



United States Department of Agriculture

Soil Health 101



Soil School

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Soil Colors of the US (25 cm depth)



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Objectives

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

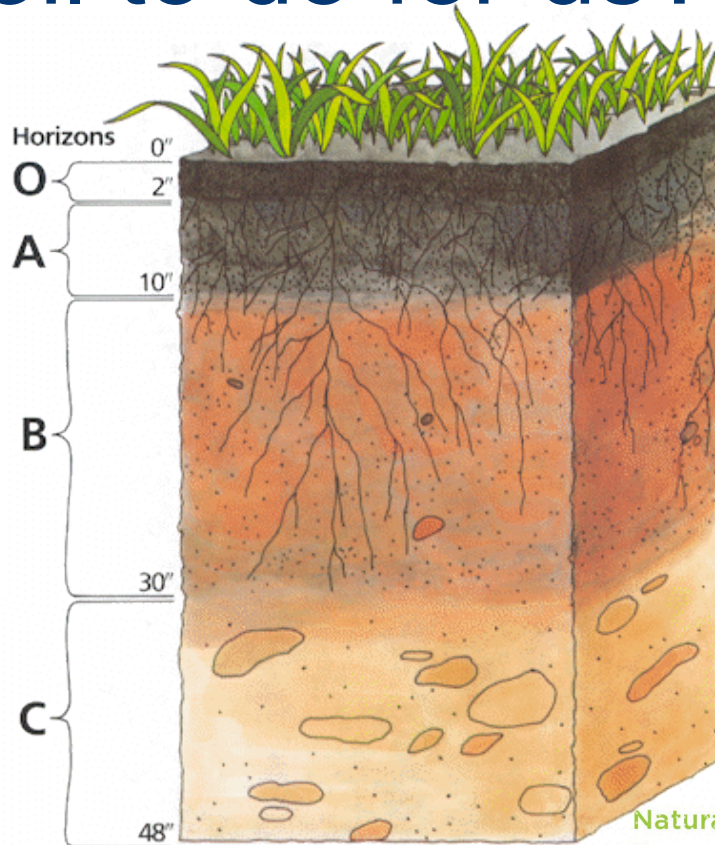
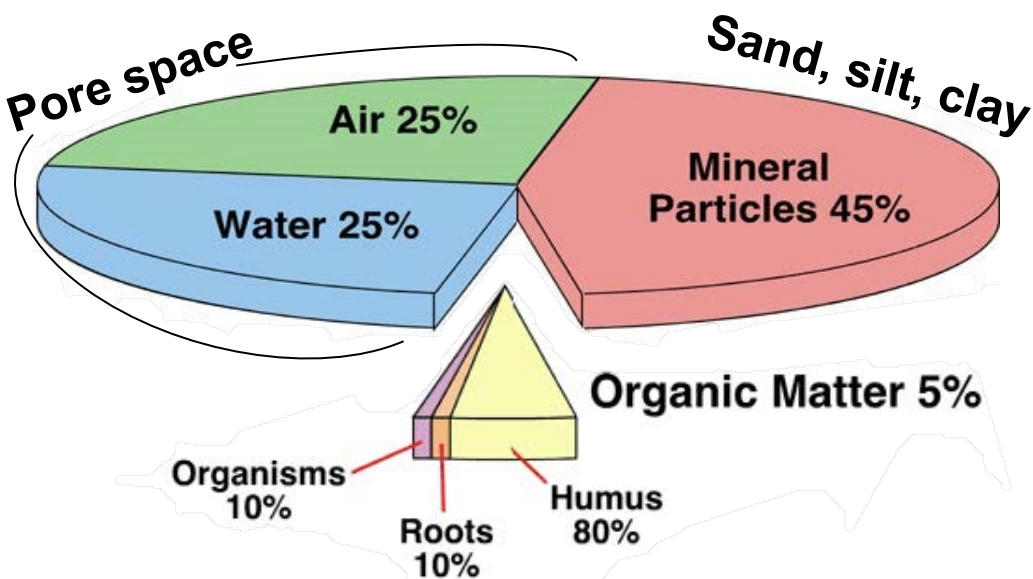


Soil Health Principles To Support High Functioning Soils



Soil Function

What do we want soil to do for us?



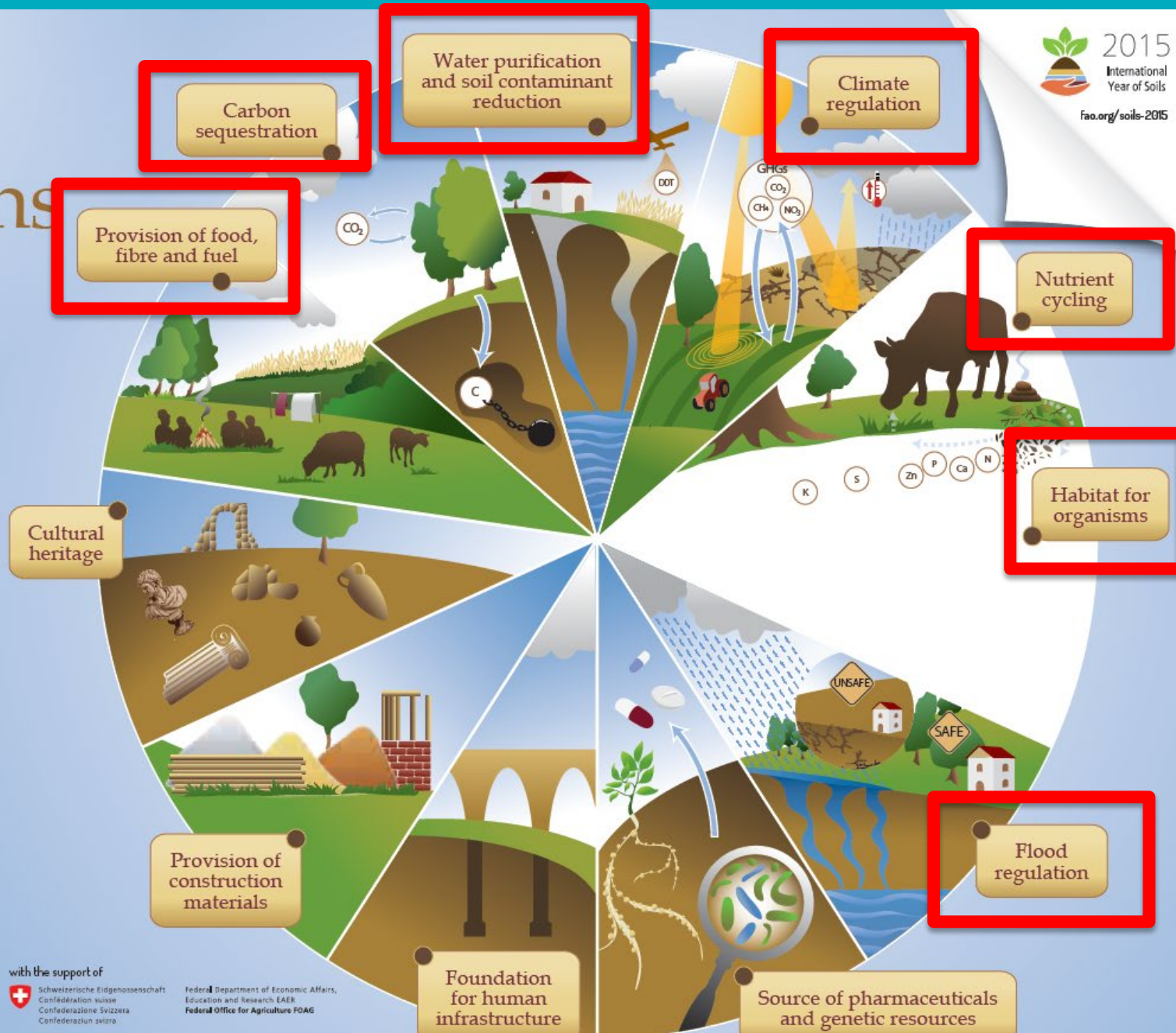
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Soil functions

Soils deliver ecosystem services that enable life on Earth



Important Soil Functions

- Support productive plants
- Be stable and resist erosion
- Efficient at cycling nutrients internally
- Allow H₂O to enter quickly
- Drain well to avoid drowning plant roots
- Store H₂O 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
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BIOLOGY

