USDA United States Department of Agriculture

Soil Biology

Dean P. Moberg
USDA-NRCS Earth Team Volunteer
Tualatin Soil & Water Conservation District Director

USDA United States Department of Agriculture

Bio

- Degrees:

  Plant Sci., Teaching, Env. Sci. & Eng.
- Farms: CA, IL, NY.
- NRCS: OR, MI, WI.
- SWCD Director
- Fly fish,

bird, raft, garden,

bees, read.

Objectives

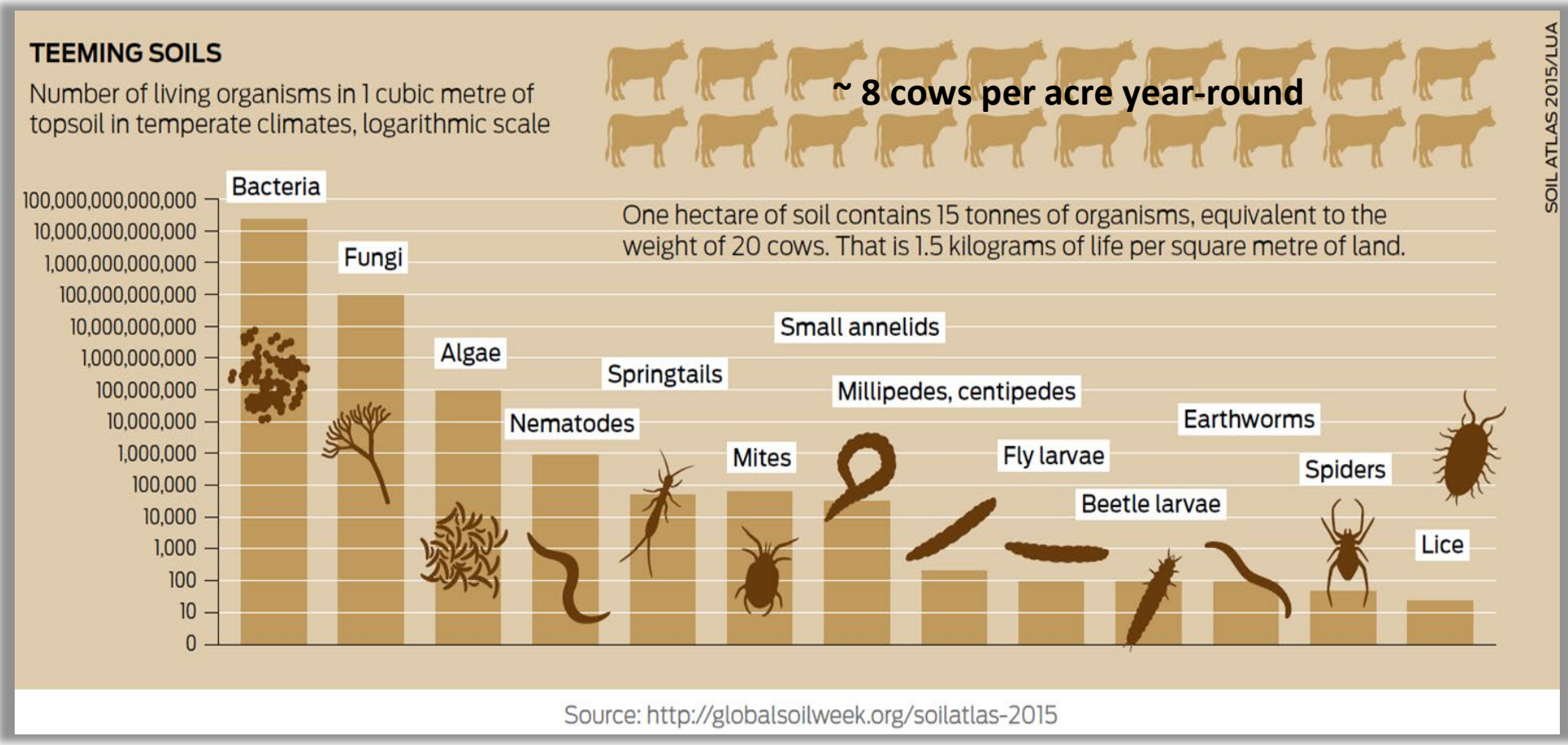
1. Review basics about organic matter, biodiversity
2. Introduce ideas of functional groups and hotspots
3. Briefly discuss management and references

Some Basics

- Biodiversity
- Energy flow
- Organic matter

Image from Orgiazzi et al., 2016

Soils Host Vast Numbers, Mass, and Diversity of Organisms



Biodiversity Definition

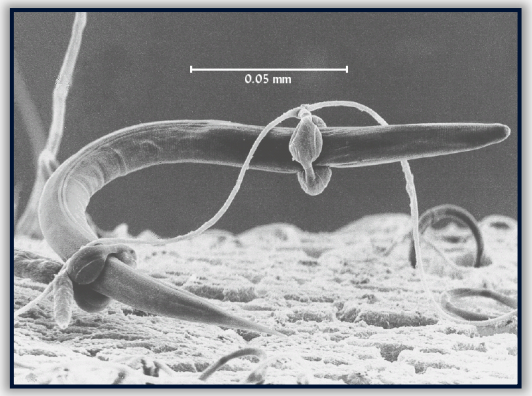
Soil biodiversity can be defined as the variation in soil life, from genes to communities, and the variation in soil habitats, from micro-aggregates to entire landscapes.

Turbé et al., 2010

Soil biodiversity: functions, threats and tools for policy makers (cnrs.fr)

Belowground Competition

Nematode-trapping Fungi

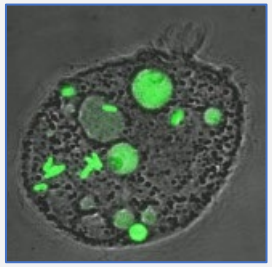


Vampyrellids (protist) eating a fungal root pathogen involved in take-all disease

Protection from *Rhizoctonia solani*

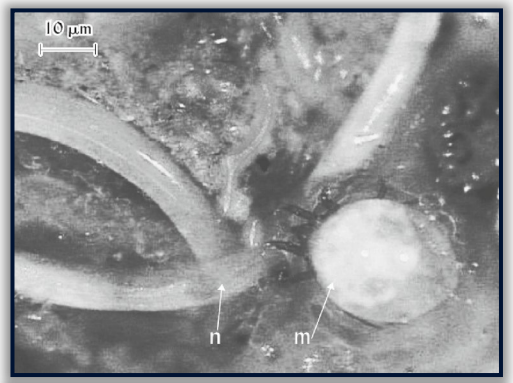
Roots with springtails

Roots without springtails



A single protozoan can eat billions of bacteria each day!

