Impacts of microbes and biochar on soil health

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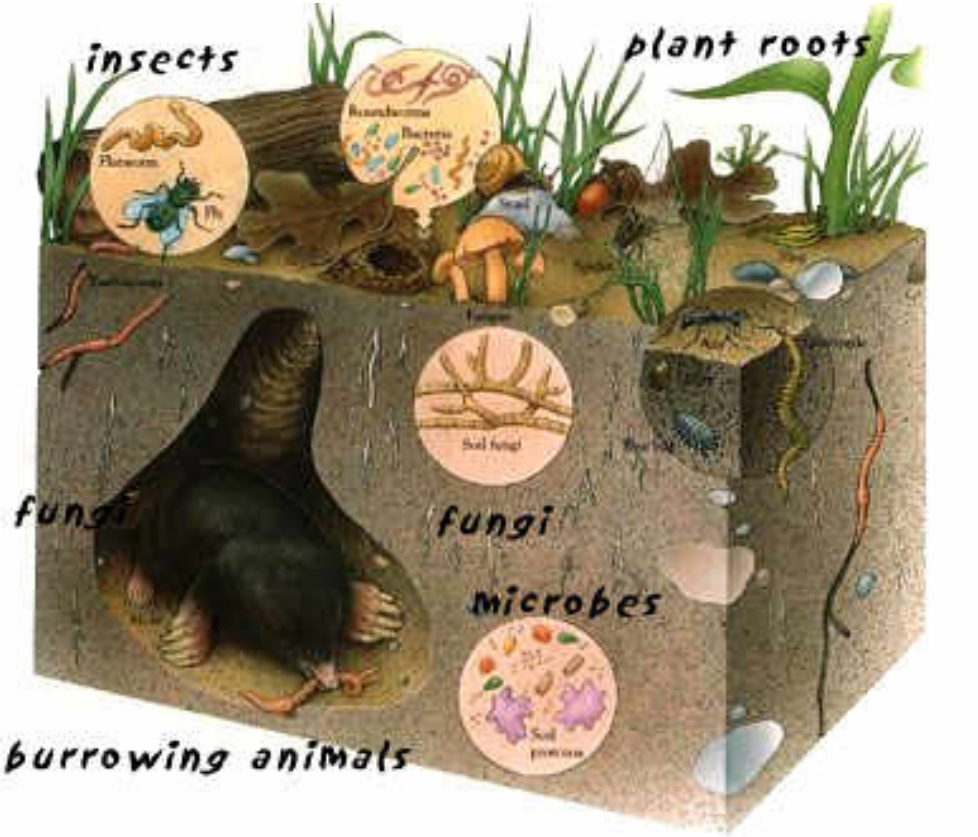


www.livingearthfarm.net

Video showing decomposition in compost and soil

https://www.facebook.com/earthwormsoc/posts/1945299029030730

What is "soil health"?

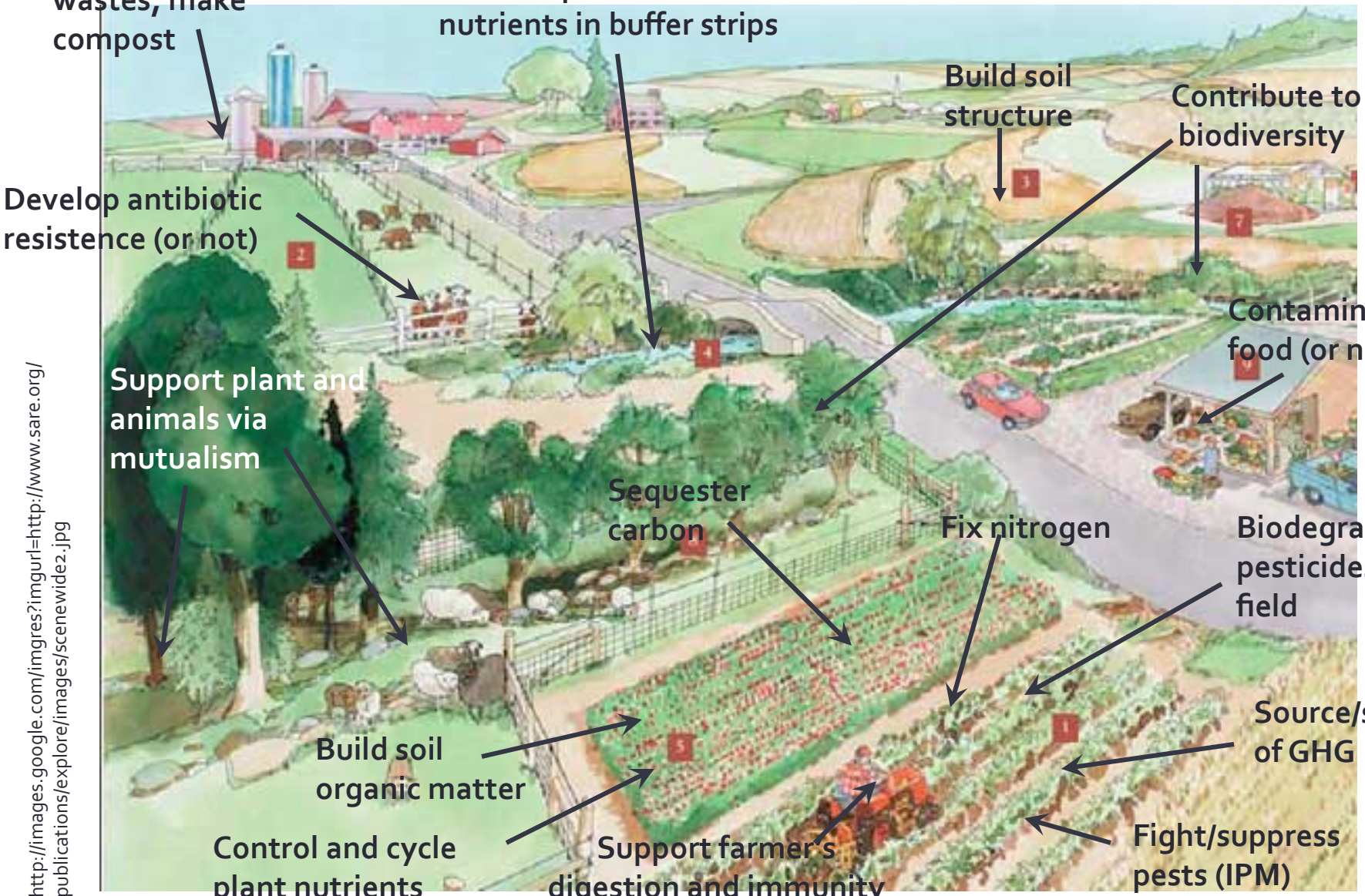
Services:
- Efficient nutrient use
- Building and regeneration
- Strong skeleton/musculature
- Disease prevention

Self-maintaining

Services:
- Efficient/tight nutrient cycles
- C transformations
- Soil structure maintenance
- Disease/pathogen resistance

Self-maintaining

www.theatlantic.com/health/archive/2013/06/healthy-soil-microbes-healthy-people/276710/

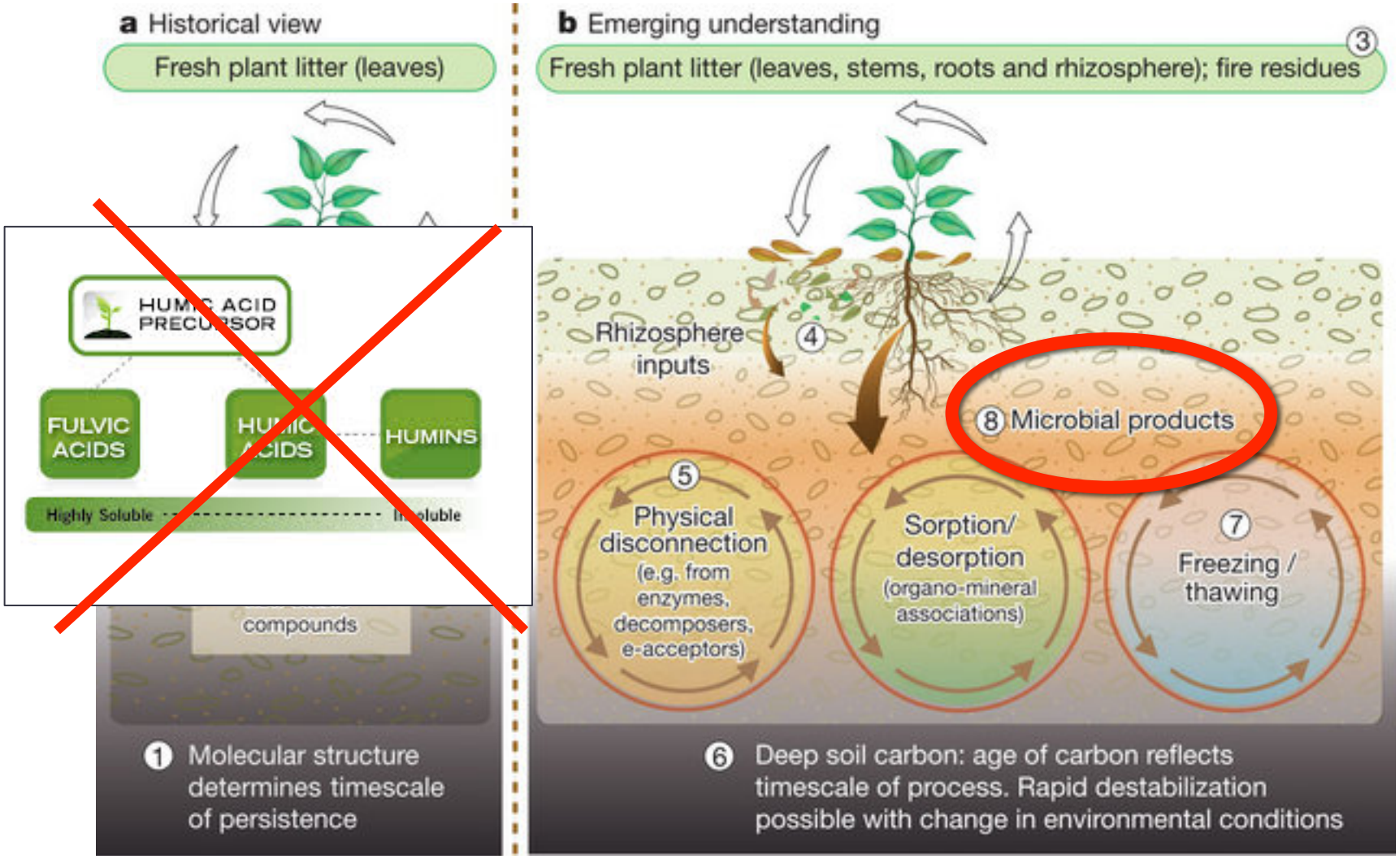


http://images.google.com/imgres?imgurl=http://www.sare.org/publications/explore/images/scenewide2.jpg

How microorganisms contribute to agricultural ecosystems (the good, the bad and the ugly)

