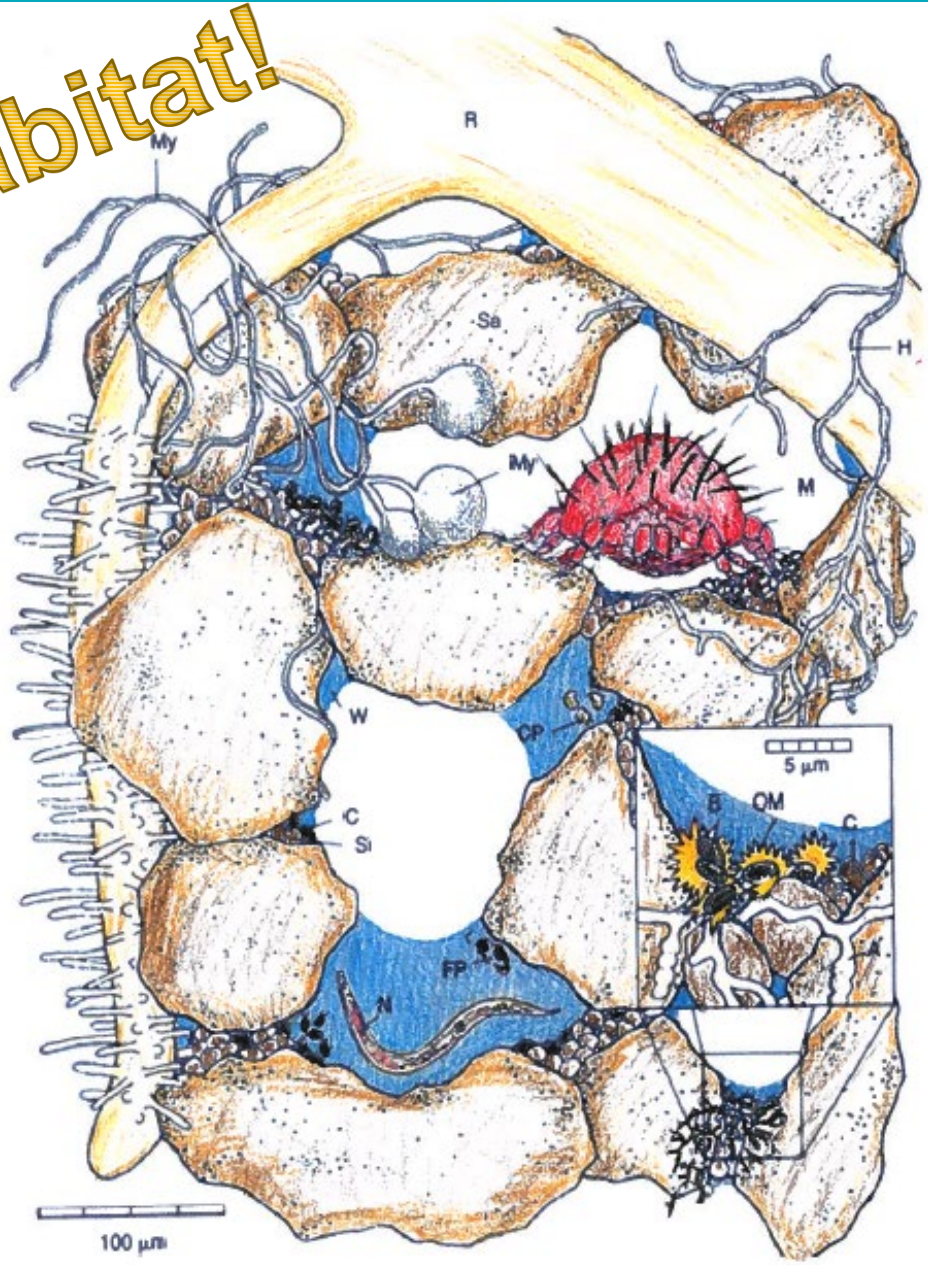
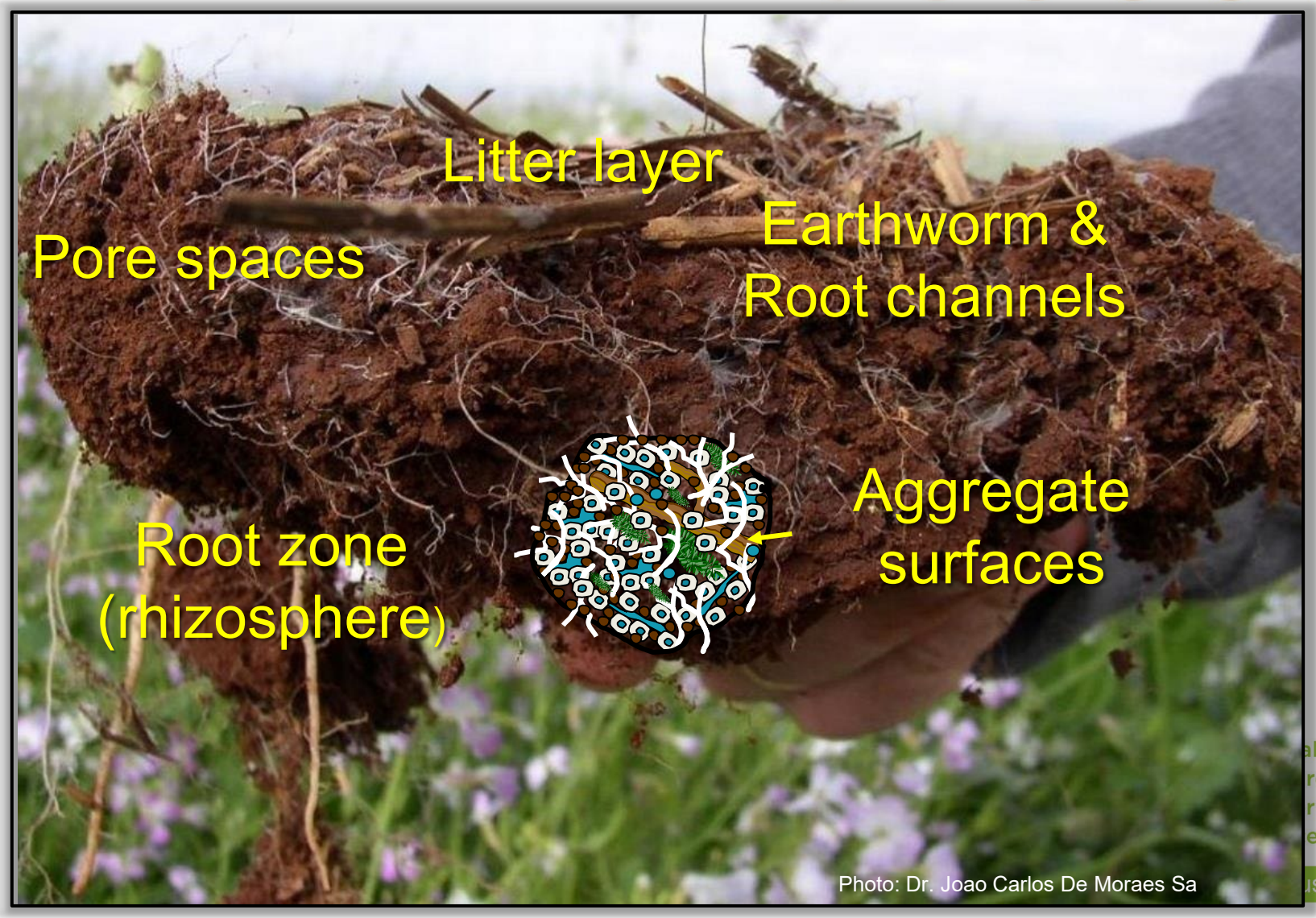
Manage for healthy soils = Considering biology and function in everything you do.



Soil is habitat!