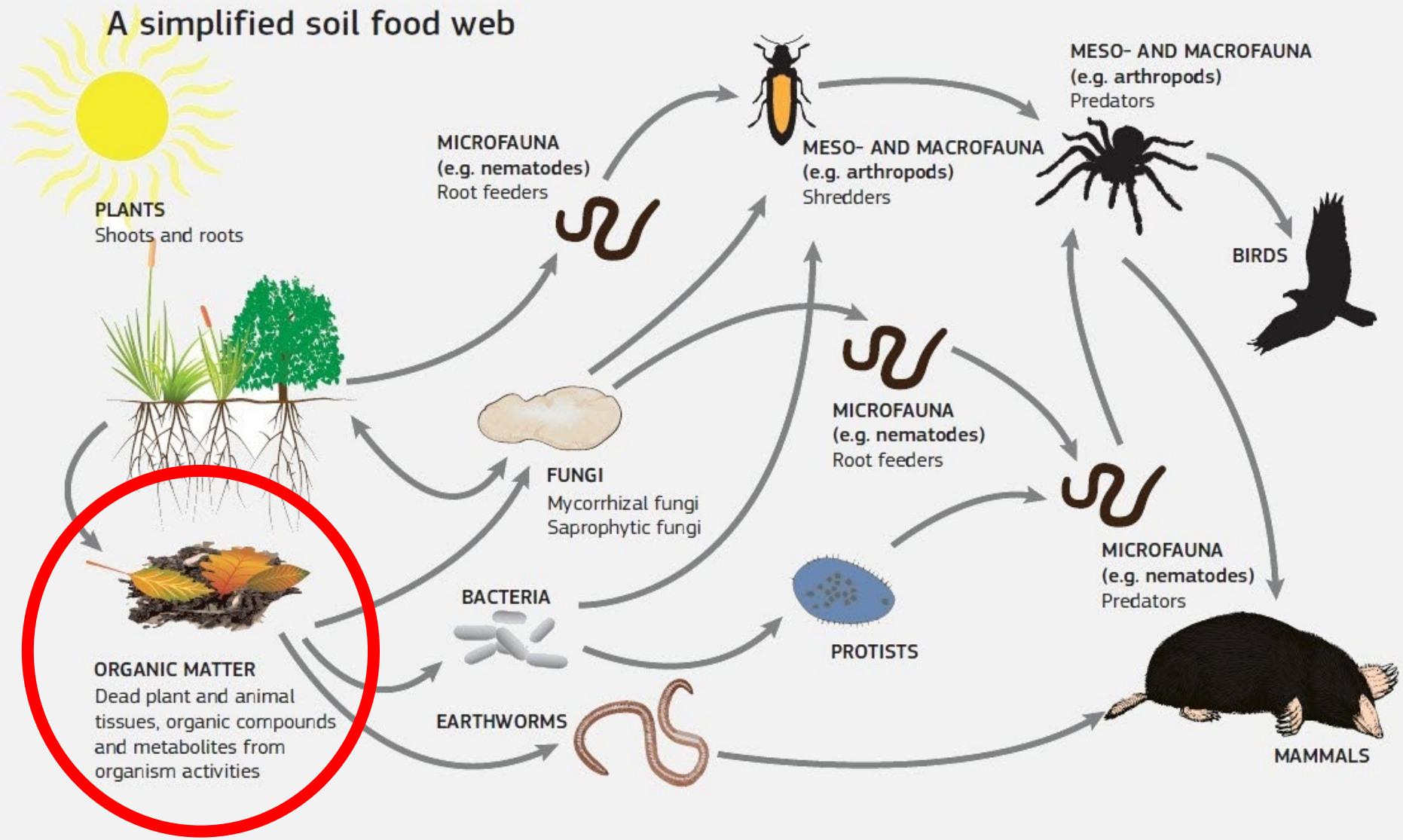
Mite preying on a nematode



Soybean cyst nematode parasitized by the fungus *Hirsutella minnesotensis*

USDA United States Department of Agriculture

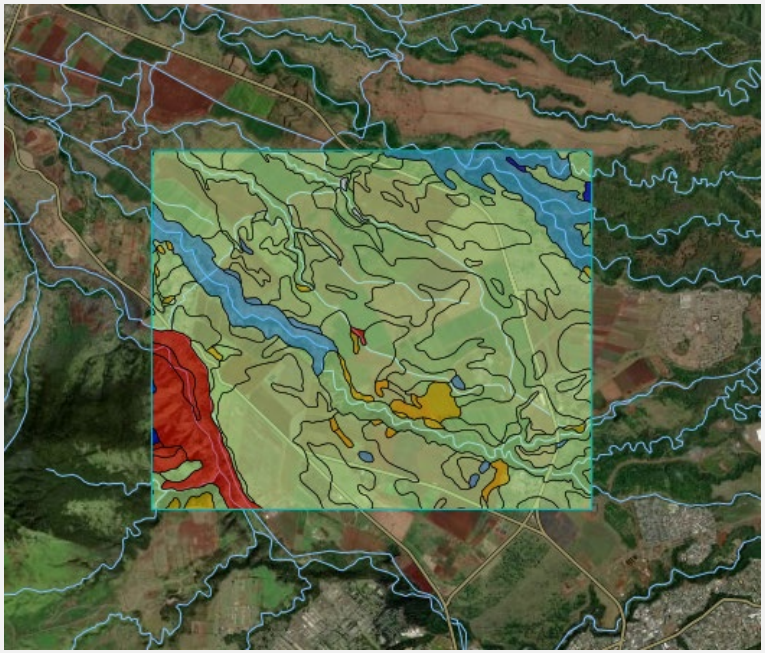
A simplified soil food web

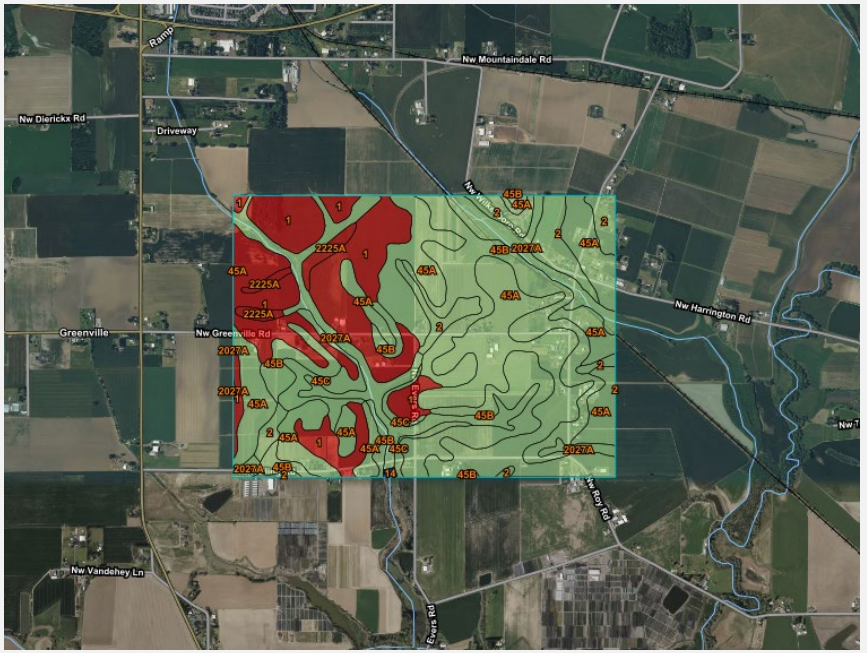


Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al. Luxembourg, European Commission, Publications Office of the European Union: **176p.**

USDA United States Department of Agriculture

Soil Organic Matter (SOM)





Oahu ag soils:
- -SOM 1.5 – 3.5%
- -Depletion risk moderately high

Oregon ag soils:
- -SOM 2.5 – 4.0%
- -Depletion risk moderately high

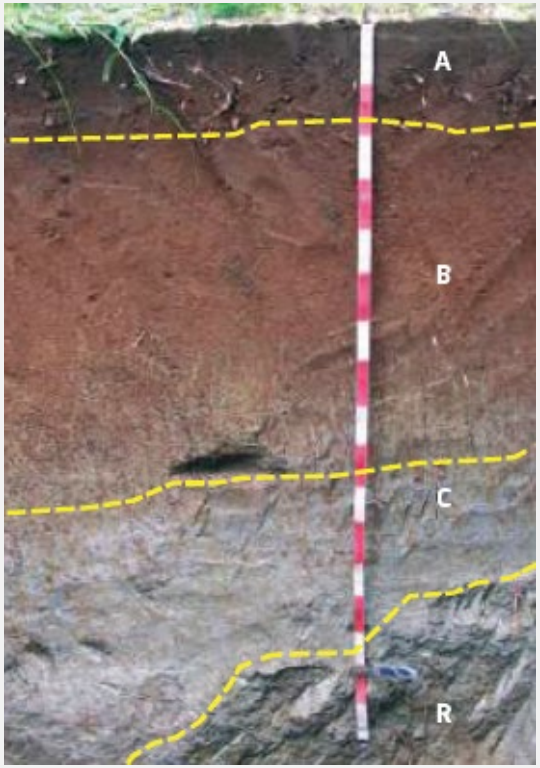
USDA United States Department of Agriculture

Types of Organic Matter

1. Active (days-years)
   - dead organisms
   - root exudates
   - dissolved

2. Variable (days-decades)
   -particulate

3. Stable: (decades-centuries)
   - mineral-associated (e.g. clay)



USDA United States Department of Agriculture

Paradigm Shift (simplified)

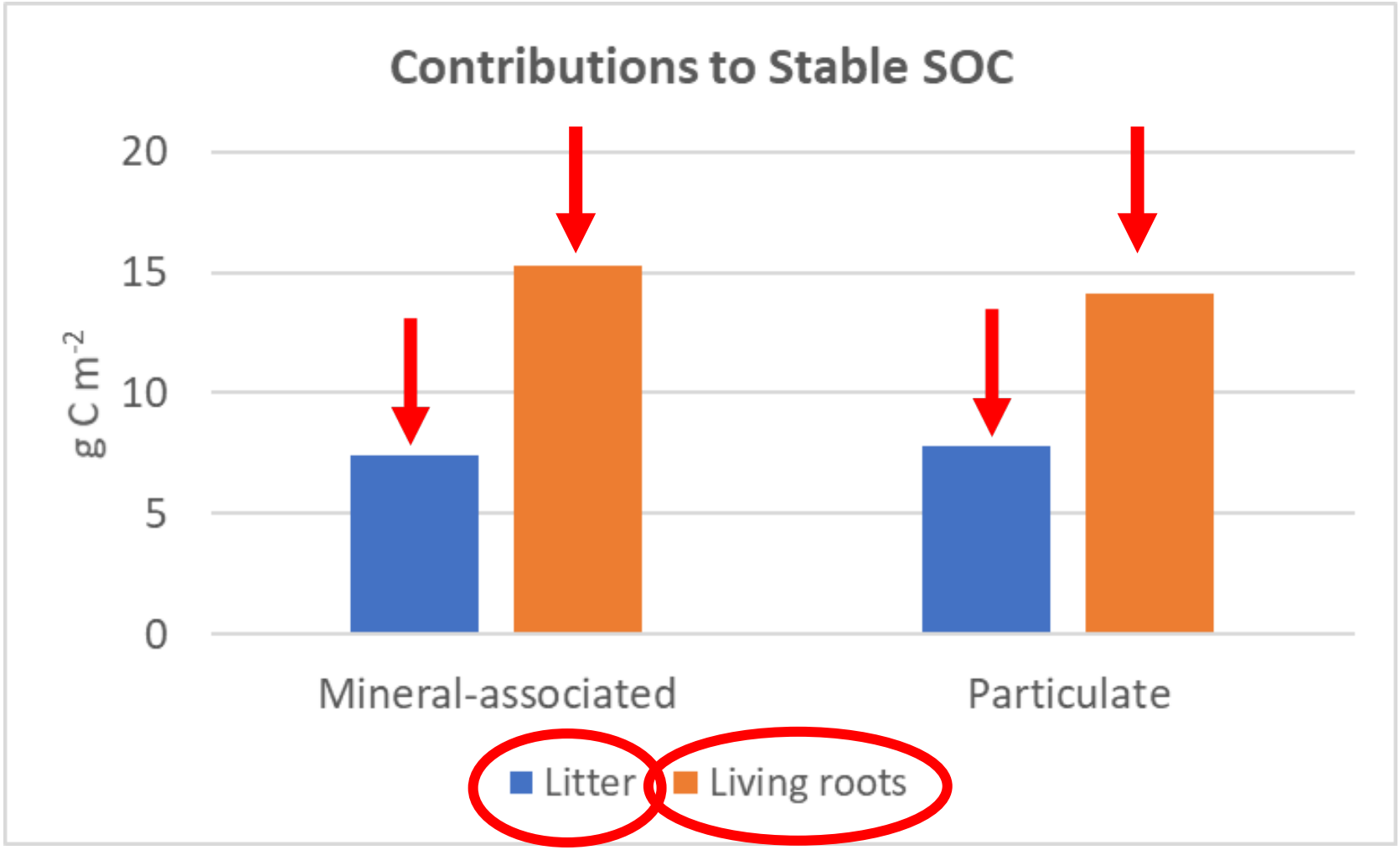
1. Old school:

plant litter lignin → stable SOM (humus)