Our understanding of SOM formation and stability has changed

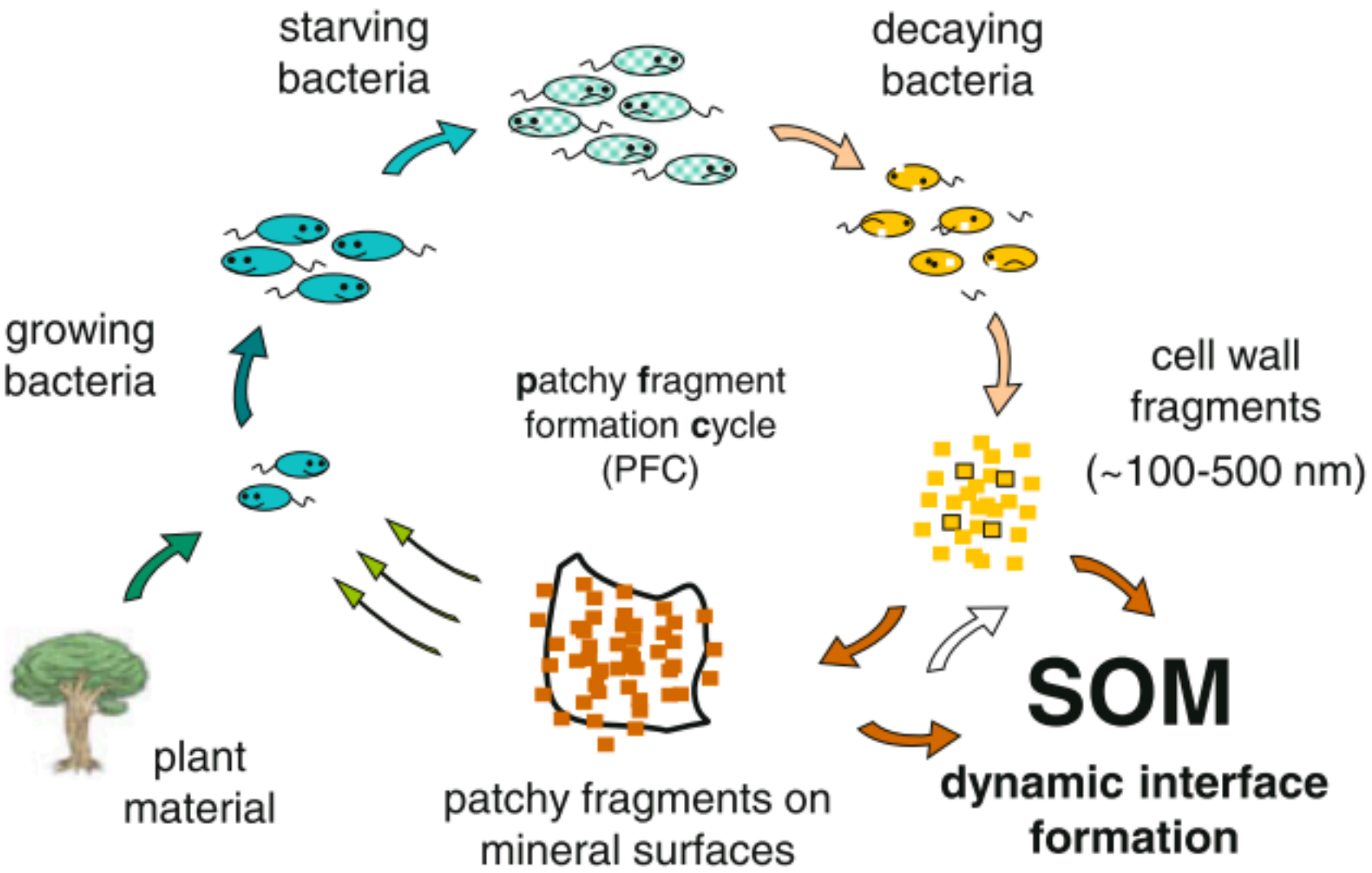
Microbes are drivers and also "feedstock" for SOM



Persistence of soil organic matter as an ecosystem property (2011) Schmidt et al. Nature 478, 49–56

Miltner et al., *Biogeochemistry*, 2008

Studies estimate that ~ 80% of SOC can be derived from microbial biomass



Miltner et al., *Biogeochemistry*, 2008

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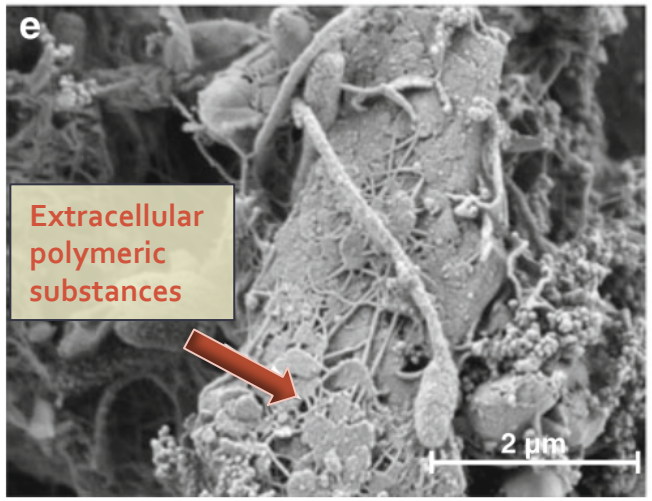
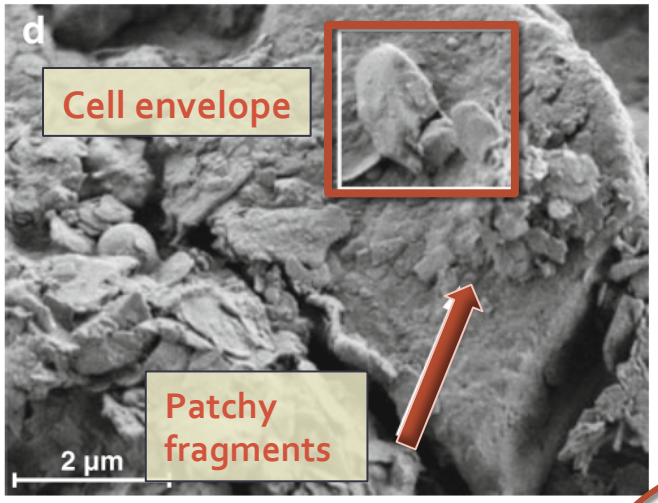




decaying bacteria

patchy fragment formation cycle (PFC)

cell wall fragments (~100-500 nm)

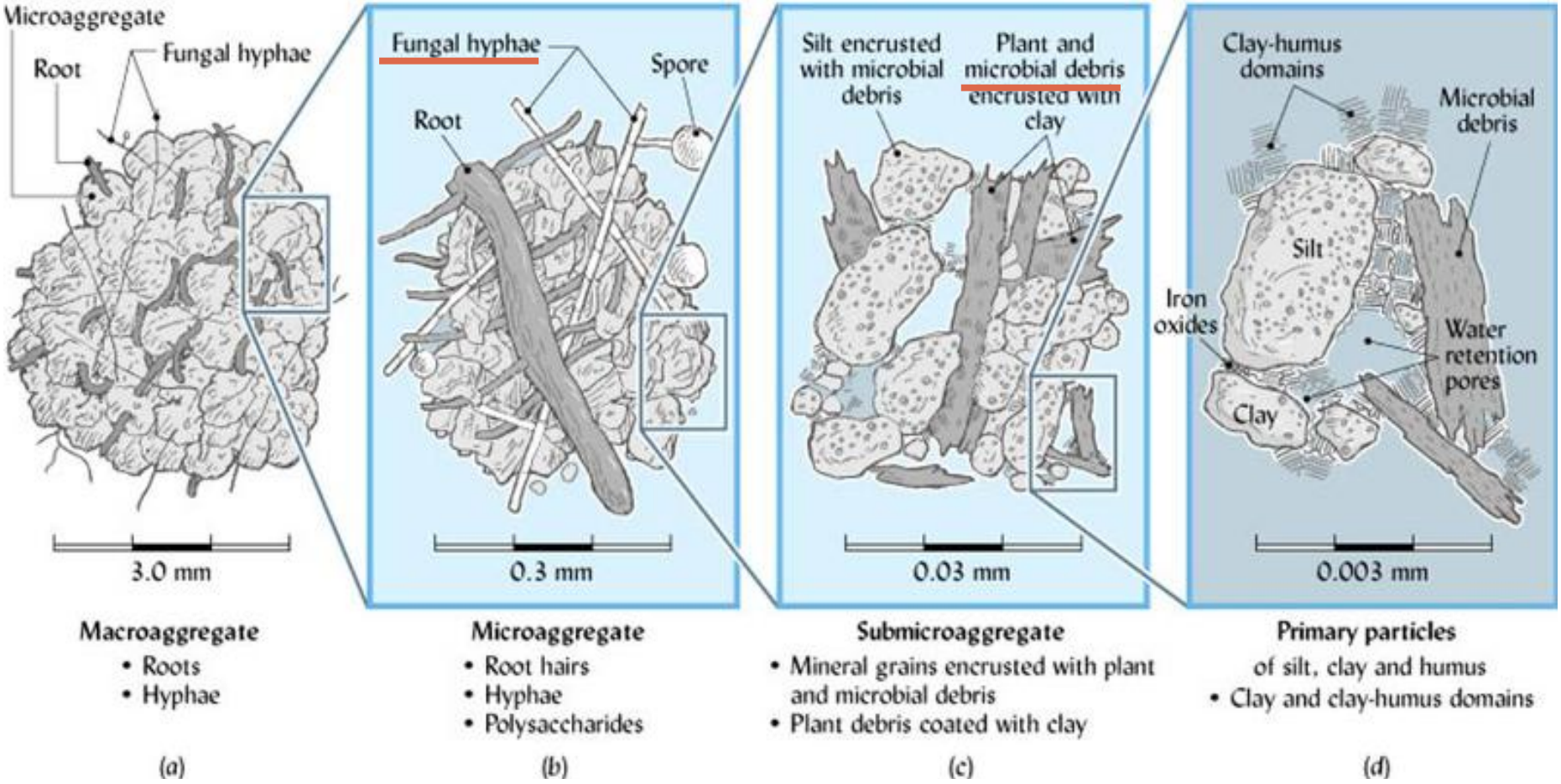
SOM

dynamic interface formation

patchy fragments on mineral surfaces

material

Biological processes are very important to aggregate formation, particularly at larger (microaggregate) scales and in low clay soils



From Brady and Weil, 2008

Well-structured soil allows for more storage and movement of water and gases, and habitat for organisms