Biological Hot Spots



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Soil Aggregate Stability Demonstrations

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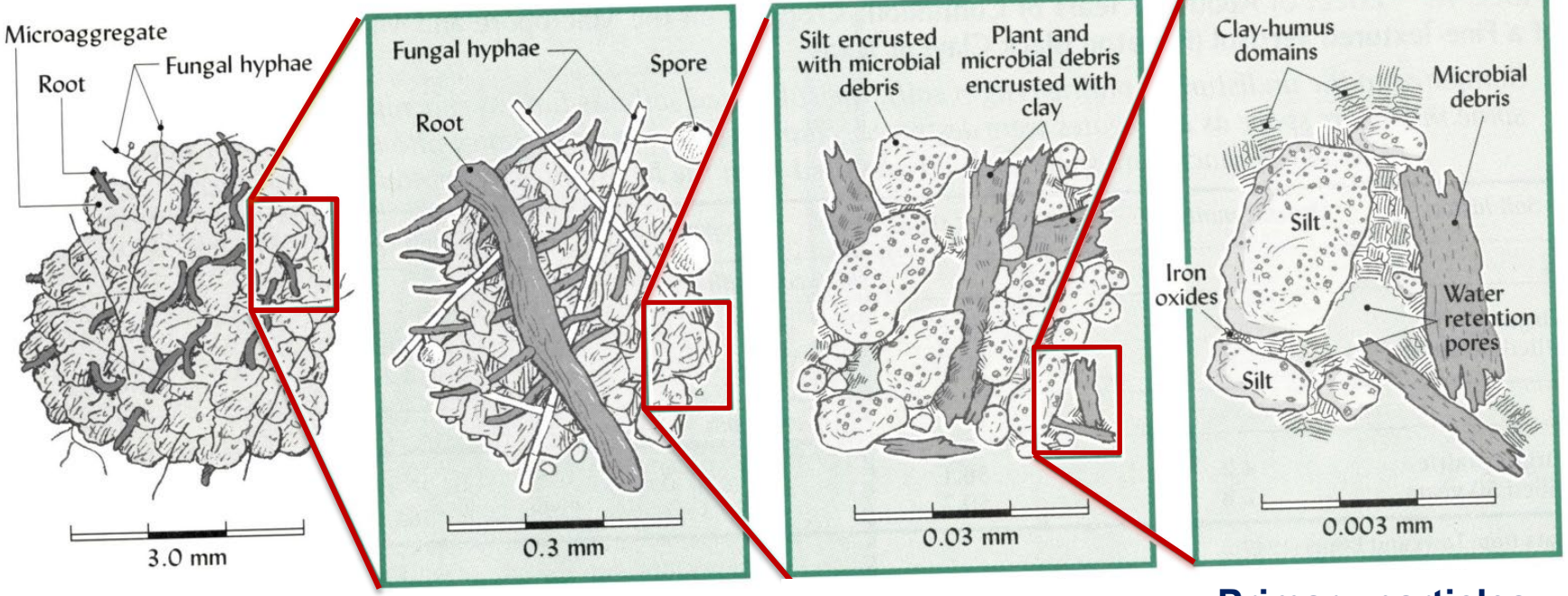
Soil Aggregation:

Where texture and organic matter meet

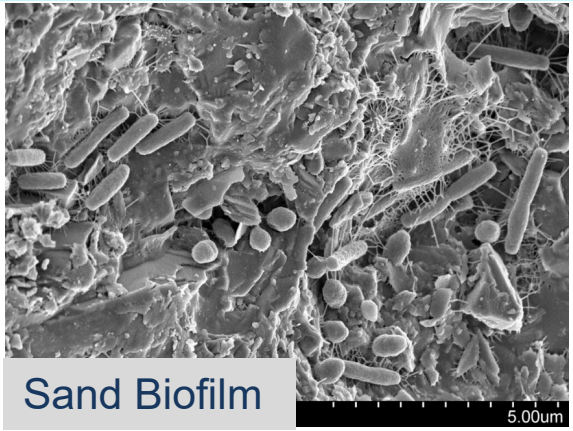


Macroaggregate
- Root
- Fungal hyphae

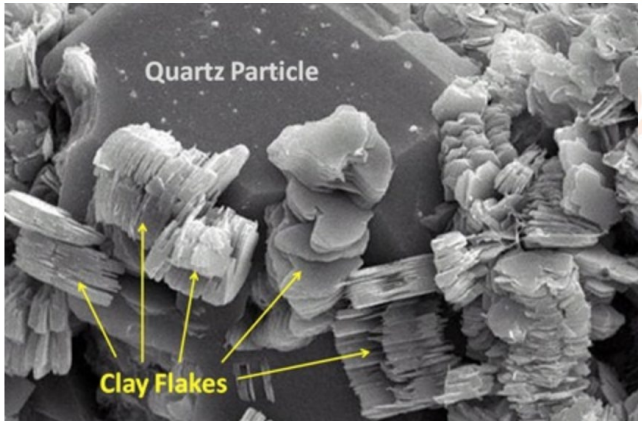
Microaggregate
- Root hairs
- Fungal hyphae
- Polysaccharides