2. New school:

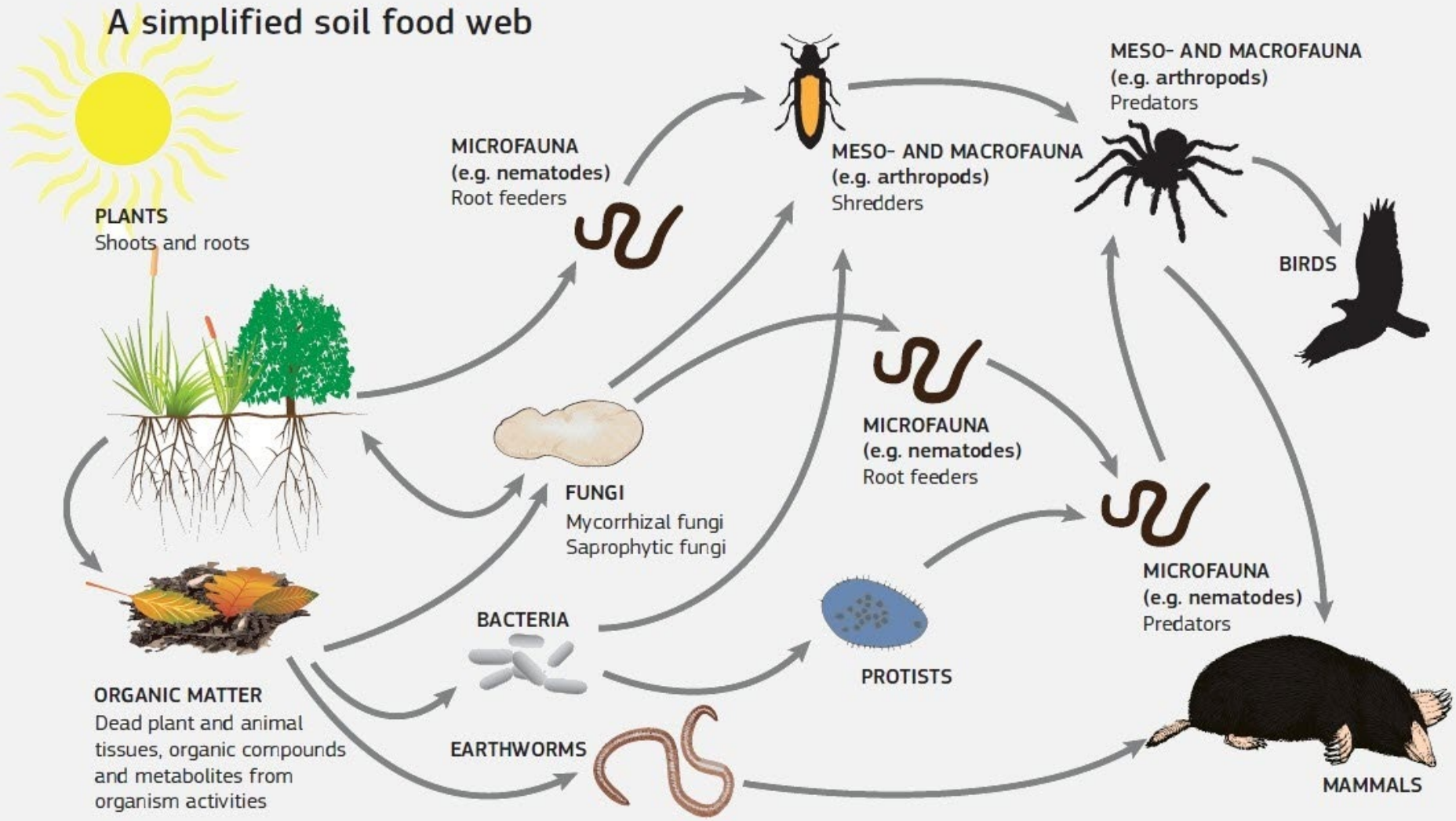
dissolved SOM → microbial biomass → stable SOM stable SOM (mineral-associated)

Images from Orgiazzi et al., 2016



Data from Sokol et al., 2019

A simplified soil food web



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

Functional Groups

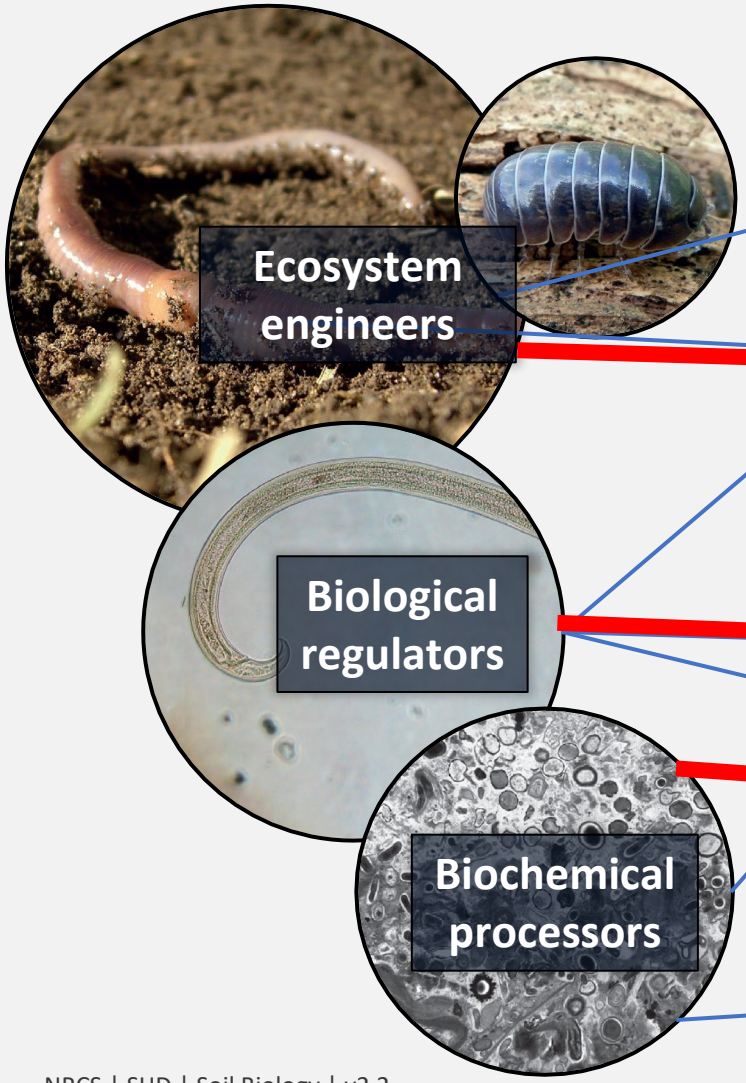
An alternative to food webs that considers physical, chemical, and biological processes.