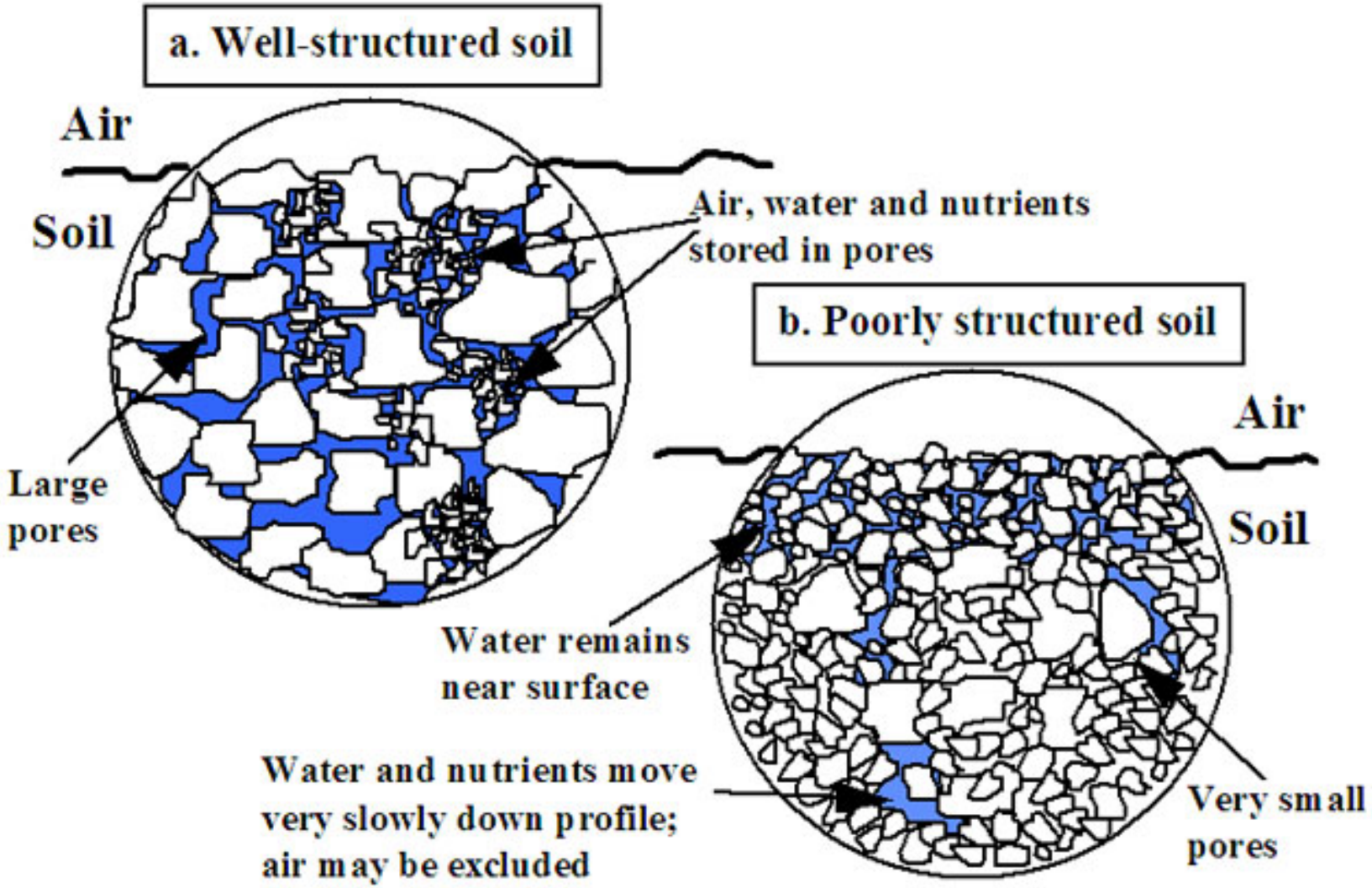
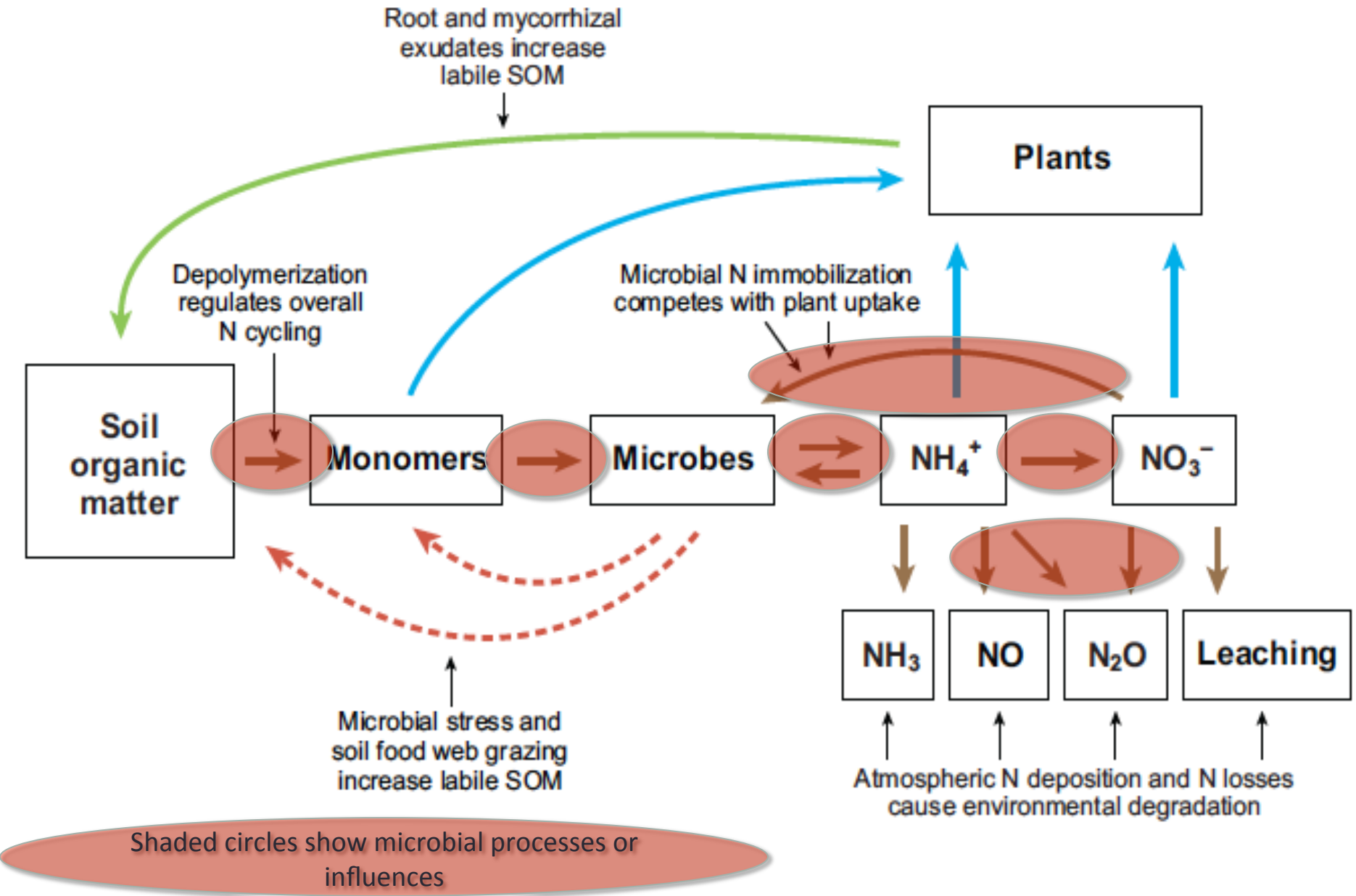
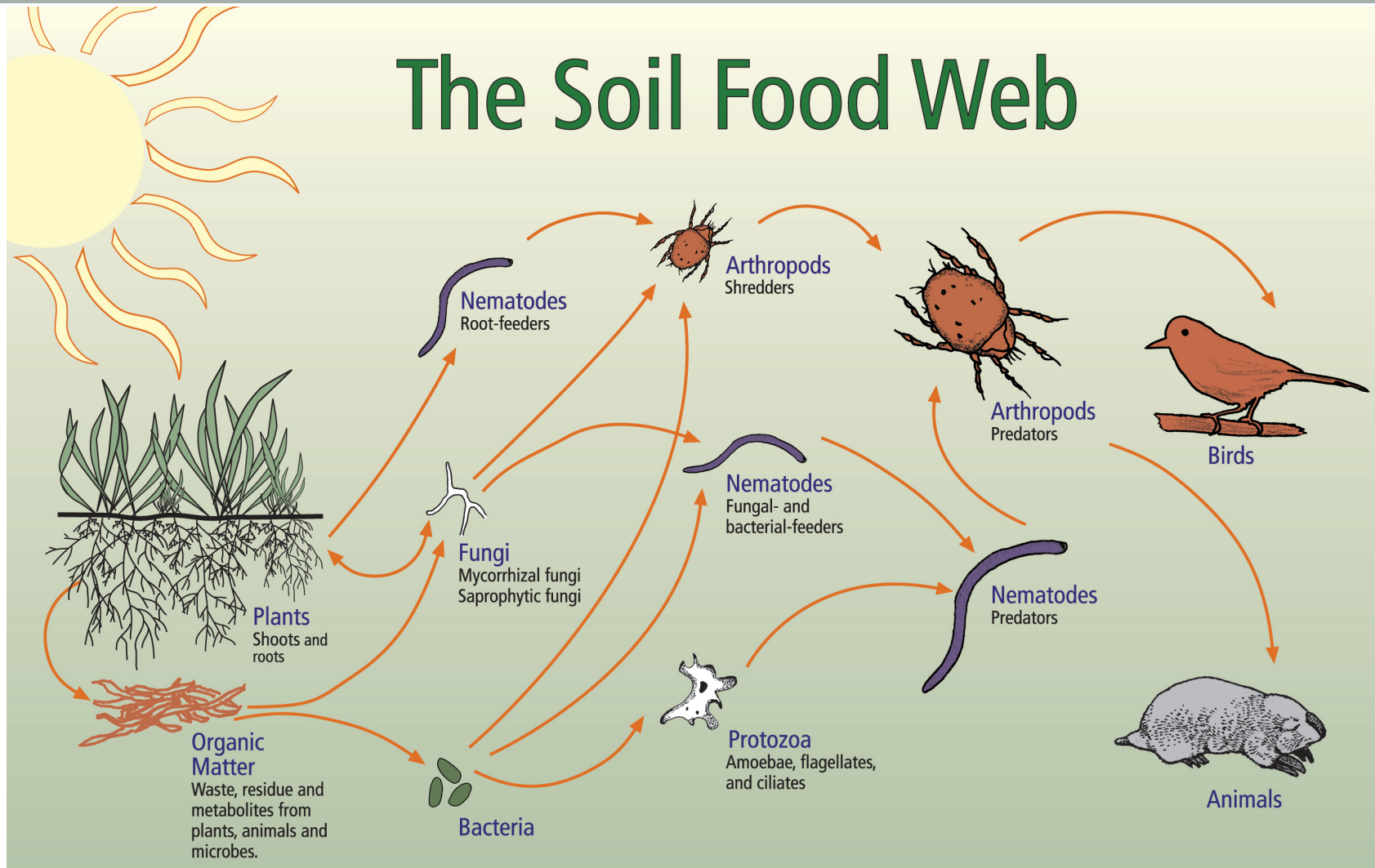


Diagram from Jackson et al., 2008 (Ann Rev Plant Biol 59)

Managing the N cycle means managing microbes



The Soil Food Web



First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, Parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

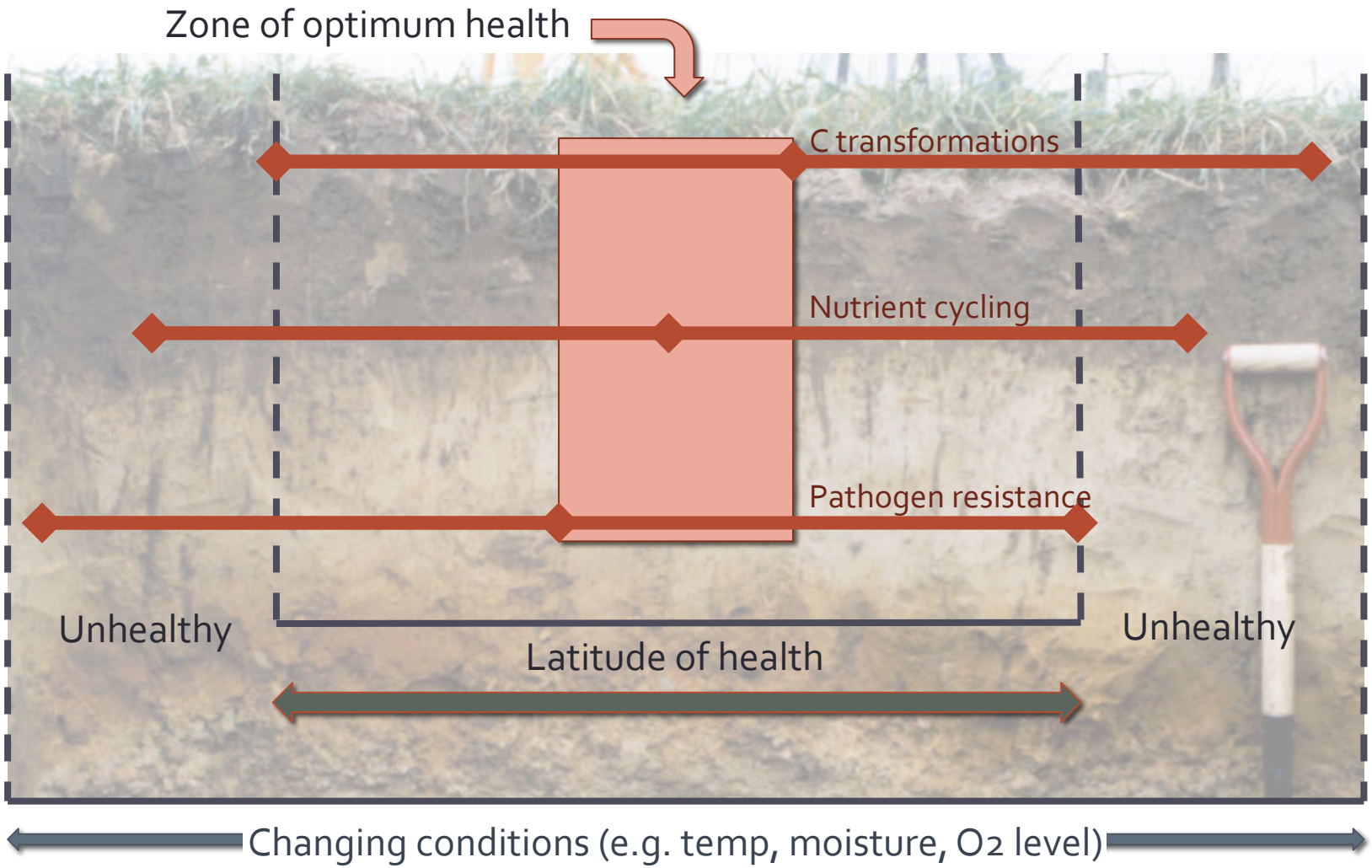
Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators

Aggregate Ecosystem Functions	Functional Assemblages
C Transformations	• Decomposers  • Fungi, bacteria, microbivores, detritivores
Nutrient cycling	• Nutrient transformers  • Decomposers, element transformers, N-fixers, mycorrhizae
Soil structure maintenance	• Ecosystem engineers  • Megafauna, macrofauna, fungi, bacteria
Biological population regulation	• Biocontrollers  • Predators, microbivores, hyperparasites

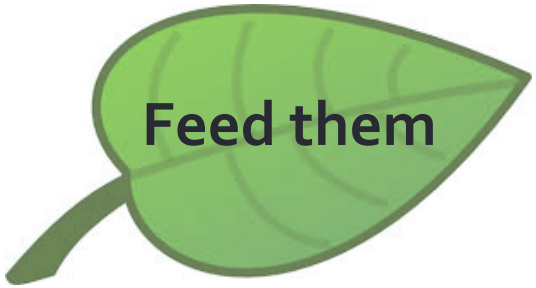
Does soil biodiversity matter?