Sub-microaggregate
Mineral grains coated with plant and microbial exudates

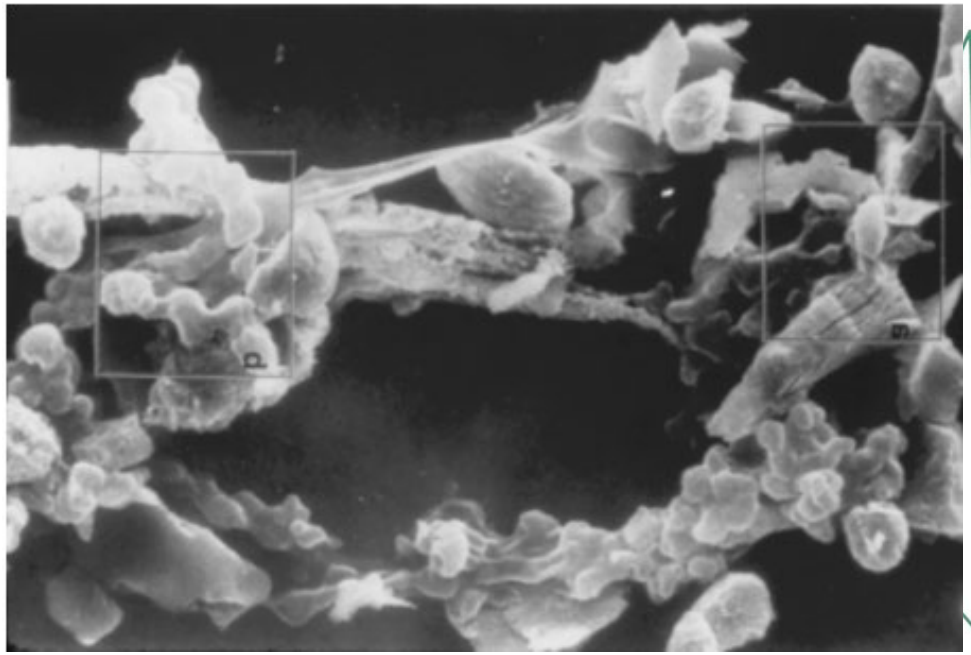
Primary particles
Silt, clay and humus



Sand Biofilm



Iron Oxide



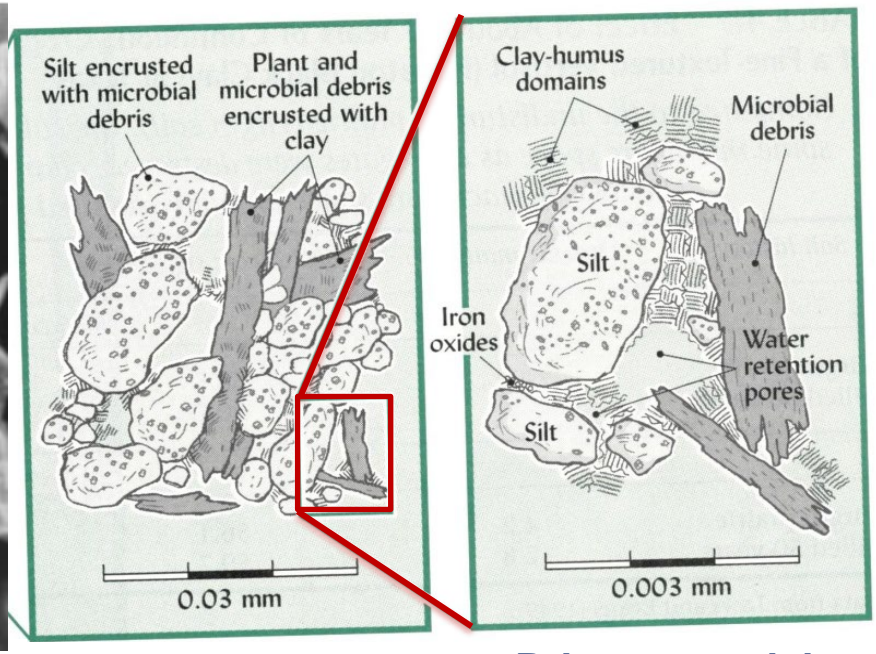
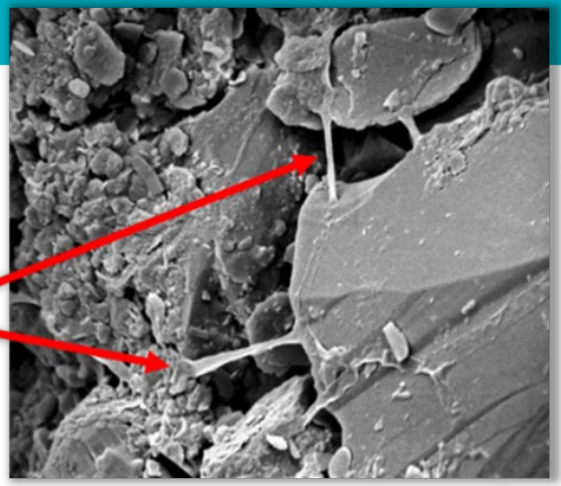


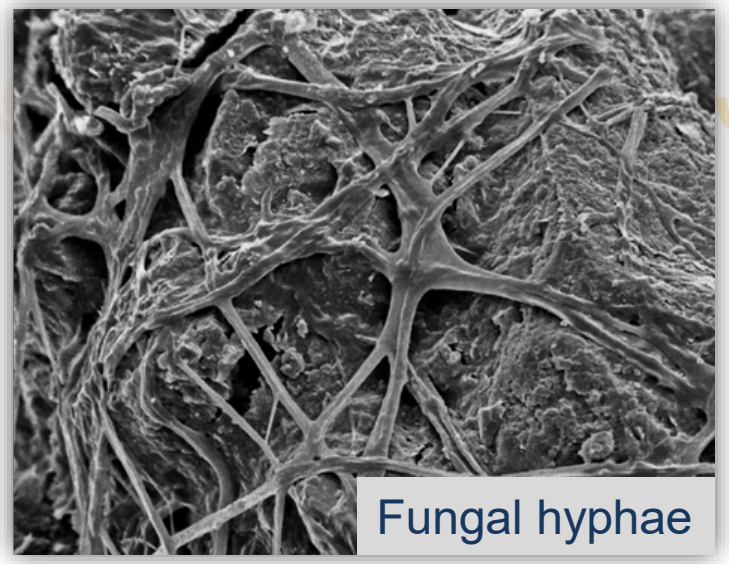
Photo Credits
https://lmecol.evsc.virginia.edu/soils/handouts/strom/
https://teara.govt.nz/en/photograph/12281/soil-texture
Sand Biofilm 10 | A natural community of bacteria growing on… | Flickr
Clay - The Daily Garden

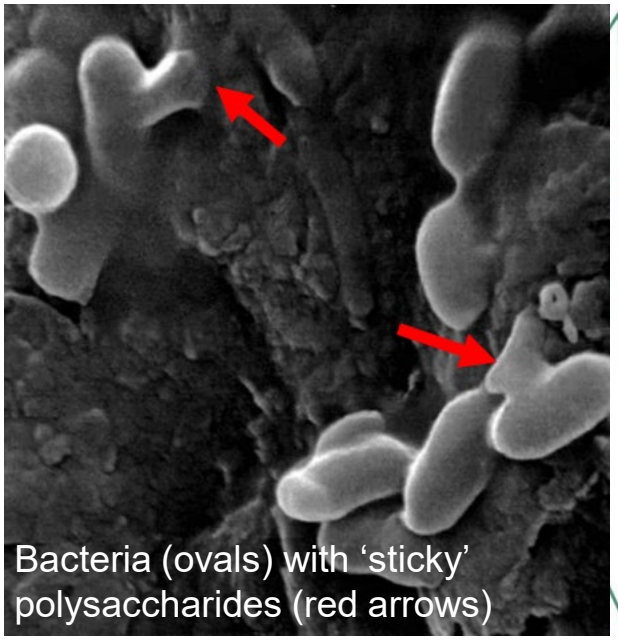
Sub-microaggregate
Mineral grains coated with plant and microbial exudates

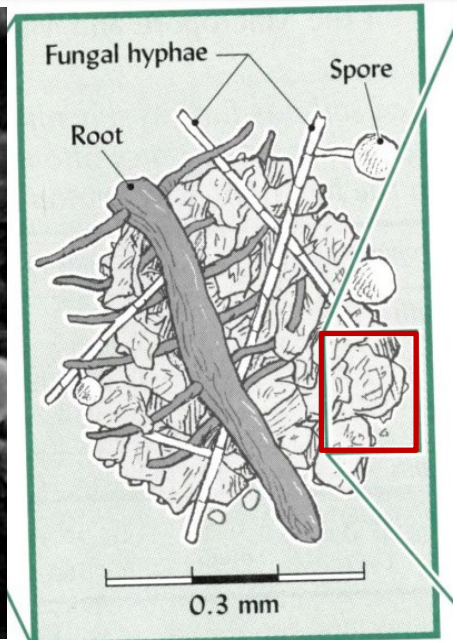
Primary particles
Silt, clay and humus

Stabilization of soil structure by actinomycete (bacterial) filaments





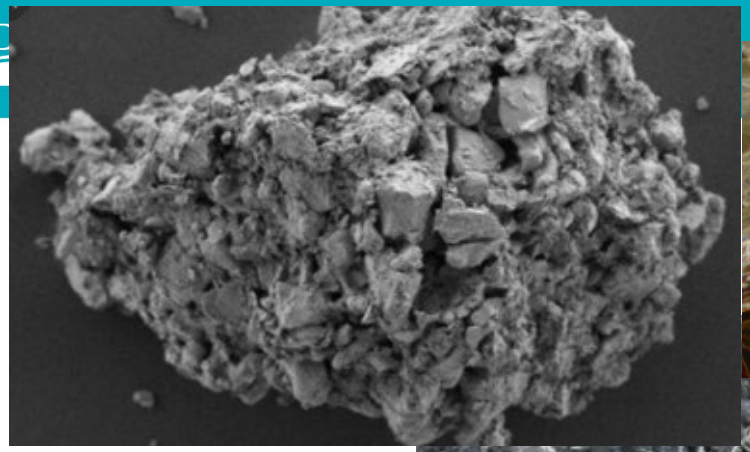




SEM photo source: Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen

Microaggregate

- Root hairs
- Fungal hyphae
- Polysaccharides



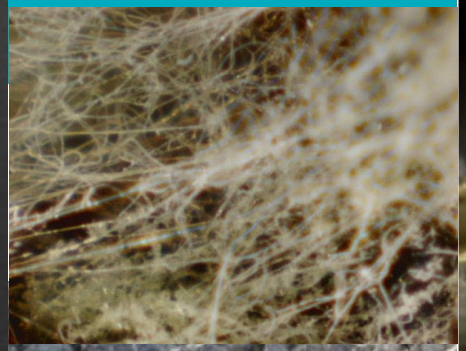


Figure 4.2. A soybean root heavily colonized with mycorrhizal fungi (*Rhiziphagus irregularis*). Photo by Yoshihiro Kobae.

Macroaggregate

- Root
- Fungal hyphae

https://www.agweek.com/business/4434742-start-digging-aggregation-soil-health-indicator

http://www.csun.edu/science/scale/4th_grade/graphics/columns/columns-Pages/Image4.html

Magnificent Mycorrhiza❣️

Mycorrhiz
roots to access more soil and acquire nutrients and water more efficiently.