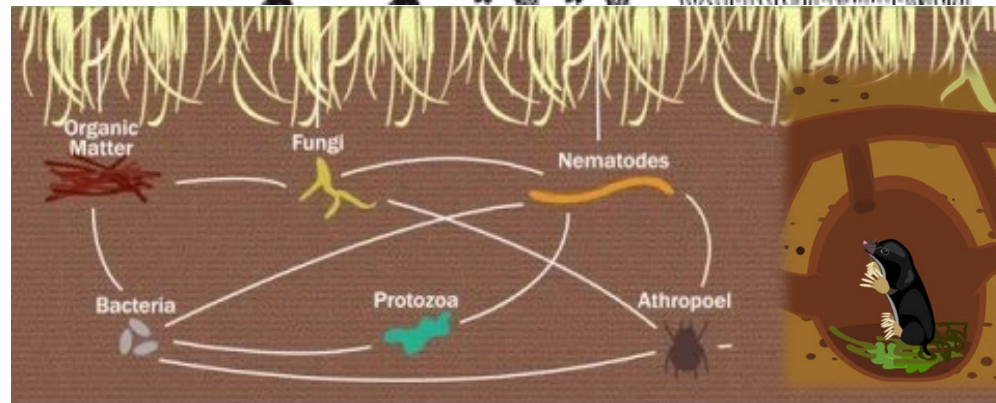
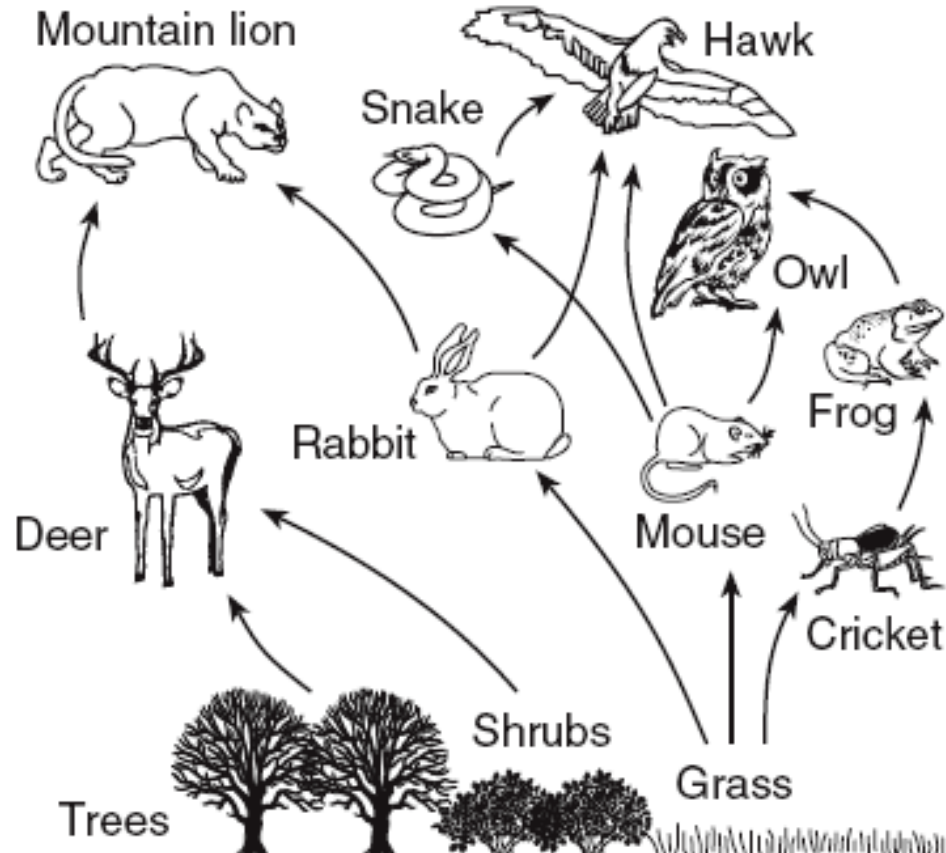
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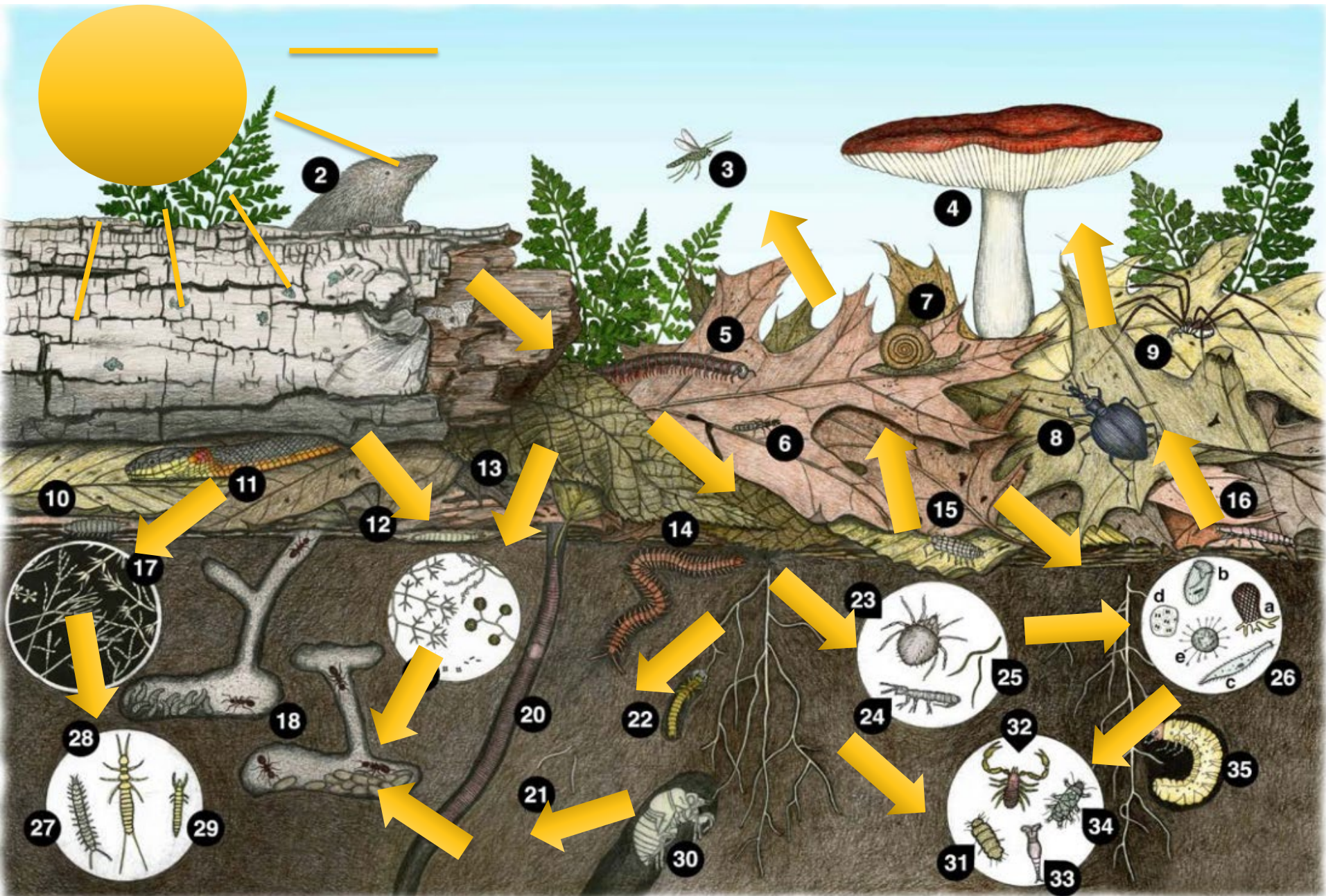
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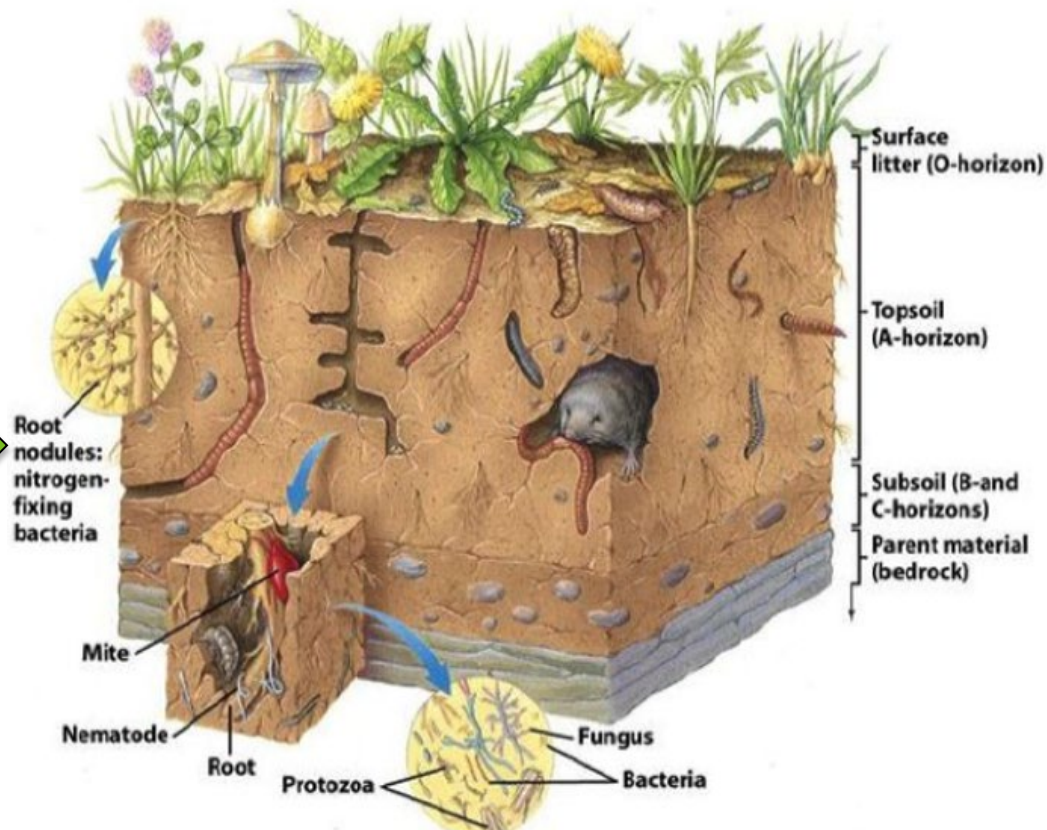
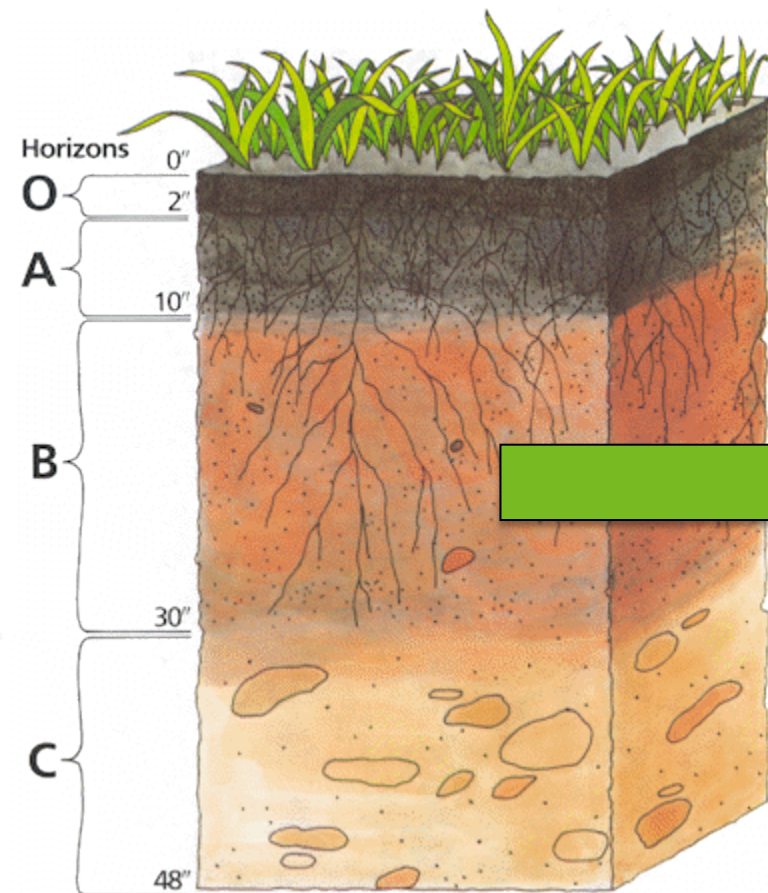
Food Webs are everywhere!



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



Soil is ALIVE!



