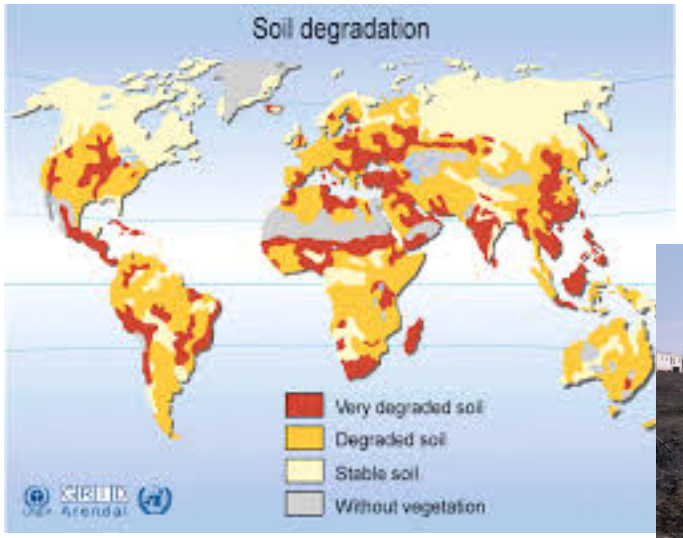
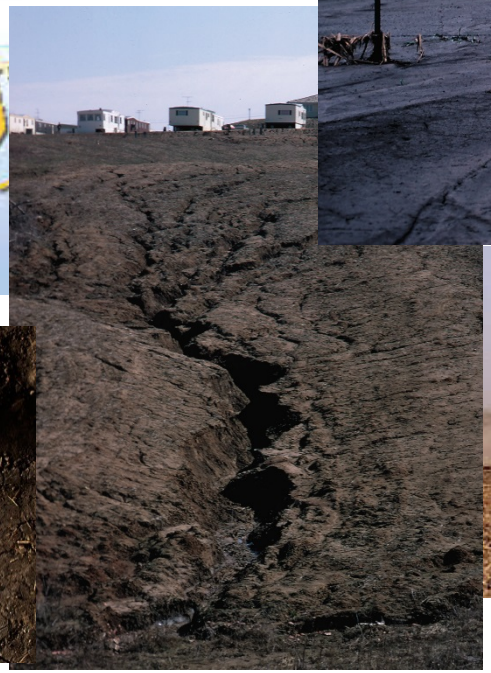
It's All About Carbon: Building a Thriving Soil Biological Community

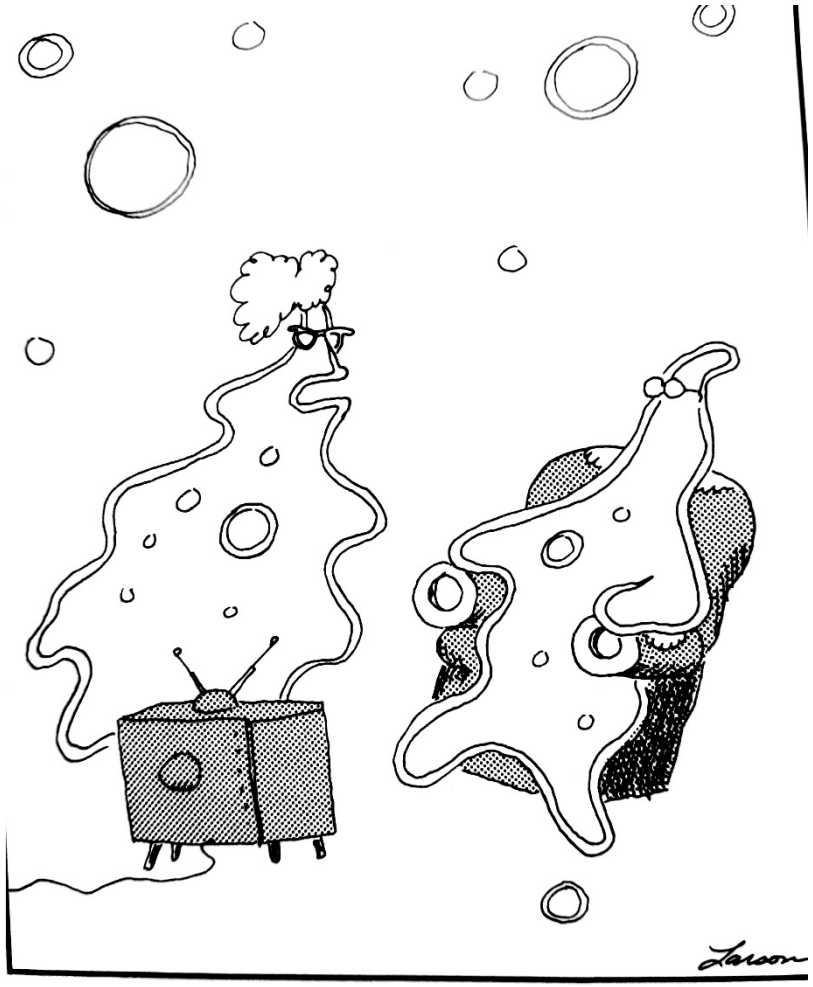
Dennis Chessman, USDA-NRCS, Lexington, KY

Soil degradation



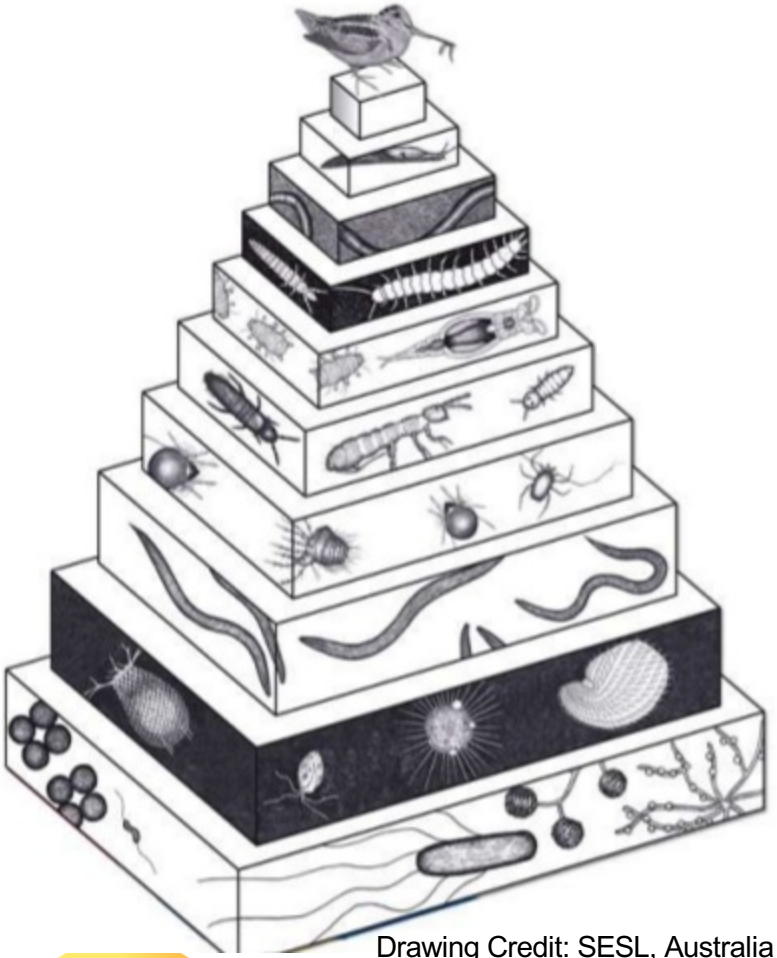


"Hey, I got news for you, sweetheart! … I *am* the lowest form of life on earth!"

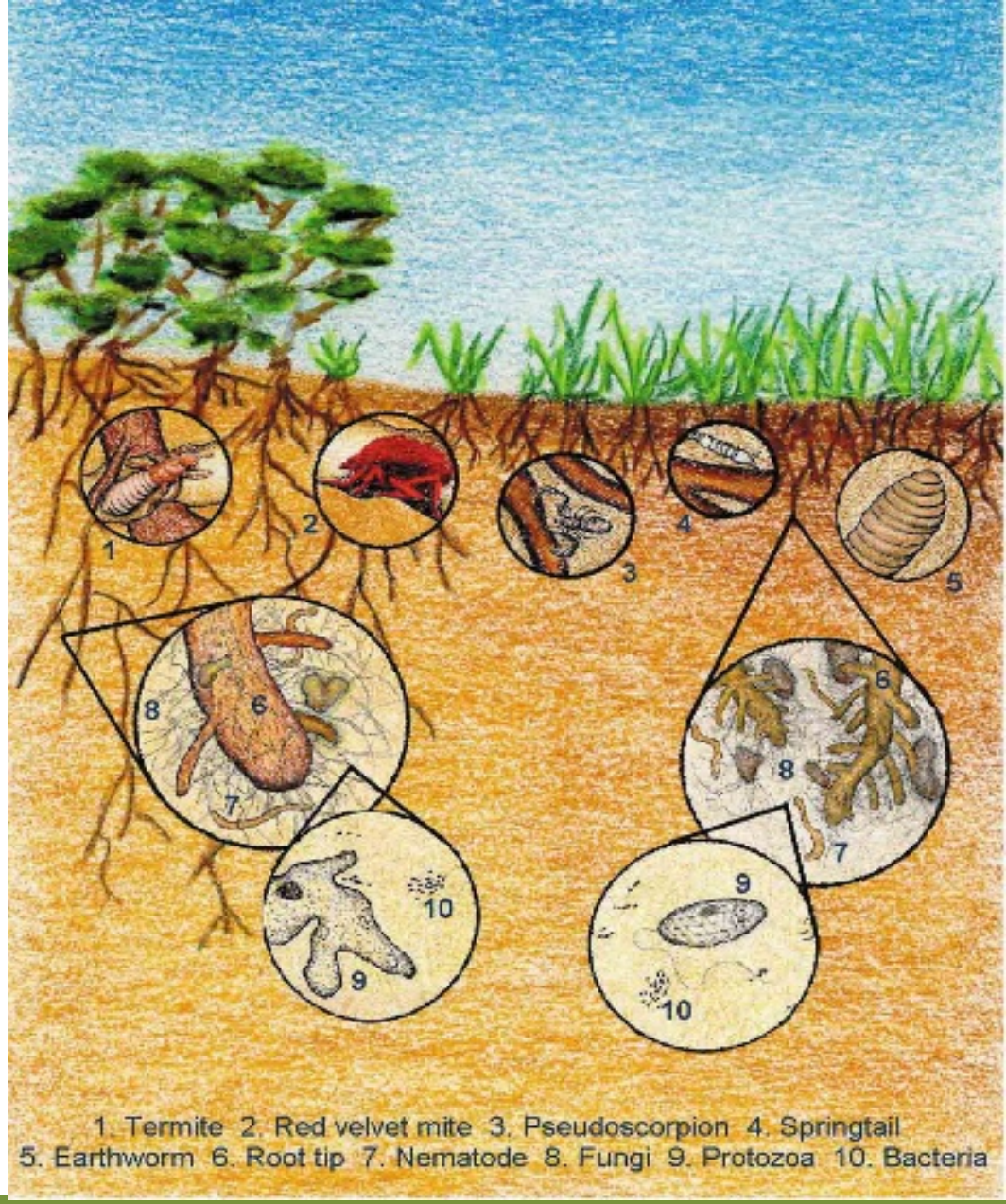


"Stimulus, response! Stimulus, response! Don't you ever *think*?"