Does soil biodiversity matter?



The more diversity in each function, the wider our "latitude of health" or **resilience**

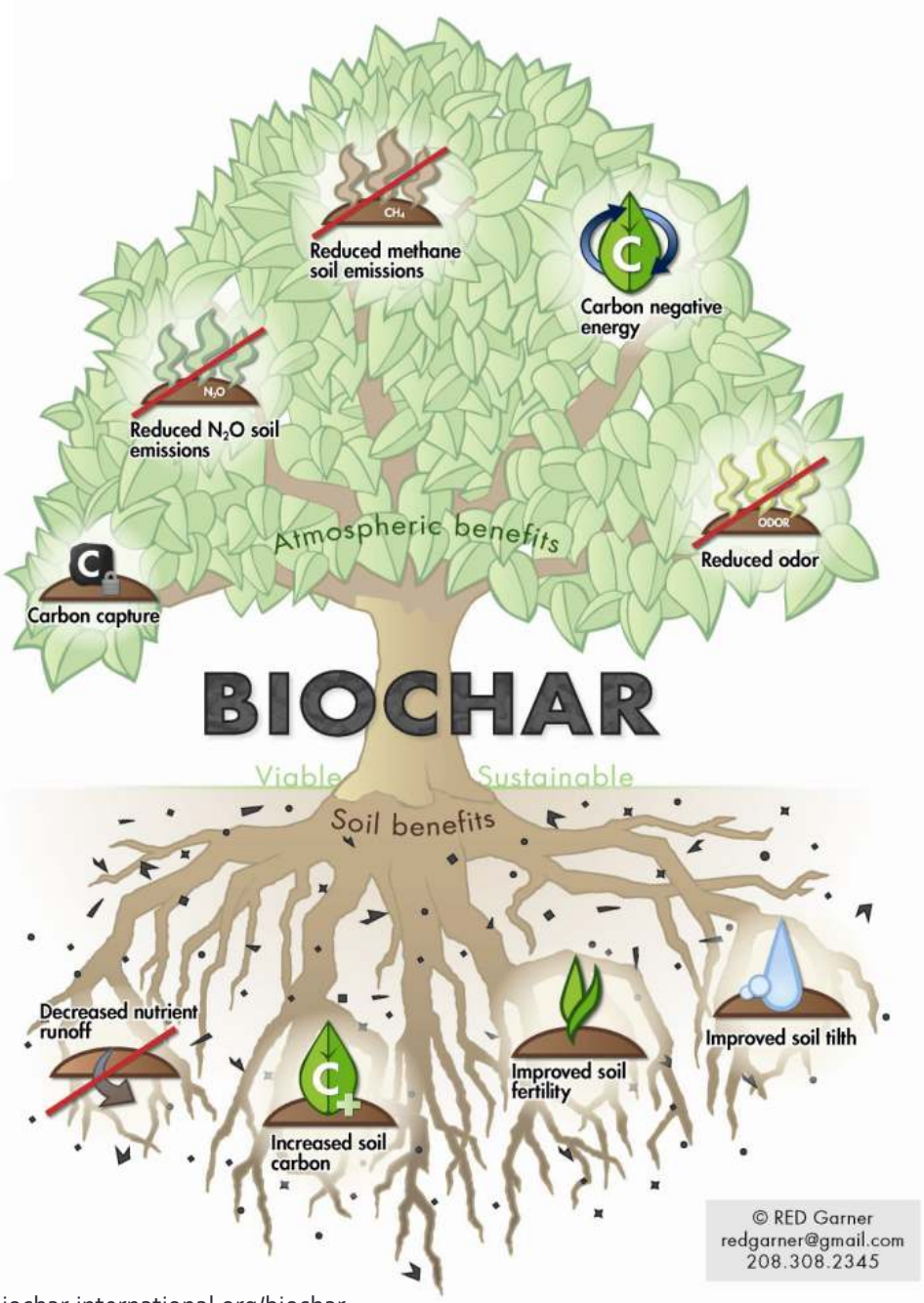
So how do we manage soil for microbes?



- More **carbon** inputs to soil
  - Compost
  - Cover crops
  - Crop residues
  - Living roots
  - Biochar (?)

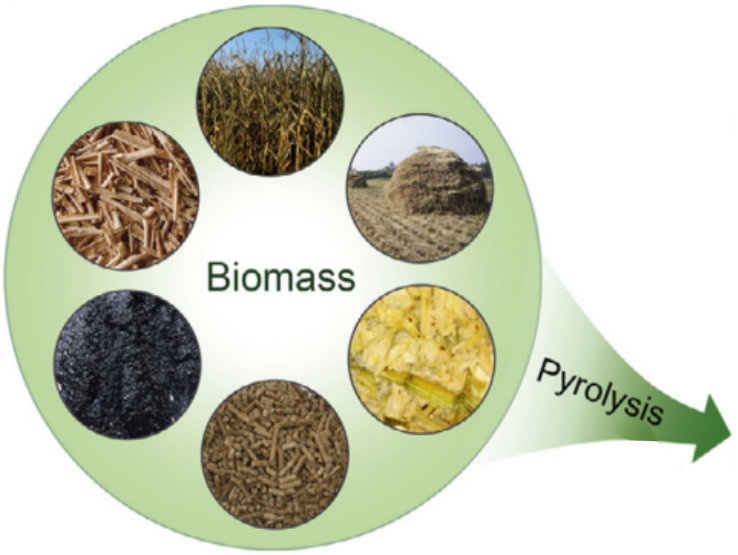
- Create conditions that favor **aggregation** formation
  - Smart timing/amount of tillage
  - Increased microbial biomass and activity

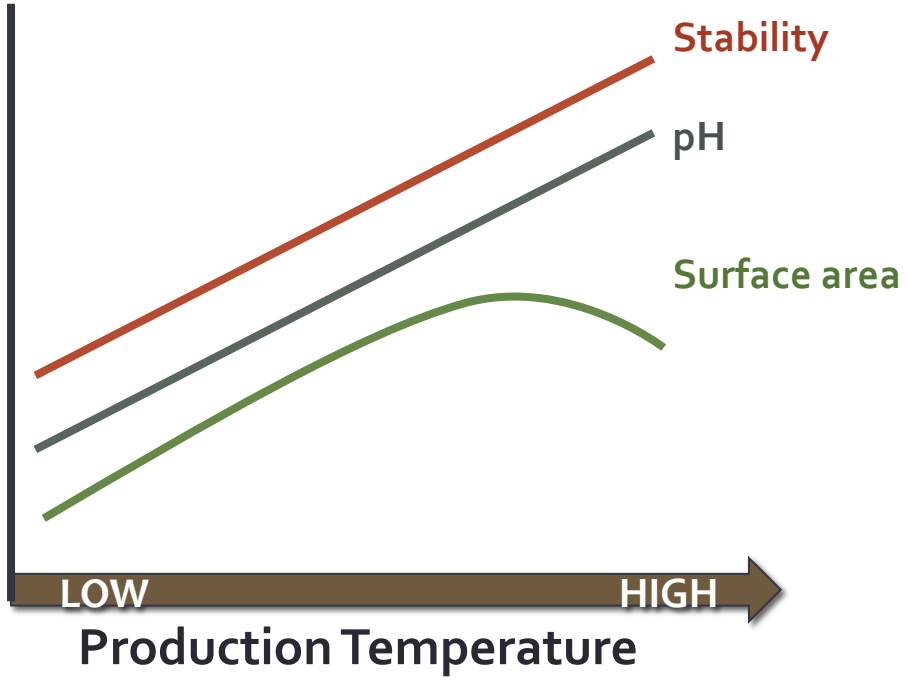
There are still many questions regarding changes in microbial diversity and composition and what they **really mean.**

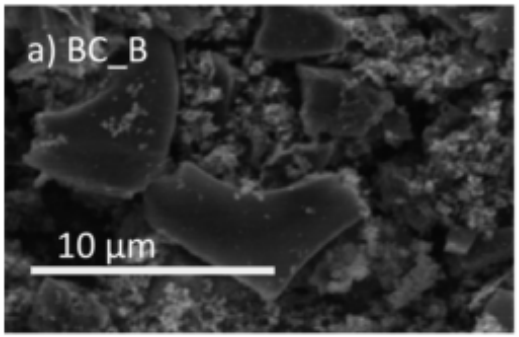


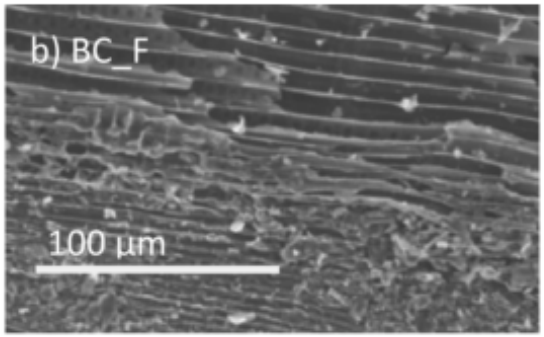
biochar-international.org/biochar

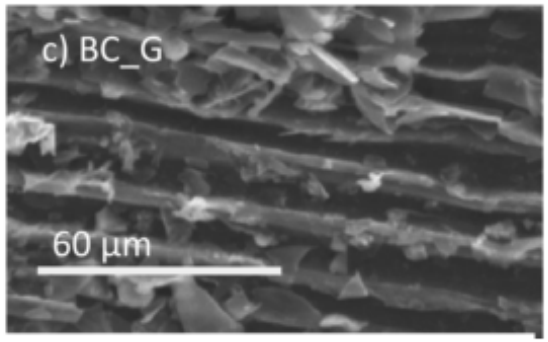
Biochar: Thermal degradation of an organic feedstock through pyrolysis under low/no O_2 conditions.