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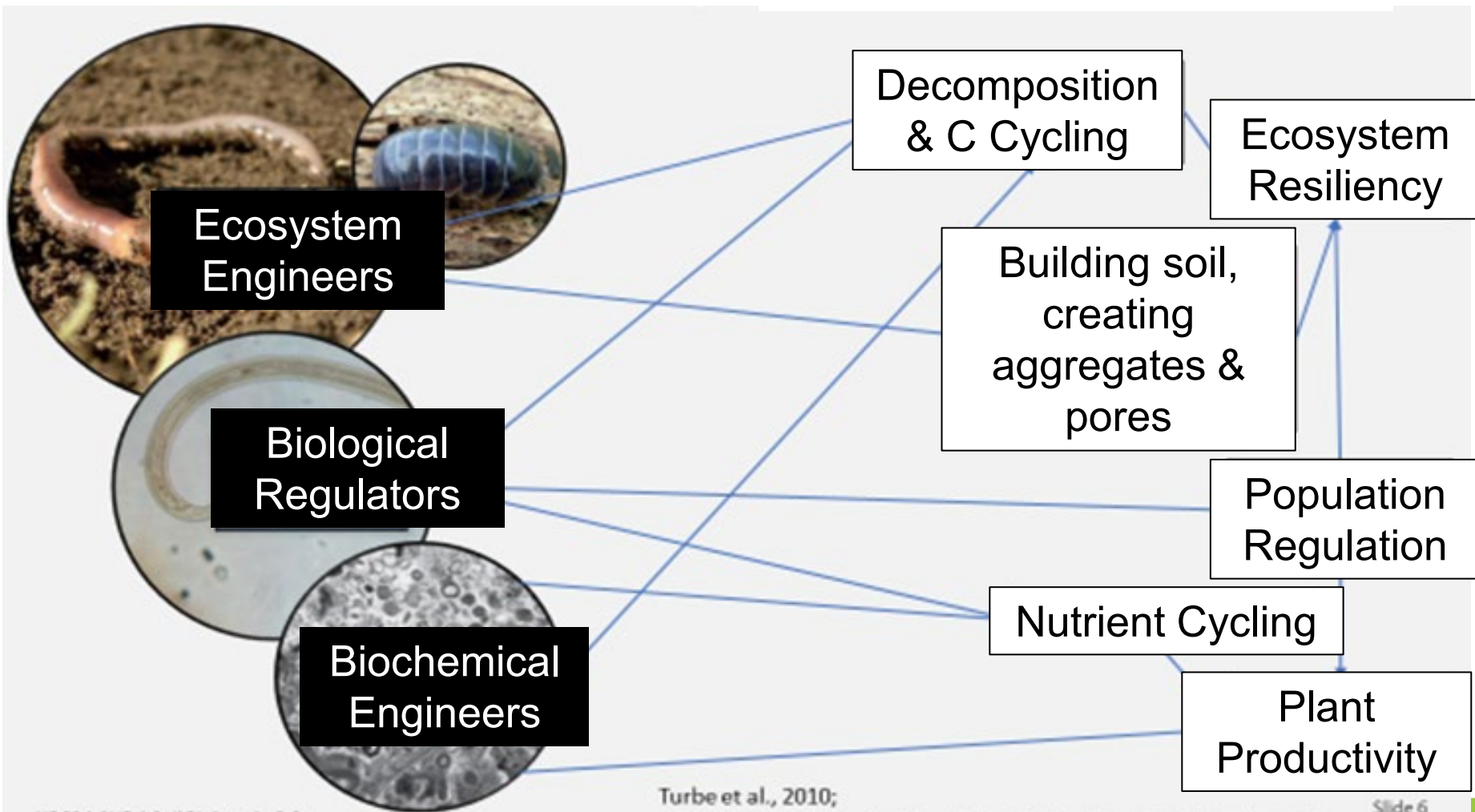
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Soil Organisms

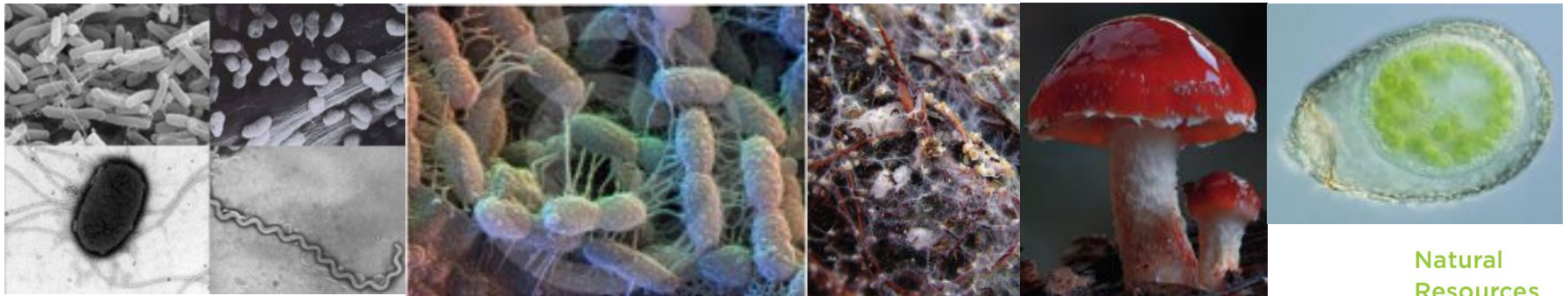
3 Functional Groups

Key Ecosystem Functions



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)



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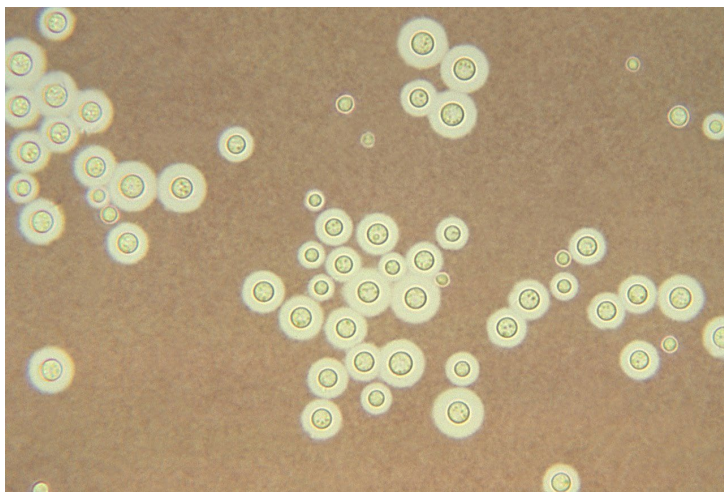
Turbe et al., 2010; Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.



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

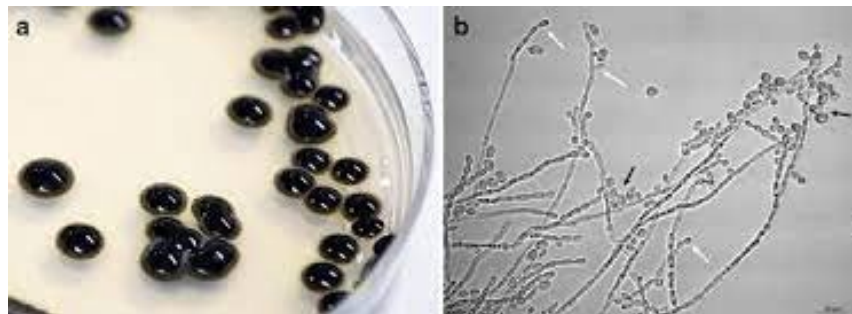
(E. Dadachova et al., 2007)



Cryptococcus neoformans



Cladosporium sphaerospermum



Exophiala dermatitidis

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Biology is Resilient

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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, tardigrades)



Nematodes



Tardigrades



Springtails and Mites



Protozoa

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Soil Organisms Functional Group: Ecosystem Engineers

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



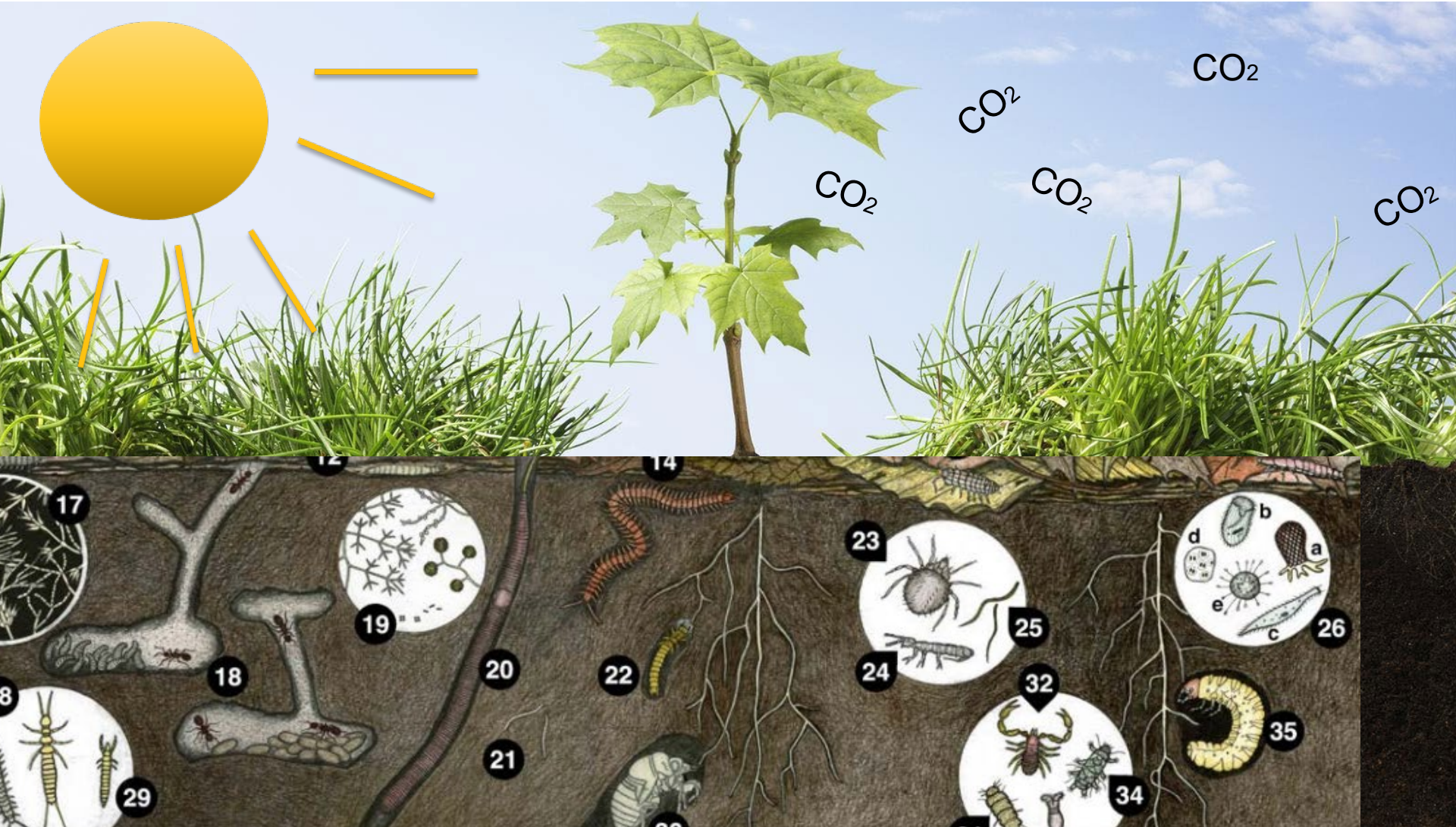
Bioturbation video:
<https://vimeo.com/222168889>