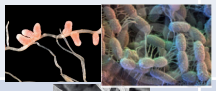
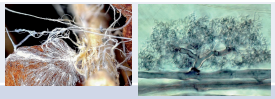
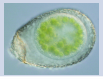
The diverse underground world



Drawing Credit: SESL, Australia



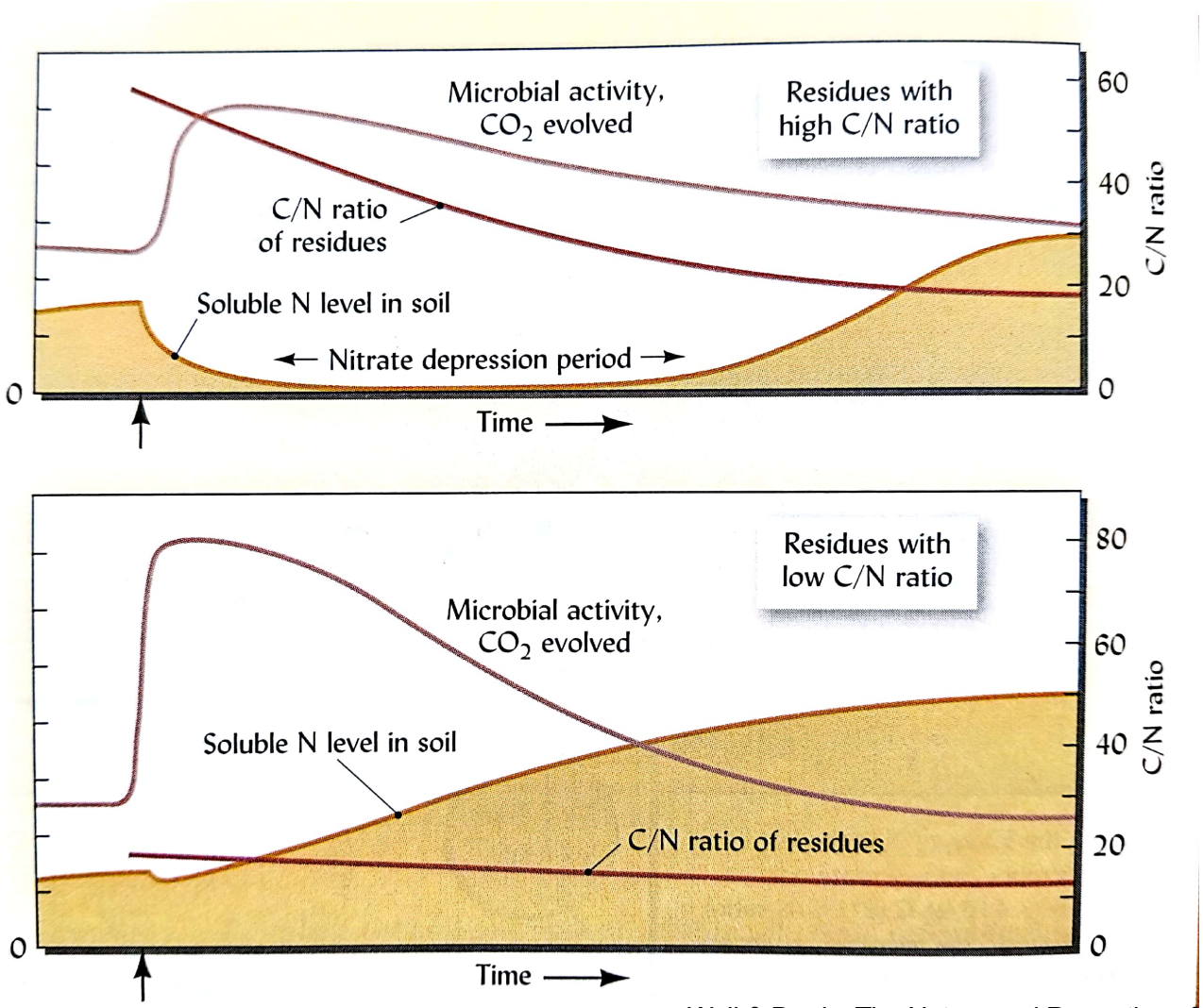
Life Belowground Supports Life Aboveground

Organisms	Number (per 10 ft^2)
Microorganisms	
Bacteria & Archaea 	100 trillion – 1 quadrillion
Actinobacteria 	1-10 trillion
Fungi 	1-10 million per 3 ft
Algae 	1-10 billion
Fauna	
Protists 	10 million – 100 billion
Nematodes 	100,000 – 10 million
Mites 	100 - 1 million
Collembola 	100 - 1 million
Earthworms 	10 - 100
Other fauna 	100-10,000

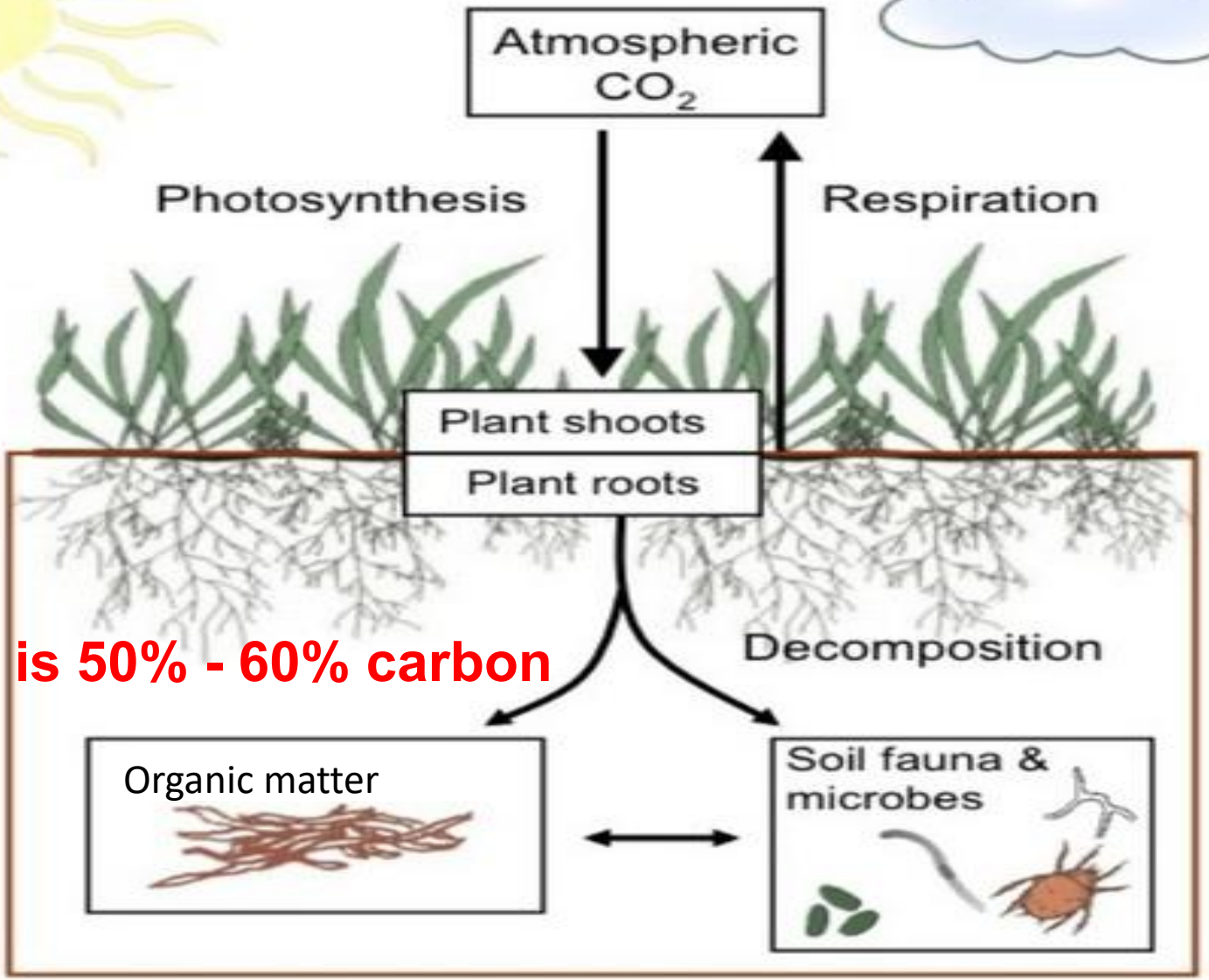
1 acre may be home to 10,000 - 30,000 lb of belowground biomass!

Sources: Weil & Brady, The Nature and Properties of Soil, 15e; Lindo, Kozlowski & Robinson (eds), Know Soil Know Life; Orgiazzi , Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas

Microbes consume carbon (and N)