Tan et al., 2015 (biomass image); Lehmann & Joseph, 2009 ; Mukome et al., 2013 (SEM image)

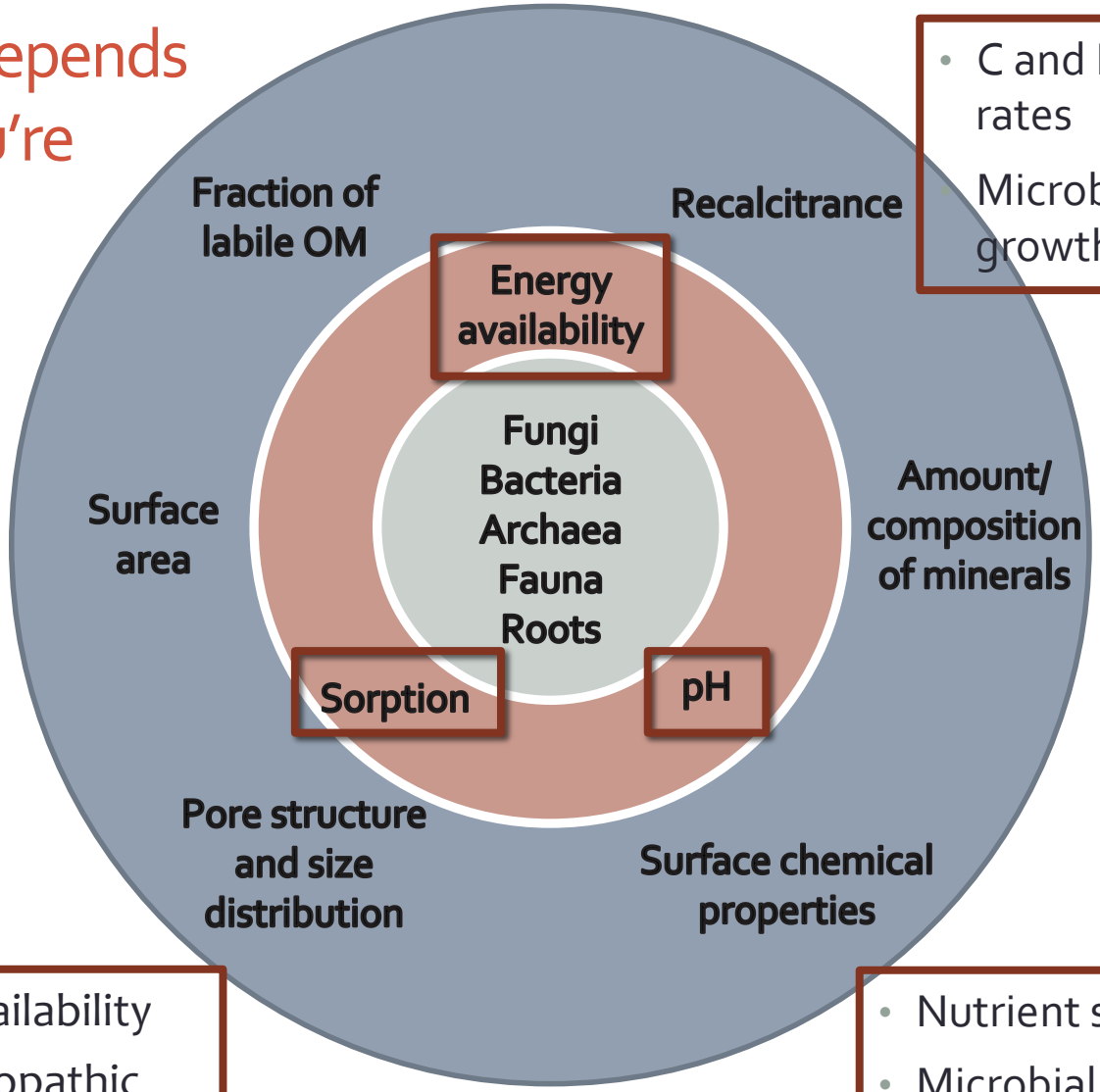
Soil variables affecting organisms

- Soluble carbon
- Nutrient availability
- pH
- Pore space
- Sorption potential – enzymes, signaling, nutrients, toxins
- Soil moisture
- Presence of inhibitory compounds and contaminants

- Changes in:
  - Microbial abundance
  - Microbial activity
  - Community composition

Modified from Lehmann et al., *Soil Biol Biochem*, 2011

Change also depends on the **soil** you're adding it to



- C and N mineralization rates
- Microbial habitat and growth

- Substrate bioavailability
- Sorption of allelopathic compounds
- Disruption of quorum sensing

- Nutrient solubility
- Microbial biomass & composition
- Microbial processes sensitive to pH

What can happen when biochar changes pH?

- Affects **nutrient** availability
  - Could increase or decrease
- **Microbial biomass** tends to increase with increasing pH
- Many microbial processes **sensitive to pH**
  - Nodulation and N fixation
  - Nitrification

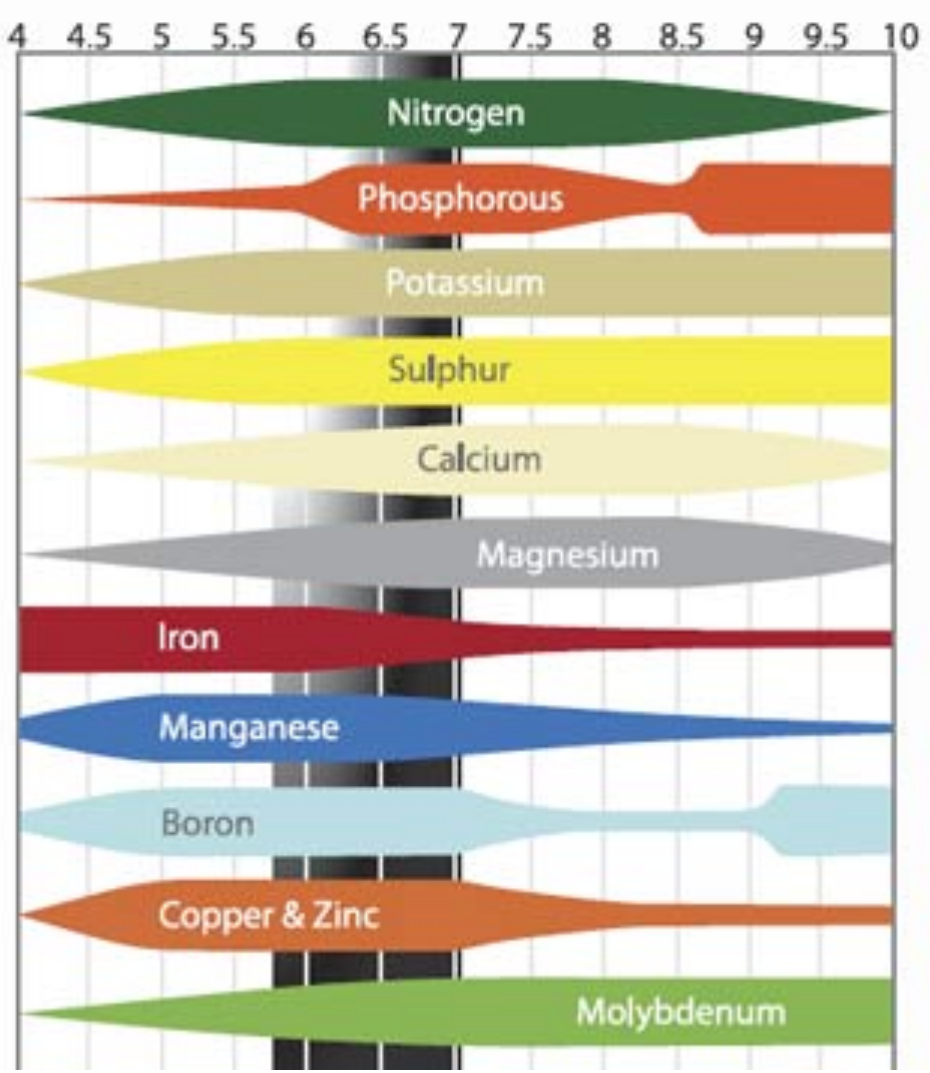
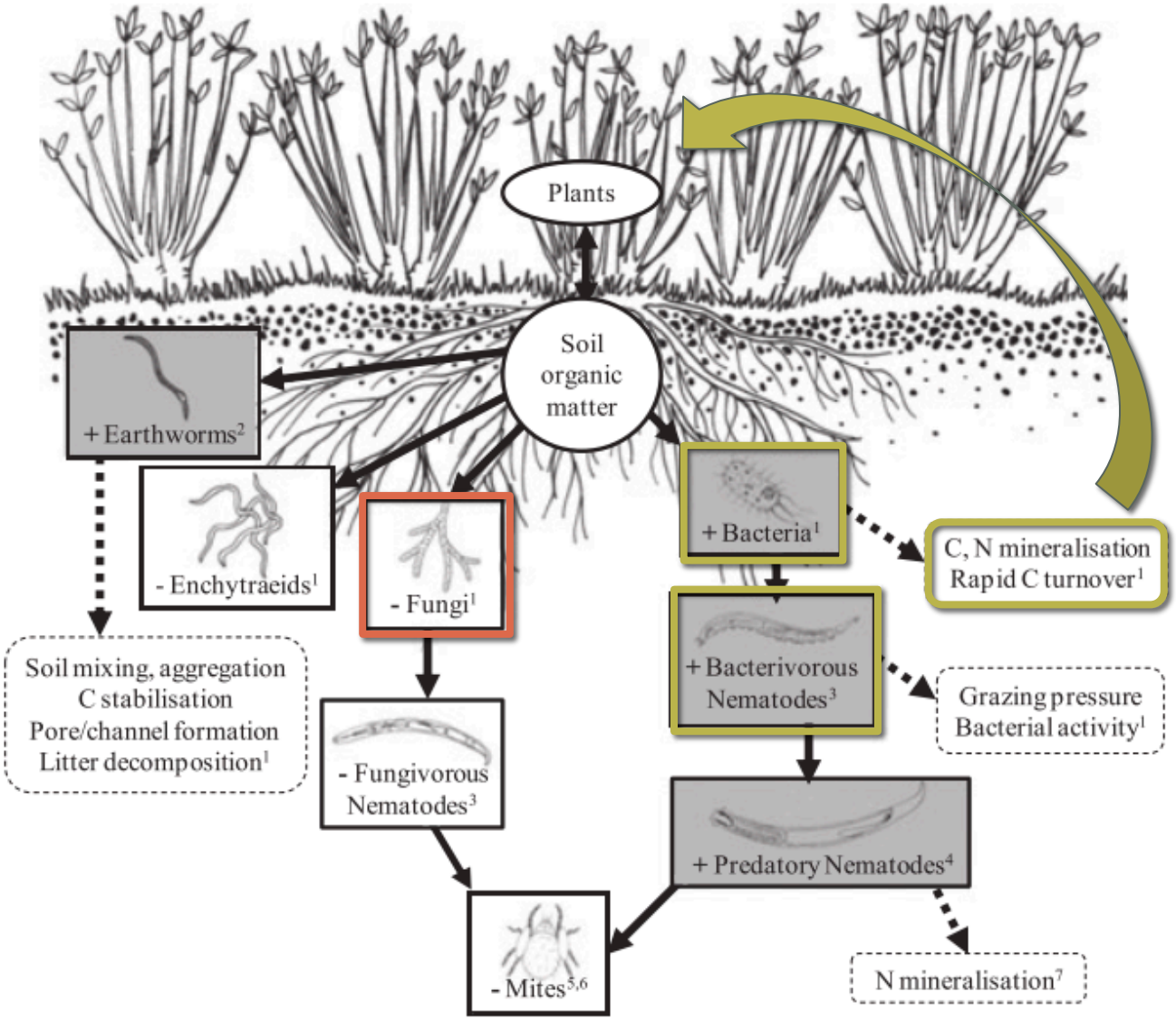


Image from supernaturalbrand.com

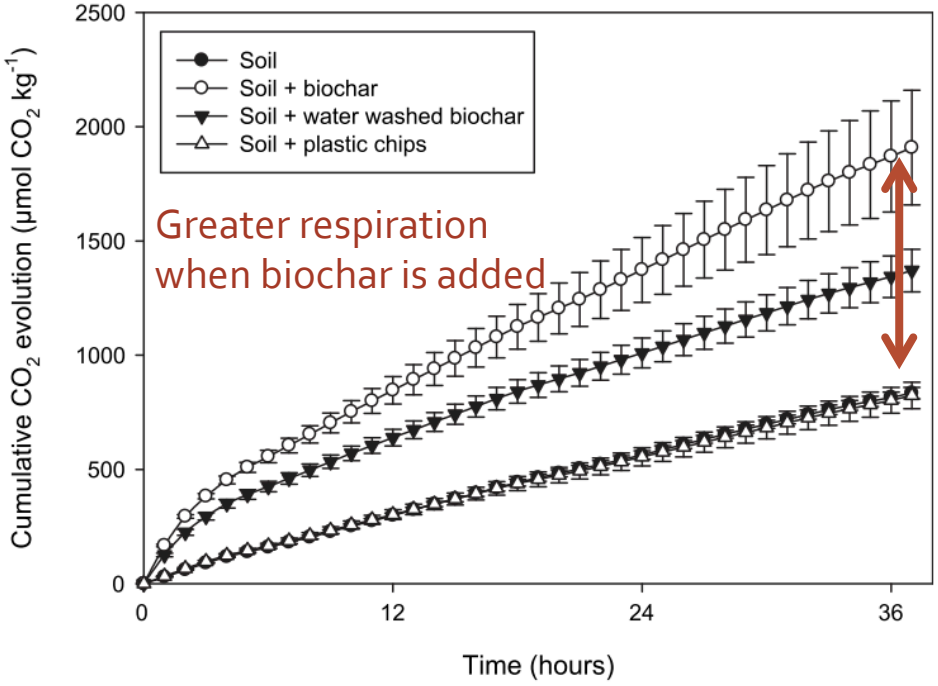
Anticipated effects of raising pH from 3-4 to 5-6 with biochar