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

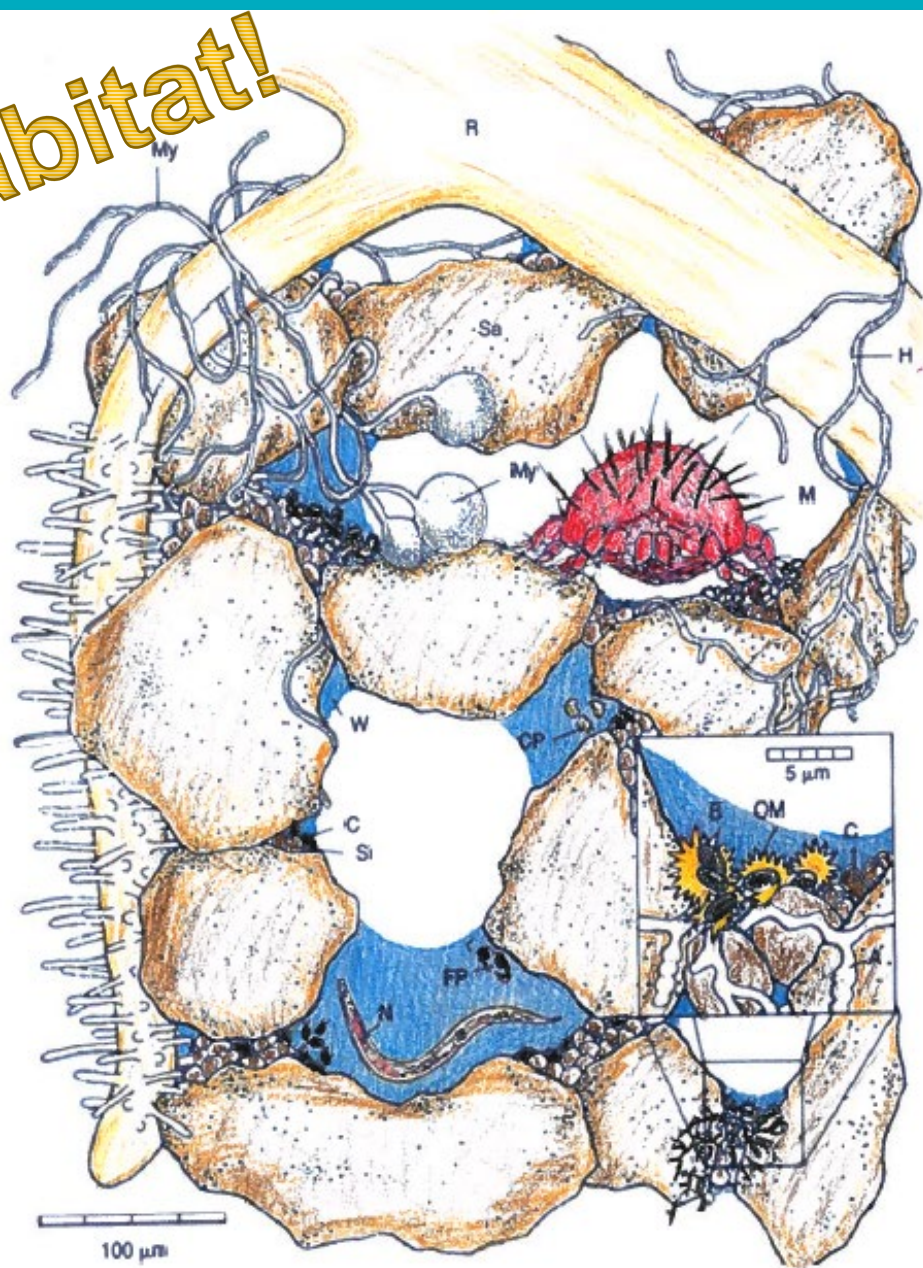
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Manage for healthy soils = Considering biology and function in everything you do.



Soil is habitat!



Biological Hot Spots

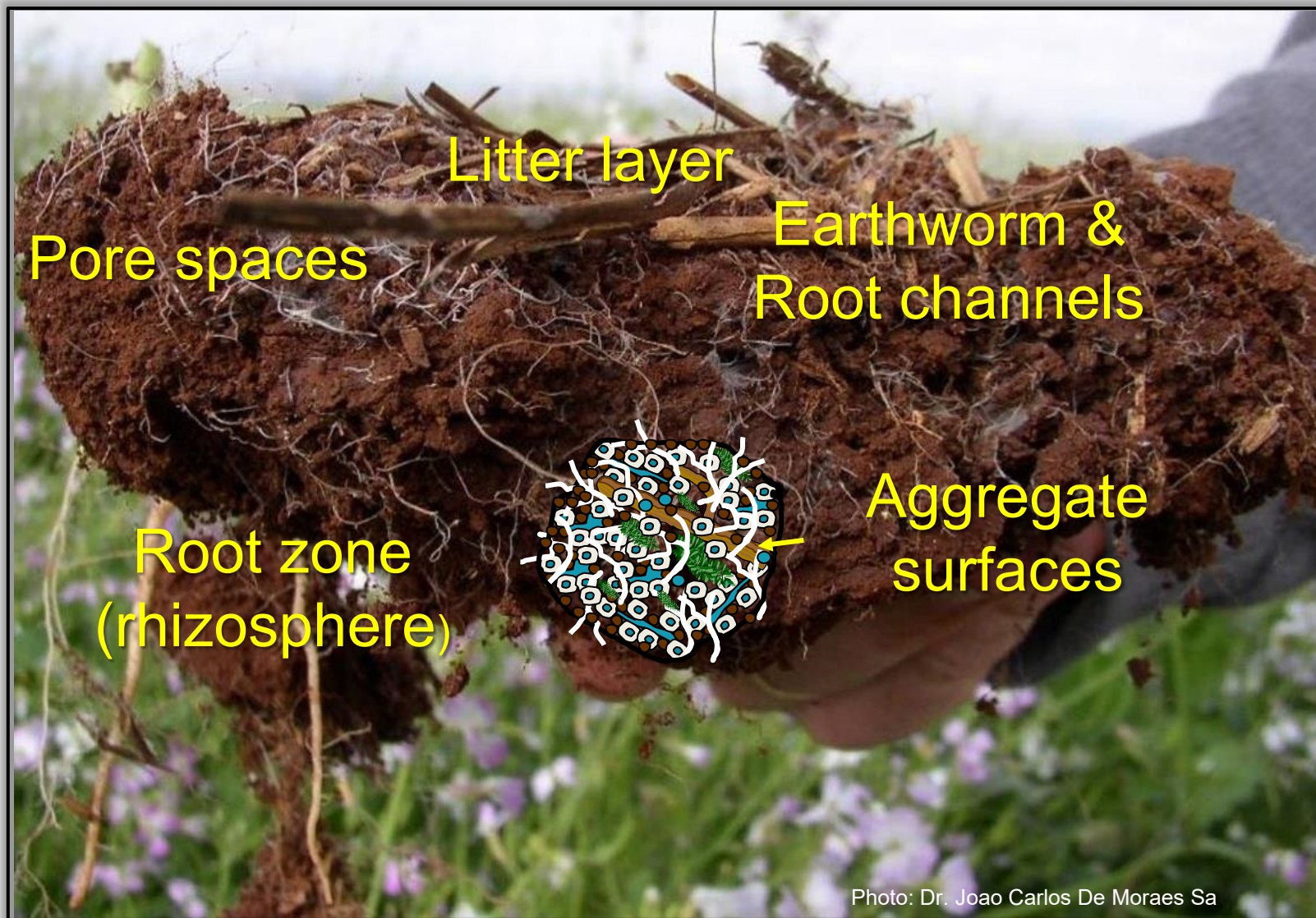


Photo: Dr. Joao Carlos De Moraes Sa

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United States Department of Agriculture

Soil Aggregate Stability Demonstrations

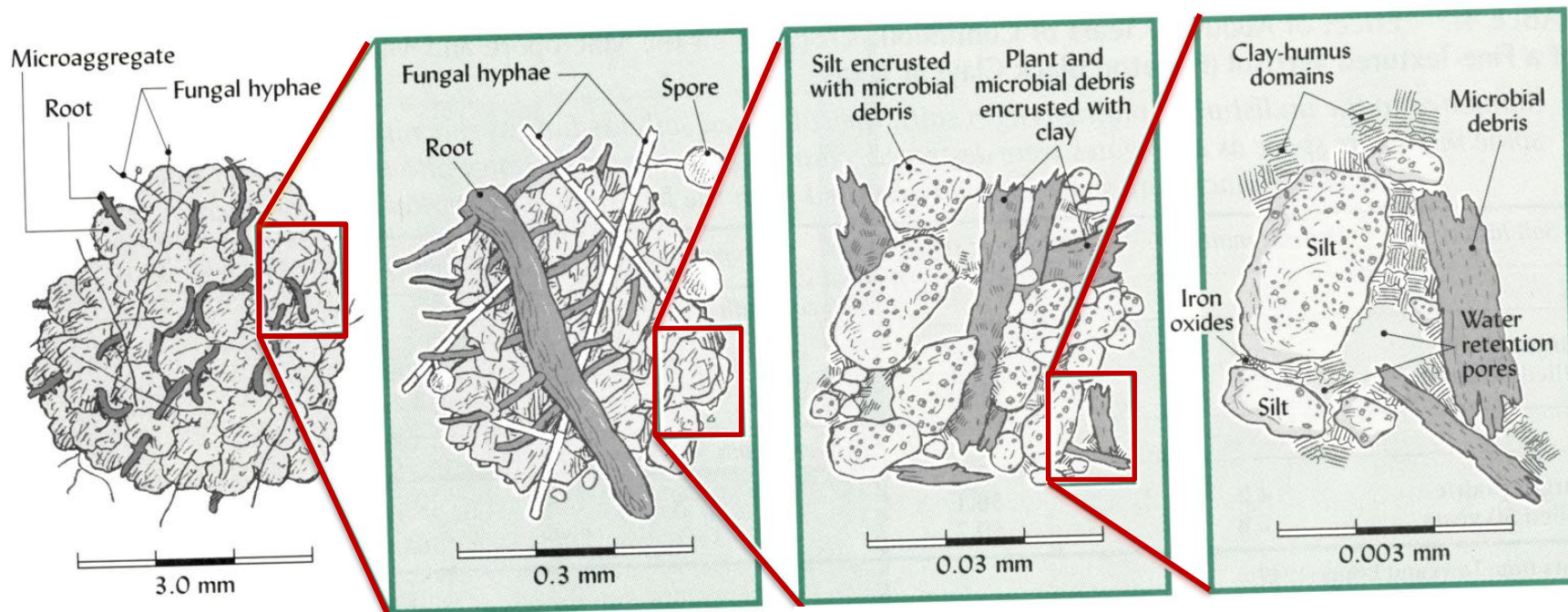


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Soil Aggregation:

Where texture and organic matter meet



Macroaggregate

- Root
- Fungal hyphae

Microaggregate

- Root hairs
- Fungal hyphae
- Polysaccharides

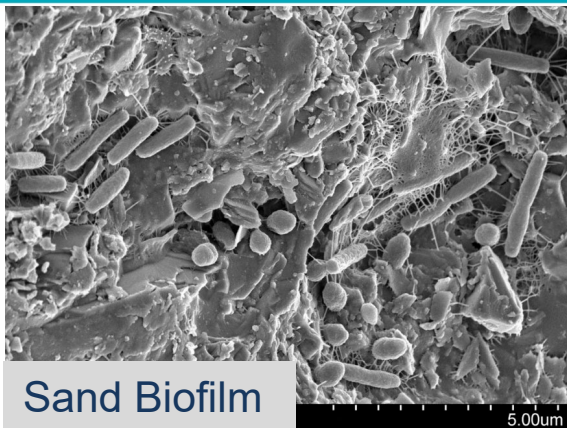
Sub-microaggregate

Mineral grains coated with plant and microbial exudates

Primary particles

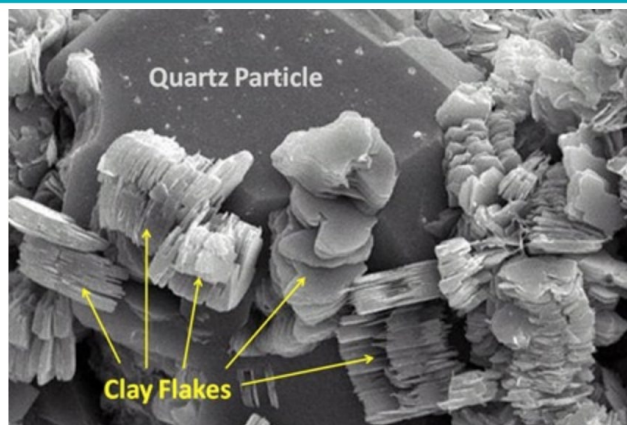
Silt, clay and humus





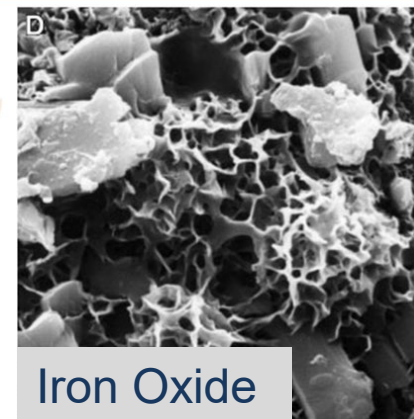
Sand Biofilm

5.00um

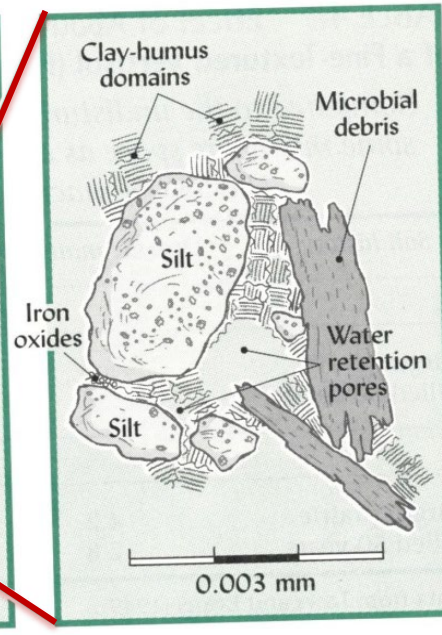
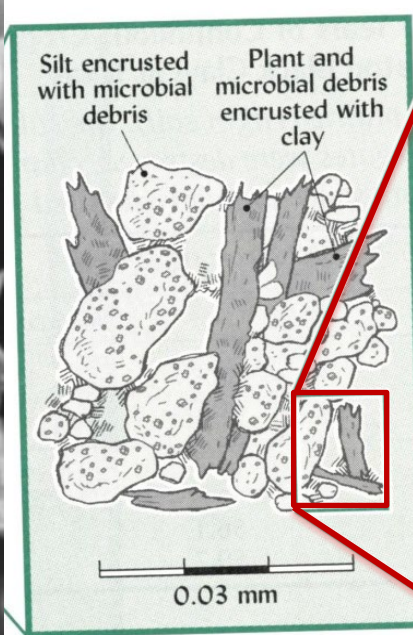
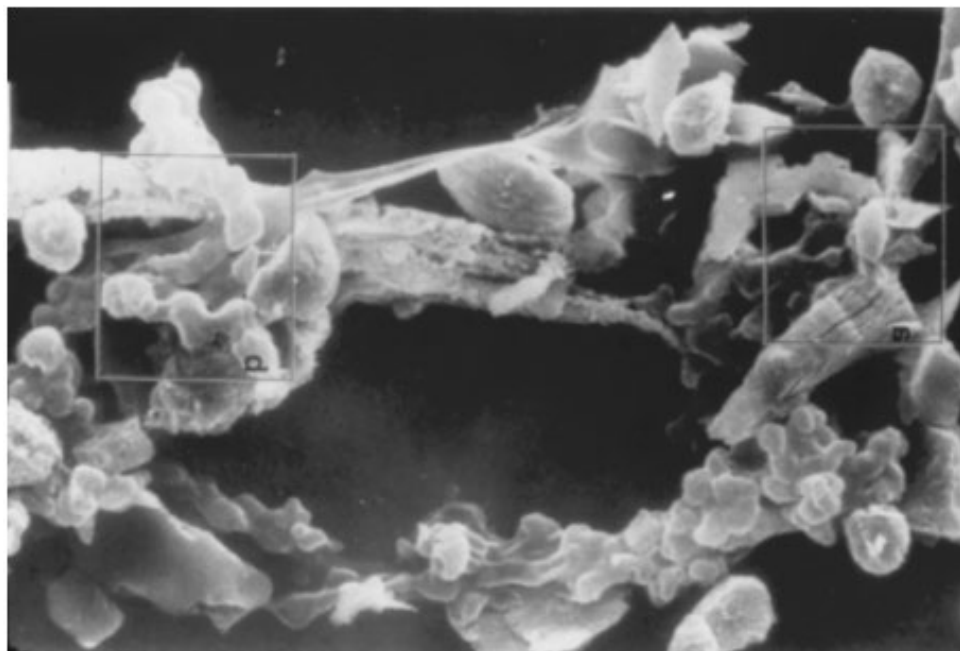


Quartz Particle

Clay Flakes



Iron Oxide



Sub-microaggregate
Mineral grains coated with plant and microbial exudates

Primary particles
Silt, clay and humus

Photo Credits

<https://imecol.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...

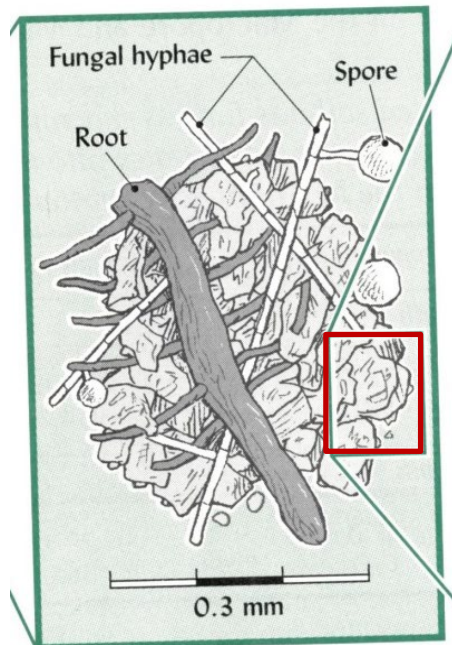
| Flickr

Clay - The Daily Garden



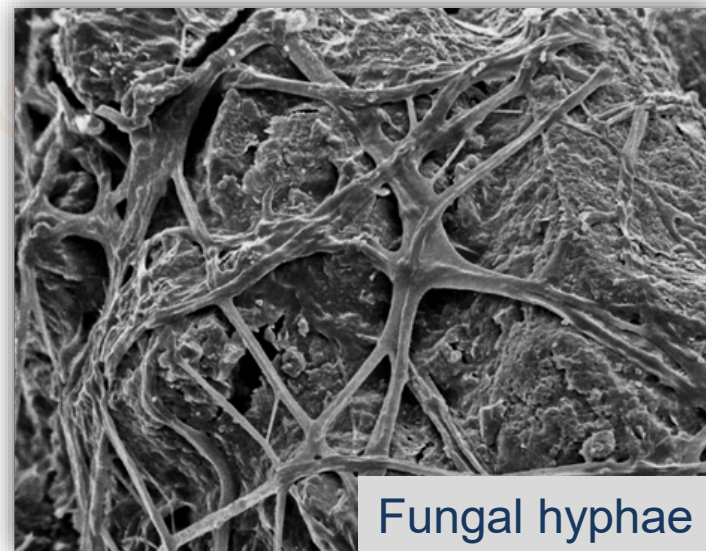
Microaggregate

- Root hairs
- Fungal hyphae
- Polysaccharides

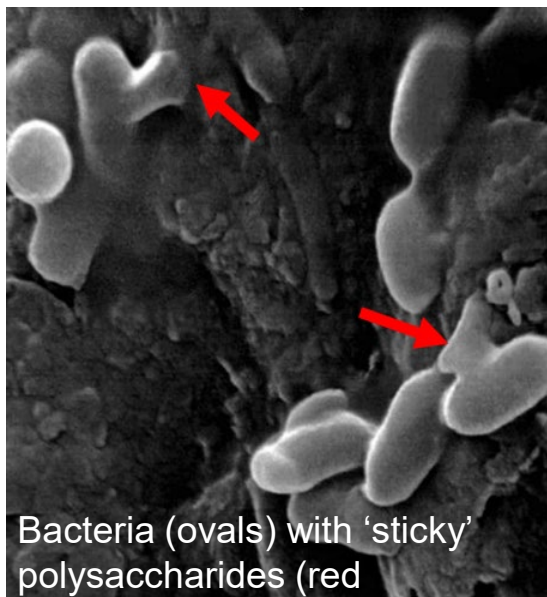


Microaggregate

- Root hairs
- Hyphae
- Polysaccharides

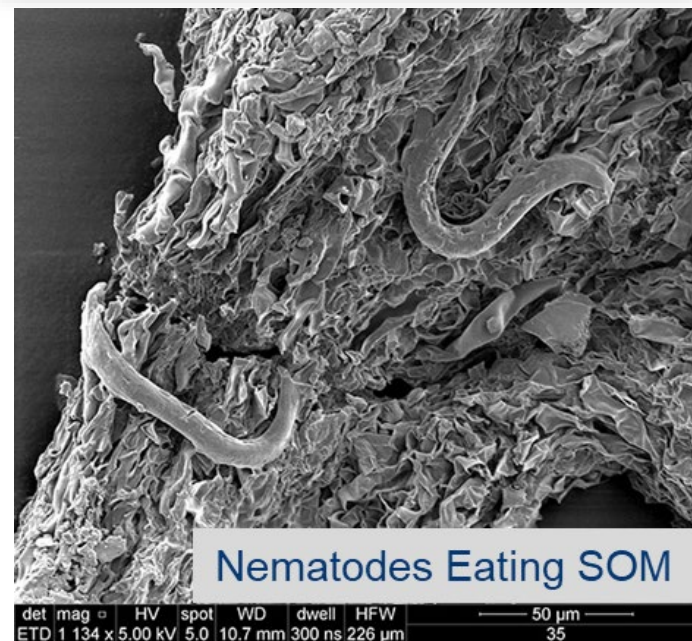
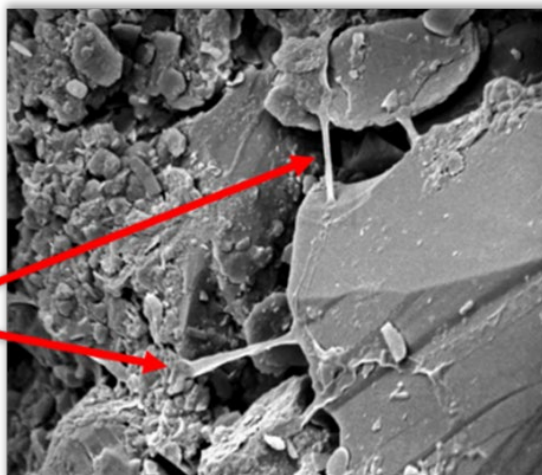


Fungal hyphae



Bacteria (ovals) with 'sticky' polysaccharides (red)

Stabilization of soil structure by actinomycete (bacterial) filaments



Nematodes Eating SOM

det mag HV spot WD dwell HFW
ETD 1 134 x 5.00 kV 5.0 10.7 mm 300 ns 226 µm 50 µm 35