Mycorrizal fungi holding soil aggregates together

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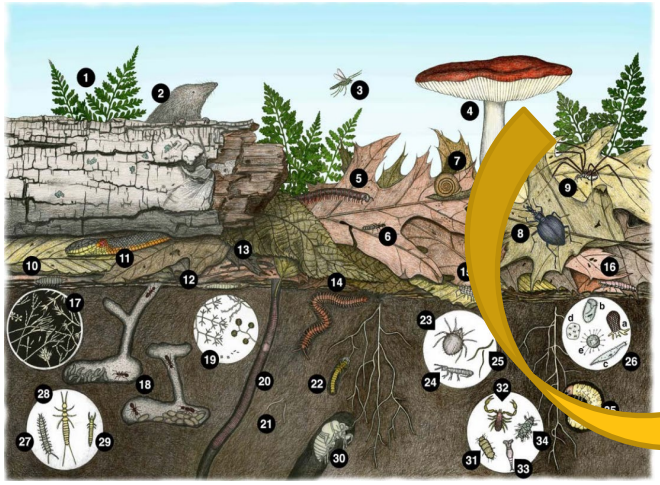
Soil Aggregation:

Physical /Chemical Factors:

- Drying & Wetting
- Freeze – Thaw
- Fire
- Inorganic binding agents
  - Oxides
  - Calcium

https://www.pinterest.com/pin/502855114622813480/
https://www.uidaho.edu/cals/soil-orders/aridisols
https://www.summitdaily.com/news/new-reports-gauge-severity-of-soil-damage-from-east-troublesome-williams-fork-fires/

1. Organic matter feeds the soil food web



2. The soil food web creates stable aggregates

3. Soil functions as an ecosystem

Important Soil Functions

- Support productive plants
- Be stable and resist erosion
- Efficient at cycling nutrients internally
- Allow H_2O to enter quickly
- Drain well to avoid drowning plant roots
- Store H_2O for future plant use
- Resist pests, pathogens, and disease
- Help plants grow during 'stressful' events

"The formation and maintenance of a high degree of aggregation is one of the most difficult tasks of soil management, yet it is also one of the most important, since it is a potent means of influencing ecosystem function." Brady & Weil

Father of Conservation

Hugh Hamond Bennett (1881-1960)

"If we are bold in our thinking, courageous in accepting new ideas, and willing to work with instead of against our land, we shall find in conservation farming an avenue to the greatest food production the world has ever known."

Soil Degradation Spiral

intensive tillage, soil erosion, and insufficient added residues

aggregates break down

soil organic matter decreases

increased erosion by wind and water

surface becomes compacted, crust forms

less soil water storage, less diversity of soil organisms, fewer nutrients for plants

more soil organic matter is lost

crop yields are reduced

hunger and malnutrition result

Building Soils for Better Crops – Ecological Management for Healthy Soils
Image modified from Topp et al. (1995)

Photo Credit: https://www.istockphoto.com/photo/the-demolition-of-the-house-gm544323062-97797213

Soil Degradation Spiral

intensive til
and insufficien

soil organic m

surface

water

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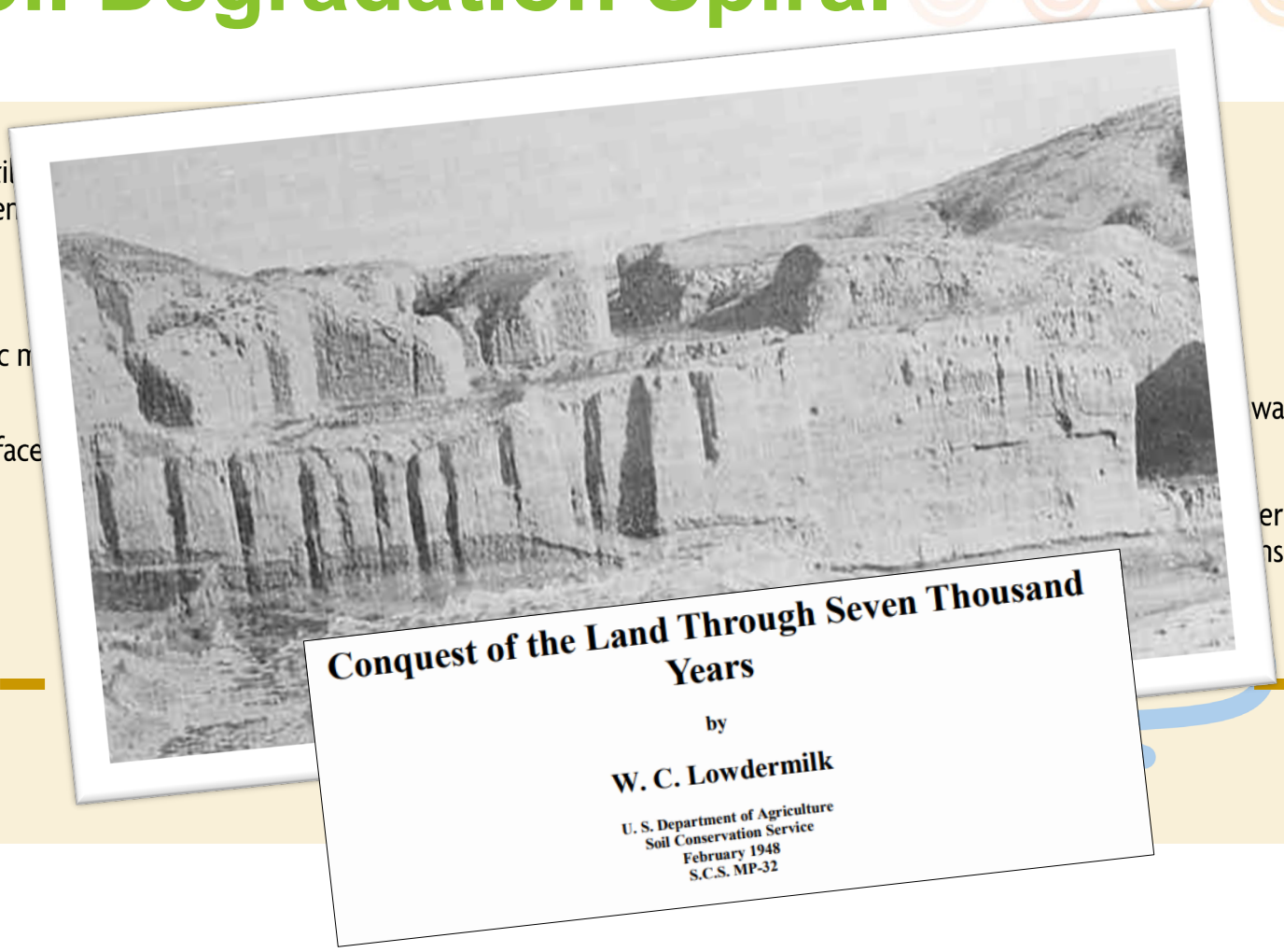
ns, fewer nutrients for plants