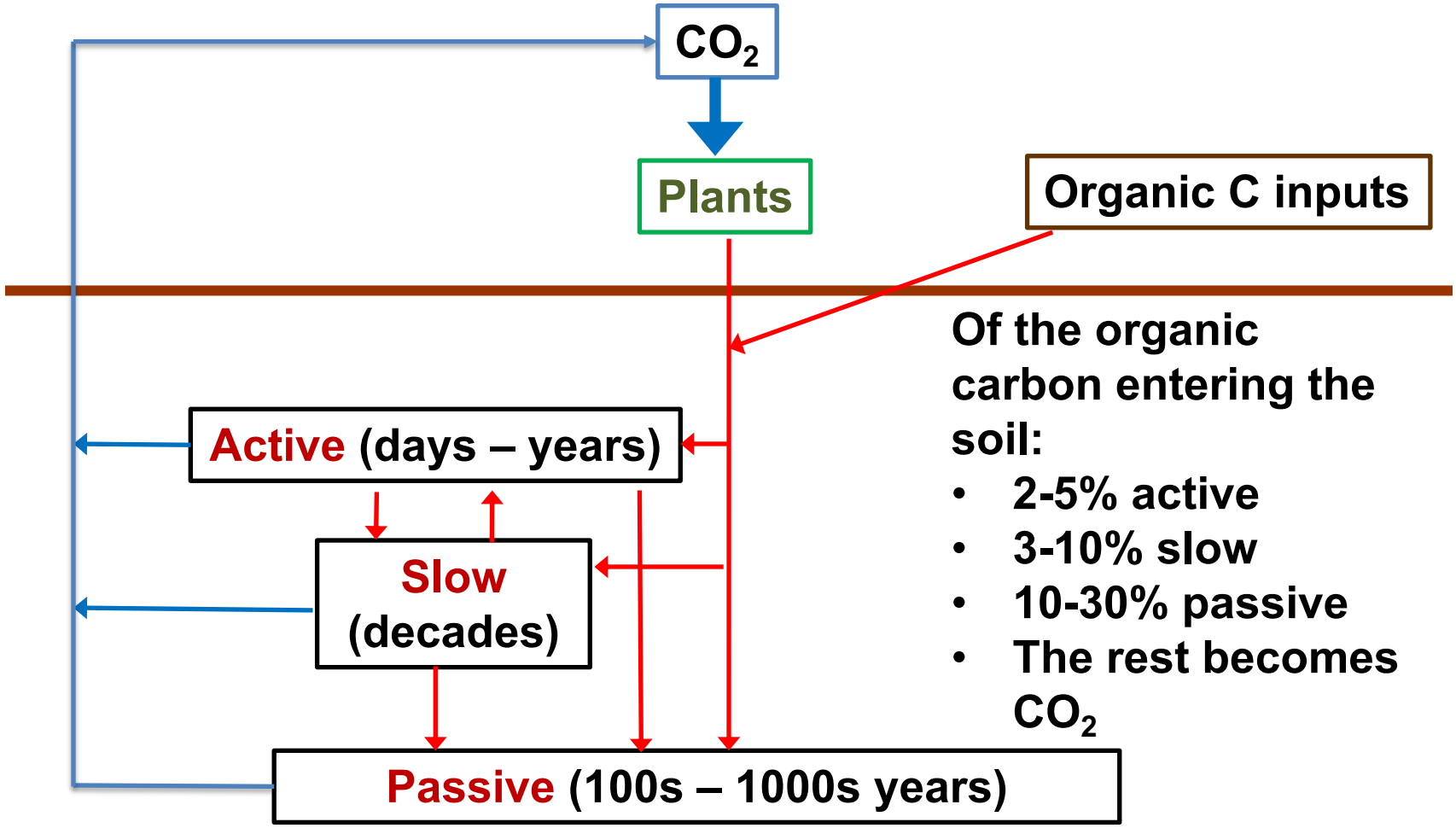


Weil & Brady, The Nature and Properties of Soils, 15th edition



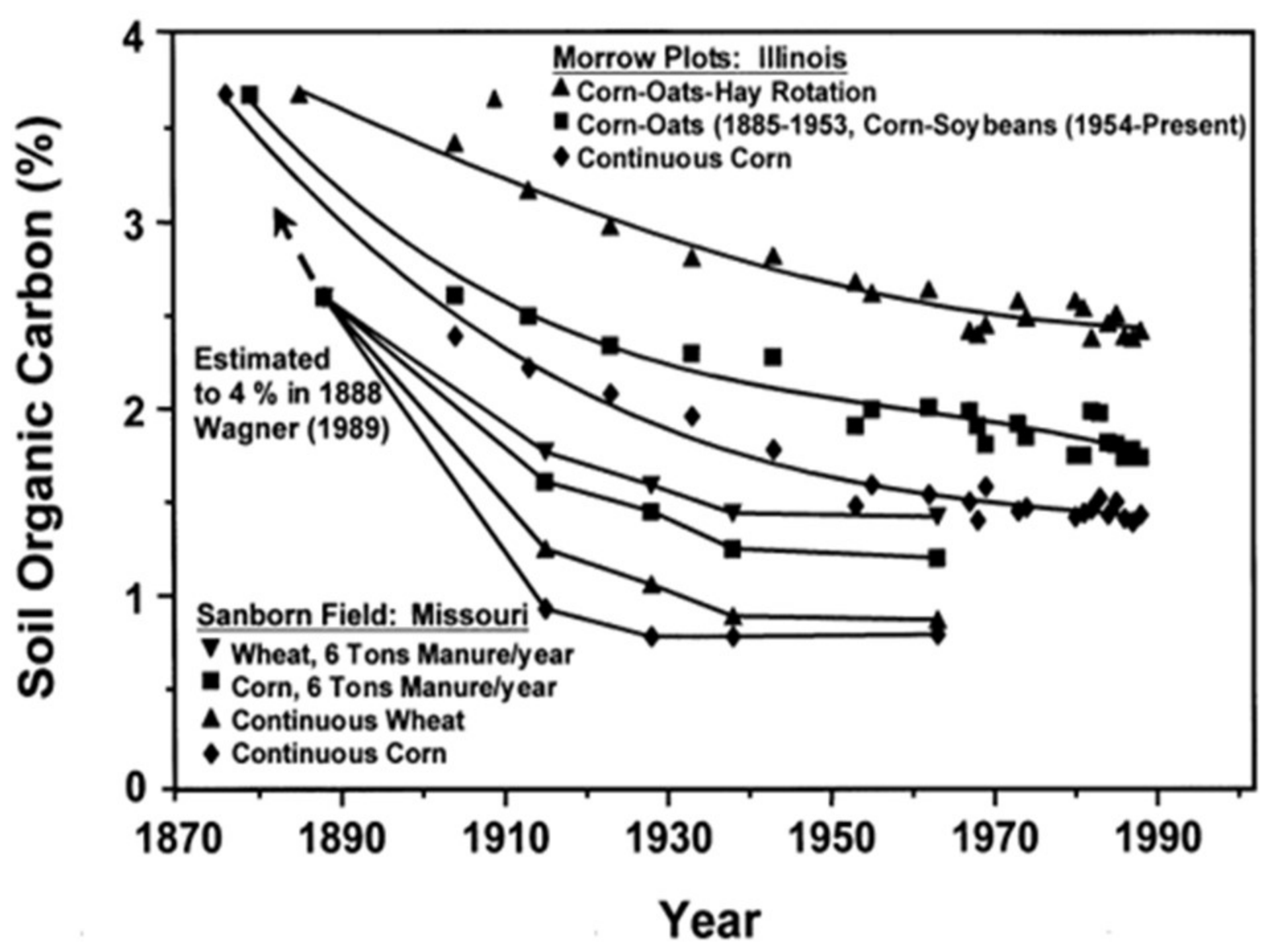
SOM is 50% - 60% carbon

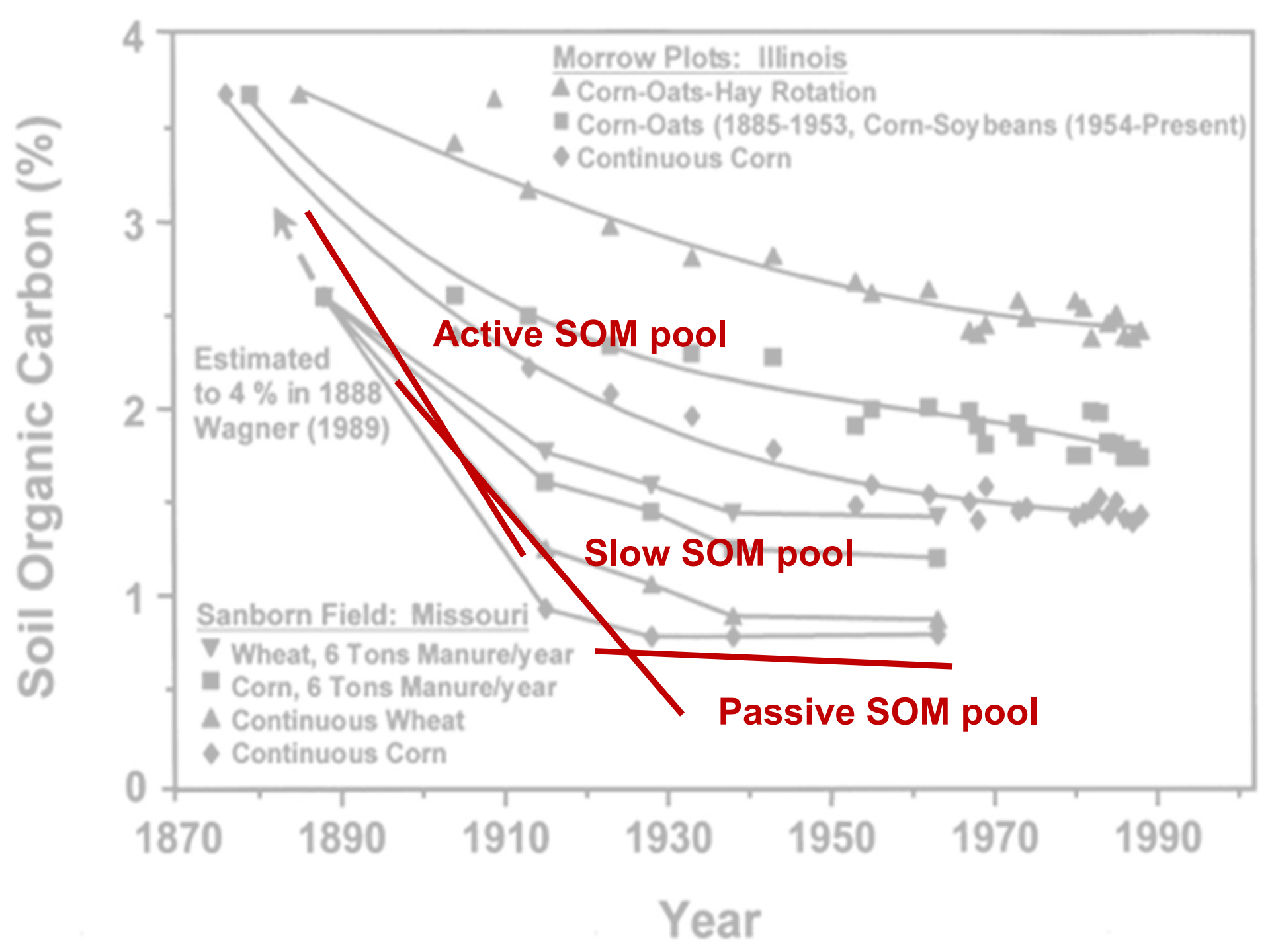
Carbon and soil organic matter



Of the organic carbon entering the soil:

- 2-5% active
- 3-10% slow
- 10-30% passive
- The rest becomes CO_2


Soil Organic Carbon (%)
4
3
2
1
0
1870
1890
1910
1930
1950
1970
1990
Year
Morrow Plots: Illinois
Corn-Oats-Hay Rotation
Corn-Oats (1885-1953, Corn-Soybeans (1954-Present)
Continuous Corn
Estimated
to 4 % in 1888
Wagner (1989)
Sanborn Field: Missouri
Wheat, 6 Tons Manure/year
Corn, 6 Tons Manure/year
Continuous Wheat
Continuous Corn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Corn-Oats-Hay Rotation
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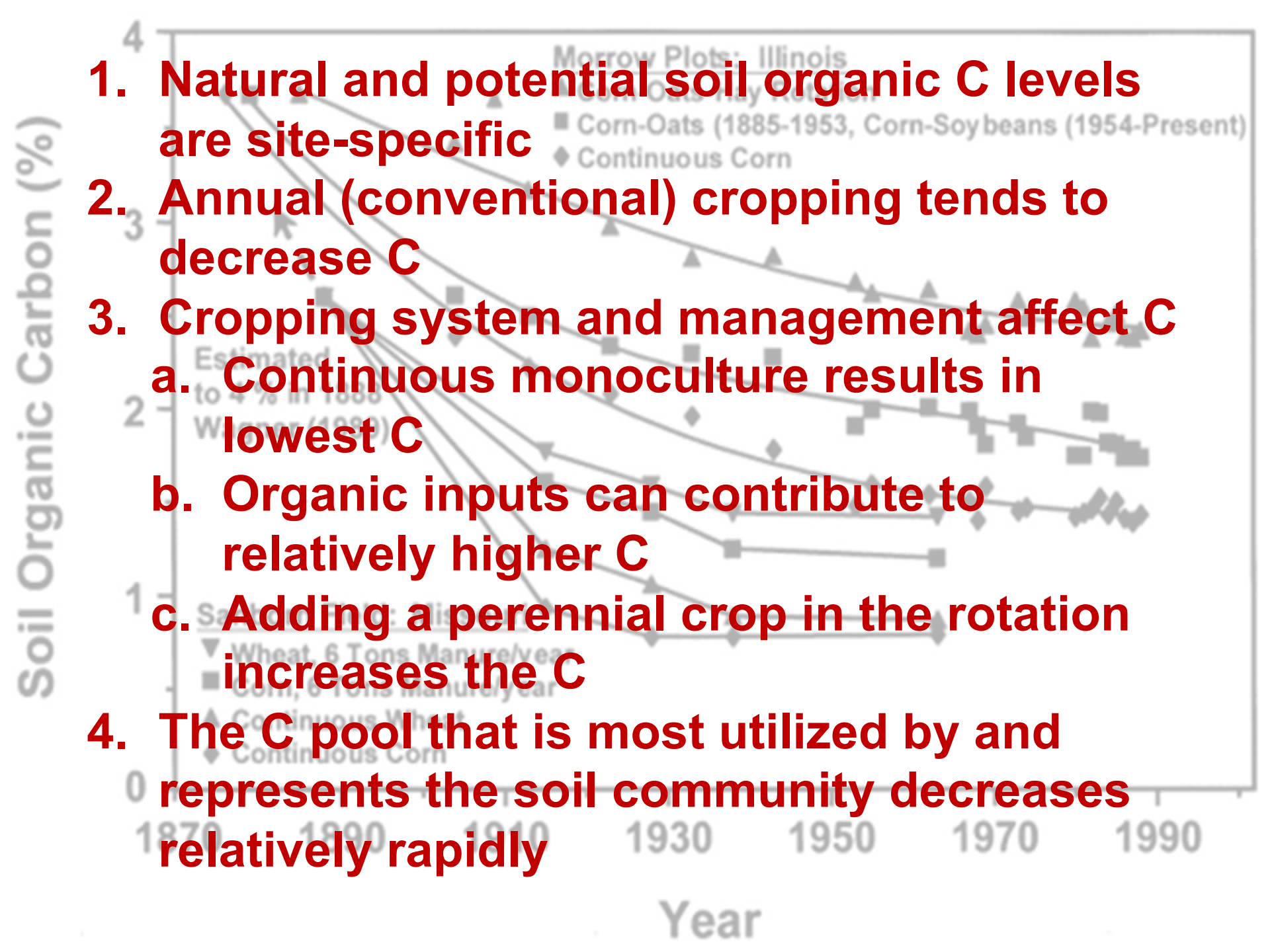
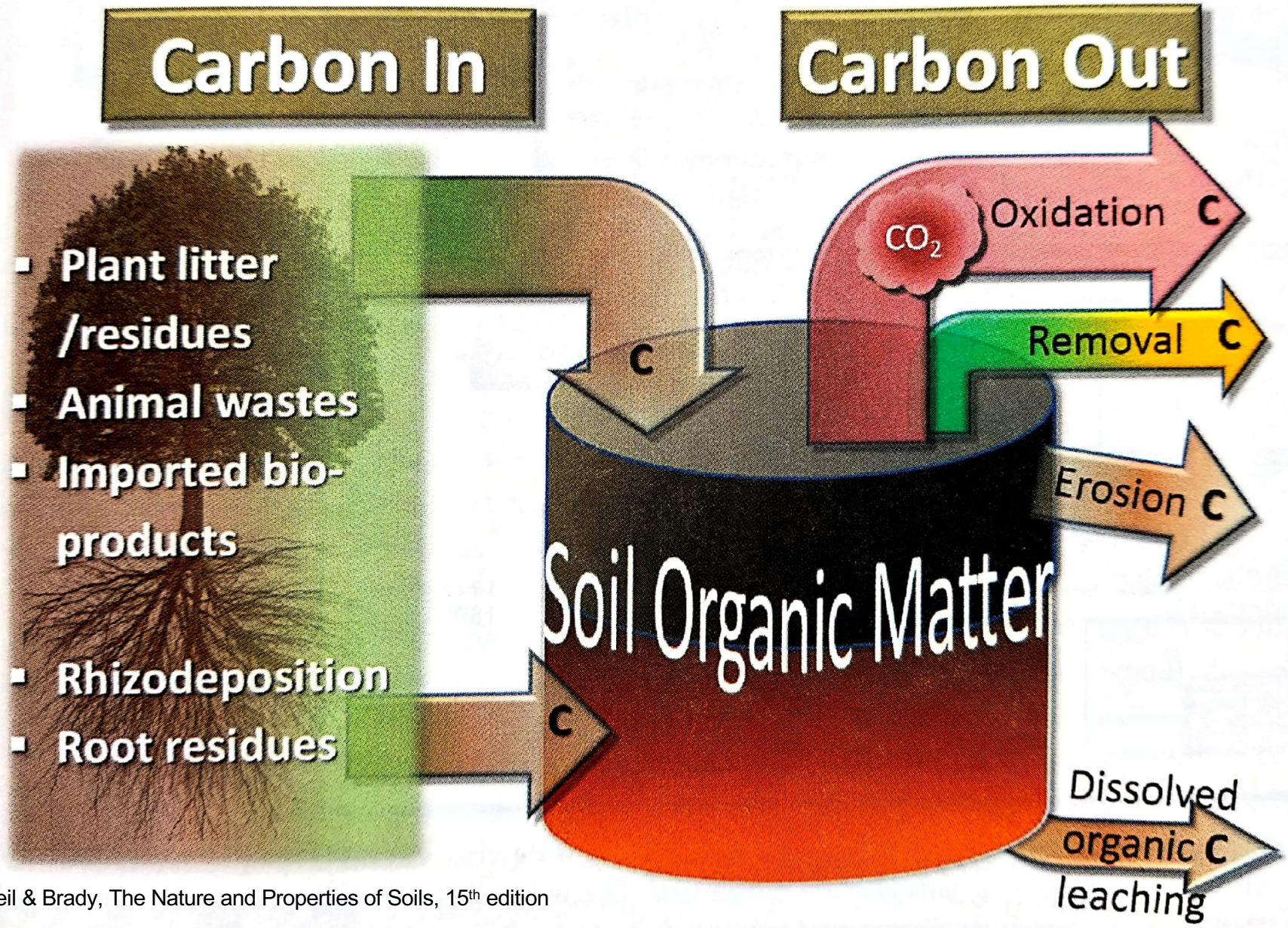
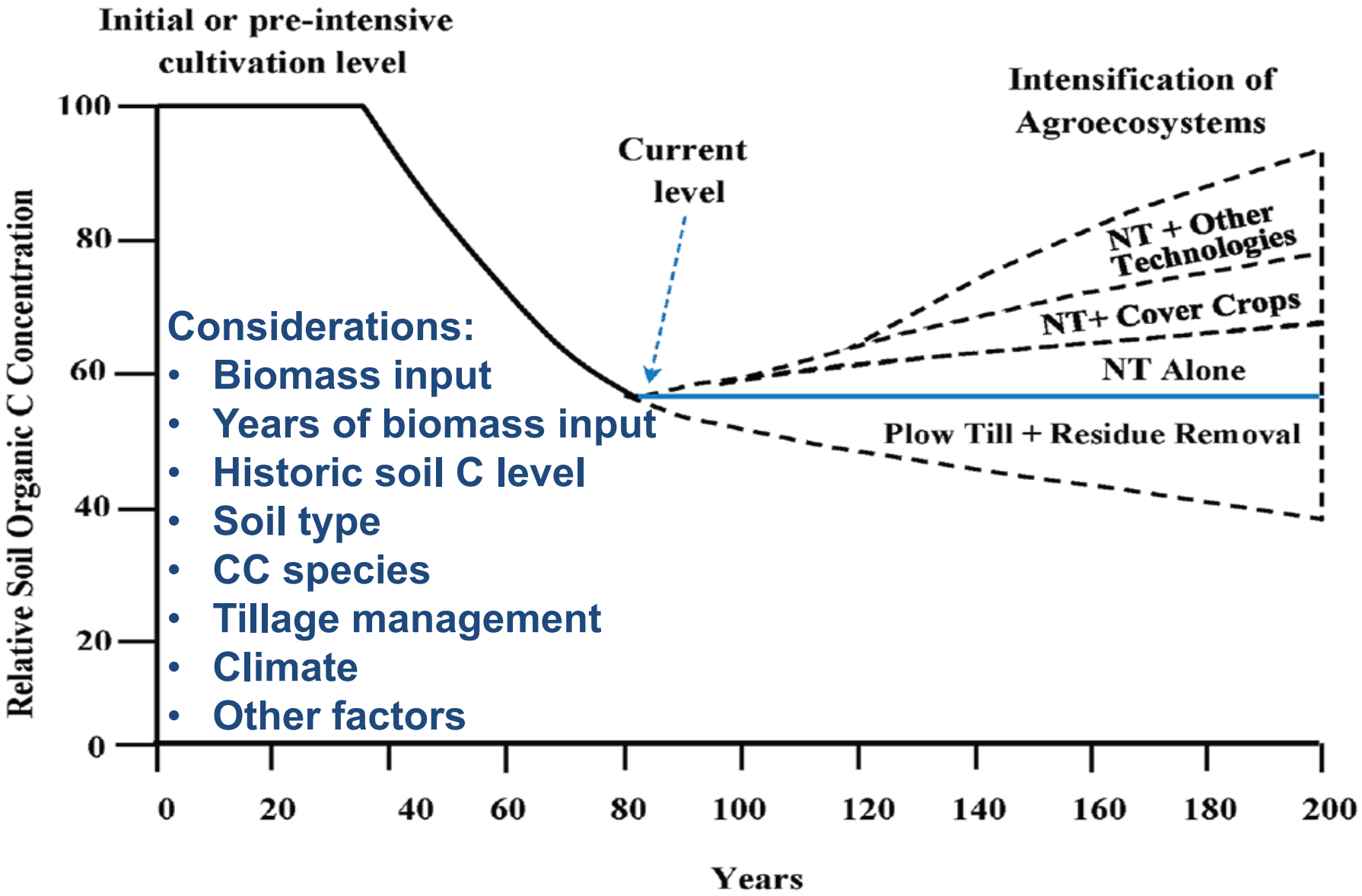
Continuous Corn
Estimated
to 4 % in 1888
Wagner (1989)
Active SOM pool
Slow SOM pool
Passive SOM pool
Sanborn Field: Missouri
Wheat, 6 Tons Manure/year
Corn, 6 Tons Manure/year
Continuous Wheat
Continuous Corn

