Soil Biology

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June 23, 2021
Bi-State ASHT Workshop #1
Monmouth, IL

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Objectives

1. List 1 key activity performed by each of the 3 functional groups for soil organisms
2. List 2 soil organisms that represent each functional group
3. Describe biological hotspots & how they relate to key ecosystem functions

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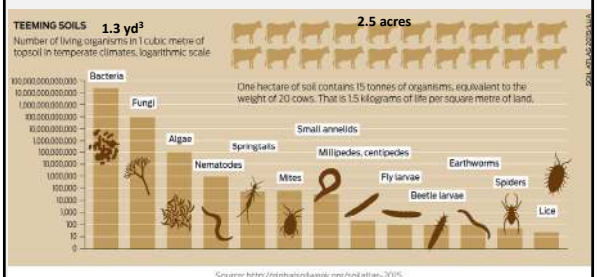
Soils Host Vast Numbers, Mass, and Diversity of Organisms



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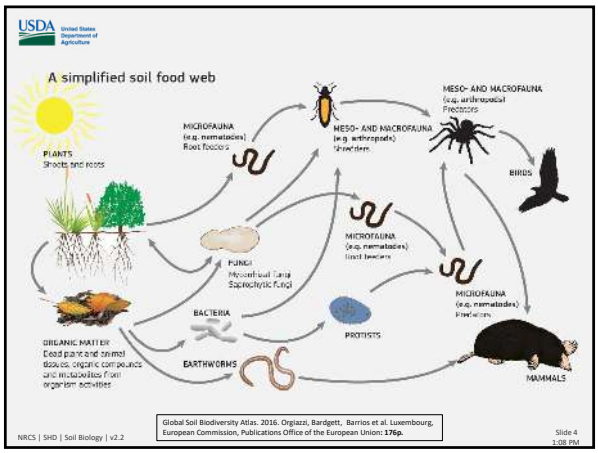
USDA
A simplified soil food web
PLANTS
Shoots and roots
MICROFAUNA
(e.g. nematodes)
Root feeders
MESO- AND MACROFAUNA
(e.g. arthropods)
Shredders
MESO- AND MACROFAUNA
(e.g. arthropods)
Predators
BIRDS
MICROFAUNA
(e.g. nematodes)
Fungal feeders
FUNGI
Mycorrhizal fungi
Saprophytic fungi
MICROFAUNA
(e.g. nematodes)
Predators
BACTERIA
PROTISTS
ORGANIC MATTER
Dead plant and animal tissues, organic compounds and metabolites from organism activities
EARTHWORMS
MAMMALS
Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al. Luxembourg, European Commission, Publications Office of the European Union: 176p.
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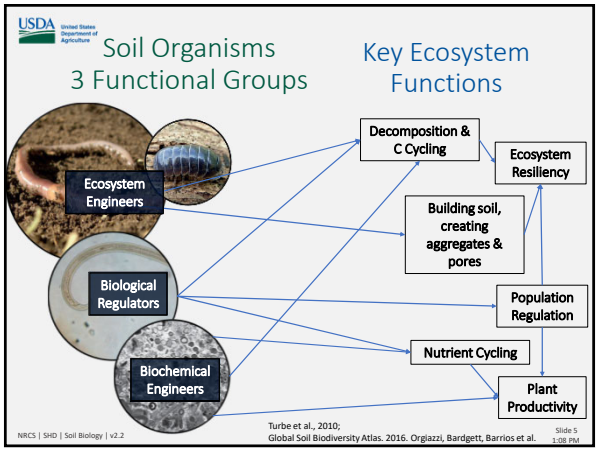
USDA
Soil Organisms
3 Functional Groups
Key Ecosystem Functions
Ecosystem Engineers
Biological Regulators
Biochemical Engineers
Decomposition & C Cycling
Ecosystem Resiliency
Building soil, creating aggregates & pores
Population Regulation
Nutrient Cycling
Plant Productivity
Turbe et al., 2010;
Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.
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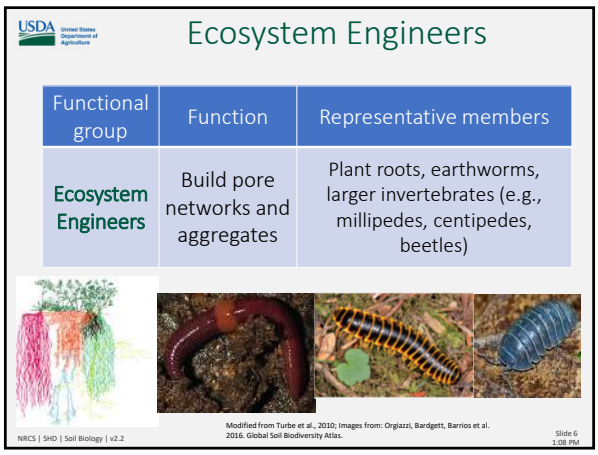
USDA
Ecosystem Engineers
Functional group
Function
Representative members
Ecosystem Engineers
Build pore networks and aggregates
Plant roots, earthworms, larger invertebrates (e.g., millipedes, centipedes, beetles)
Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.
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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.