Conquest of the Land Through Seven Thousand Years

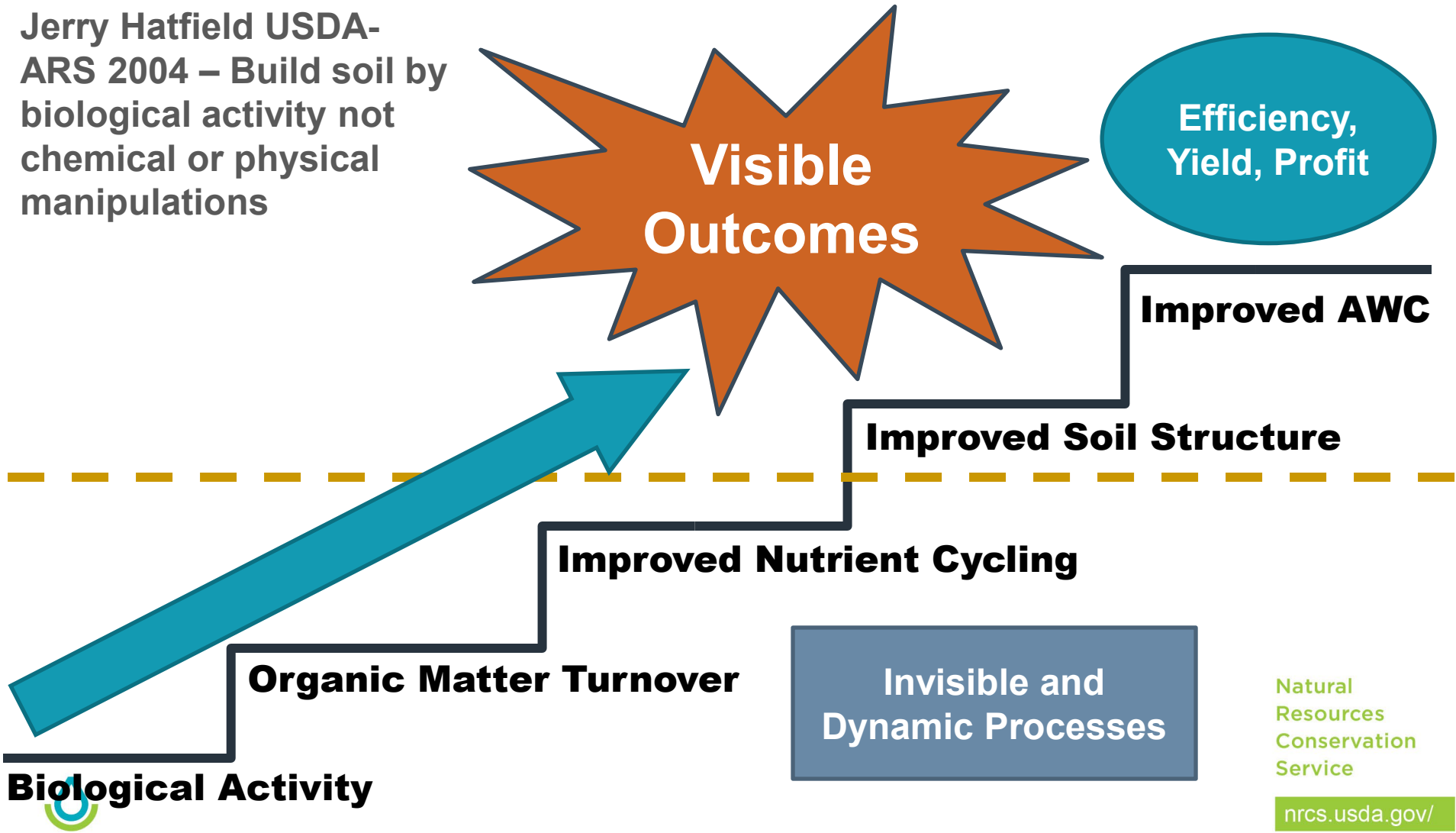
by

W. C. Lowdermilk

U. S. Department of Agriculture
Soil Conservation Service
February 1948
S.C.S. MP-32

Soil Aggregation Climb

Jerry Hatfield USDA-ARS 2004 – Build soil by biological activity not chemical or physical manipulations



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Think like a root! Which soil would you like better?

Marla Riekman, Soil Management Specialist, Manitoba Agriculture

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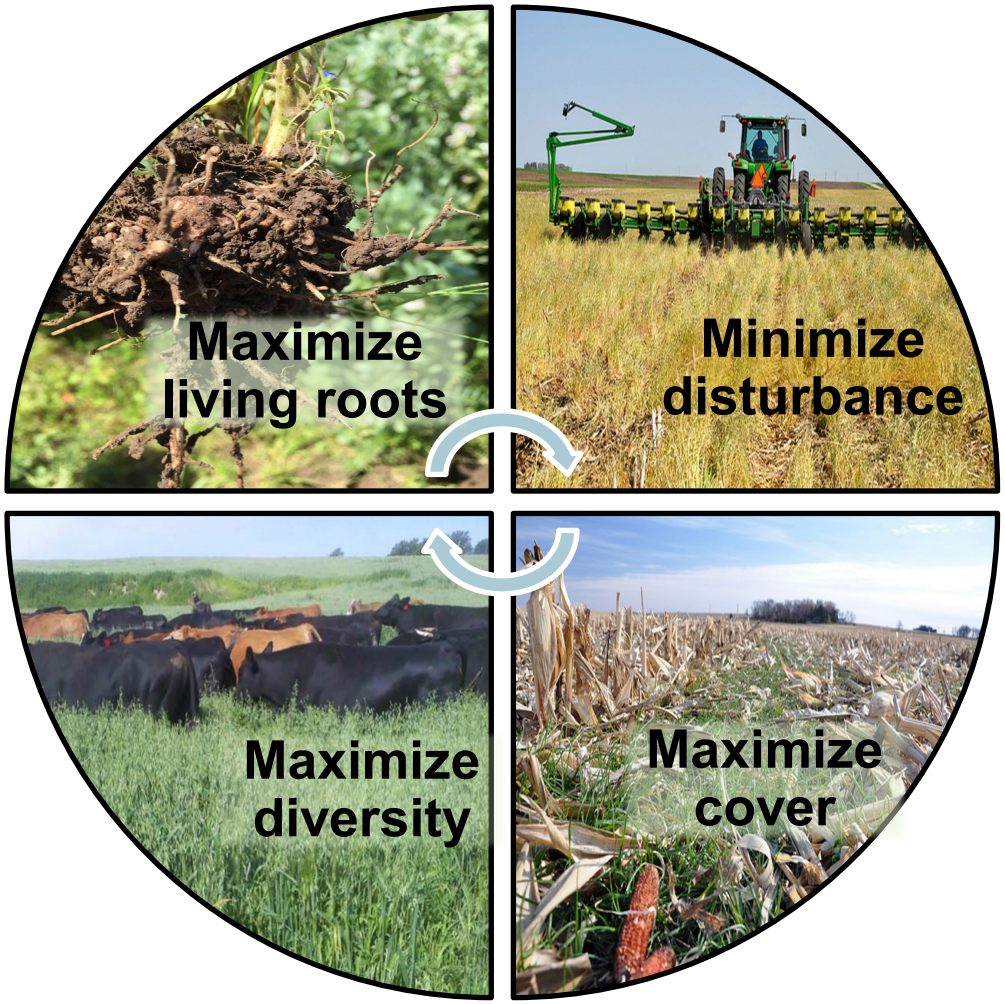
HOW

Soil Health Principles To Support High Functioning Soils



Soil Health Principles To Support High Functioning Soils

FEED

Soil Biology
Improve Resilience
Continuous C input
(SOM)

PROTECT

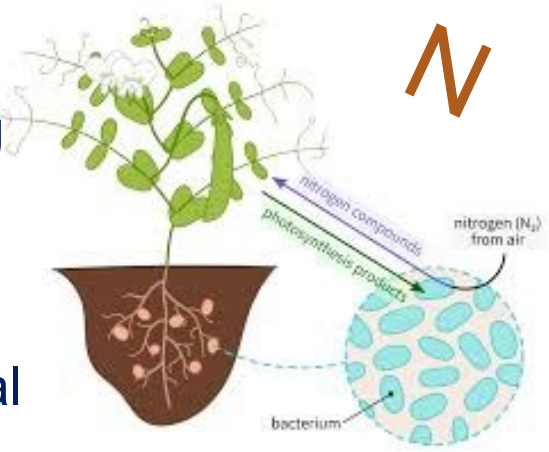
Organism Habitat
Soil aggregates
Soil Organic Matter (SOM)

