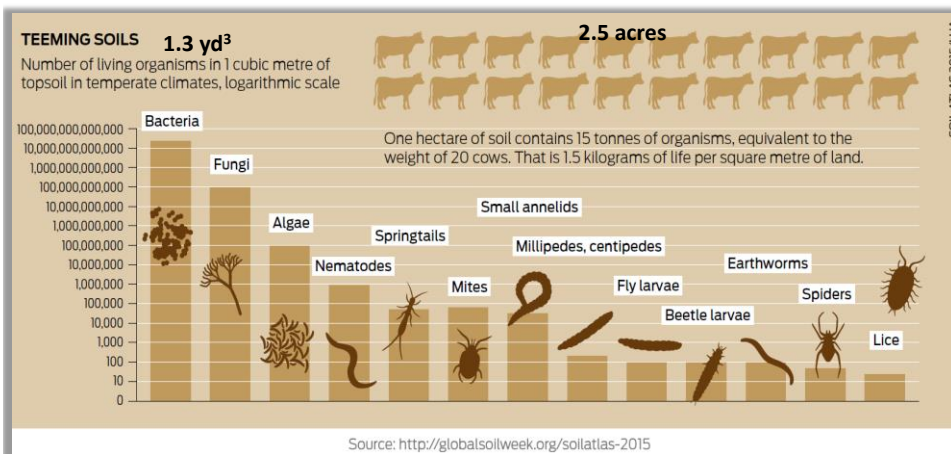


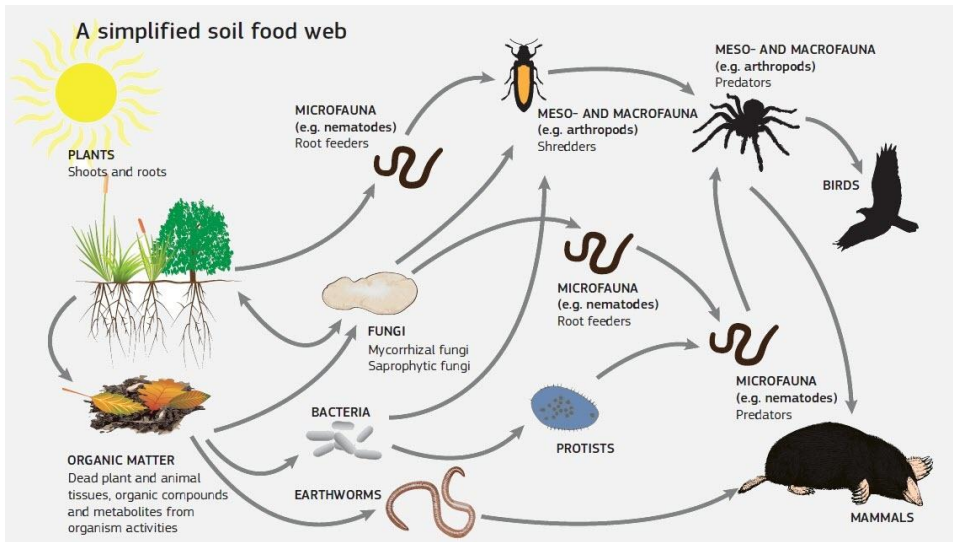


1

Soils Host Vast Numbers, Mass, and Diversity of Organisms



3

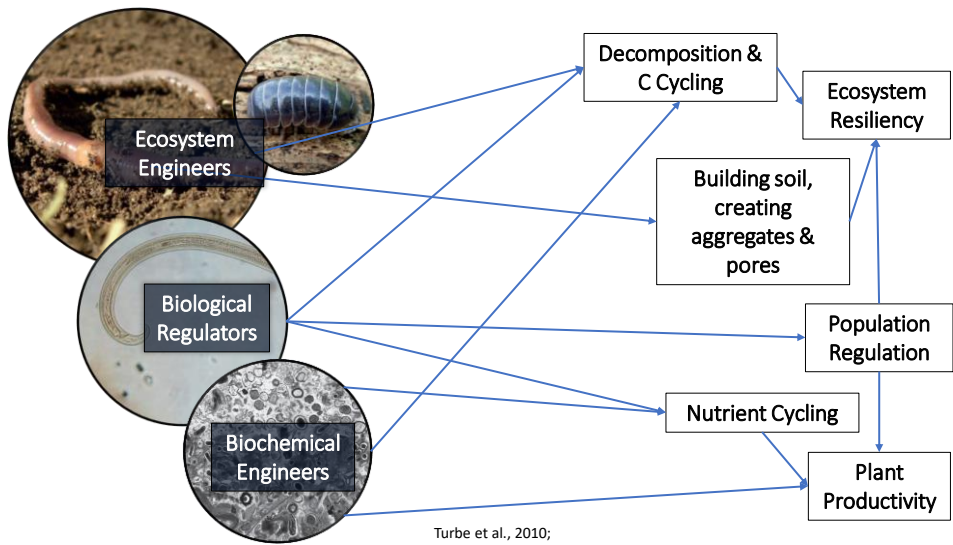


Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al. Luxembourg, European Commission, Publications Office of the European Union: 176p.

4

Soil Organisms 3 Functional Groups

Key Ecosystem Functions



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

5

Ecosystem Engineers

Functional group	Function	Representative members
Ecosystem Engineers	Build pore networks and aggregates	Plant roots, earthworms, larger invertebrates (e.g., millipedes, centipedes, beetles)



Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

6

Ecosystem Engineers

- Earthworms: easy to observe and can be good indicators
- Vertical boring (often introduced)
- Horizontal boring
- Residue dwelling (more so in forest environments)

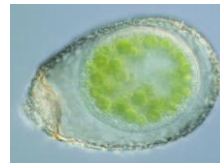
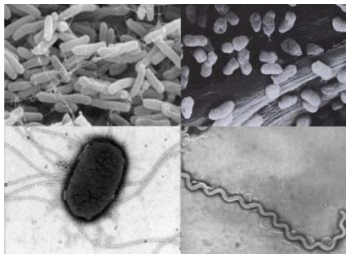
A close-up photograph of soil with a finger pointing to a hole. The soil is dark and crumbly, with visible vertical and horizontal boring. The background shows a field of dry straw or mulch.

A yellow sign with a black border that says "WORMS AT WORK" with a drawing of two worms. The sign is mounted on a wooden post in a field.

7

Chemical Processors (Engineers)

Functional group	Function	Representative members
Chemical Processors	Regulate 90% of energy flow in soil; Build soil organic matter & aggregates	Soil microbes (bacteria, fungi, protozoa)



Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

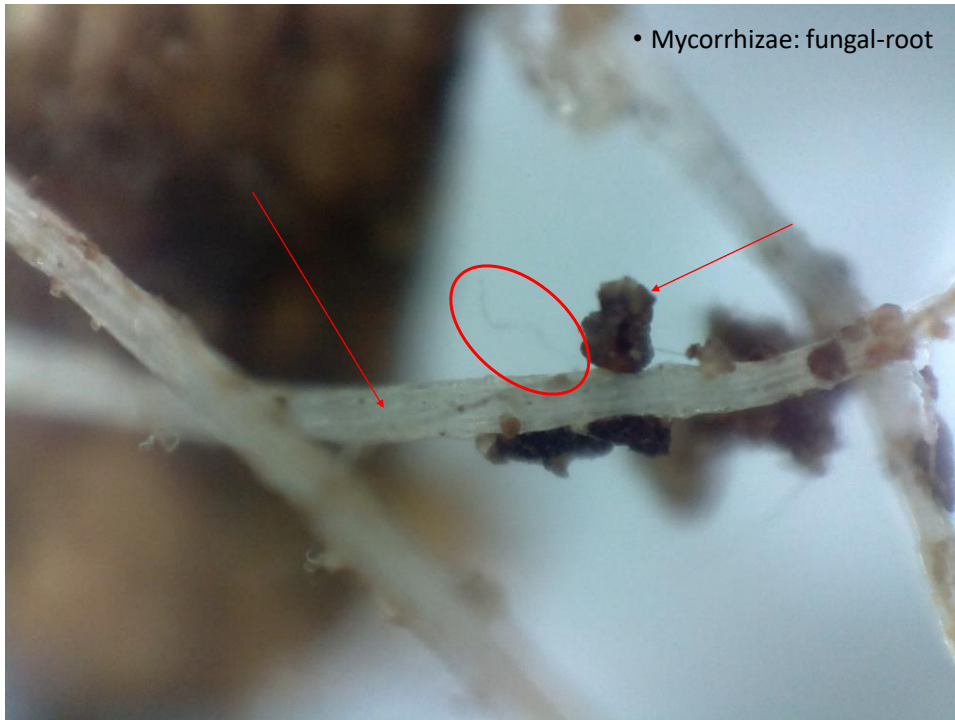
8

Fungi

More than mushrooms and mold

Slide 9
11:33 AM

9



10

Biological Regulators

Functional group	Function	Representative members
Biological Regulators	Regulate populations of other soil organisms	Protozoa, nematodes, and other small invertebrates (e.g., springtails, mites but also microbes)



Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

11



12



13



Managing for Soil life

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Continuous Flow of C Drives System

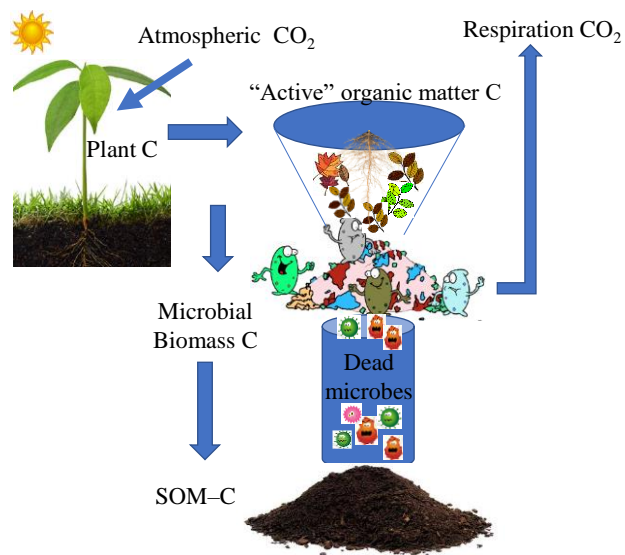
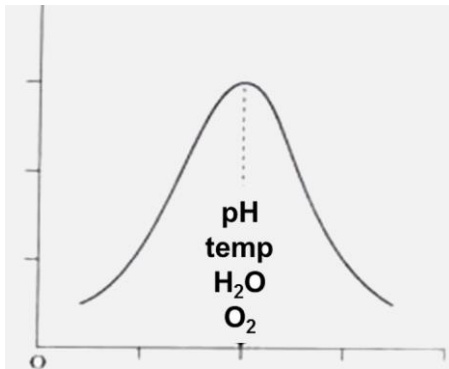


Image courtesy of Dr. Chenhui Li

15

Optimal Activity in Most Ag Systems Occurs When Conditions are 'Just Right'

> 90% bacteria in soil are inactive!



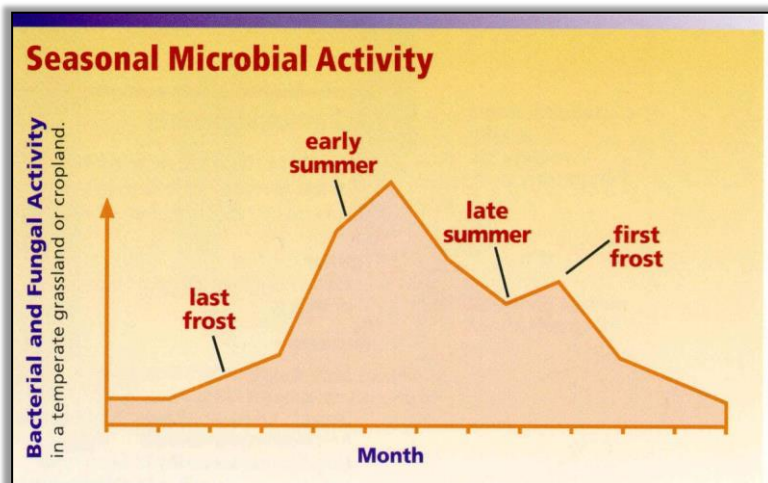
Near neutral pH
Moderate temps
Moist conditions
Aerated
Abundant food (C)