Image from Orgiazzi et al., 2016

USDA United States Department of Agriculture

Soil Organisms 3 Functional Groups

Key Ecosystem Functions



Decomposition & C cycling

Ecosystem resiliency

Aggregate & pore creation

Population regulation

Nutrient cycling

Plant productivity

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

USDA United States Department of Agriculture

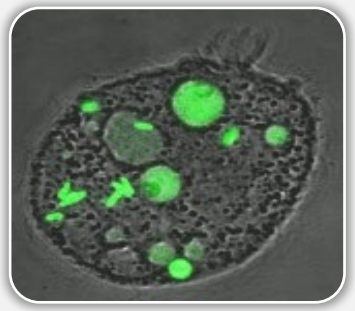
Ecosystem Engineers

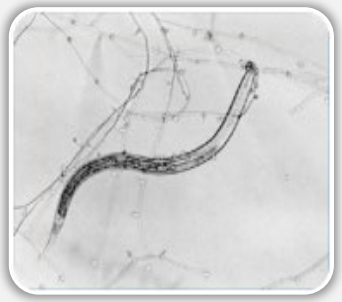
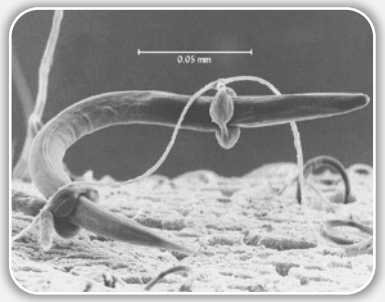
Functional group	Function	Representative members
Ecosystem Engineers	Build pore networks and aggregates	**Plant roots**, earthworms, larger invertebrates (e.g., millipedes, centipedes, beetles)

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

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)

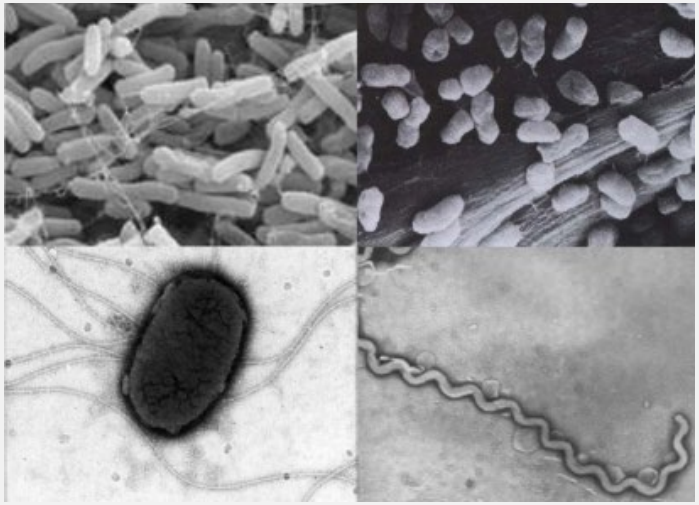


Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

Biochemical Processors

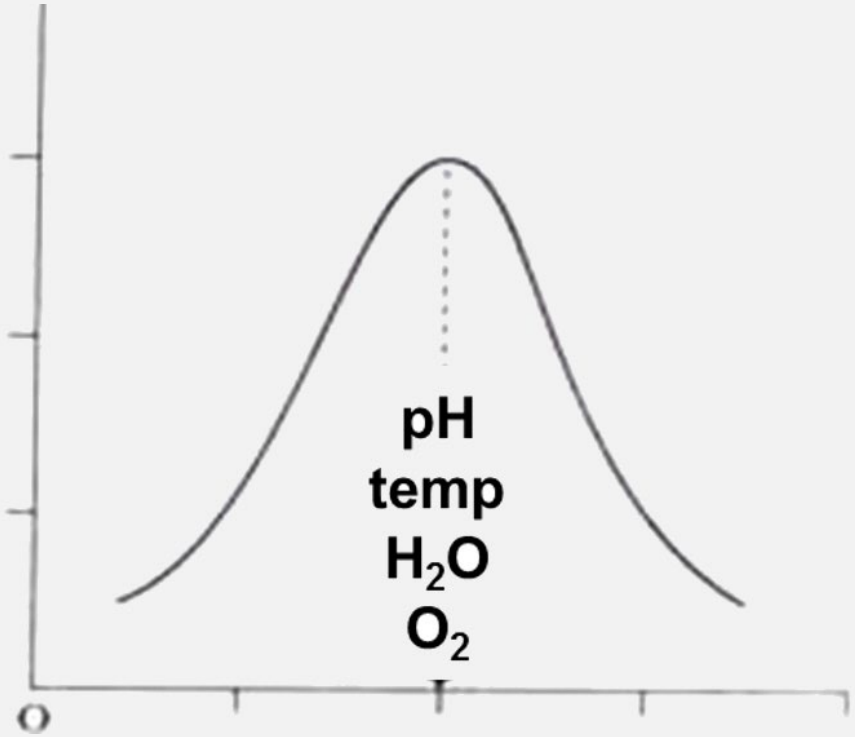
Functional group	Function	**Representative members**
Chemical Processors	Regulate 90% of energy flow in soil; Build soil organic matter & aggregates	Soil microbes (bacteria, fungi, protozoa)



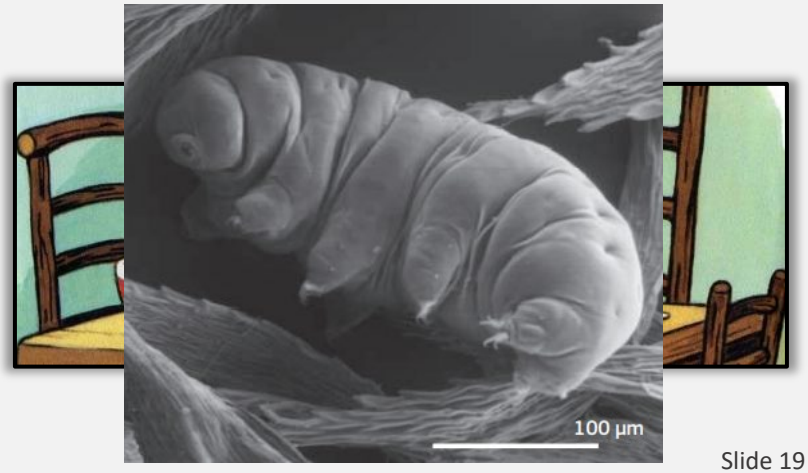
Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

Optimal Activity: When Conditions are 'Just Right'