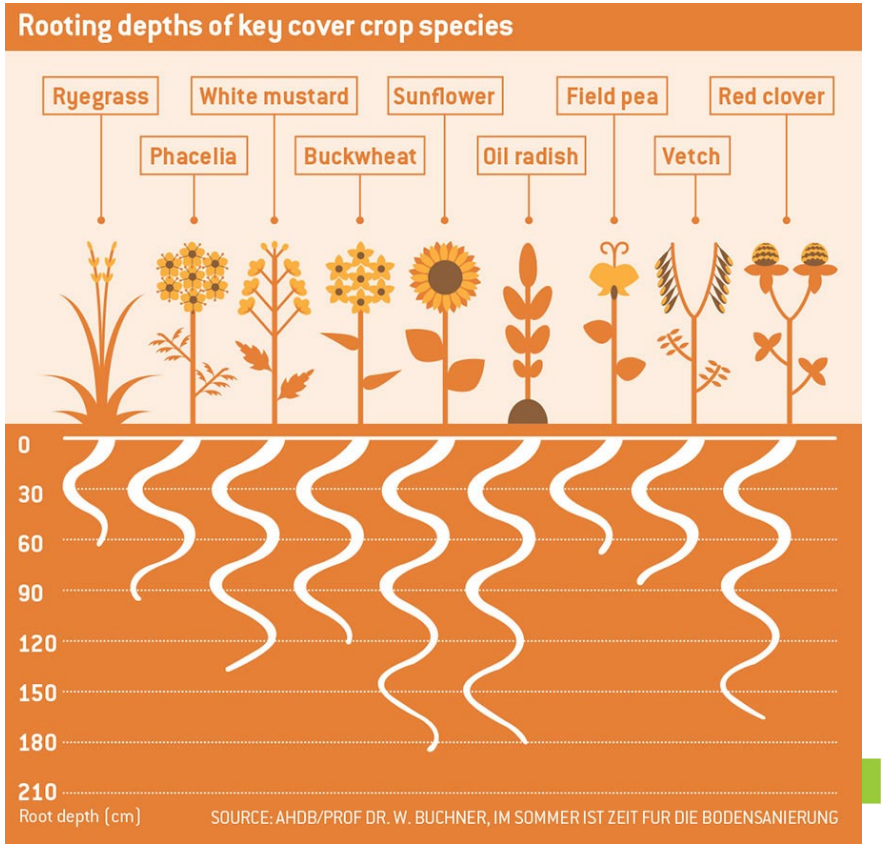
FEED BIOTA

Maximize Living Roots & Maximize Diversity

- Break disease/pest cycles
- Stimulate/change belowground diversity
- Increase soil organic matter (SOM)
- Increase nutrient cycling
- Enhance plant growth
- Increase predator & pollinator populations

- Cover Cropping
- Avoid fallow
- Increase re-cropping interval





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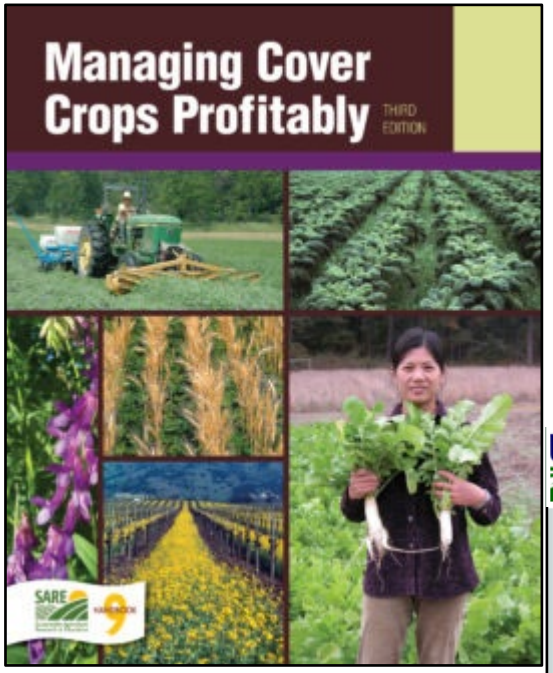
Cover Cropping Resources



FS 304
Reprinted February 1999

Cover Crops for Home Gardens

R.L. Rackham and R. McNeilan

Cover crops planted in late summer are an inexpensive way to build better soil for gardening. Cover crops often are called *green manure crops.* They are grains, grasses, or legumes that will grow during fall and winter and that you can plow, spade, or till under in the spring.

During their growth, cover crops help reduce soil compaction and prevent erosion. Their roots penetrate and help loosen heavy-textured soils, allowing

Which crop should I use?

Cover crops for home vegetable gardens should grow quickly, cover the area to shade out weeds, and be easy to work into the soil in the spring. Table 1 lists some suggested cover crops for garden soils. You can combine a legume with a grass or cereal plant crop to produce and store nitrogen. Vetch with rye or oats, or Austrian peas or garden peas with winter wheat or rye make

Fertilizing for legumes. These have little need for nitrogen. However, you will need to till phosphorus, potassium, and lime into your soil before you plant (lime to pH 5.8 or above). Use any low-nitrogen formulation of fertilizer that will supply 1 to 2 lb each of phosphorus and potassium per 1,000 square feet.

Wood ashes. If you plan to use these in your garden, see EC 1503, *Fertilizing Your Garden: Vegetables, Fruits, and Ornamentals*

OSU Oregon State University

USDA Natural Resources Conservation Service
Plant Materials Program

Pacific Northwest Cover Crop Selection Tool

This Cover Crop Selection Tool for Idaho, Oregon, and Washington is intended as a guide to help growers and conservation planners select cover crop species adapted to their climate, soils, and the purposes of the cover crop.

Oregon State University | OSU Extension Service

TOPICS GET INVOLVED ABOUT CONTACT US

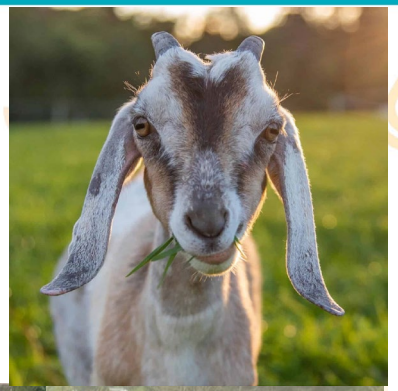
Home / Crop Production / Soil

Establishing Winter Cover Crops

nrcs.usda.gov/

Companion Planting

Relay Cropping



Incorporate Livestock

Crop Rotation

Row Intercropping

Attract Pollinators

PROTECT SOIL HABITAT AND ORGANIC MATTER

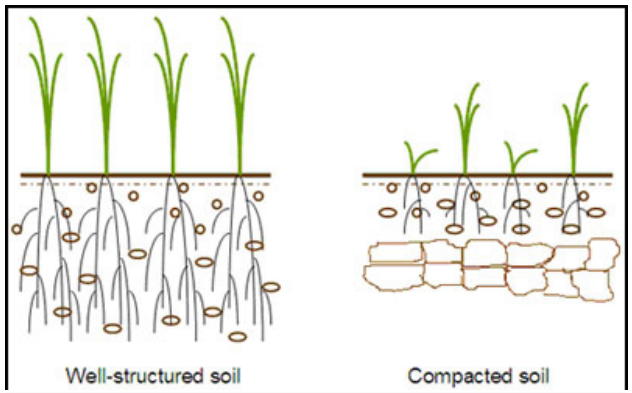
Image courtesy of Barry Fisher, NRCS-SHD

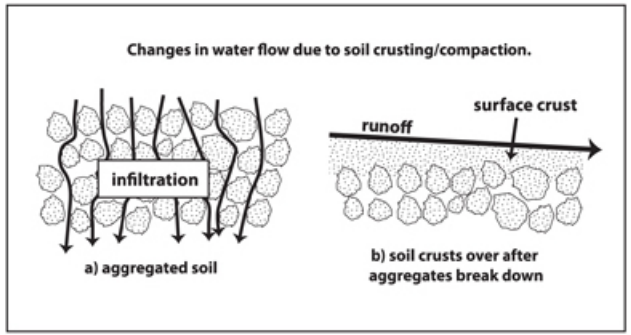
Minimize Disturbance & Maximize Soil Cover

- Maintain stable aggregates
- Reduce erosion and runoff risk
- Buffer temperature
- Reduce evaporation
- Maintain soil organic matter
- Habitat for soil organisms
- Reduce weed pressure