1. Natural and potential soil organic C levels are site-specific
2. Annual (conventional) cropping tends to decrease C
3. Cropping system and management affect C
   a. Continuous monoculture results in lowest C
   b. Organic inputs can contribute to relatively higher C
   c. Adding a perennial crop in the rotation increases the C
4. The C pool that is most utilized by and represents the soil community decreases relatively rapidly





Weil & Brady, The Nature and Properties of Soils, 15th edition



Considerations:

- Biomass input
- Years of biomass input
- Historic soil C level
- Soil type
- CC species
- Tillage management
- Climate
- Other factors

Blanco-Canqui H., et al., 2015. Agron. J. 107:2449-2474.

Natural systems are different than most agricultural systems

Photo: Lynn Betts, NRCS

When compared to their native counterpart, agricultural systems in general have:

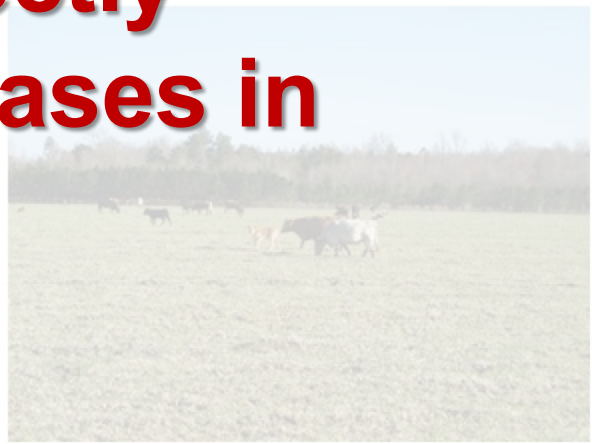
Photo: Lynn Betts, NRCS

- **Less C stored as OM**
- **Decreased hydrologic function (infiltration & storage)**
- **Inadequate nutrient cycling**
- **Less vigorous & more pest-susceptible plants**
- **Lower system stress resistance and resilience**

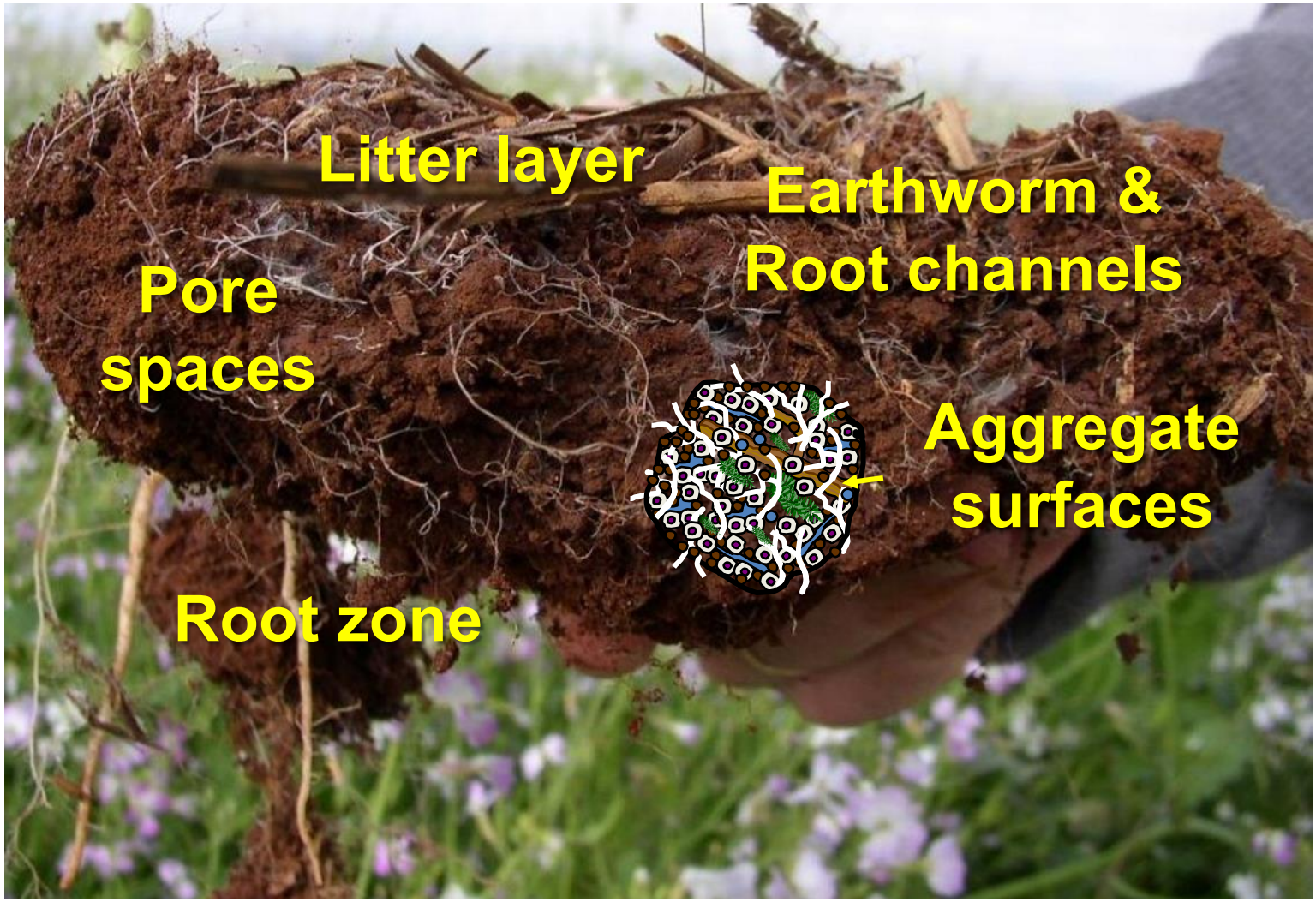
When compared to their native counterpart, agricultural systems in general have:

Suppressed soil biological community structure and function resulting from management directly contributes to decreases in soil function

Photo: Lynn Betts, NRCS



Where do soil organisms live?



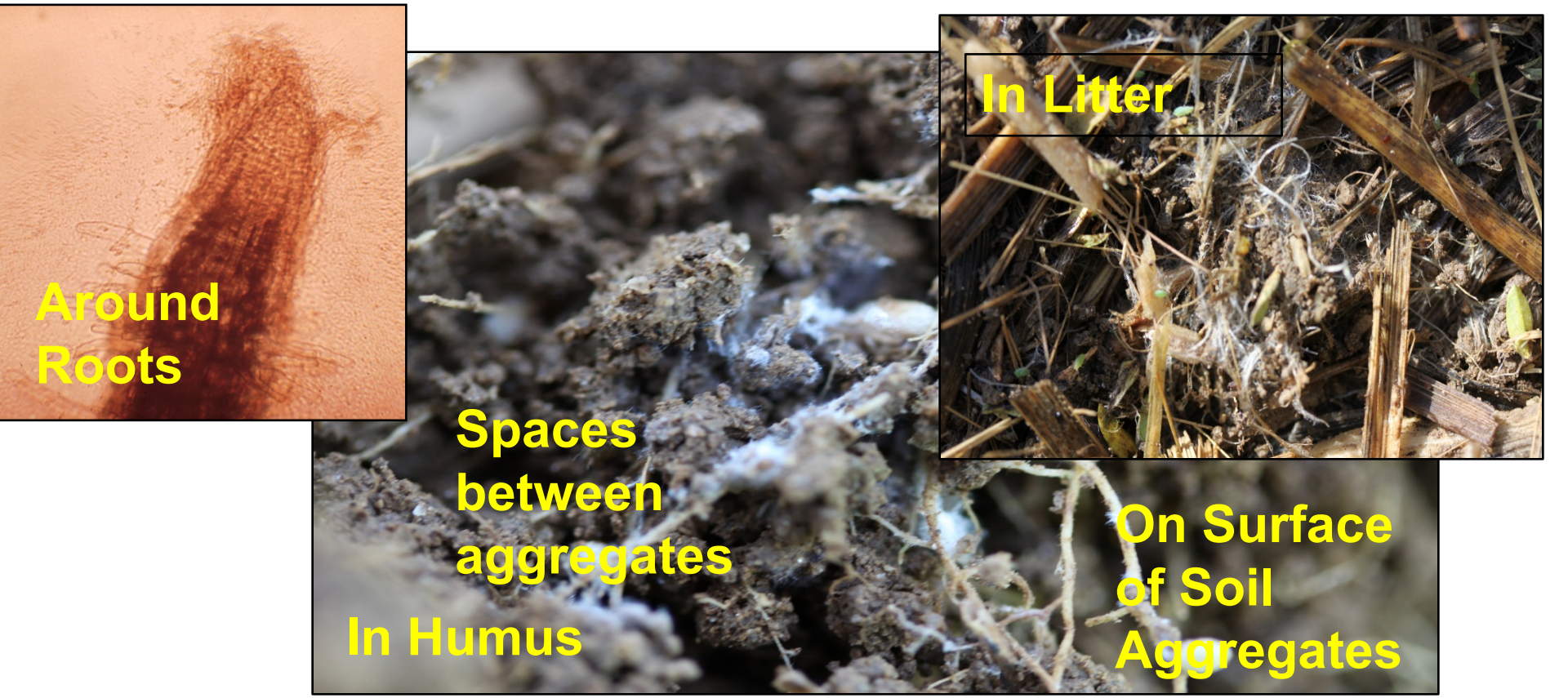
Beare et al. 1995. Plant & Soil 170:5-22