16

Seasonal Microbial Activity

Microbes are impacted by temp and moisture



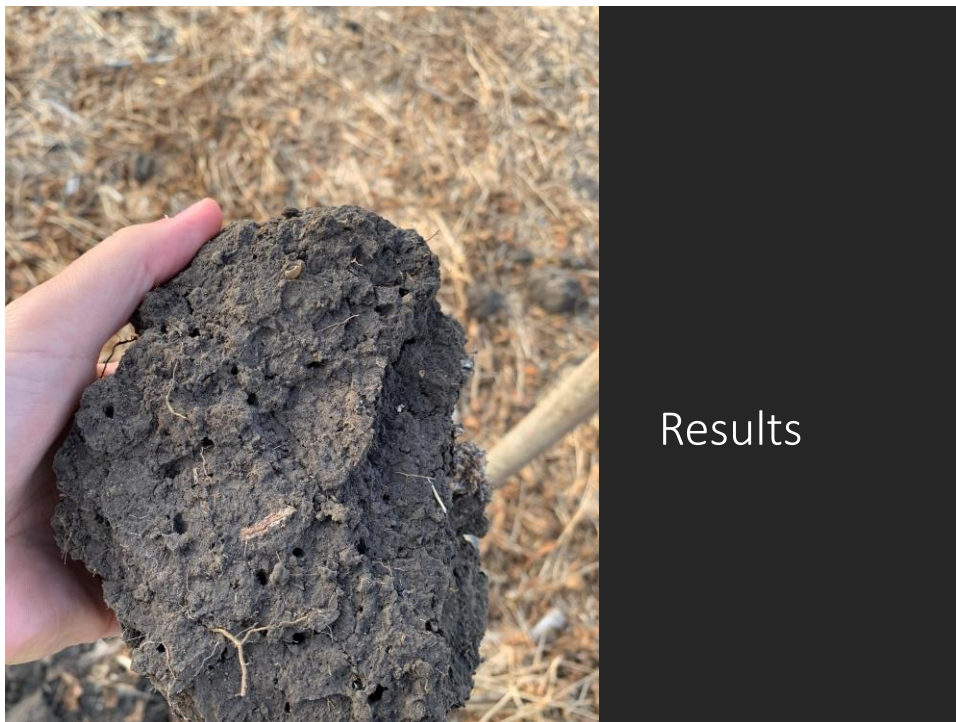
17

Soil Fauna Awaken Soil Microbes

15 week time lapse



18

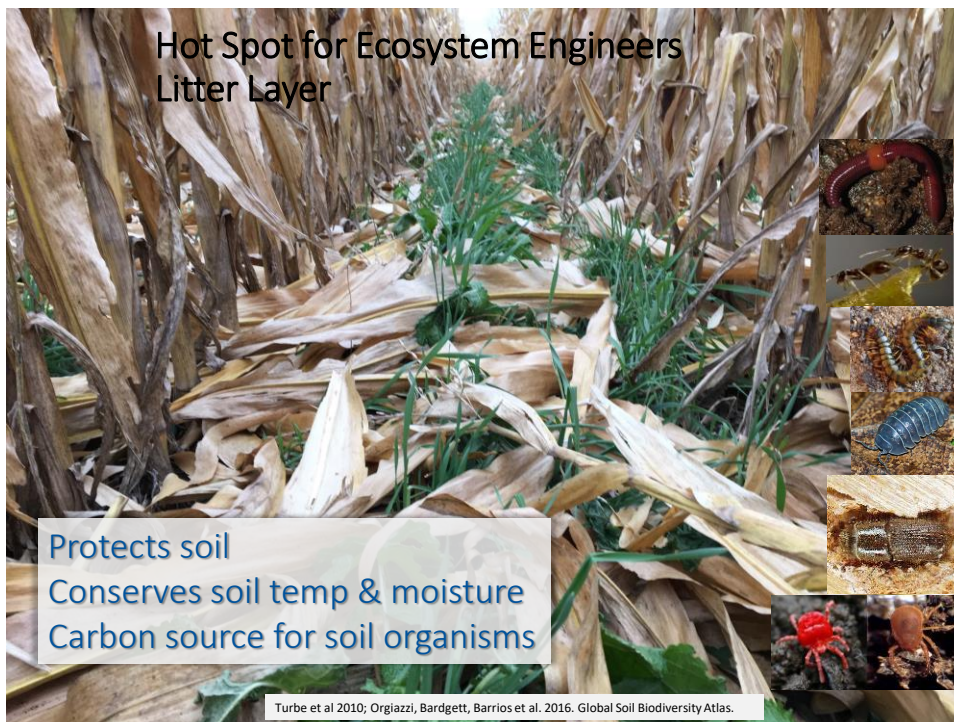


19

Biological Hot Spots



21



22

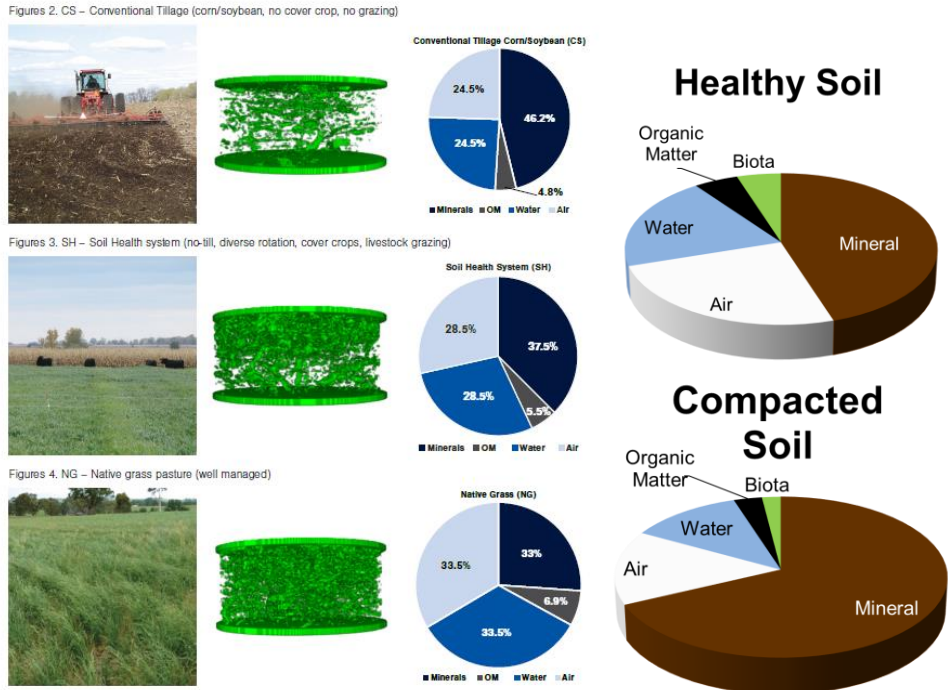
Hot Spot for Ecosystem Engineers Earthworm and Root Channels

Biopores

- Mixes and moves residues
- Large pores
- Nutrient rich
- Microbial enriched
- Air and water flow
- Roots grow & take advantage

Beare et al. 1995. Plant & Soil 170:5-22; Kuzyakov et al. 2015. Soil Biol Biochem 83:184-199

23

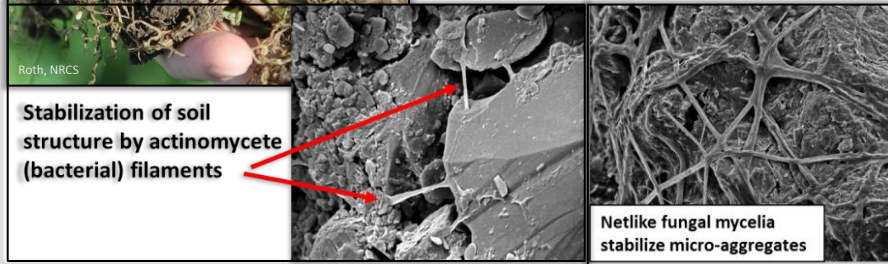


25

Soil Organisms Physically Stabilize Soil Aggregates



- Plant roots enmesh soil particles
- Earthworm casts
- Fungal and bacterial filaments physically enmesh soil particles