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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.

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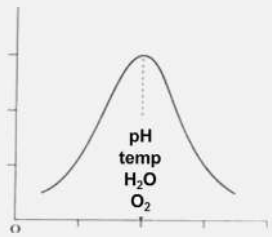
Optimal Activity in Most Ag Systems Occurs When Conditions are 'Just Right'

> 90% bacteria in soil are inactive!



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

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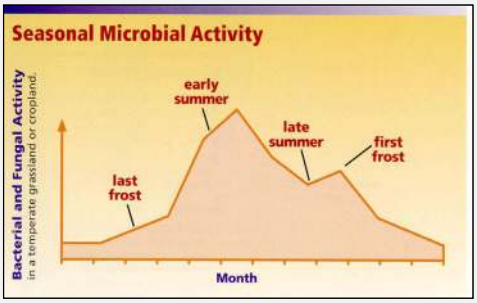
Seasonal Microbial Activity

Microbes are impacted by temp and moisture



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Soil Fauna Awaken Soil Microbes

15 week time lapse

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Made by: Wim van Egmond
https://vimeo.com/222168889

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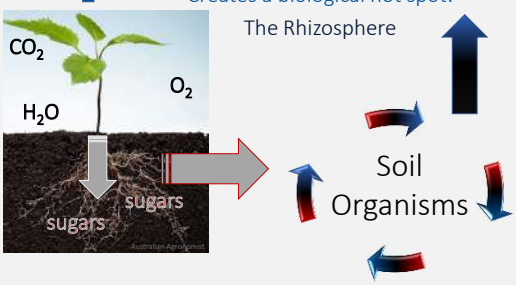
1. Capture Solar Energy
2. Make Organic Carbon

Creates a biological hot spot:

The Rhizosphere



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Continuous Flow of C Drives System

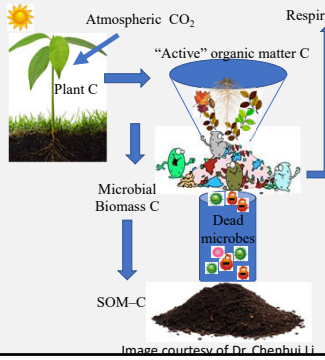

Image courtesy of Dr. Chenhui Li

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Biological Hot Spots

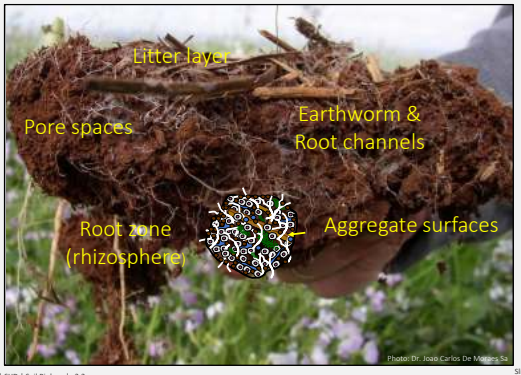

Photo: Dr. Joao Carlos De Moraes Sa

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Hot Spot for Ecosystem Engineers Litter Layer

Protects soil
Conserves soil temp & moisture
Carbon source for soil organisms

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

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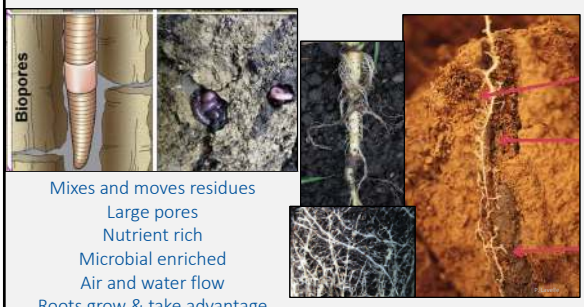
Hot Spot for Ecosystem Engineers Earthworm and Root Channels



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

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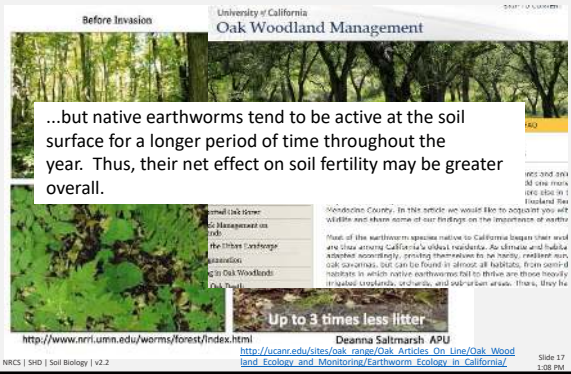
Not all Earthworms are Beneficial



...but native earthworms tend to be active at the soil surface for a longer period of time throughout the year. Thus, their net effect on soil fertility may be greater overall.

http://ucanr.edu/sites/oak_range/Oak_Articles_On_Line/Oak_Woodland_Ecology_and_Monitoring/Earthworm_Ecology_in_California/