Kuzyakov et al. 2015. Soil Biol Biochem 83:184-199

Photo: Dr. José Carlos De Moraes Sa

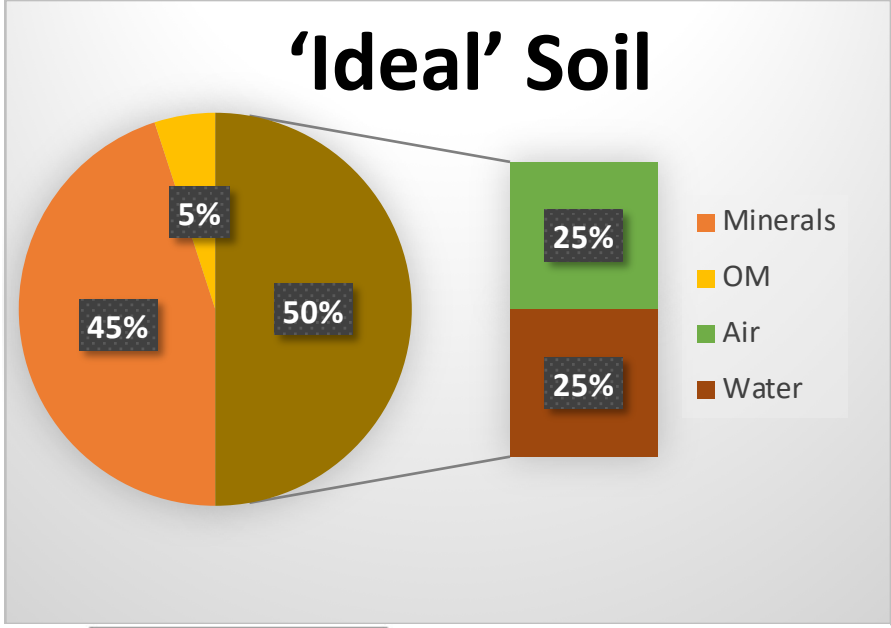
Where do Soil Organisms Live?

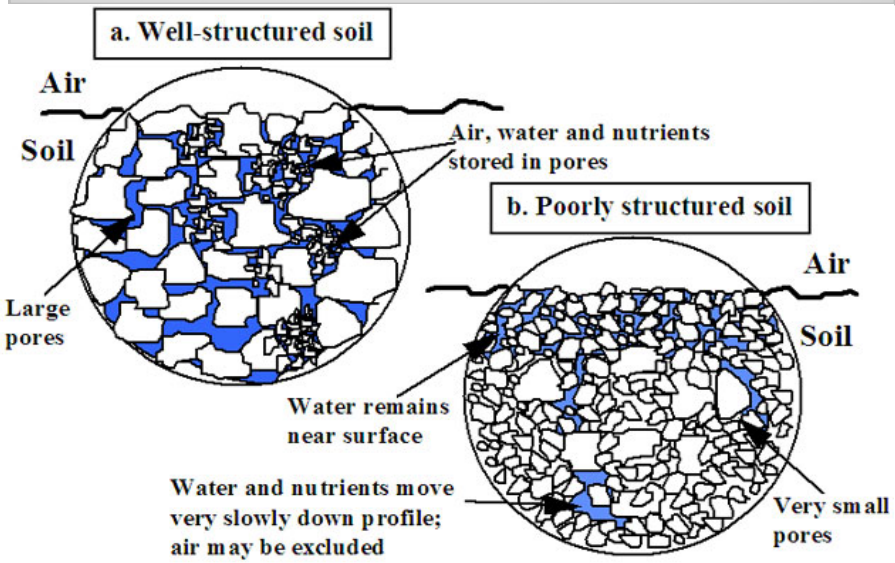
In spaces– small and large



Pore space is critical

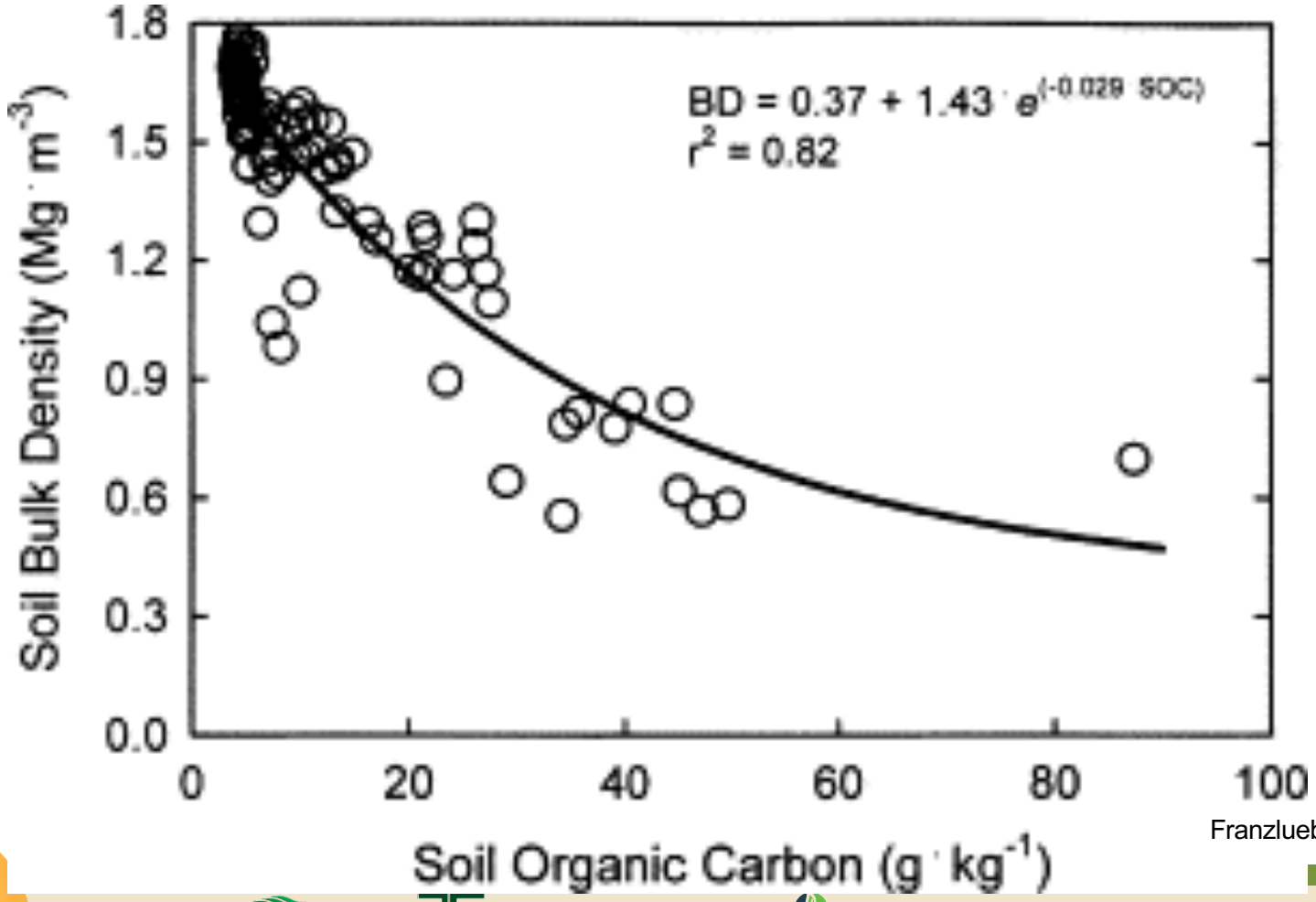
- "Respiratory & circulatory systems"
  - Air flow
  - Water flow, storage, & availability; nutrient flow
- Biological homes & highways
- Lost through management that destroys aggregates & leads to compaction





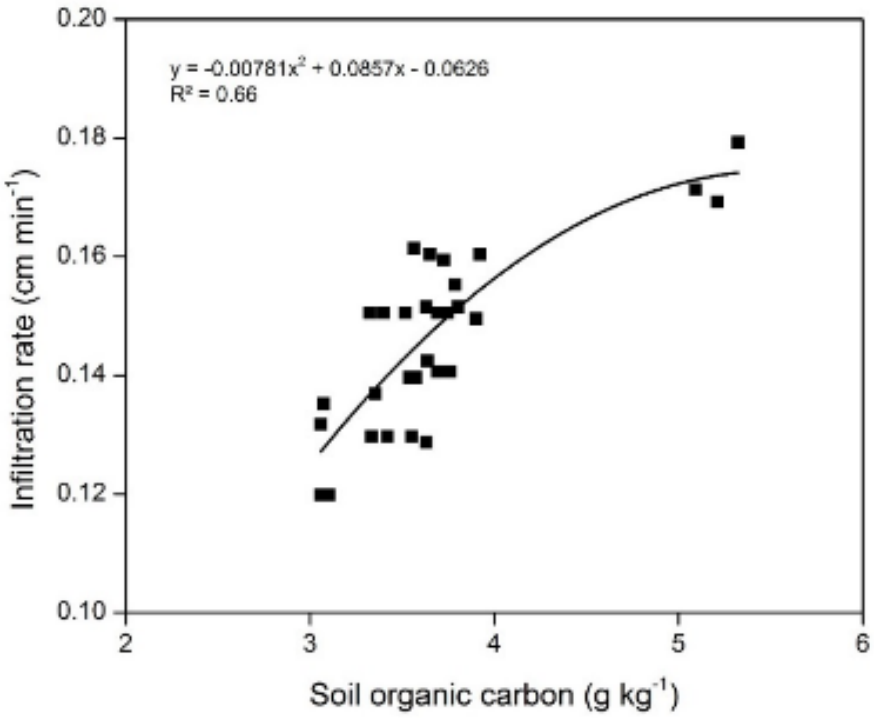
Soil microbes contribute to improved hydrologic function (infiltration & storage)

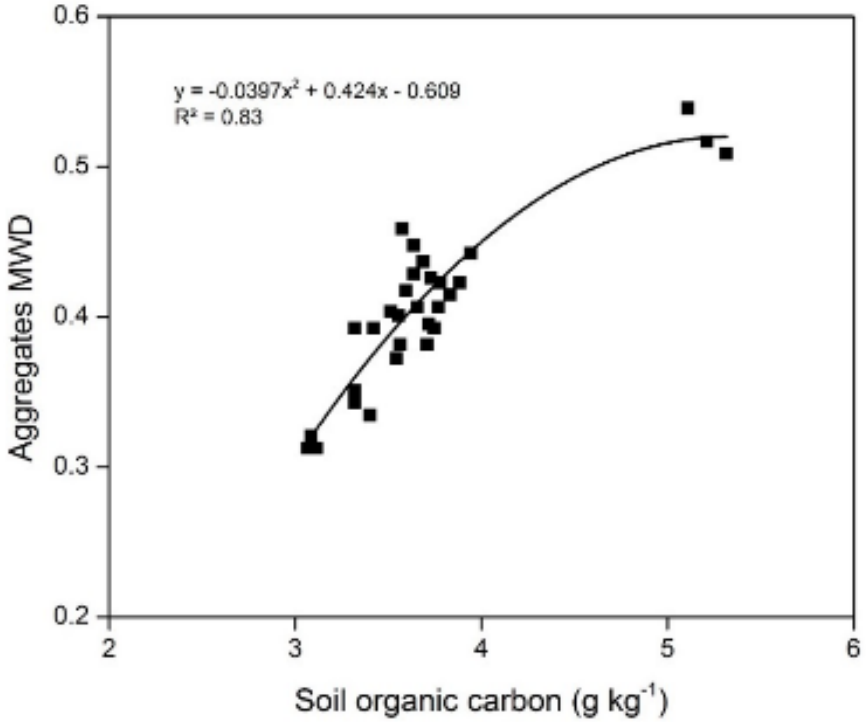
Soil organic carbon increases pore space