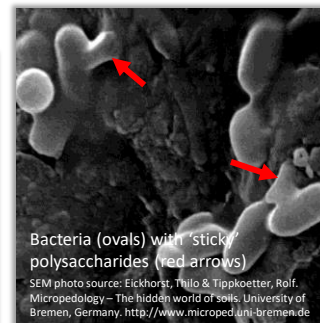
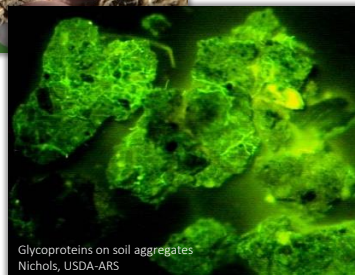
SEM photo source (accessed on 6/2/2016): Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. <http://www.microped.uni-bremen.de>

27

Soil Organisms Chemically Stabilize Soil Aggregates



- Polysaccharides released by bacteria bind particles
- Soil proteins and other biochemicals bind soil particles



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Hot Spot For Chemical Processors & Regulators - Rhizosphere

- Root exudates & chemical signals stimulates microbes & predators
 - Symbiosis
 - Protection
 - Chemical signaling
 - Nutrients
 - Resilience



29

Root Zone (Rhizosphere): Key Organisms

Bacteria

- Most numerous...**maybe**
- 2-5% of SOM but responsible for 90% of energy flow
- 1 g can contain 10 million bacteria and one million species.
- 0.5-3 tons per acre (Killham 1994)

Fungi

- Saprophytic
- Mycorrhizae
- Pathogenic
- Up to 5 tons per acre

Protozoa & Nematodes

- * Consume microbes and recycle nutrients to plant roots

Turbe et al 2010; Coleman & Crossley 1996; Nannipieri & Badalucco 2003; Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.

30

Rhizosphere Key Organisms

Mycorrhizae

Extension of Corn Root Surface Area through
Mycorrhizal Fungi

Mykós (fungus)- riza (root)



USDA-SARE

- Plants use 5-20% of C from photosynthesis to 'feed' fungi
- Fungi increase adsorptive root surface area at least 10x
- Fungi increase nutrient uptake especially P and Zn
- Fungi suppress pests and diseases
- Fungal networks build soil aggregates

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How Can the Soil Microbiome be Manipulated?

- Select different plant species, varieties, or control at various plant stages (e.g., crop rotation, cover crop selection, planting timing and termination)
- Fertilization (4 R's)
- Soil amendments, including biologicals (promise but fraught with issues)
- Manage the environment to minimize stress (e.g., pathogens, drought, temperature extremes, etc.)
 - Temperature
 - Moisture
 - Maximize presence and duration of hot spots

33

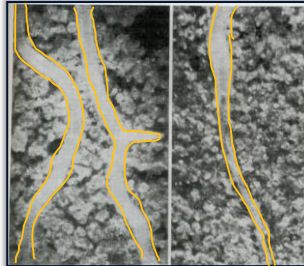
Belowground Competition

Nematode-trapping Fungi



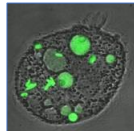
Vampyrellids (protist) eating a fungal root pathogen involved in take-all disease

Protection from *Rhizoctonia solani*



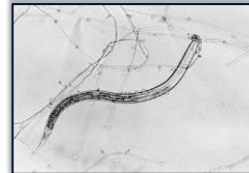
Roots with springtails

Roots without springtails



A single protozoan can eat billions of bacteria each day!