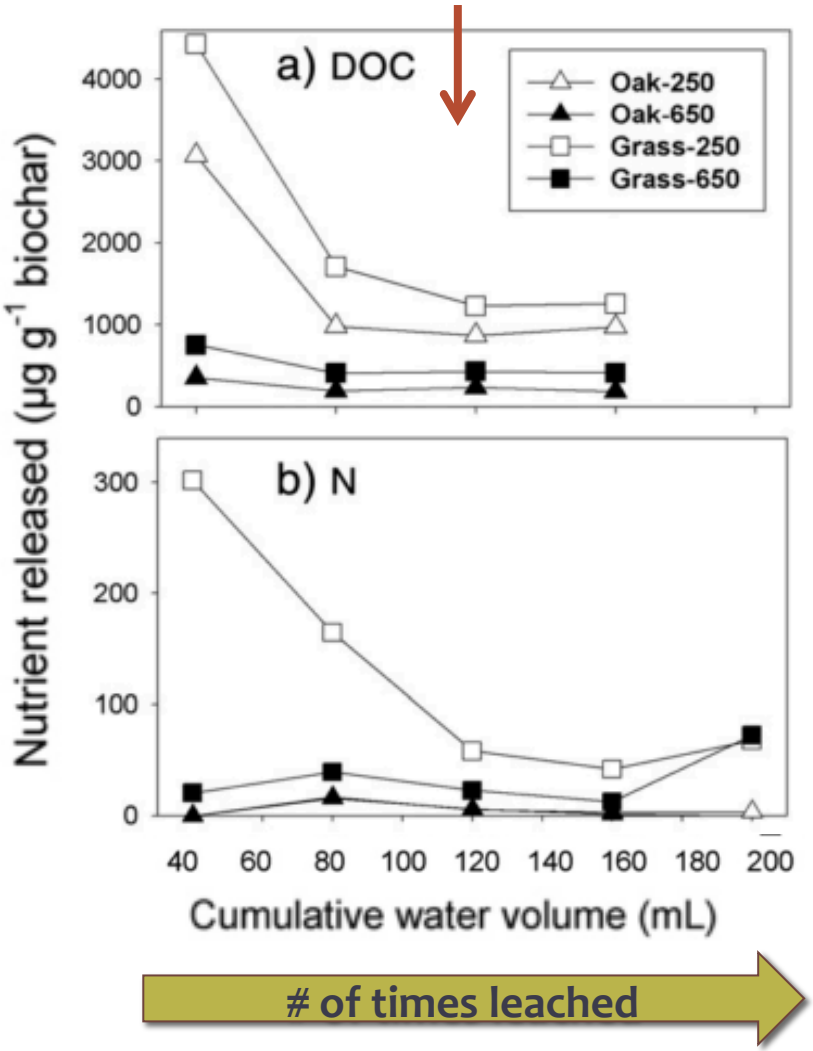
McCormack et al., *GCB Energy*, 2013

Sometimes biochar adds a C and nutrient source

- Short term burst of activity from soluble C?
- *Co-location* of enzymes, C compounds, and microbes?

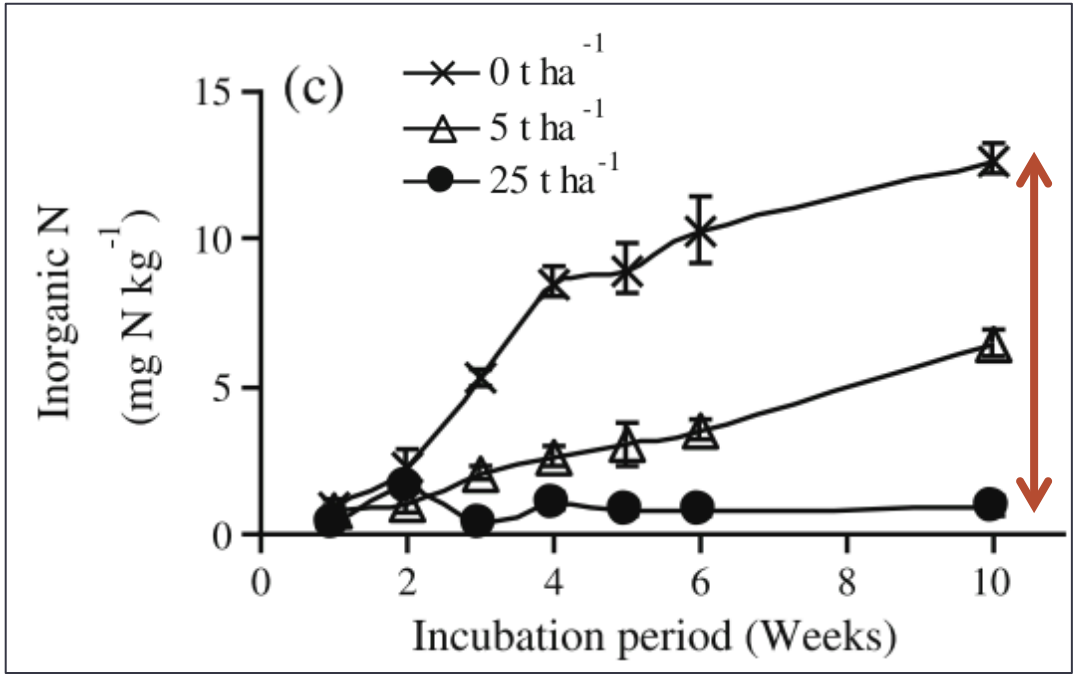


C and N released from biochars



In other cases, there can be decreased microbial activity

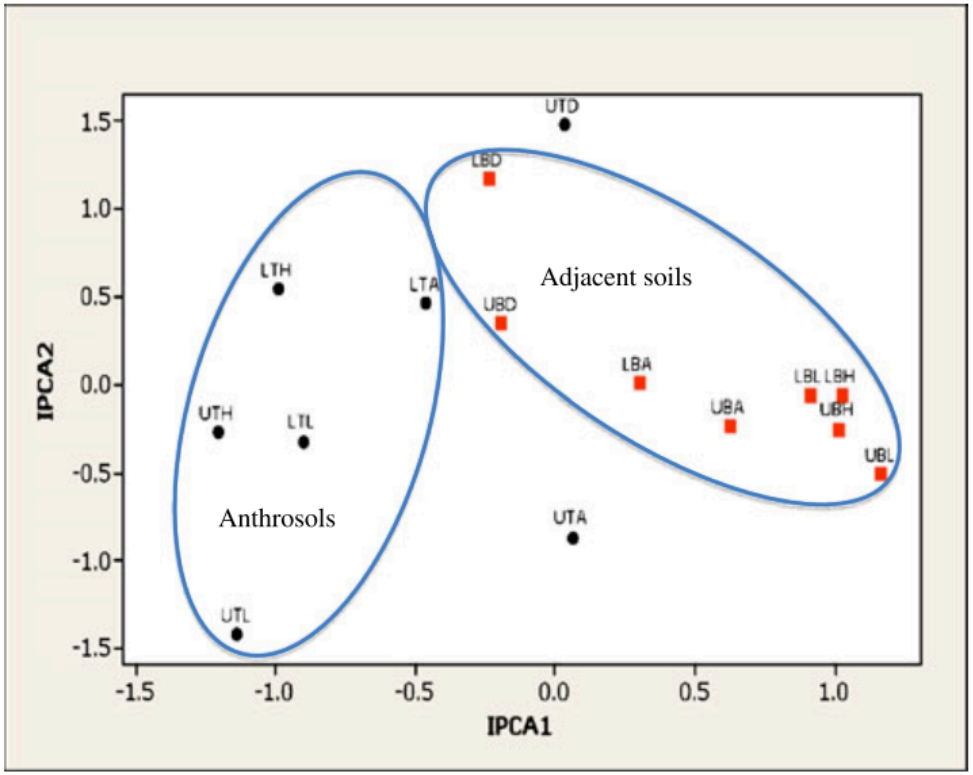
- **Lower** net N mineralization and nitrification rates
  - Lower microbial biomass?
  - Sorption of ammonium (NH_4^+)?
  - Negative priming of SOM?