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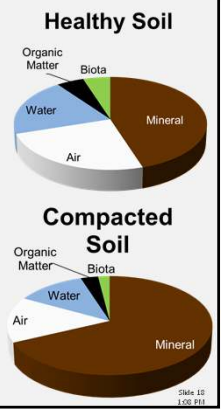
Hot Spot for Chemical Processors & Regulators in Pore Spaces

- Created via roots, organisms & SH management
- "Lungs & circulatory system"
- Air flow
- Water flow, storage, & availability
- Biological highways



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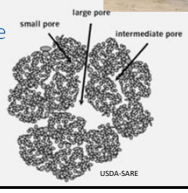
Aggregate Surfaces

- Built with minerals and organic materials
- Creates stability and resists erosion
- Protects organic matter and microbes
- Physically supports pore spaces
- Created by microbial glues, fungal hyphae, dead cells



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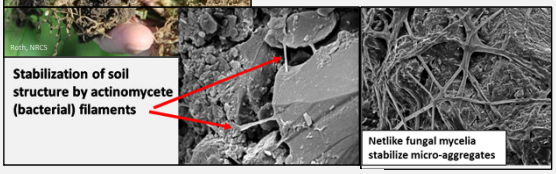
Soil Organisms Physically Stabilize Soil Aggregates

- 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

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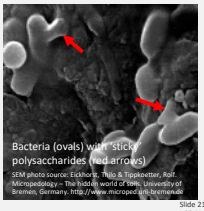
Soil Organisms Chemically Stabilize Soil Aggregates

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



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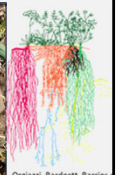
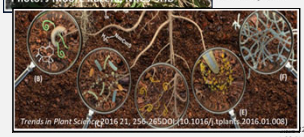
Hot Spot For Chemical Processors & Regulators - Rhizosphere

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





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Root Zone (Rhizosphere): Key Organisms

Bacteria
- Most numerous
- 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.

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Rhizosphere Key Organisms Mycorrhizae

Extension of Corn Root Surface Area through Mycorrhizal Fungi

Mykós (fungus)- riza (root)

- 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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N-Fixing Bacteria (Rhizosphere)

Bradyhizobium Japonicum for Soybean & Cowpea

Rhizobum trifolii for most Clovers

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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

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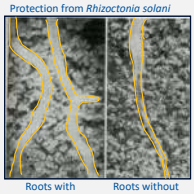
Belowground Competition

Nematode-trapping Fungi

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

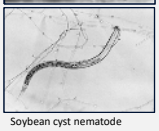
Protection from *Rhizoctonia solani*



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*

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Summary: Managing for Soil Biology

- Most ag soils are carbon depleted
- Disturbances destroys habitat and hyphal networks
- Bare, fallow fields provide little protection, no C
- Agrichemicals have mixed effects
- Many fertilizer concentrations too high for symbiosis

- Manage for hot spots
- Support biology to build aggregates and create pore space
- Protect the habitat
- Feed the soil so it can feed us
- Optimize biological nutrient cycling
- Optimize plant-microbe interactions for plant defense optimization

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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

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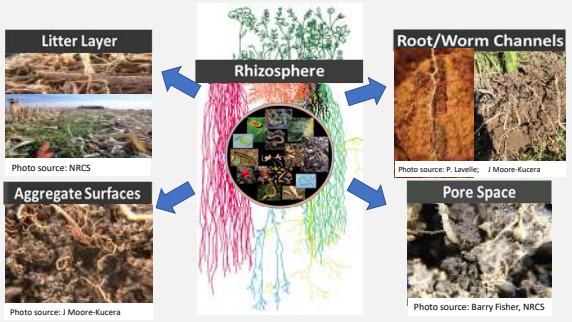
Biological Hot Spots to Optimize Function



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

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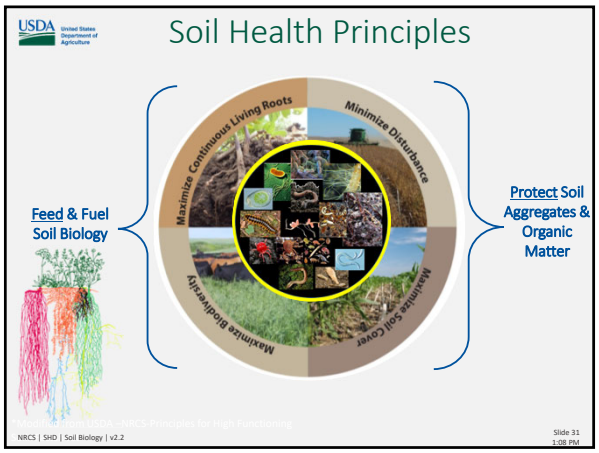
Soil Health Principles
Feed & Fuel Soil Biology
Protect Soil Aggregates & Organic Matter
Maximize Continuous Living Roots
Minimize Disturbance
Maximize Biodiversity
Maximize Soil Cover
* Modified from USDA - NRCS Principles for High Functioning
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Meek, NRCS
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