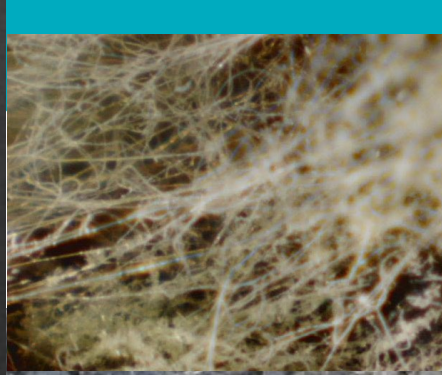
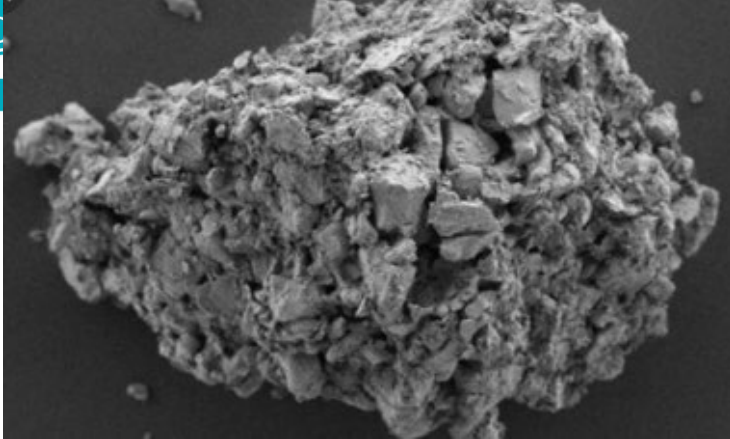
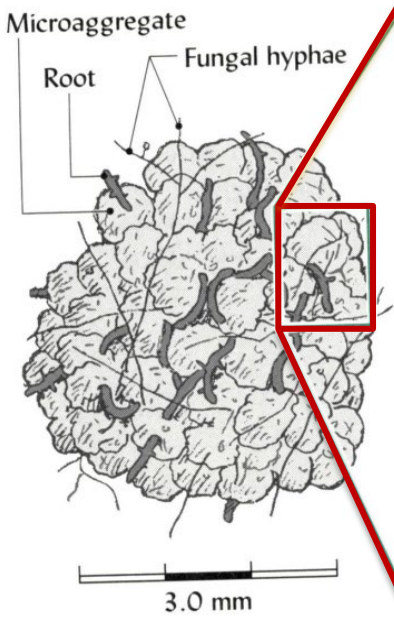


Figure 4.2. A soybean root heavily colonized with mycorrhizal fungi (*Rhizophagus irregularis*). Photo by Yoshihiro Kobae.



Macroaggregate

- Root
- Fungal hyphae

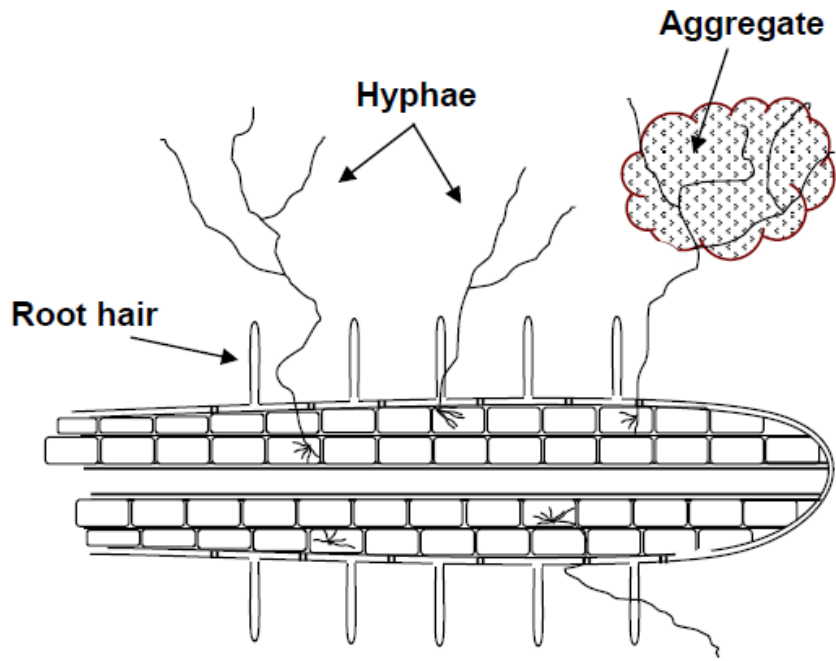
<https://www.agweek.com/business/4434742-start-digging-aggregation-soil-health-indicator>
http://www.csun.edu/science/scale/4th_grade/graphics/columns/columns-Pages/Image4.html

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Magnificent Mycorrhiza



Mycorrhizal hyphae can grow beyond roots to access more soil and acquire nutrients and water more efficiently.



Mycorrhizal fungi holding soil aggregates together

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Magnificent Mycorrhiza



Root hair



Mycorrhizal hyphae can grow beyond roots to access more soil and acquire nutrients and water more efficiently.

Mycorrhizal fungi holding soil aggregates together

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Soil Aggregation:

Physical /Chemical Factors:

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



Conservation
Service

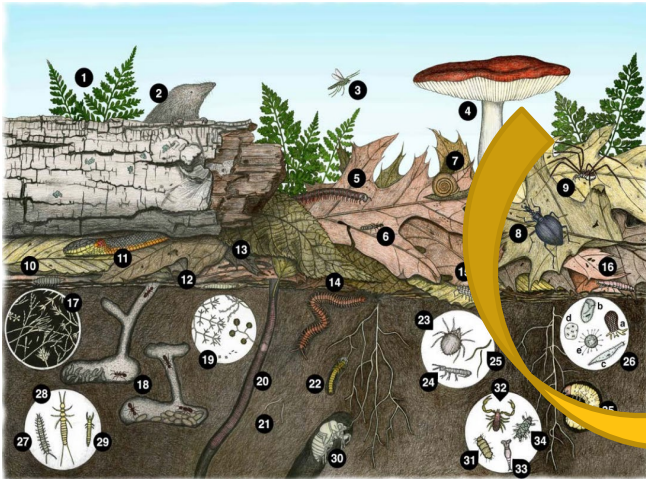
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<https://www.pinterest.com/pin/502855114622813480/>

<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 H₂O to enter quickly
- Drain well to avoid drowning plant roots
- Store H₂O 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)



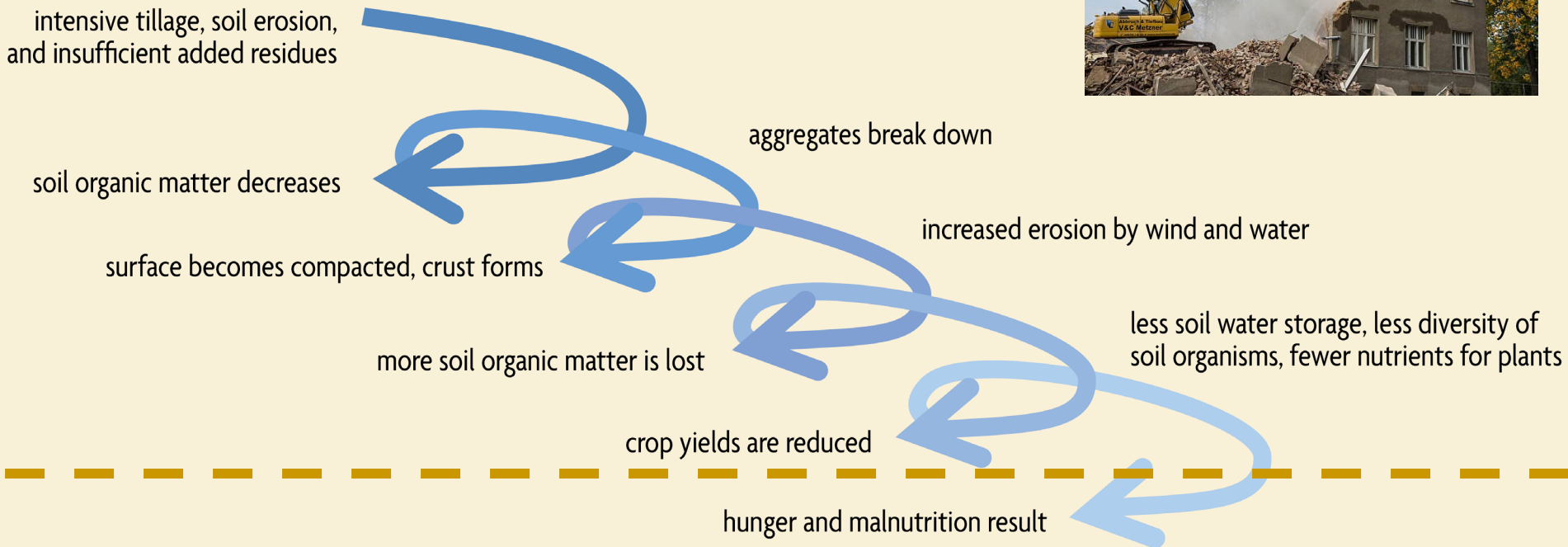
“If we are bold in our thinking, courageous in accepting new ideas, and willing to work with instead of against our land, we shall find in conservation farming an avenue to the greatest food production the world has ever known.”

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Soil Degradation Spiral



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

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

Soil Degradation Spiral



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

intensive tillage
and insufficient

soil organic matter

surface

water

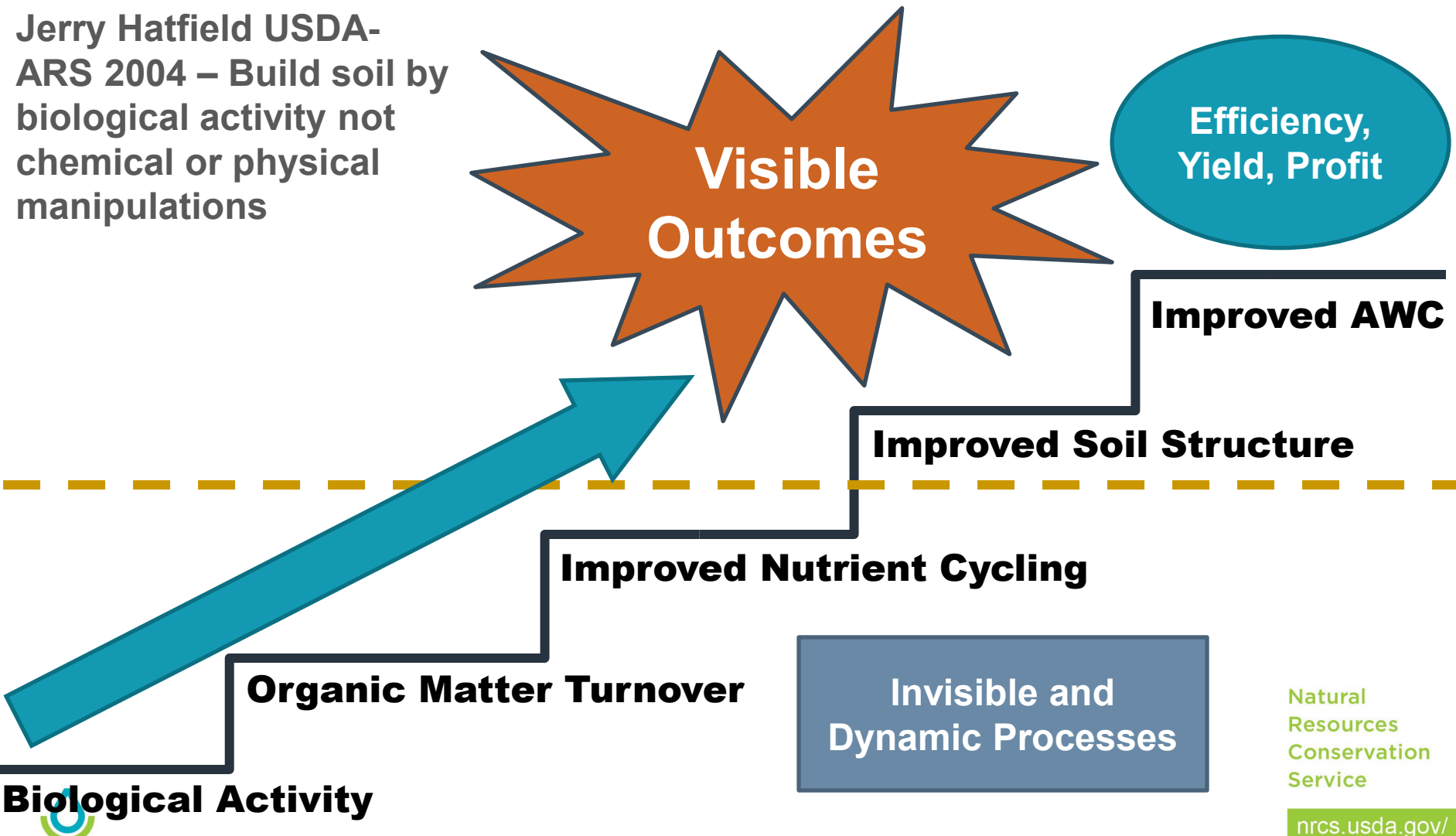
water storage, less diversity of
plant species, fewer nutrients for plants