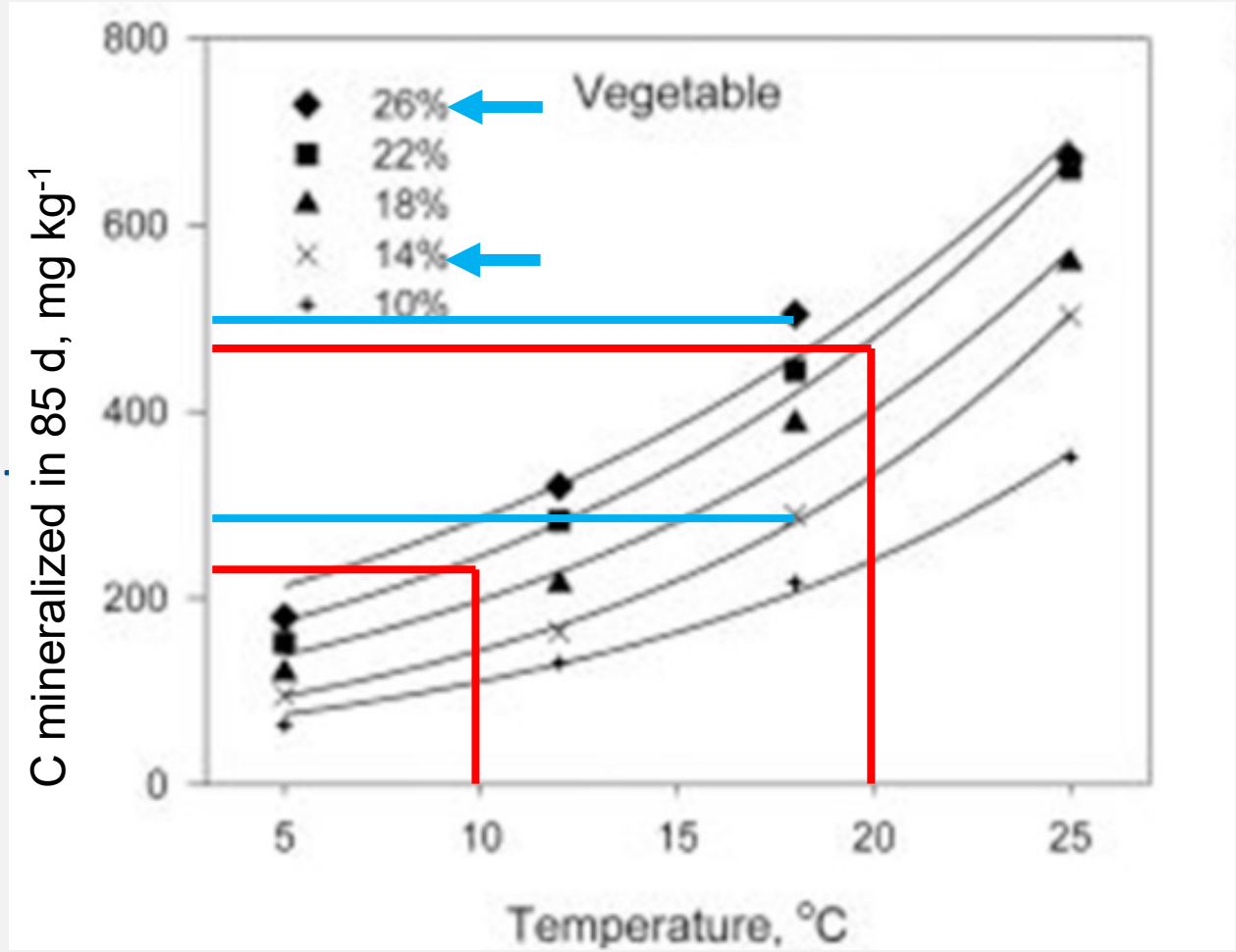
> 90% bacteria in soil are inactive



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



Effect of Climate, Weather



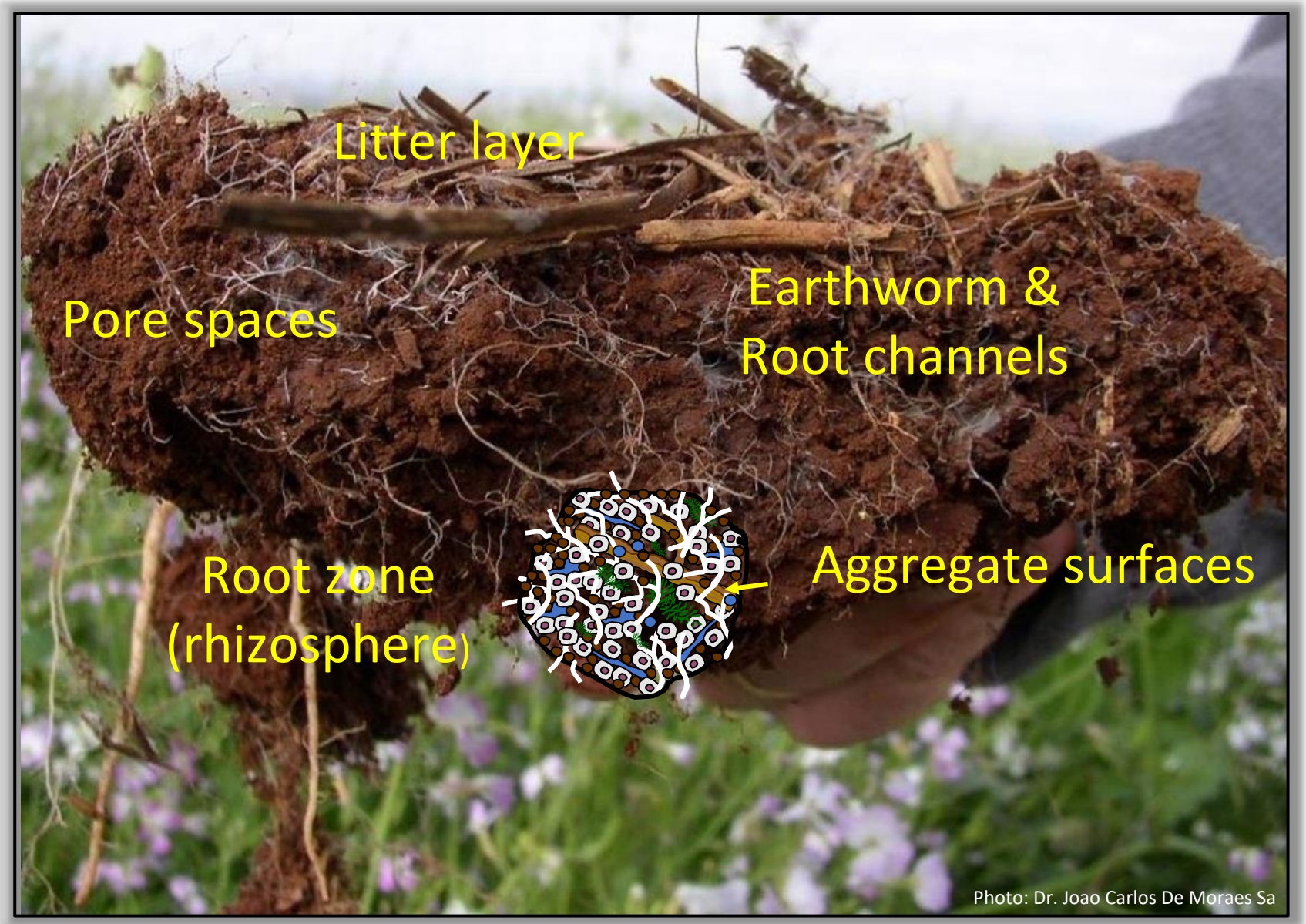
Curtin et al., 2012

Hot Spots

Sites in the soil with high biological activity.

Image from Orgiazzi et al., 2016

Biological Hot Spots



Litter Layer

Absorbs the impact of rain
Conserves soil temp & moisture
Carbon source for organisms