Mite preying on a nematode



Soybean cyst nematode parasitized by the fungus *Hirsutella minnesotensis*

34

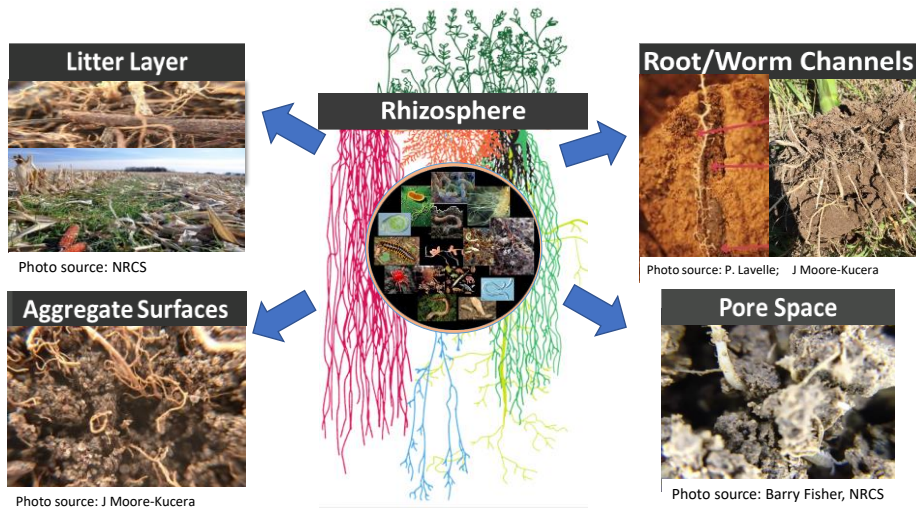


What do Soil Organisms Need?

- How can we feed belowground life?
 - Choose practices that provide diverse, near continuous inputs and build reserves (SOM)
- How can we provide & protect habitat?
 - Choose practices that minimize disturbance of habitat (aggregates) and food sources (SOM + residue)
 - Choose practices that support a stable habitat from major swings in temperature, water, & chemistry

36

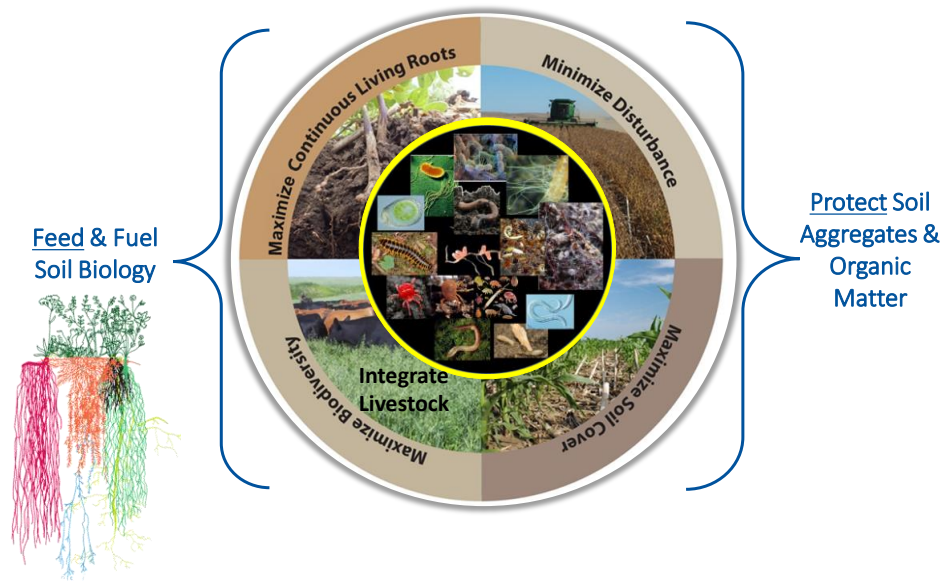
Biological Hot Spots to Optimize Function



Root cartoon and organism images: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.; Slide design by J Moore-Kucera

37

Soil Health Principles



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Farm Forever!

- If you're not planning to build soil, plan on losing it!
- Thank you, Questions? Comments?
- Kent Vlieger
- kent.vlieger@usda.gov
- 605-570-1312