Soil Aggregation Climb



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



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



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)



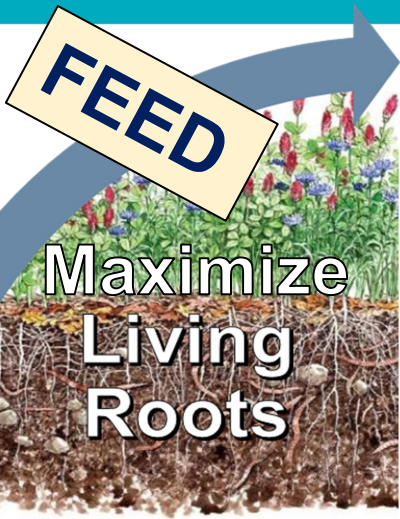
FEED BIOTA



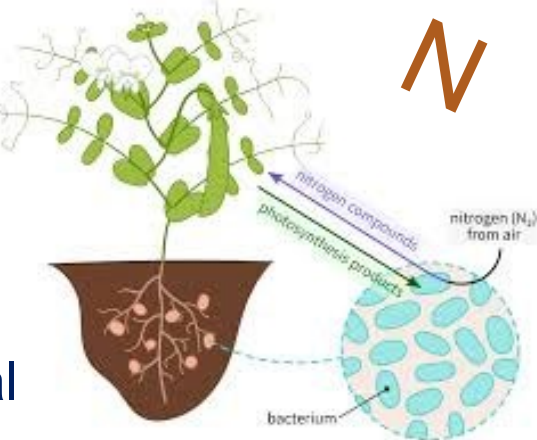
Maximize Living Roots & Maximize Diversity

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





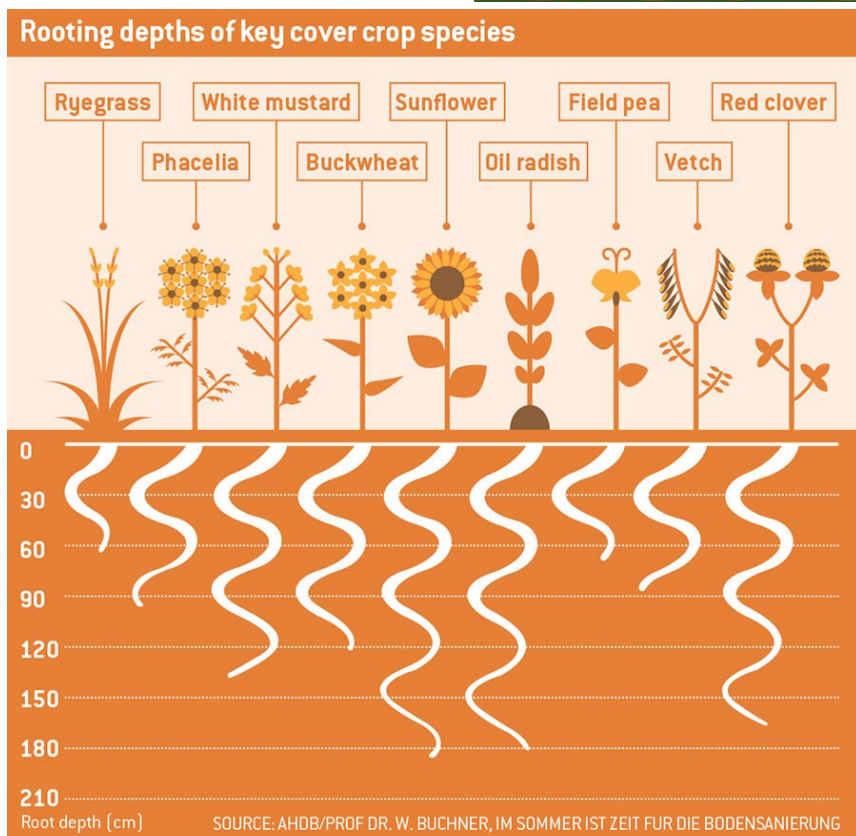
Cover Cropping
 Avoid fallow
 Increase re-cropping interval



Winter Pea,
 Crimson Clover



Cereal rye
 cover crop mix



Cover Cropping Resources

Managing Cover Crops Profitably

THIRD EDITION



Cover Crops for Home Gardens West of the Cascades



WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS111E



Northwest Cover Crops for Climate Resilience



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.

COVER CROPS



TOPICS GET INVOLVED ABOUT CONTACT US

Home / Crop Production / Soil

Establishing Winter Cover Crops

Home Topics Team Downloads Partners Related Tools Help

Basic Search

Scientific Name Go

- Characteristics Search
- Duration Search
- Fact Sheets/Plant Guides
- Group Search
- Growth Habit Search
- Image Search
- Invasive/Noxious Search
- Rarity Search
- State Search
- Wetland Search

You are here: Home

Release Notes

PLANTS Database

Plant List of Attributes, Names, Taxonomy, and Symbols

The PLANTS Database provides standardized information about the vascular plants, mosses, liverworts, hornworts, and lichens of the U.S. and its territories.

PLANTS

Cover Crop Chart

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

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

Sunflower

(*Helianthus annuus* L.)

- C3 plant with warm season growth characteristics, broadleaf
 - Annual
 - Upright plant architecture
 - High water use
 - Fair salinity tolerance
 - Deep rooted
 - Effective at 'mining' mobile nutrients deep in the soil profile
 - Seeding depth: 1 – 3 ½ inches
 - Crude protein: silage 11-12%, grain 20-28%
 - C:N ratio: leaf 11-14, stem 41-46, root 50-68, flower 14-19
 - Forms arbuscular mycorrhizal associations
 - Flowers attract pollinators
- ◆ [View table for known crop sequence effects](#)





Maximize
Diversity

Row
Intercropping



Companion Planting



Relay Cropping



Incorporate
Livestock



Crop Rotation



Attract
Pollinators



PROTECT SOIL HABITAT AND ORGANIC MATTER



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

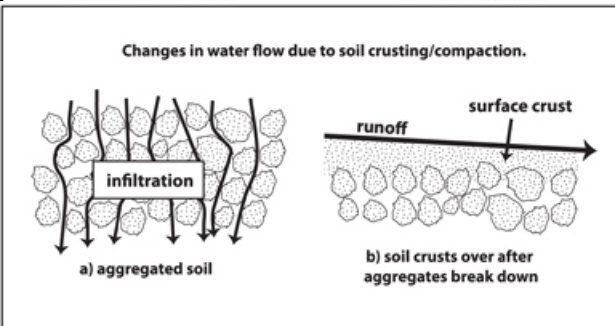
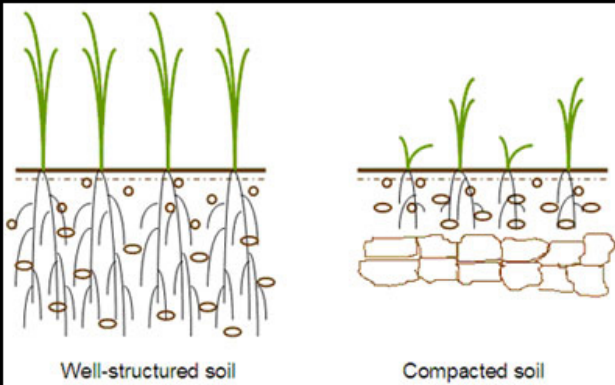


Image courtesy of Barry
Fisher, NRCS-SHD

PROTECT

Increase habitat for soil organism

Minimize Disturbance



National Historic Oregon Trail Interpretive Center
Baker City, Oregon



Control Traffic



Avoid common disturbances

- Physical
- Chemical
- Biological

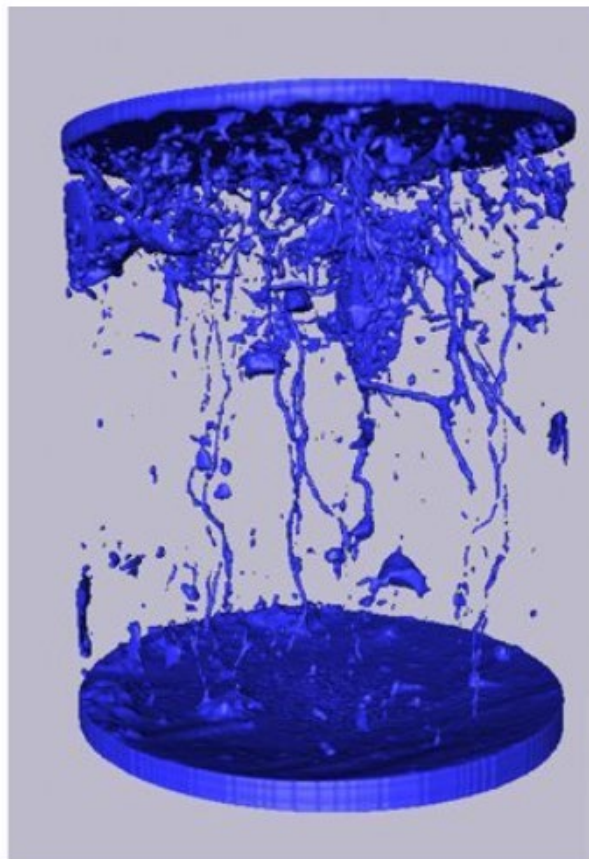
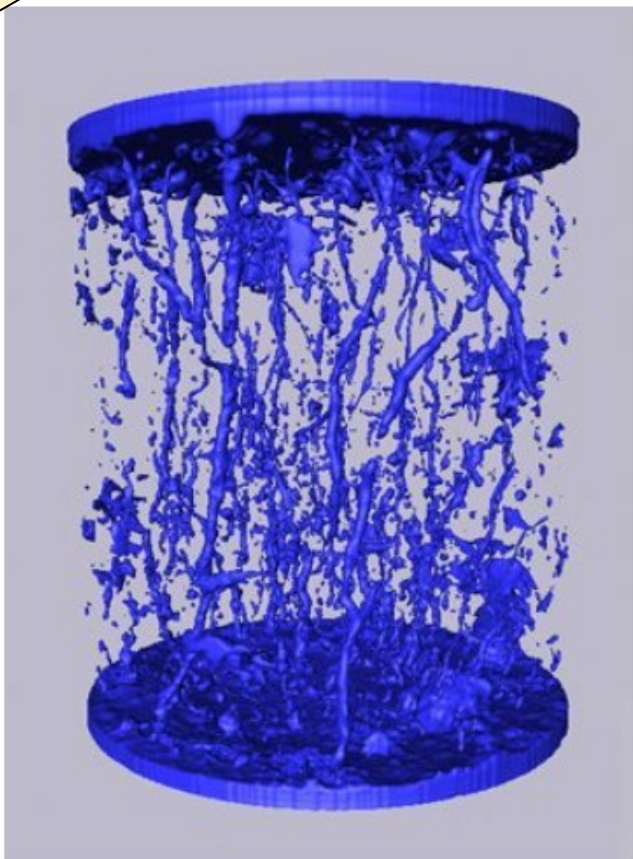
Be mindful about disturbance



PROTECT

no disturbance

Machinery compacted 14 years prior, no disturbance since



Vertical pores reduced

Horizontal pores have collapsed

Pore space = **BLUE**

Natural Resources Conservation Service

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Dorthe Wildenschild, Oregon State University

<https://www.producer.com/crops/ct-scan-tech-used-to-check-soil-health/>



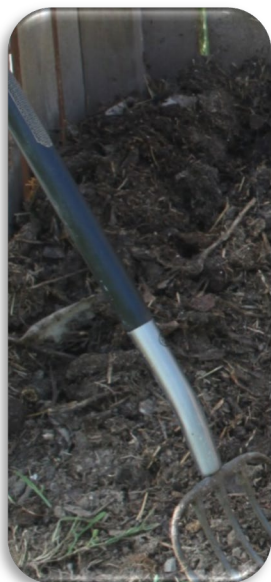
PROTECT



With What?