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

USDA United States Department of Agriculture

Importance of Animals

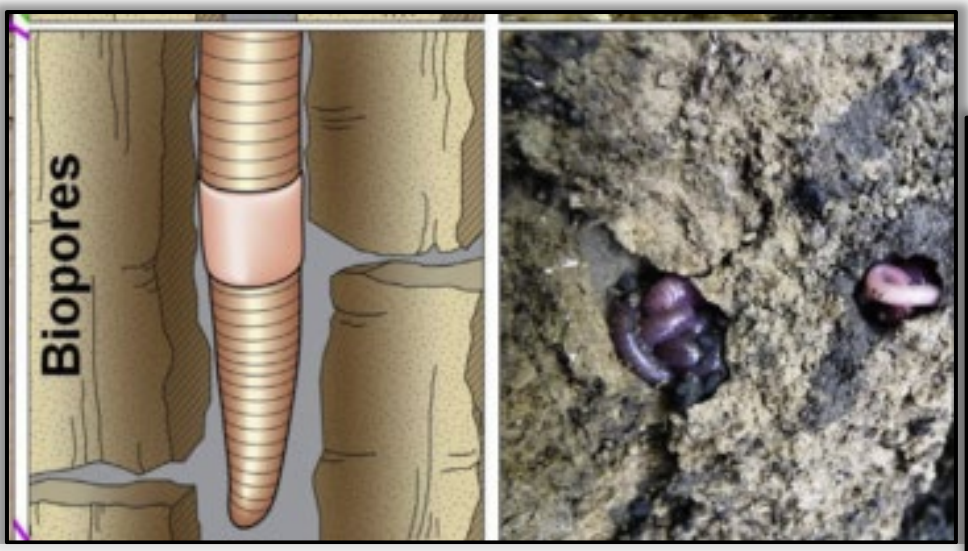
15 week time lapse

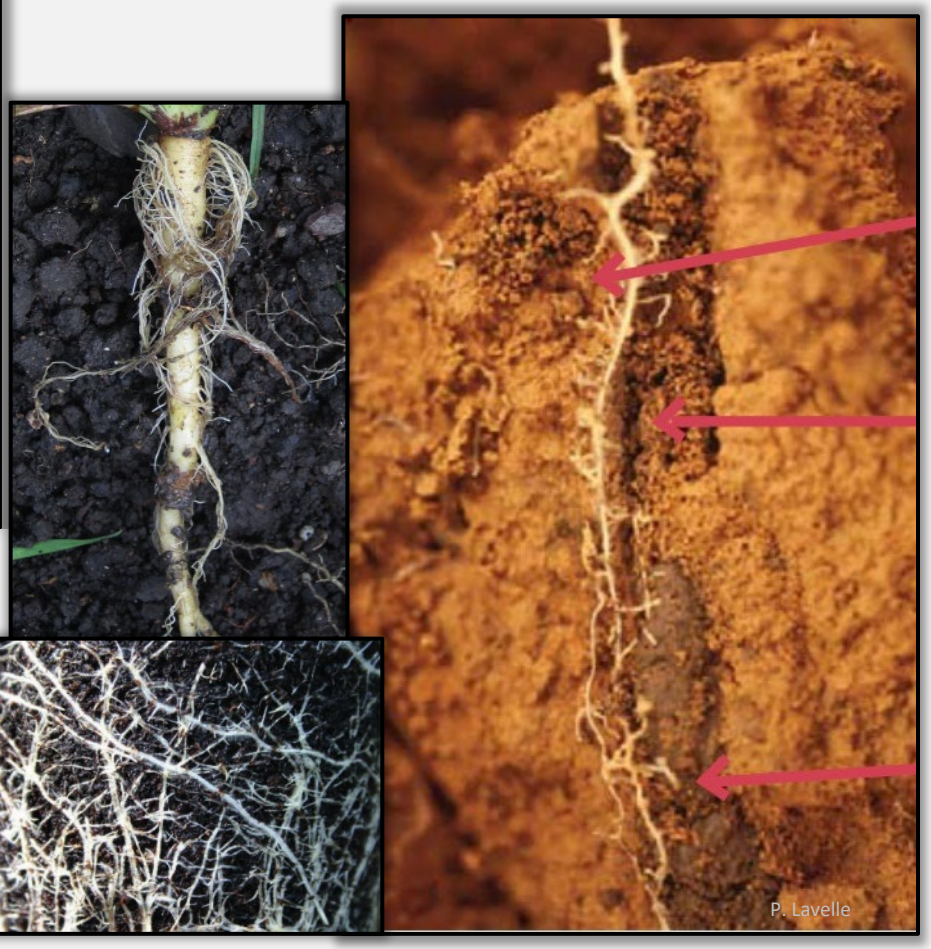
Microbes only

Diverse soil fauna

https://vimeo.com/222168889

Earthworm and Root Channels





Large pores

"Highways" for moving organic matter, air, water

Nutrient and microbe rich

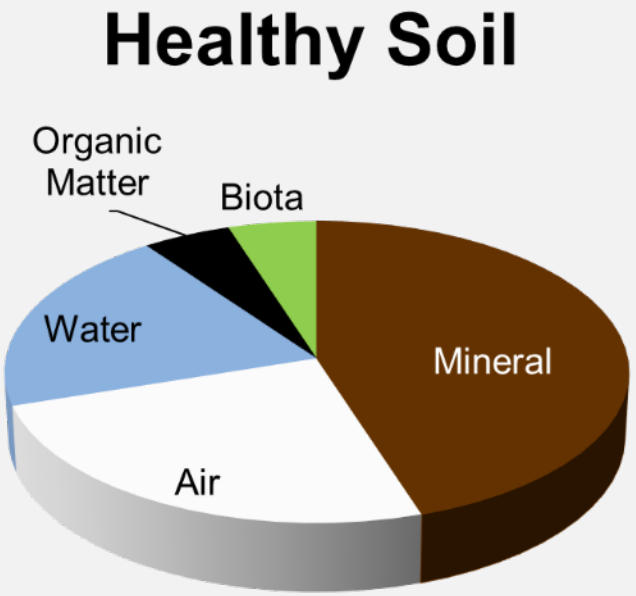
Facilitate root growth

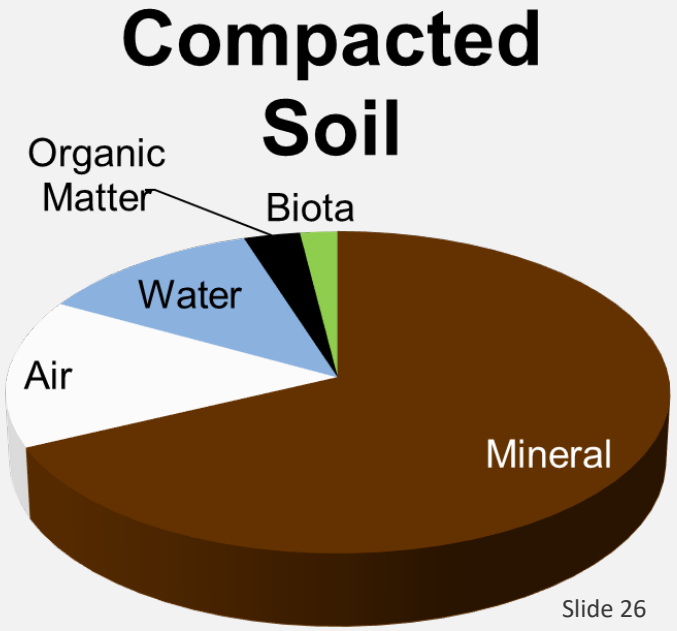
Beare et al. 1995. Plant & Soil 170:5-22; Kuzyakov et al. 2015. Soil Biol Biochem 83:184-199

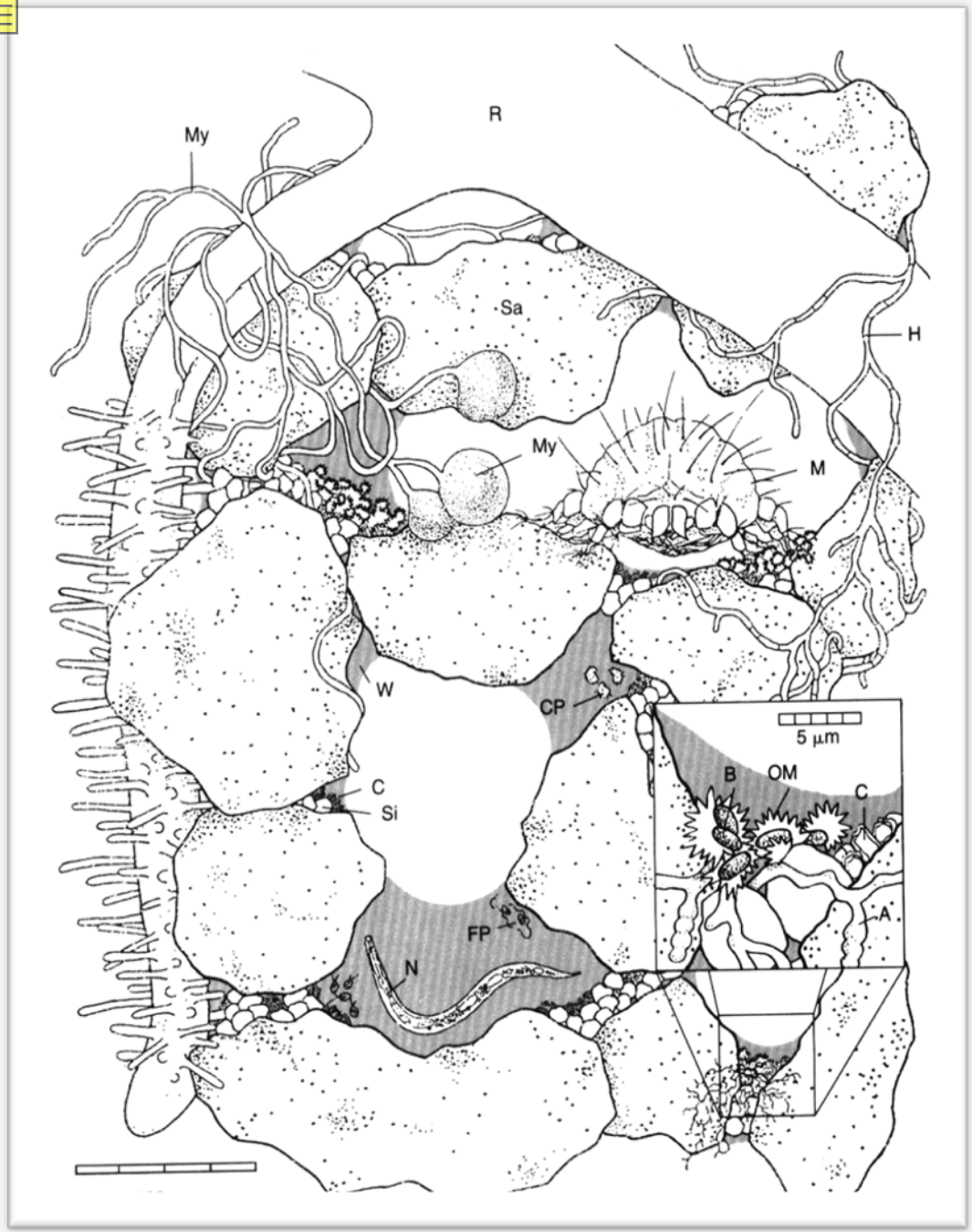
USDA United States Department of Agriculture

Pore Spaces

- Healthy soil:
  - pore space > 50%
  - bulk density < 1.33 g / cm^3)
  - range of pore sizes





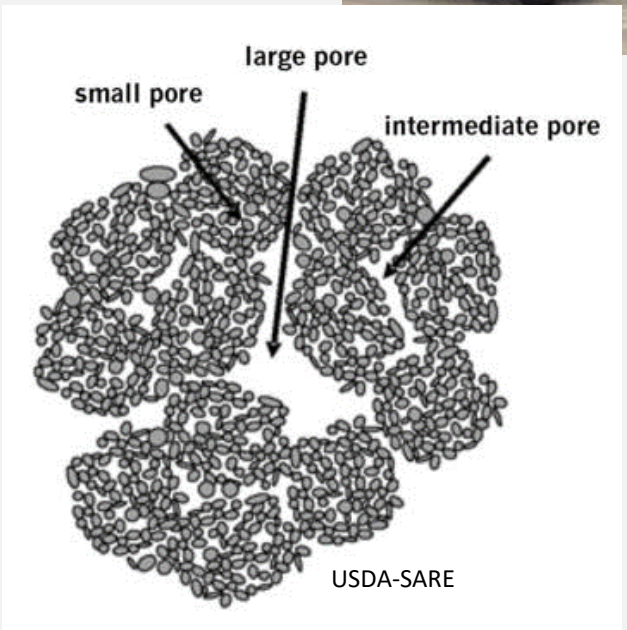


- B – Bacteria
- A – Actinomycetes
- My – Mycorrhizae
- H – Saprophitic fungus
- N – Nematode
- CP – Ciliate protozoa
- FP – Flagellate protozoa
- M – Mite
- Sa – Sand
- Si – Silt
- C - Clay
- OM – Organic matter
- W - Water

Aggregate Surfaces

- Protect organic matter and microbes
- Create pores
- Create stability and resists erosion
- Created by microbial glues, fungal hyphae, dead cells

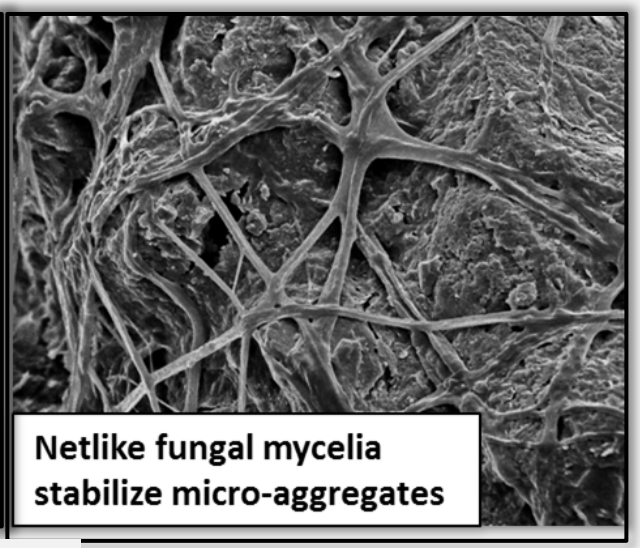

J Moore Kucera



USDA-SARE

Soil Organisms Physically Stabilize Aggregates

- Plant roots
- Earthworm casts
- Fungal and bacterial filaments

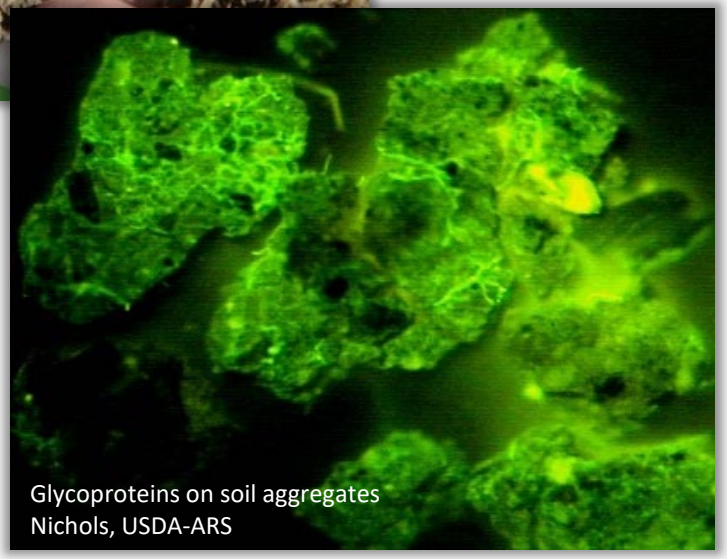


SEM photo source (accessed on 6/2/2016): Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen.de