Franzluebbers, 2002

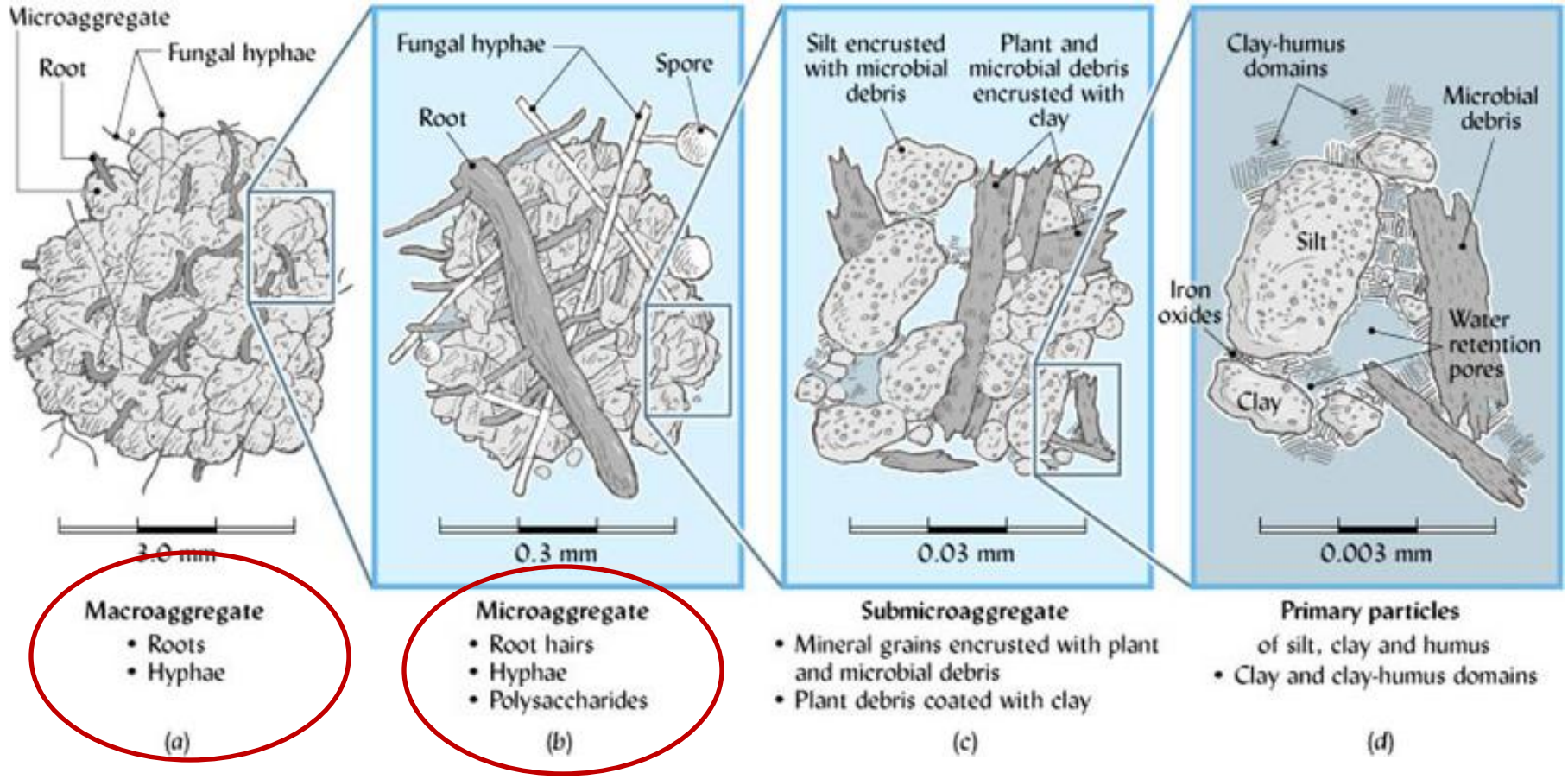
Carbon, aggregates and infiltration





Brar, et al. 2015. *Agronomy* (5)

Soil aggregates depend on biology

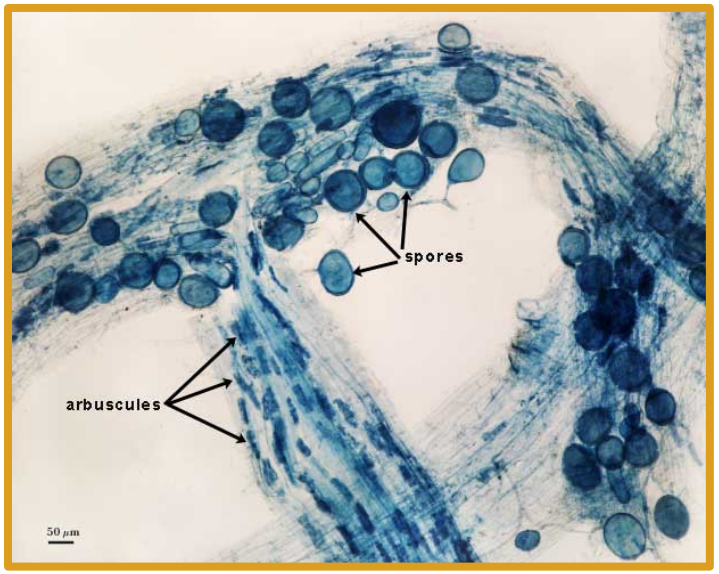


Brady & Weil, The Nature and Properties of Soils, 14th edition

Soil microbes contribute to improved nutrient cycling & availability

Mycorrhiza (literally means ‘fungus root’)

- Plant-fungal mutualism
- Benefits:
  - Increases plant nutritional status
    - P, N, Zn among others
  - Reduces disease incidence
    - Competition/barrier
    - Induced resistance?
  - Aids in plant establishment
    - Seedlings/degraded soils
  - Improves drought tolerance

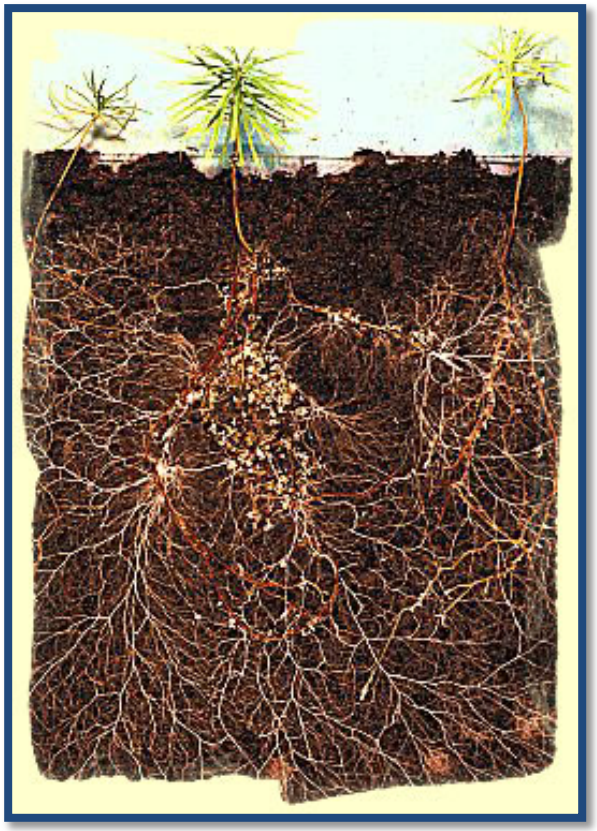


http://assets.slate.wvu.edu

Slide courtesy of Dr. Rhae Drijber

Pipeline to the soil!

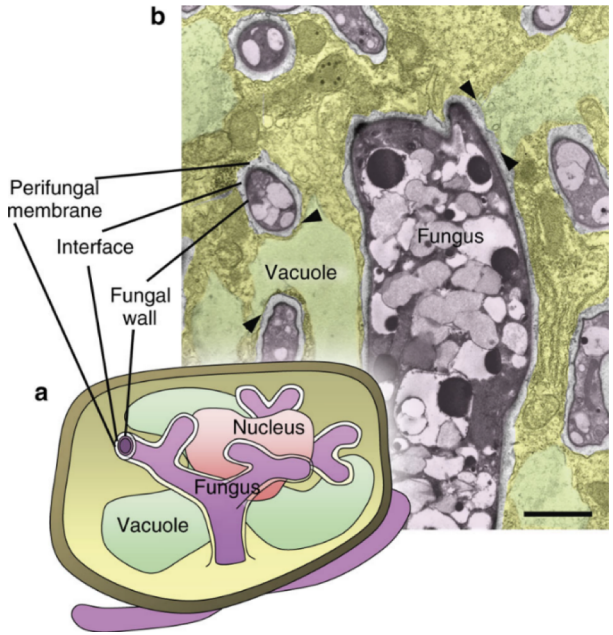
- Extraradical mycelium
  - Greater surface area for nutrient absorption
  - Greater effective soil volume
- Transport of nutrients and water to the plant
- Shared hyphae connects plant communities
- Improved aggregation
  - Physical entanglement
  - Glycoprotein “glue”
    - Glomalin (AM fungi)

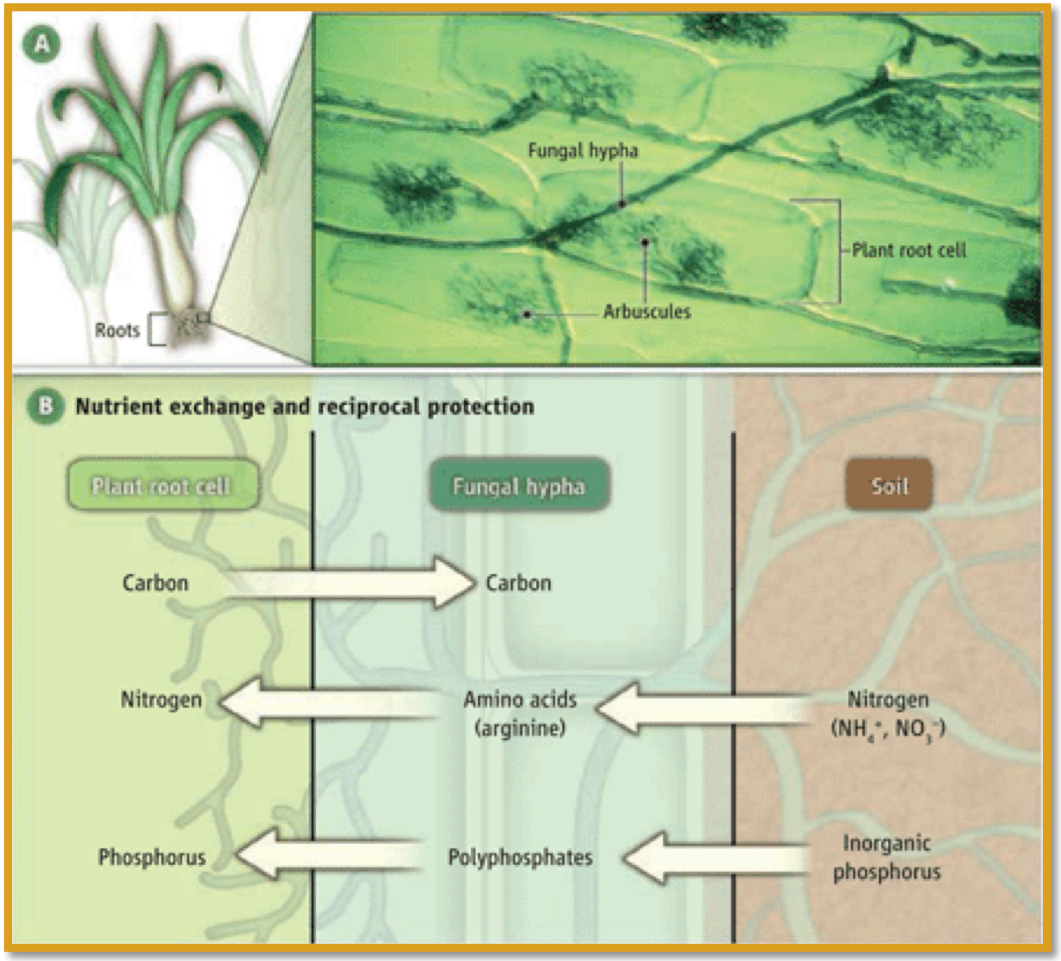


Ectomycorrhizal association with pine seedling

Slide courtesy of Dr. Rhae Drijber

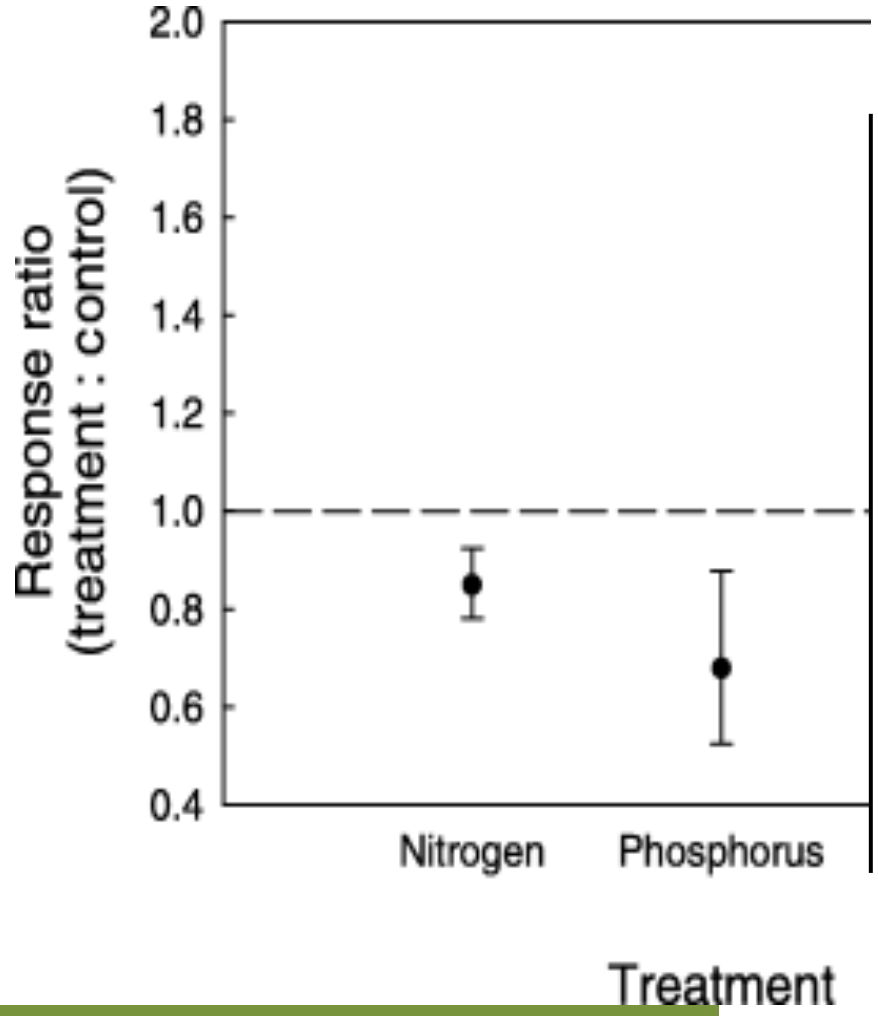
The symbiosis





Slide courtesy of Dr. Rhae Drijber. Photo Credit: B. Strauch (*Science*).