How Deep?



How Much?

How Often?



PROTECT

**Maximize
Soil Cover**

**Mitigate Soil
Erosion**



Cover Cropping



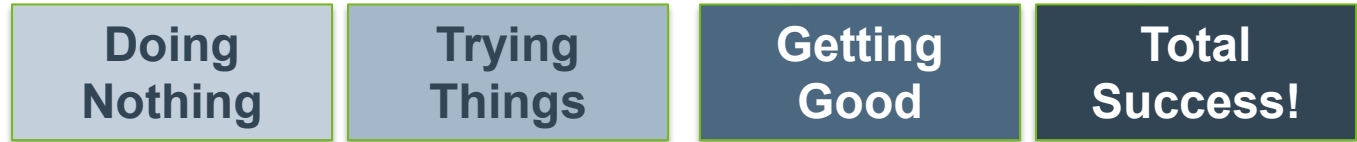
Mulch



Relay Cropping



Management Spectrum



Diversity



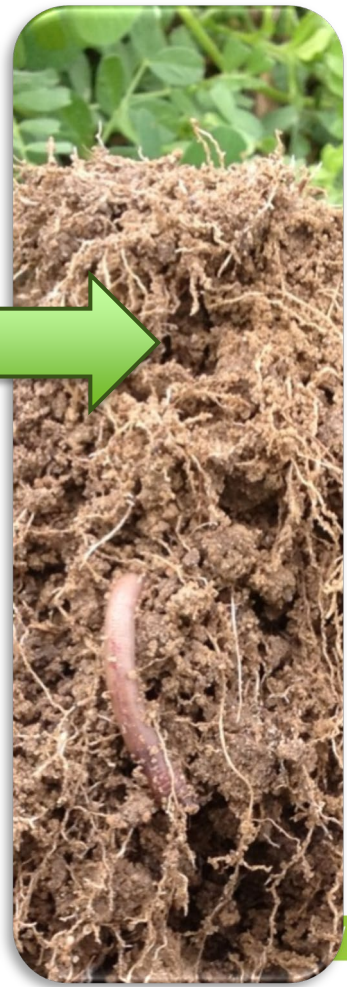
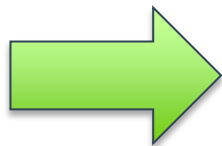
Covered



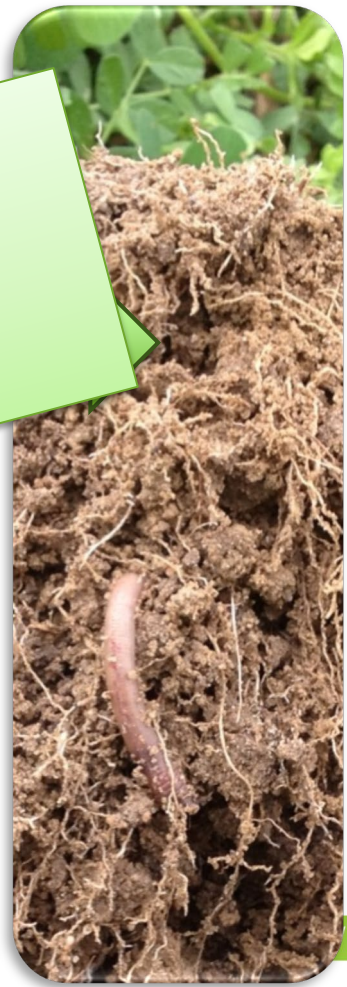
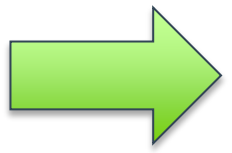
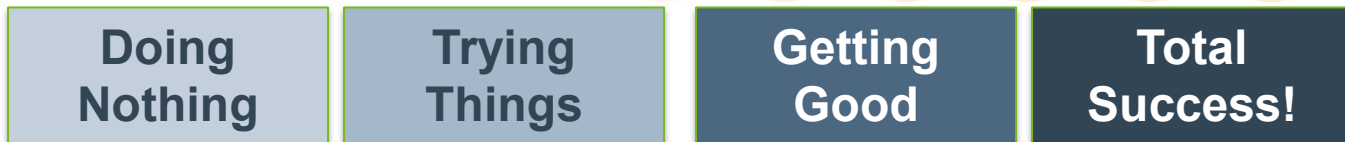
Living Root



Disturbance



Management Spectrum



“Relaxed tillage”





[Web Soil Survey](https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm)

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



Web Soil Survey



The screenshot displays the USDA Web Soil Survey interface. At the top, there is a navigation bar with links for 'Contact Us', 'Subscribe', 'Archived Soil Surveys', 'Soil Survey Status', 'Glossary', 'Preferences', 'Link', 'Logout', and 'Help'. Below this is a secondary navigation bar with buttons for 'Area of Interest (AOI)', 'Soil Map', 'Soil Data Explorer' (which is active), 'Download Soils Data', and 'Shopping Cart (Free)'. The main content area is titled 'View Soil Information By Use: All Uses' and includes tabs for 'Intro to Soils', 'Suitabilities and Limitations for Use' (selected), 'Soil Properties and Qualities', 'Ecological Sites', and 'Soil Reports'. On the left, a search panel lists various soil suitability categories, with 'Organic Matter Depletion' highlighted in a purple box. The main map area, titled 'Map - Organic Matter Depletion', shows a satellite view of a rural area with a semi-transparent map overlay. The map overlay displays various soil types and their corresponding Organic Matter Depletion ratings, with a legend on the left side of the map. The map includes labels for 'Farmer Rd' and 'Crowley Creek'. The bottom of the interface features a 'Legend' panel and a 'Scale' dropdown menu.



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

FEED

Soil Biology

Improve Resilience

Continuous C input (SOM)

Maximize living roots

Minimize disturbance

PROTECT

Organism Habitat

Soil Aggregates

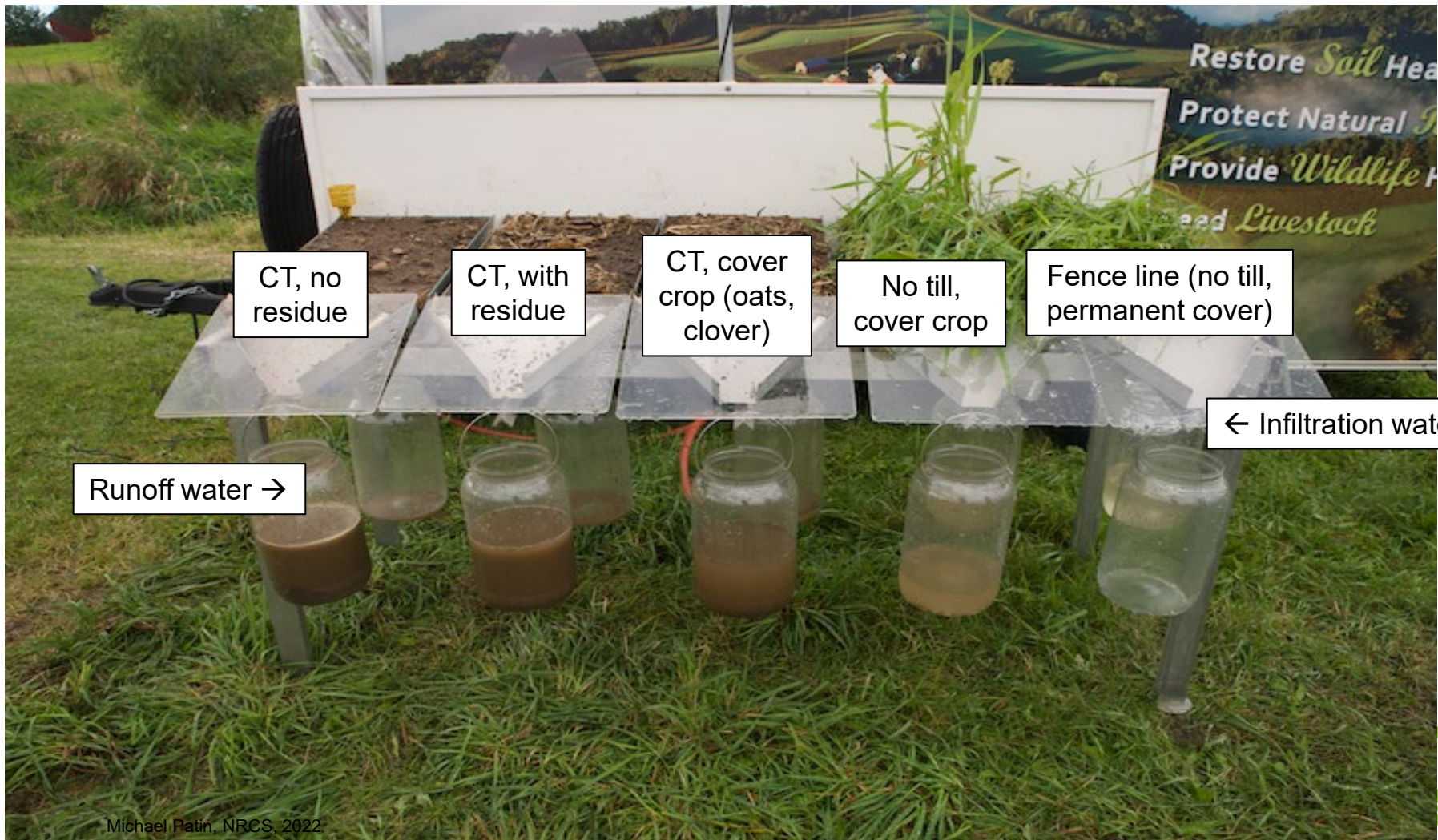
Soil Organic Matter (SOM)

Maximize diversity

Maximize cover



Interested? Rainfall simulation this afternoon!





United States Department of Agriculture

Questions, comments?

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