Increase habitat for soil organism

National Historic Oregon Trail Interpretive Center
Baker City, Oregon





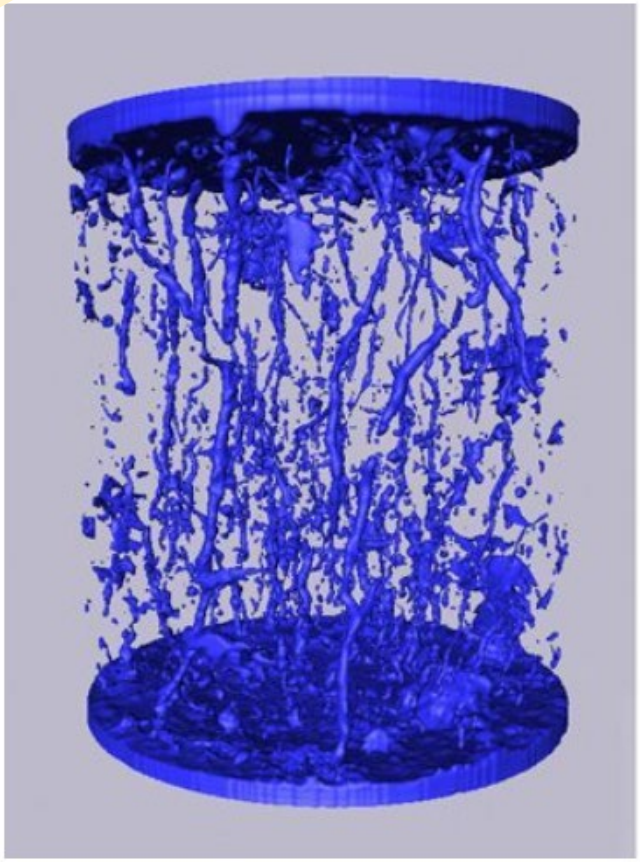
Avoid common disturbances

- Physical
- Chemical
- Biological

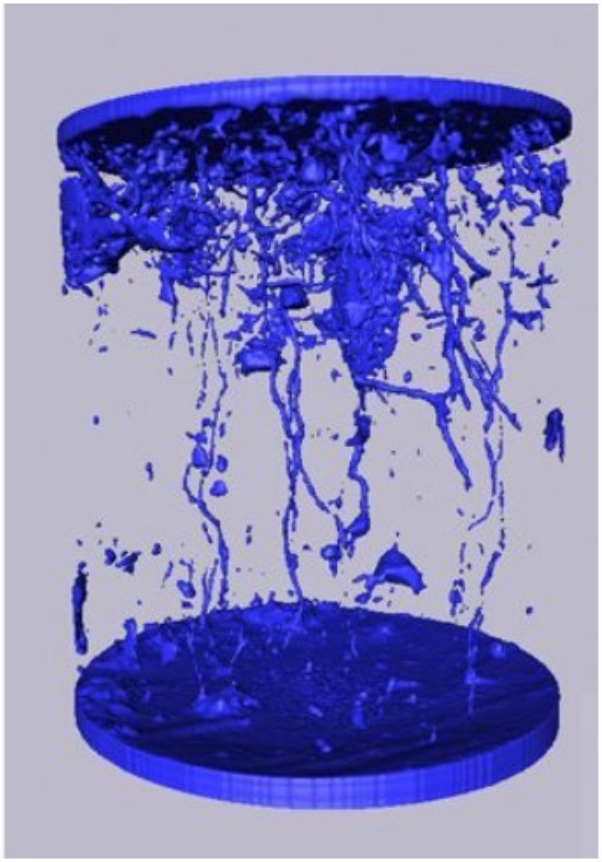
Be mindful about disturbance

PROTECT

no disturbance



Machinery compacted 14 years prior, no disturbance since



Vertical pores reduced

Horizontal pores have collapsed

Pore space = **BLUE**

Dorthe Wildenschild, Oregon State University
https://www.producer.com/crops/ct-scan-tech-used-to-check-soil-health/

USDA
United States Department of Agriculture

Be mindful about disturbance

With What?

How Much?

How Deep?

How Often?

PROTECT

Mitigate Soil Erosion

Cover Cropping

Mulch

Relay Cropping

Natural Resources Conservation Service

nrcs.usda.gov/

Management Spectrum

Doing Nothing	Trying Things	Getting Good	Total Success!

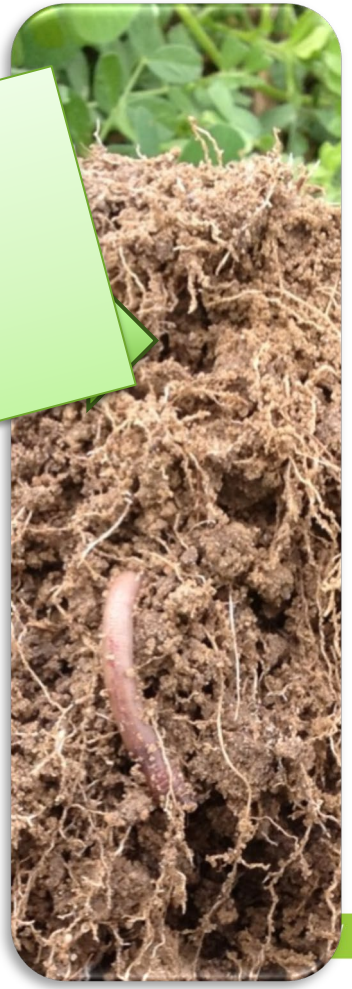
- Diversity
- Covered
- Living Root
- Disturbance

Management Spectrum

Doing Nothing	Trying Things	Getting Good	Total Success!

- Diversity
- Covered
- Living Roo
- Disturbance

SCALE AND MANAGEMENT!



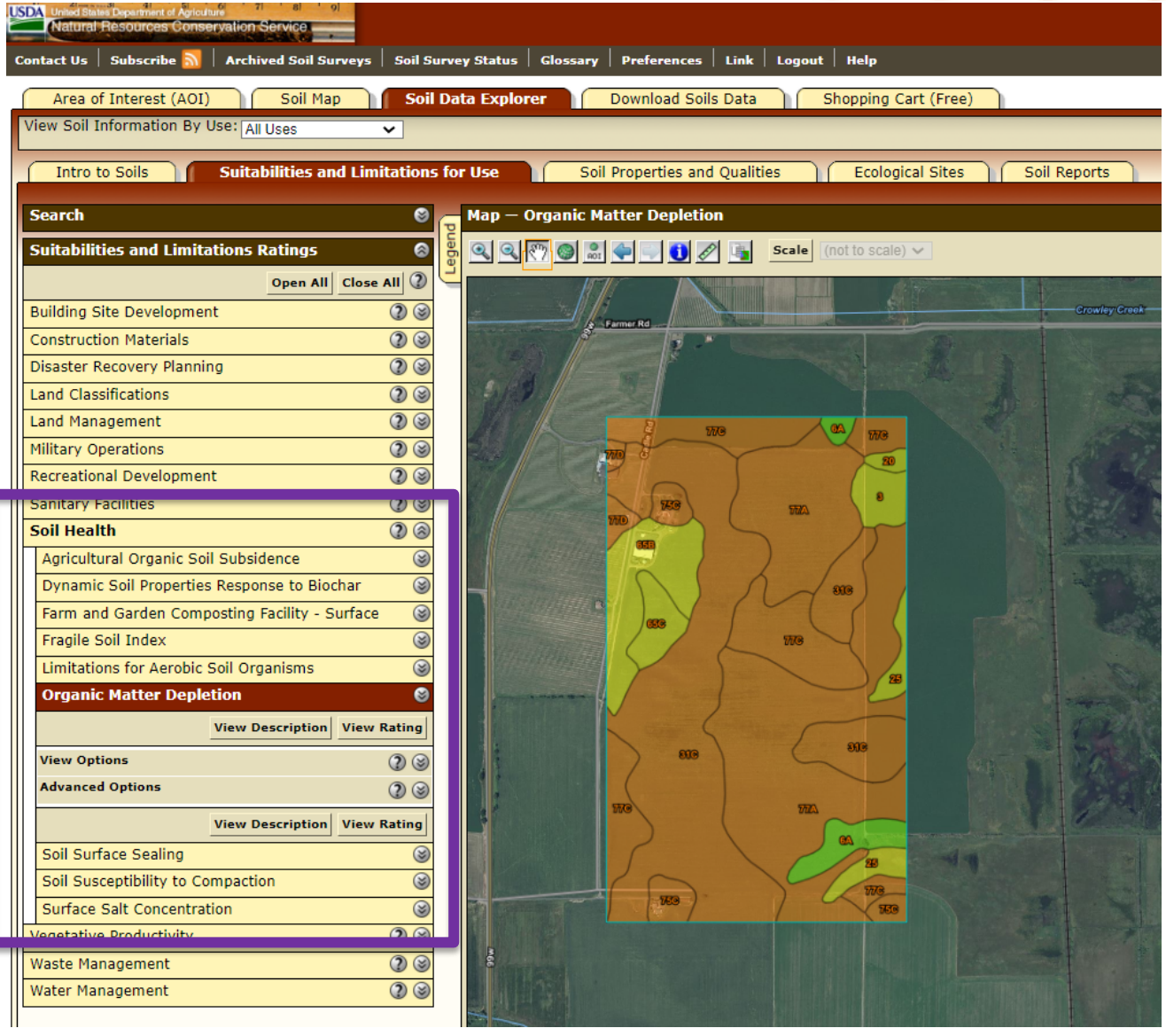
“Relaxed tillage”

Anders Suneson, 2012

Web Soil Survey

https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Web Soil Survey



Natural Resources Conservation Service

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United States Department of Agriculture

1% organic matter in top 6 inches = $750 per acre per percent

FEED

Soil Biology

Improve Resilience

Continuous C input (SOM)

PROTECT

Organism Habitat

Soil Aggregates

Soil Organic Matter (SOM)

Healthy World

Healthy Ecosystems

Healthy Animals

Healthy Food

Healthy Soil

Natural Resources Conservation Service

nrcs.usda.gov/

United States Department of Agriculture

Questions, comments?