Fertilization Reduces Mycorrhizal Fungi



15% reduction with N fertilization

32% reduction with P fertilization

Modified from Treseder (2004), New Phytologist, 164: 347–355

Soil microbes contribute to more vigorous and pest-tolerant plants with increased resistance & resilience

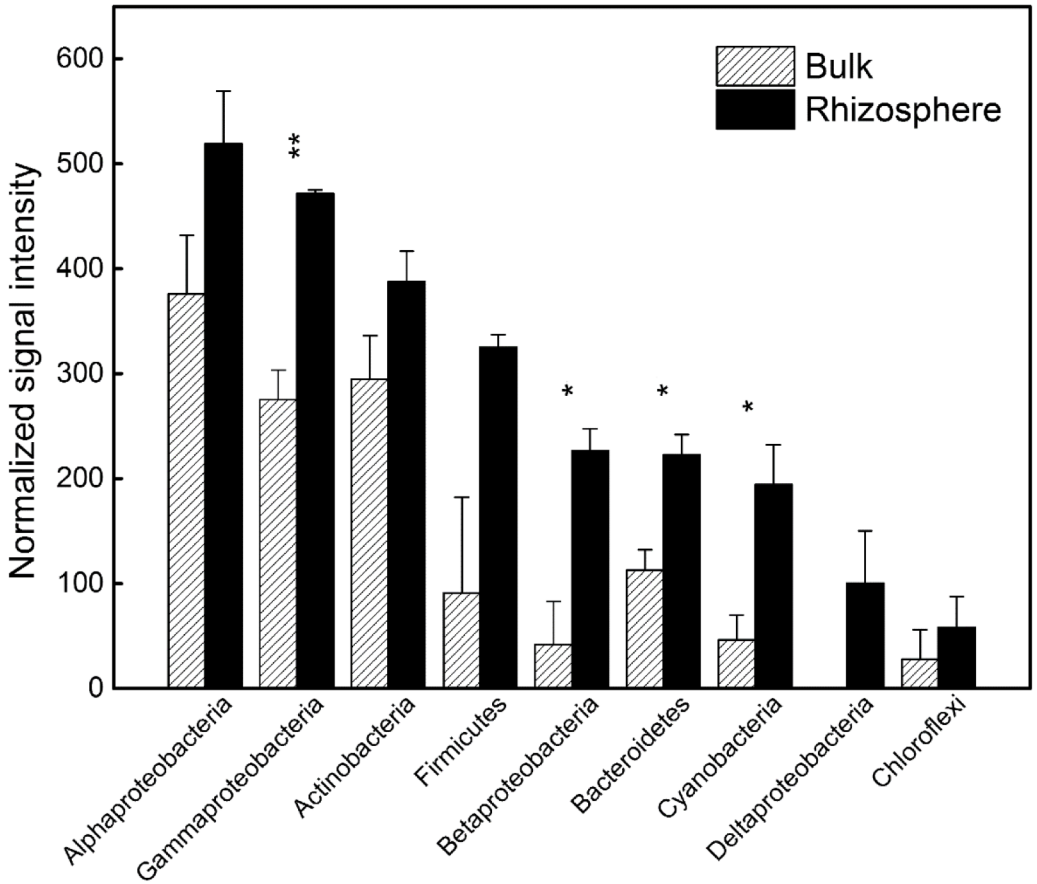
Root Zone (Rhizosphere)

- Root exudates & chemical signals stimulate microbes
- Shared carbon to gain benefit (symbiosis)
- As much as 20% of the products of photosynthesis

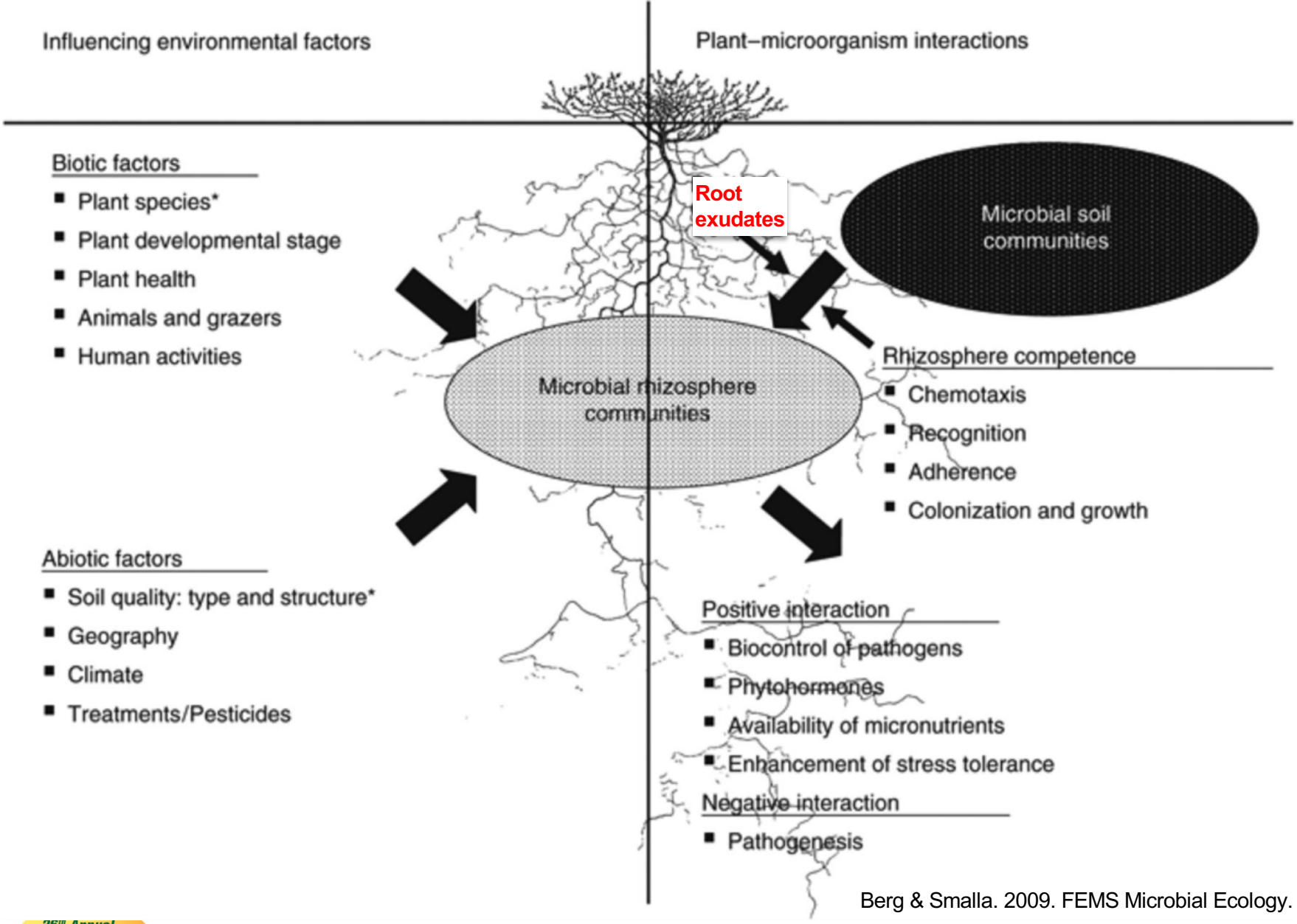
Trends in Plant Science 2016 21, 256-265DOI: 10.1016/j.tplants.2016.01.008)

Rhizosphere vs. bulk soil

- Identified genes of select bacterial genera
- The rhizosphere was a hotspot for numbers and diversity in corn
- The bulk soil serves as a “seedbank” for the rhizosphere

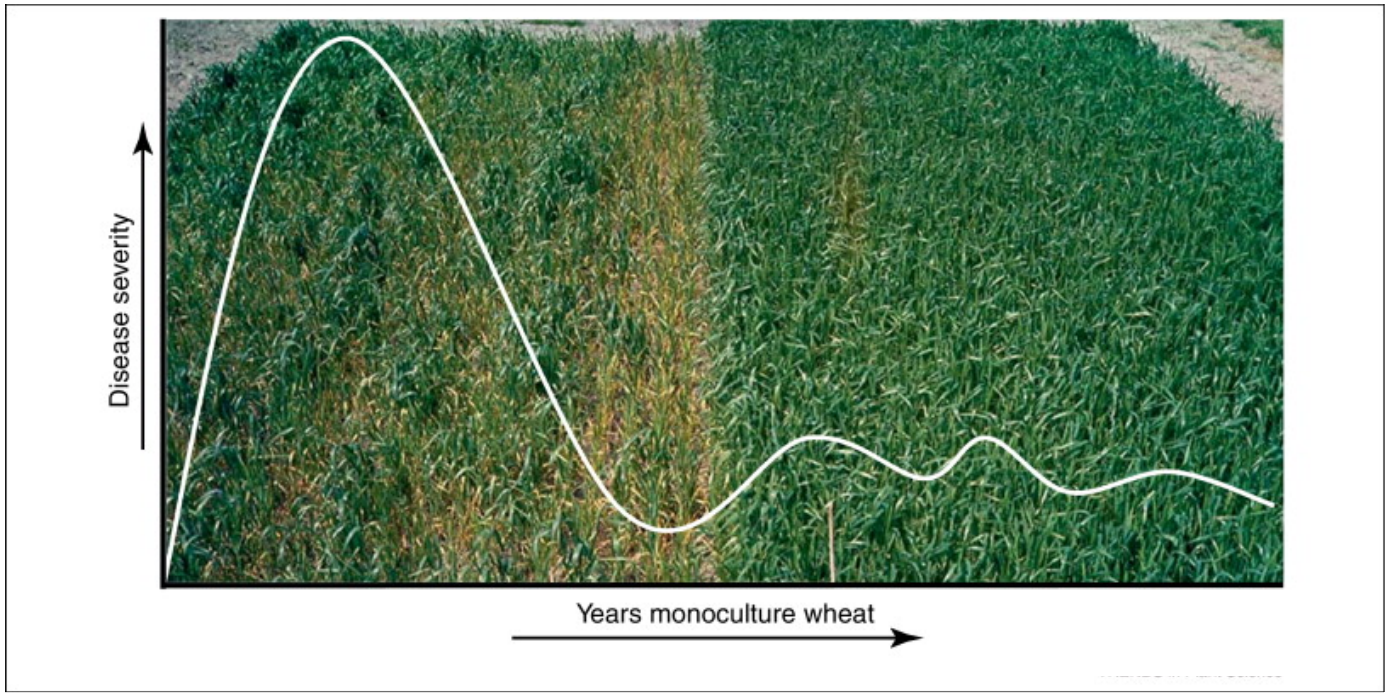


Li, X. et al., 2014. PloS One. 10:9(11)



Berg & Smalla. 2009. FEMS Microbial Ecology. 68.