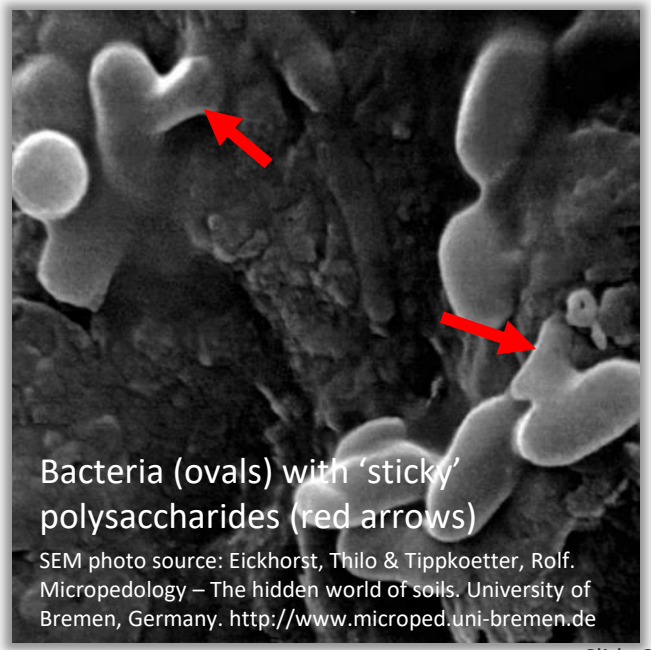
Soil Organisms Chemically Stabilize Aggregates

Image source: Aaron Roth, NRCS-OR

- Polysaccharides
- Proteins



Glycoproteins on soil aggregates
Nichols, USDA-ARS



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

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

Rhizosphere

- Root exudates stimulate microbes & predators
  - Symbiosis
  - Protection
  - Chemical signaling
  - Nutrients
  - Resilience

USDA United States Department of Agriculture

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

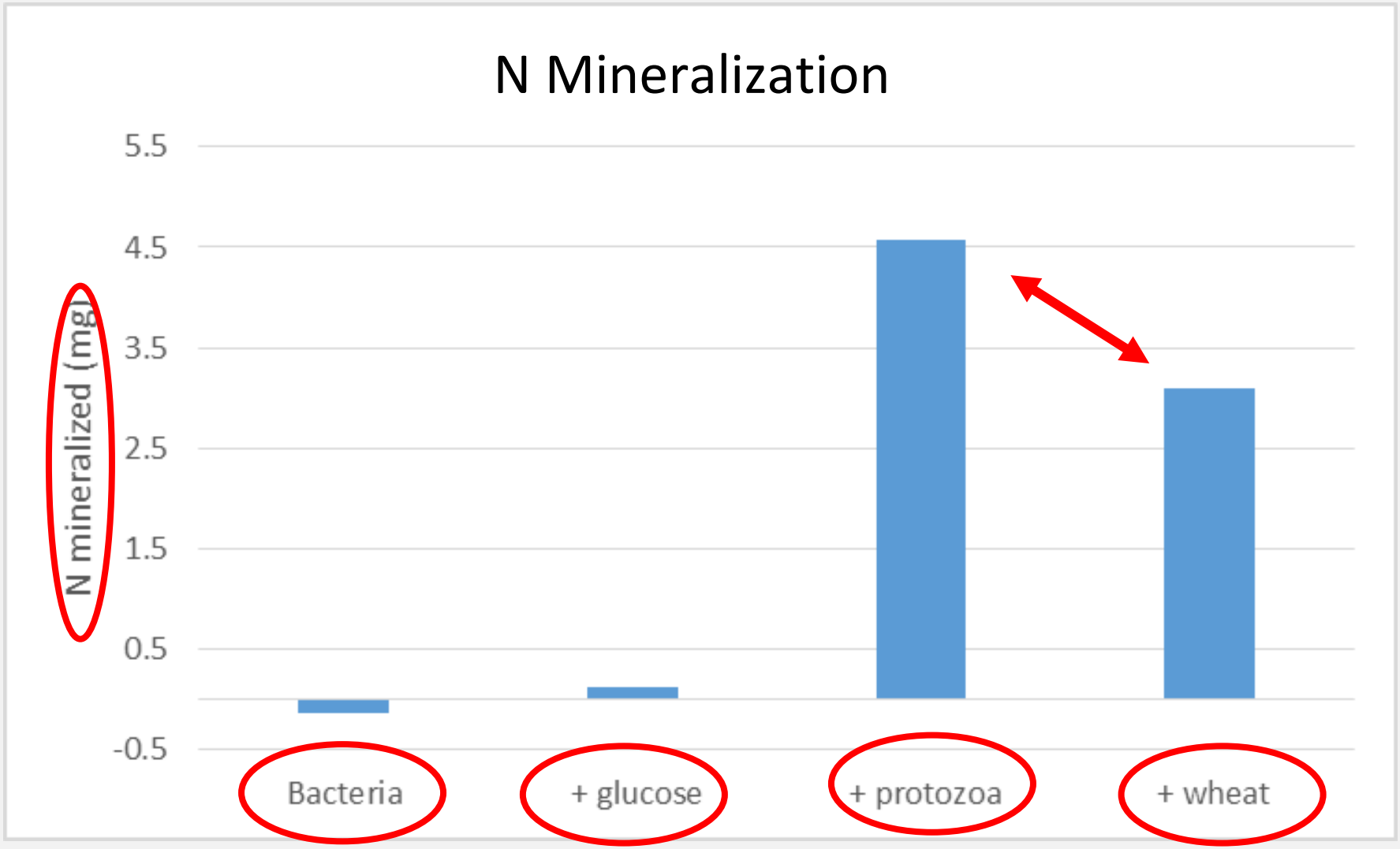
- Saprophytic
- Pathogenic
- Parasitic
- Mycorrhizae
  - Up to 5 tons per acre

Protozoa & Nematodes

*Consume microbes and recycle nutrients

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

USDA United States Department of Agriculture



Clarholm (1984)

USDA United States Department of Agriculture

Mycorrhizae

Mykós (fungus)- riza (root)

- 5-20% of photosynthetic C ‘feeds’ fungi
- Increase root surface 10x
- Nutrient uptake, especially P and Zn
- Suppress pests and diseases
- Fungal networks build soil aggregates

N-Fixing Bacteria (rhizosphere)