Theresa Brehm, Soil Conservationist

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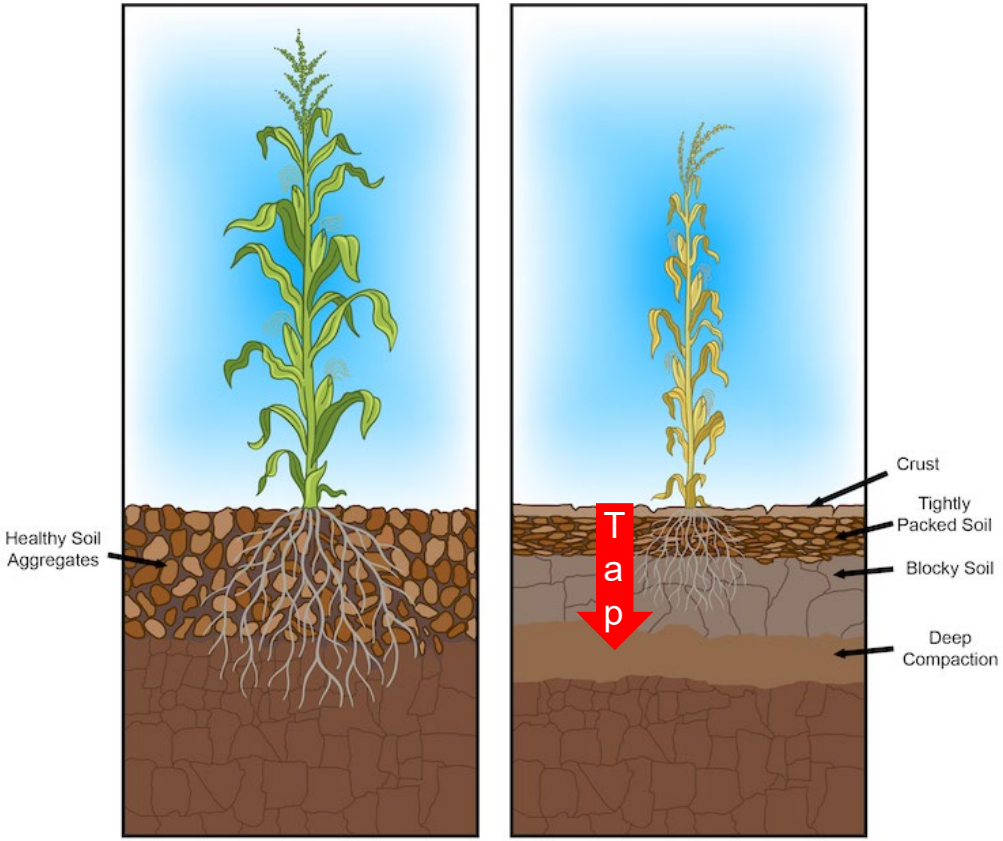
(971) 273-4814

Why these practices?
Compaction and Organic Matter Depletion

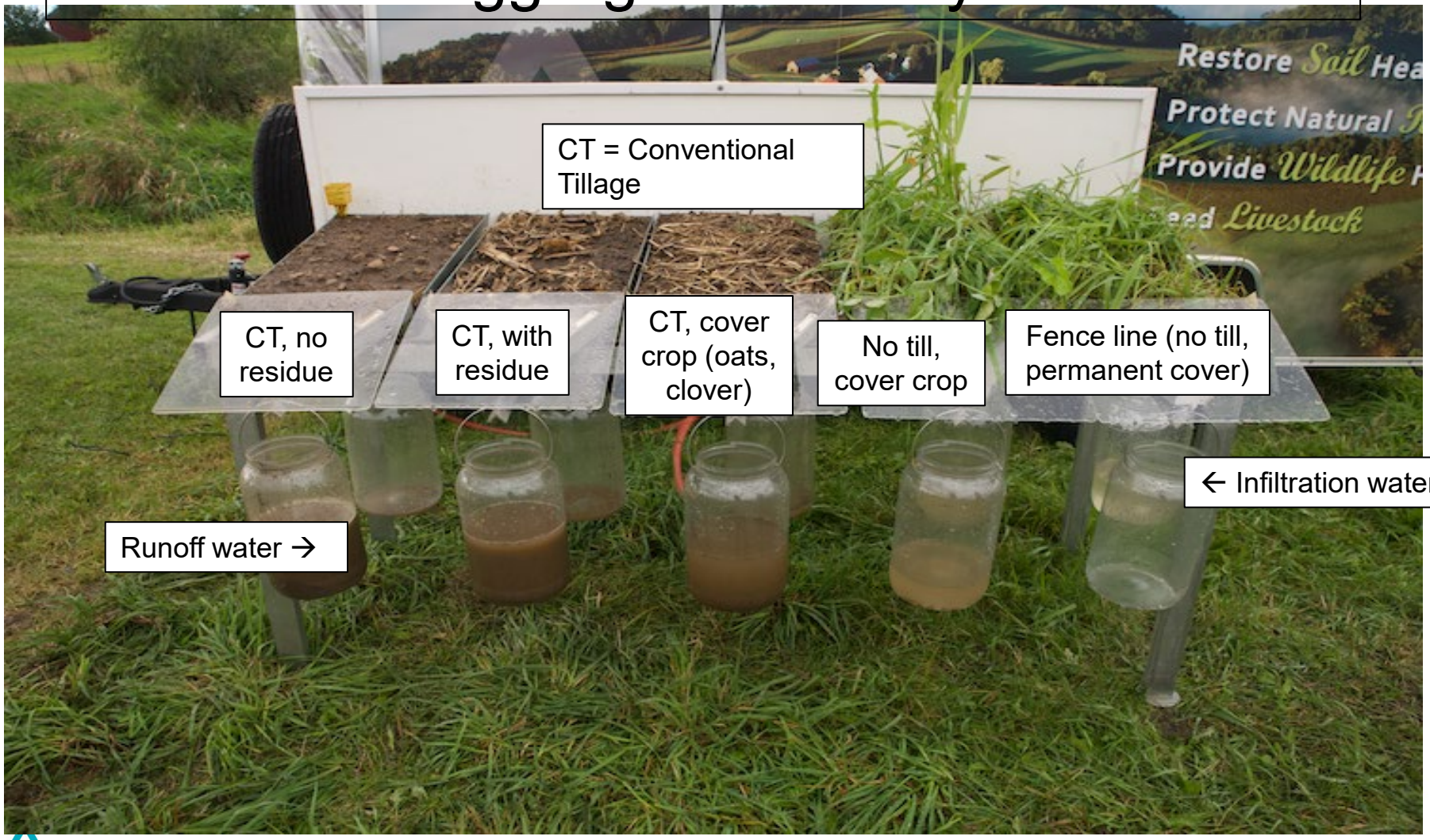


tural sources Conservation Service

nrcs.usda.gov/

Wicks and Brasher, 2021; Magdoff and van Es, 2021; Hudek, 2022

Why these practices?
Aggregate Stability



Michael Patin, NRCS, 2022