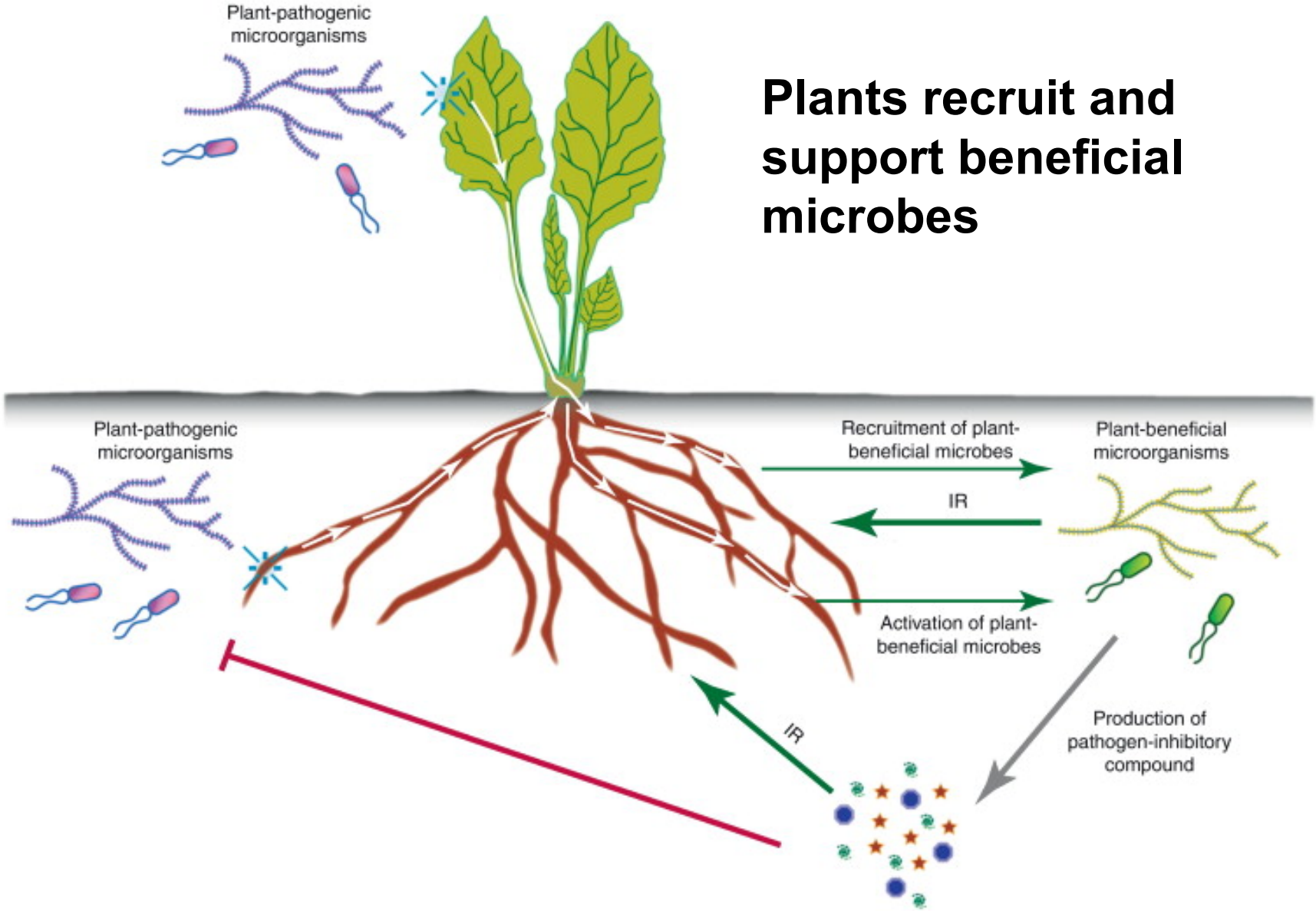
Plants modify the soil community



Soil microbiome changed with time to suppress take-all in wheat

Berendsen, et al., 2012. Trends in Plant Science. 17(8)

Plants recruit and support beneficial microbes



Berendsen, et al., 2012. Trends in Plant Science. 17(8)

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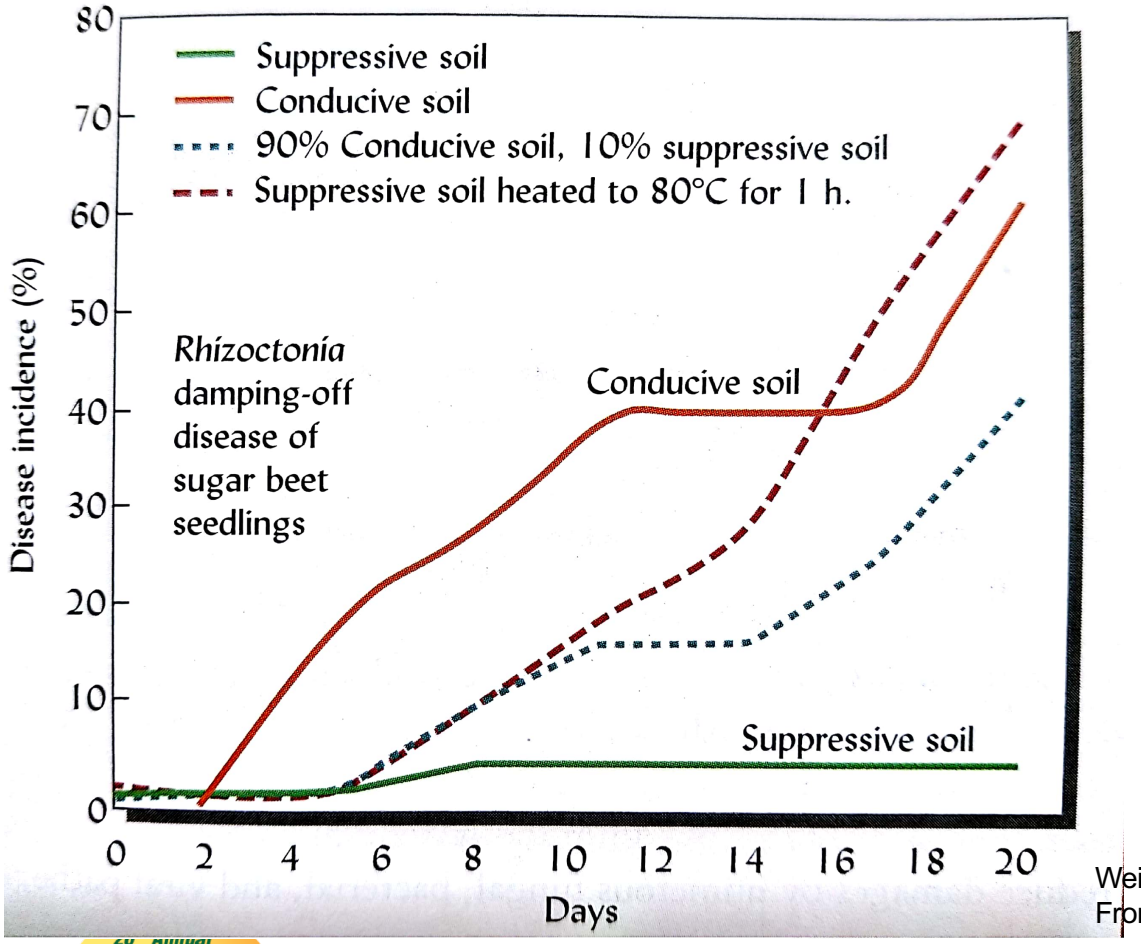
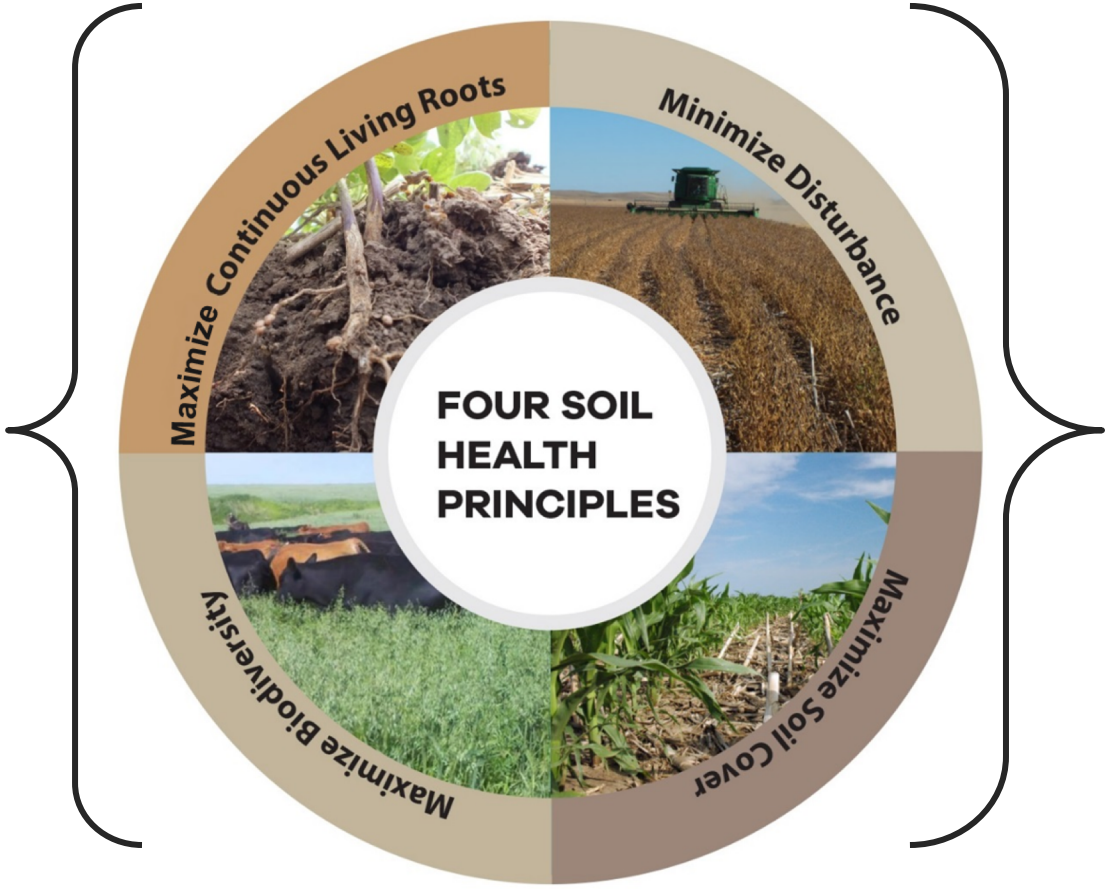


Soil microbes suppress crop pathogens!

Weil & Brady, The Nature and Properties of Soils, 15th edition. From data of Mendes et al. 2011

Four Soil Health Principles With Universal Applications

Feed & Fuel Soil Biology



Protect Soil Aggregates & Organic Matter

Soil Health Principles

Minimize Disturbance & Maximize Cover

- Maintain stable aggregates
- Reduce erosion and runoff risk
- Buffer temperature
- Reduce evaporation
- Maintain soil organic matter

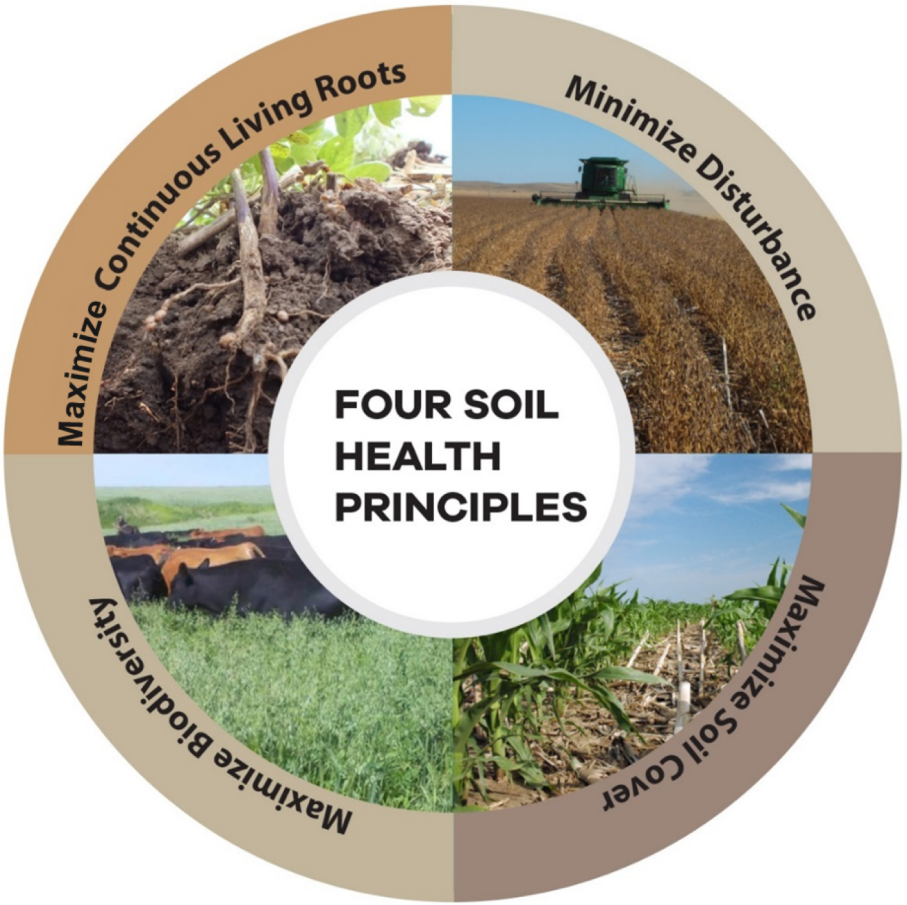
Soil Health Principles

Maximize Biodiversity & Maximize Living Roots

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

Practices that Feed & Protect

Crop rotation
Cover crop
Relay crops
Mixed forages
Maximize roots
Perennial crops



Reduced tillage
Controlled traffic
Nutrient management & IPM

Cover crop
Crop rotation
Controlled grazing
IPM
Pollinator plantings
Legumes in mix

Cover crop
Mulching
Reduced tillage
Forage & Biomass Planting
Residue retention

THANK YOU!

Direct comments and questions to:
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202-527-4000

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