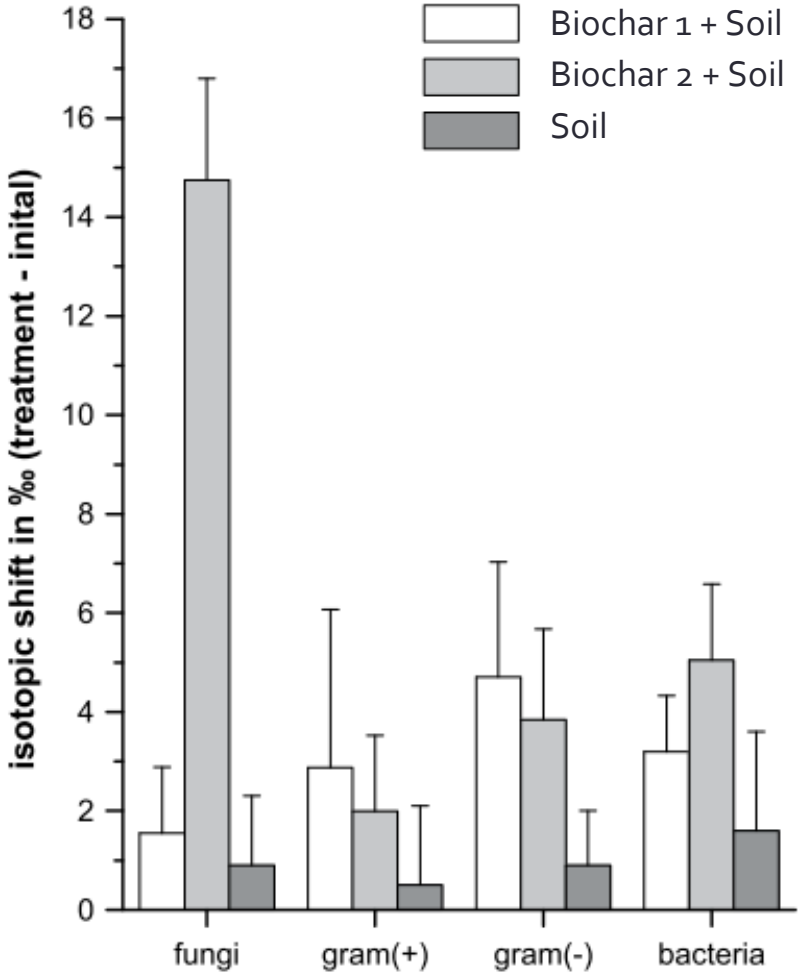


Less N available with biochar additions

Dempster et al., *Plant Soil*, 2011

Changes in microbial community composition

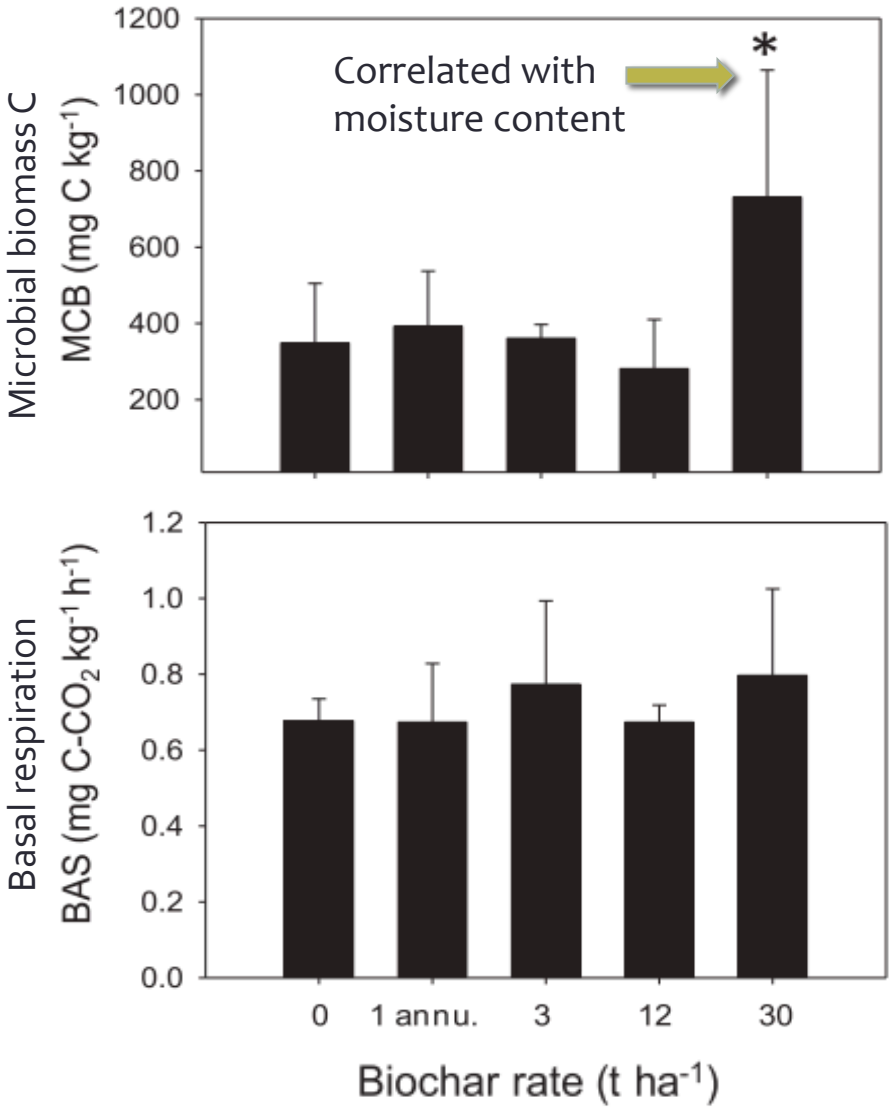




Grossman et al., *Microbial Ecology*, 2010

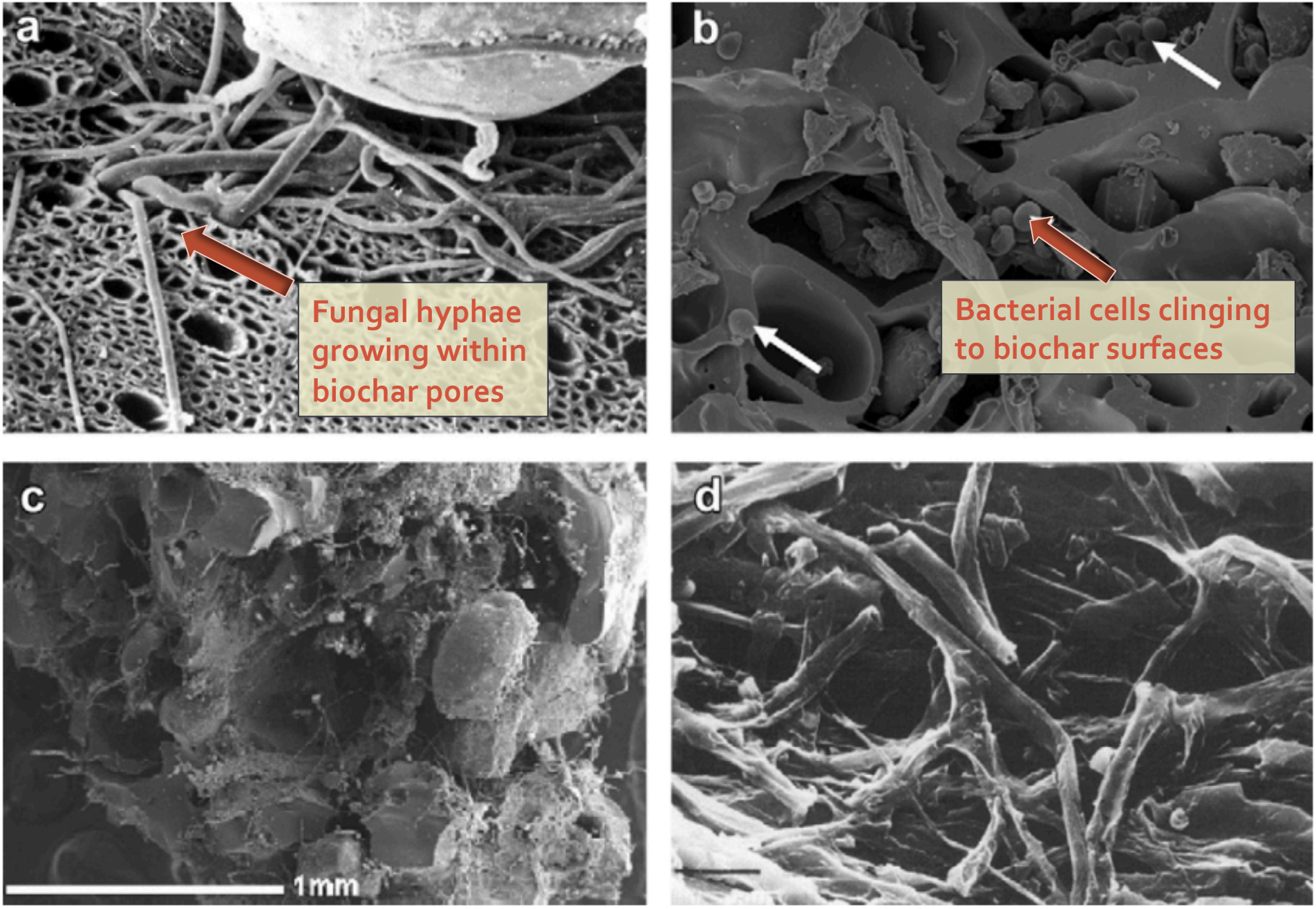
Steinbeiss et al., *Soil Biol Biochem*, 2009

Increased microbial biomass but not activity



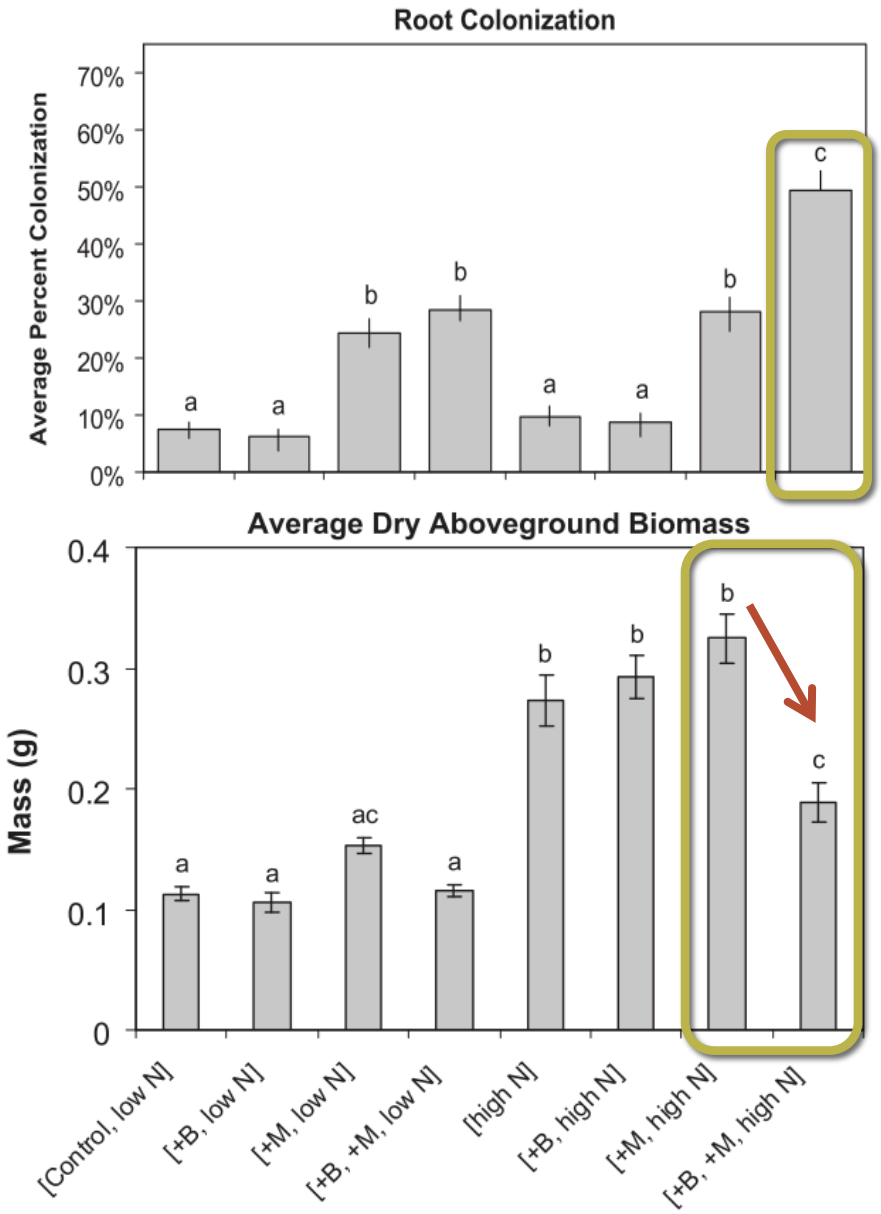
- Biochar didn't affect C transformations
- Higher microbial biomass in high biochar may be due to increased soil moisture content

Domene et al., *Soil Biol Biochem*, 2014


a
Fungal hyphae growing within biochar pores
b
Bacterial cells clinging to biochar surfaces
c
1 mm
d

Mycorrhizal colonization

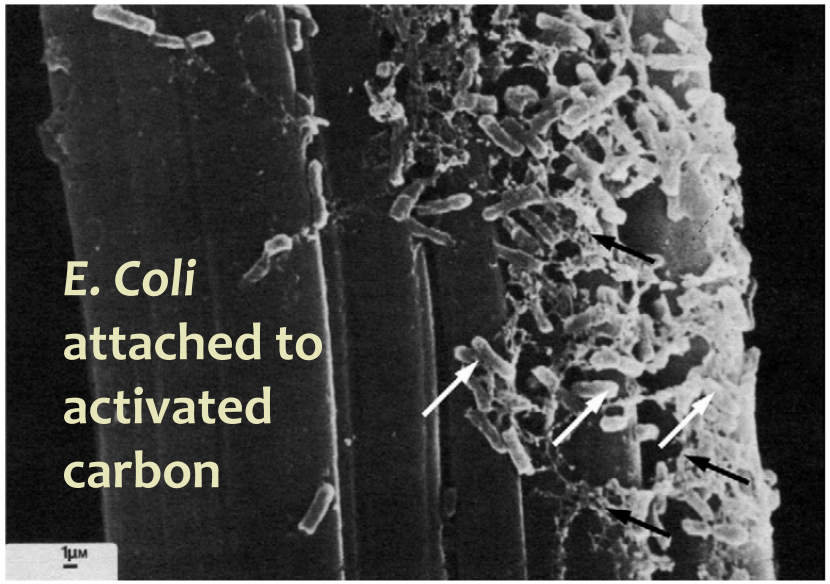
- Increased colonization with biochar
- But decreased biomass at high N + biochar treatment
- Biochar causing parasitic activity by mycorrhizae?