Bradyhizobium Japonicum
for Soybean & Cowpea

Photo: Getty Images

Rhizobum trifolii
for most Clovers

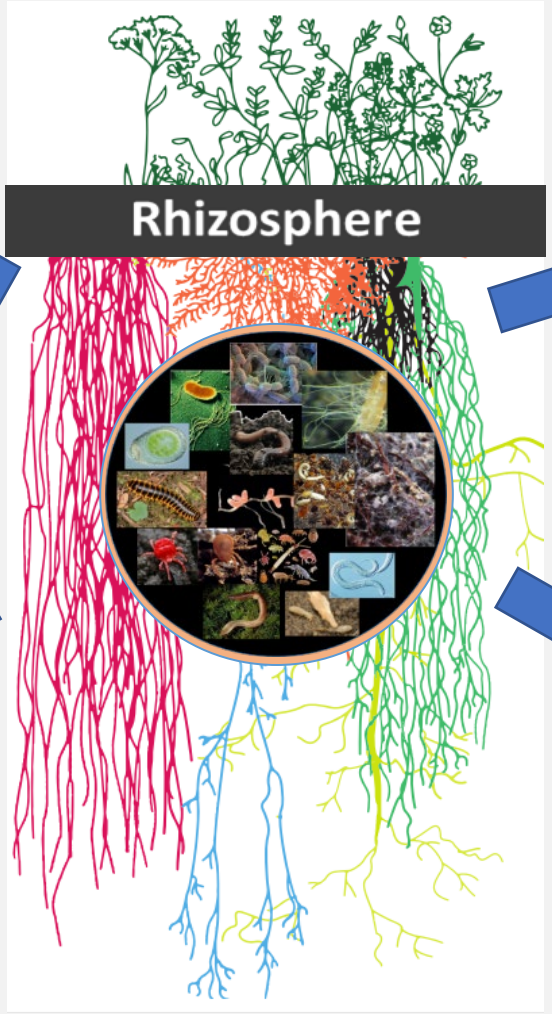

Photo: Science Source

Biological Hot Spots
Habitat Diversity = Biodiversity

Litter Layer

Photo source: NRCS

Rhizosphere



Root/Worm Channels

Photo source: P. Lavelle; J Moore-Kucera

Aggregate Surfaces

Photo source: J Moore-Kucera

Pore Space

Photo source: Barry Fisher, NRCS

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

Managing Biology

Image from Orgiazzi et al., 2016

USDA United States Department of Agriculture

Increasing Soil Biodiversity

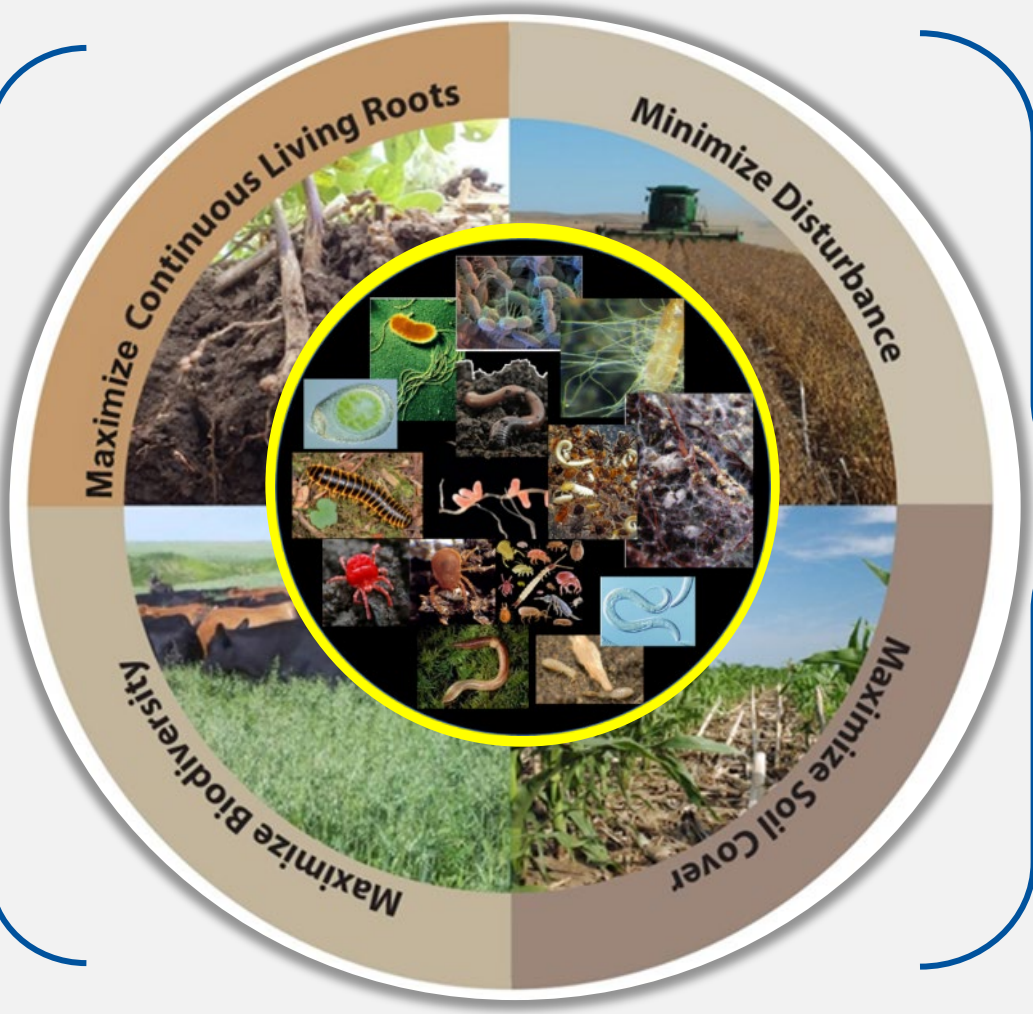
- Maximize presence and duration of hot spots
- Minimize disturbance
- Diverse plant species, varieties, stages: crop rotation, cover crops species/timing/termination
- Nutrient management
- Biologicals (promise but can be snake oil)
- Monitor functional groups

What do Soil Organisms Need?

- Food
  - Provide diverse SOM inputs
- Habitat
  - Minimize disturbance of habitat (aggregates and litter)
  - Protect against major swings in temperature, water, & chemistry

Soil Health Principles

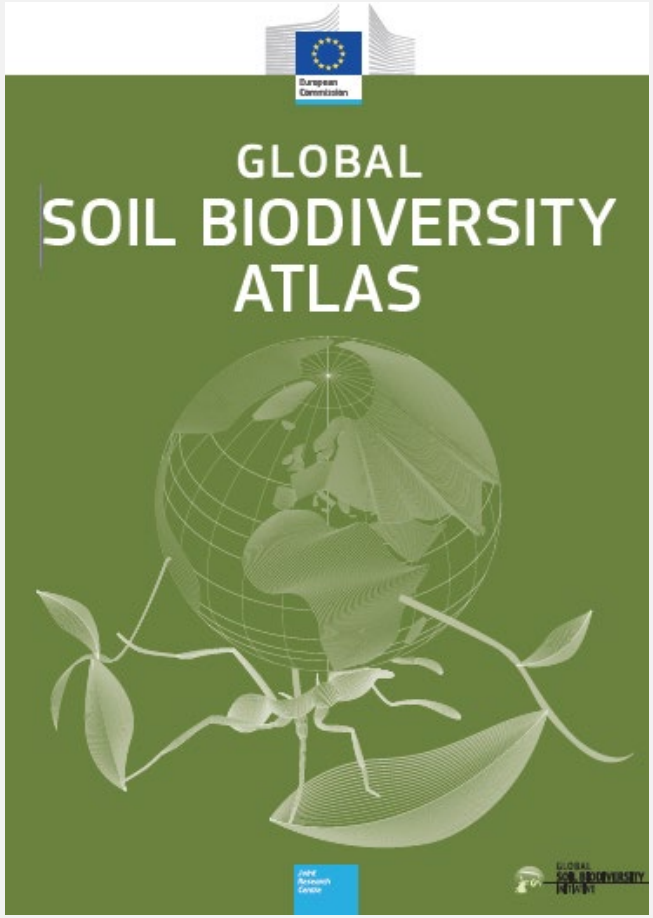
Feed & Fuel Soil Biology



Protect Soil Aggregates & Organic Matter

*Modified from USDA –NRCS-Principles for High Functioning

For More Info

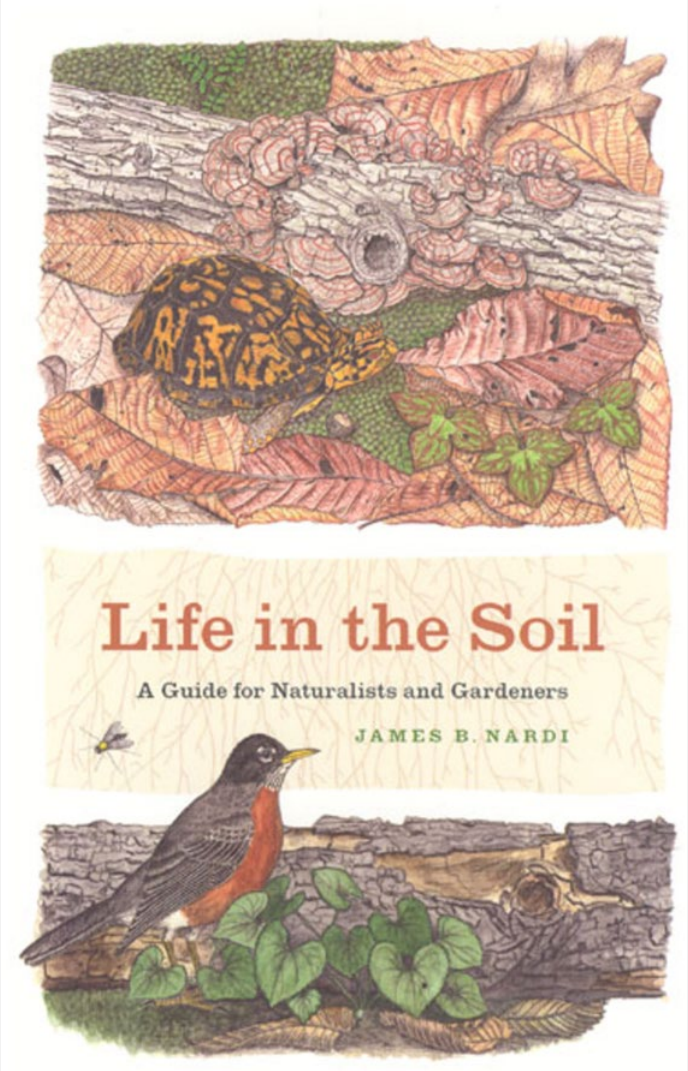


Orgiazzi et al., 2016

*Modified from USDA –NRCS-Principles for High Functioning S

Turbé et al., 2010

*Modified from USDA –NRCS-Principles for High Functioning S


Life in the Soil
A Guide for Naturalists and Gardeners
JAMES B. NARDI

Nardi, 2007


This information is provided as a public service and constitutes no endorsement by the United States Department of Agriculture or the Natural Resources Conservation Service of any service, supply, or equipment listed.
While an effort has been made to provide a complete and accurate listing of services, supplies, and equipment, omissions or other errors may occur and, therefore, other available sources of information should be consulted.
The USDA is an equal opportunity provider and employer.
Meeh, NRCS