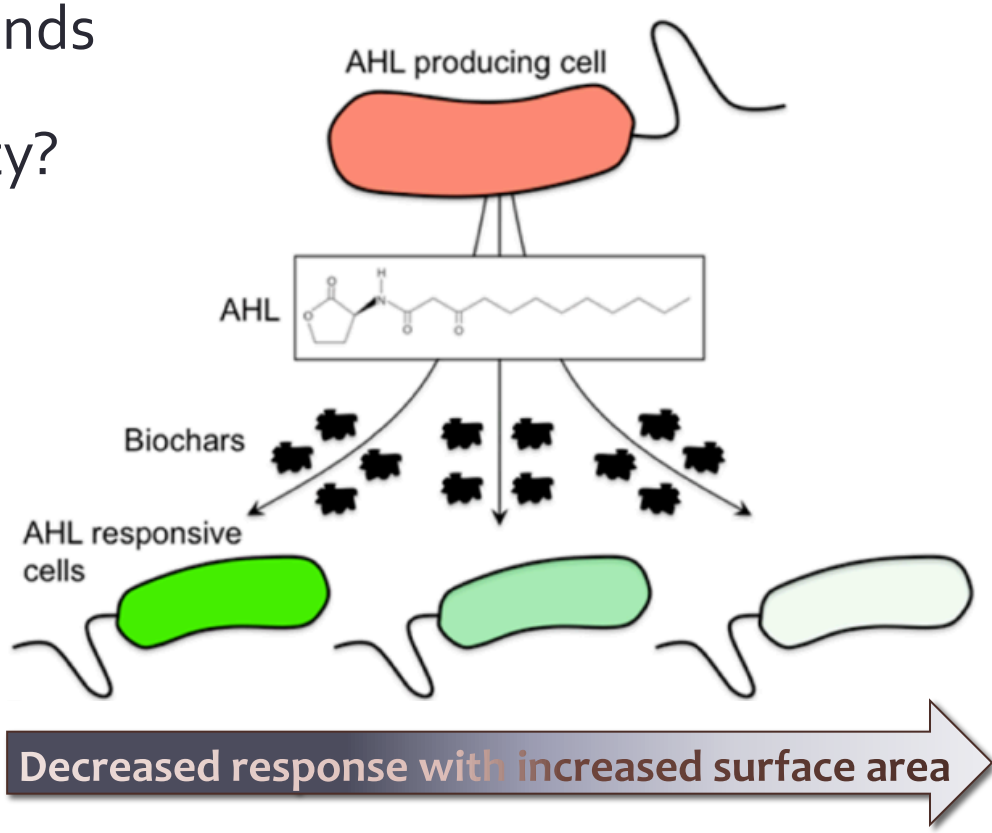


LeCroy et al., *Soil Biol Biochem*, 2013

Surface Area and Sorption Capacity

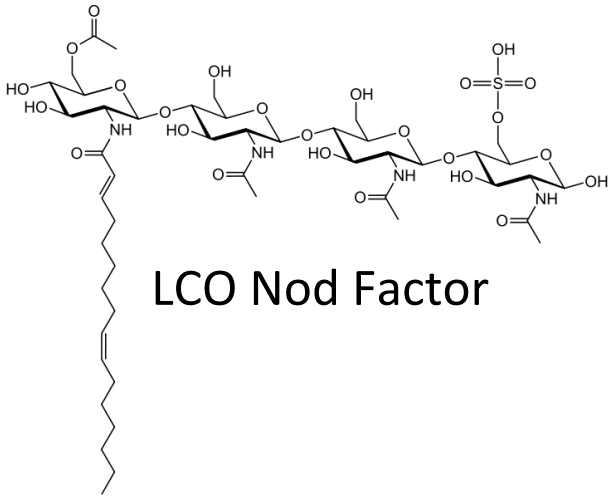
- Surfaces for biofilm formation and attachment
- Sorption of inhibitory compounds
- Sorption of signaling compounds
- Lower substrate bioavailability?





Legume-Rhizobia Signaling Process

4

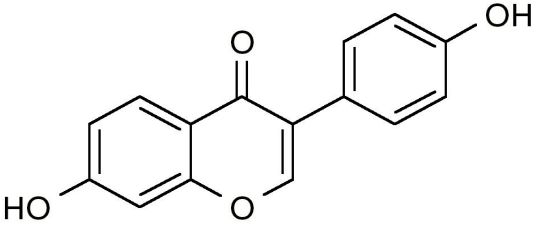


LCO Nod Factor

3

NodD activation

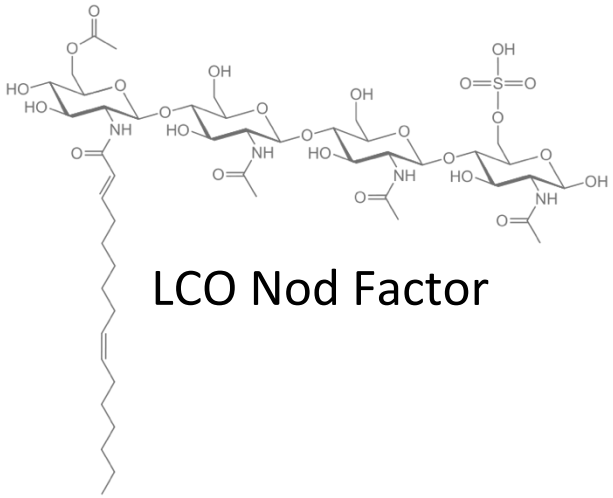
1



Flavonoid

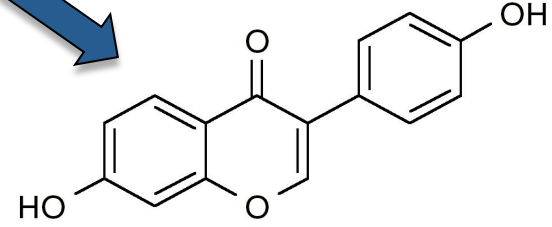
2

Can biochar interfere with this process?



LCO Nod Factor

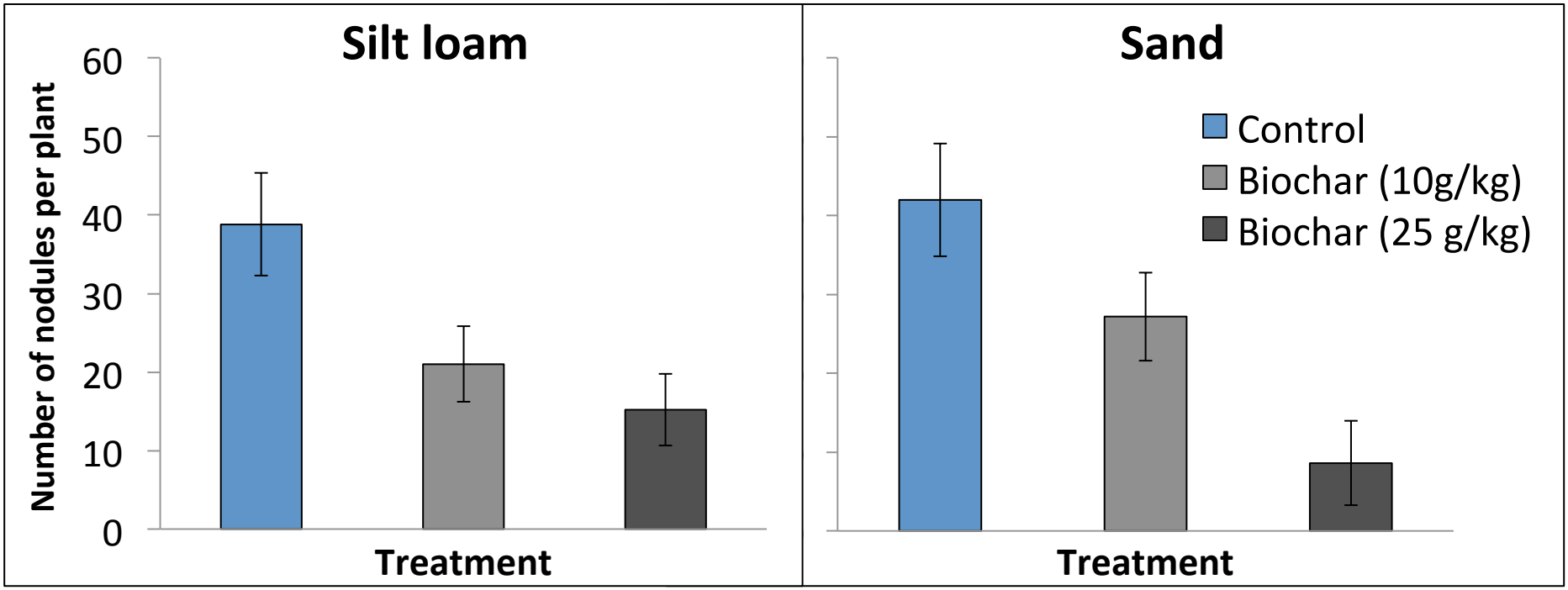
No *NodD* activation



Flavonoid

Biochar

Number of nodules per plant



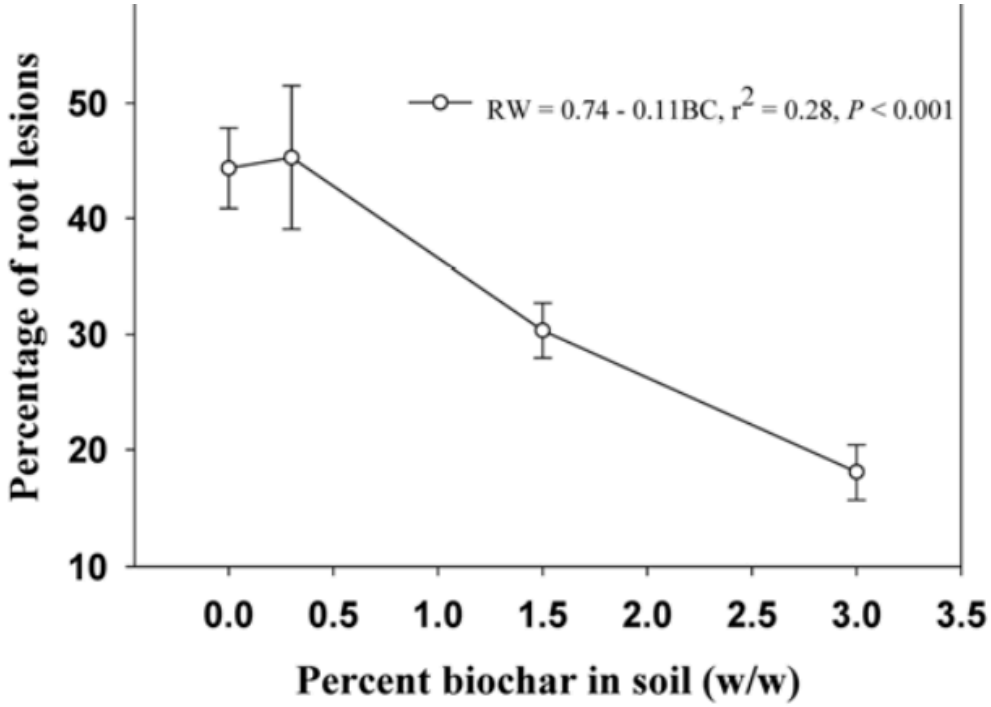
Figures 1 and 2. Mean ± SE.

Conclusions

- Walnut shell biochar has the potential to reduce nodulation in cowpeas
- Important to compare to biochars of other feedstocks/pyrolysis temperature
- Repeat experiment with method of pH adjustment for limed controls

Can we use biochar to manage microbes?

- Inoculant carrier
- Reduce pathogens



- Concerns:
  - Toxic volatile matter
  - Salts
  - Heavy metals
- Can we manipulate biochar to have the right characteristics?
- Microbes are affecting biochars' fate just as it affects them
- At what timescale is biochar having effects?

Take-home messages

- **Healthy** soils provide food/fiber while also…
  - Storing carbon
  - Cycling nutrients
  - Creating strong soil structure
  - Resisting pathogens

- **Soil organisms** play a key role in all of these services

- **Some biochars** may increase microbial activity and desired functions, but not for all biochar/soil combinations


Thank you!

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