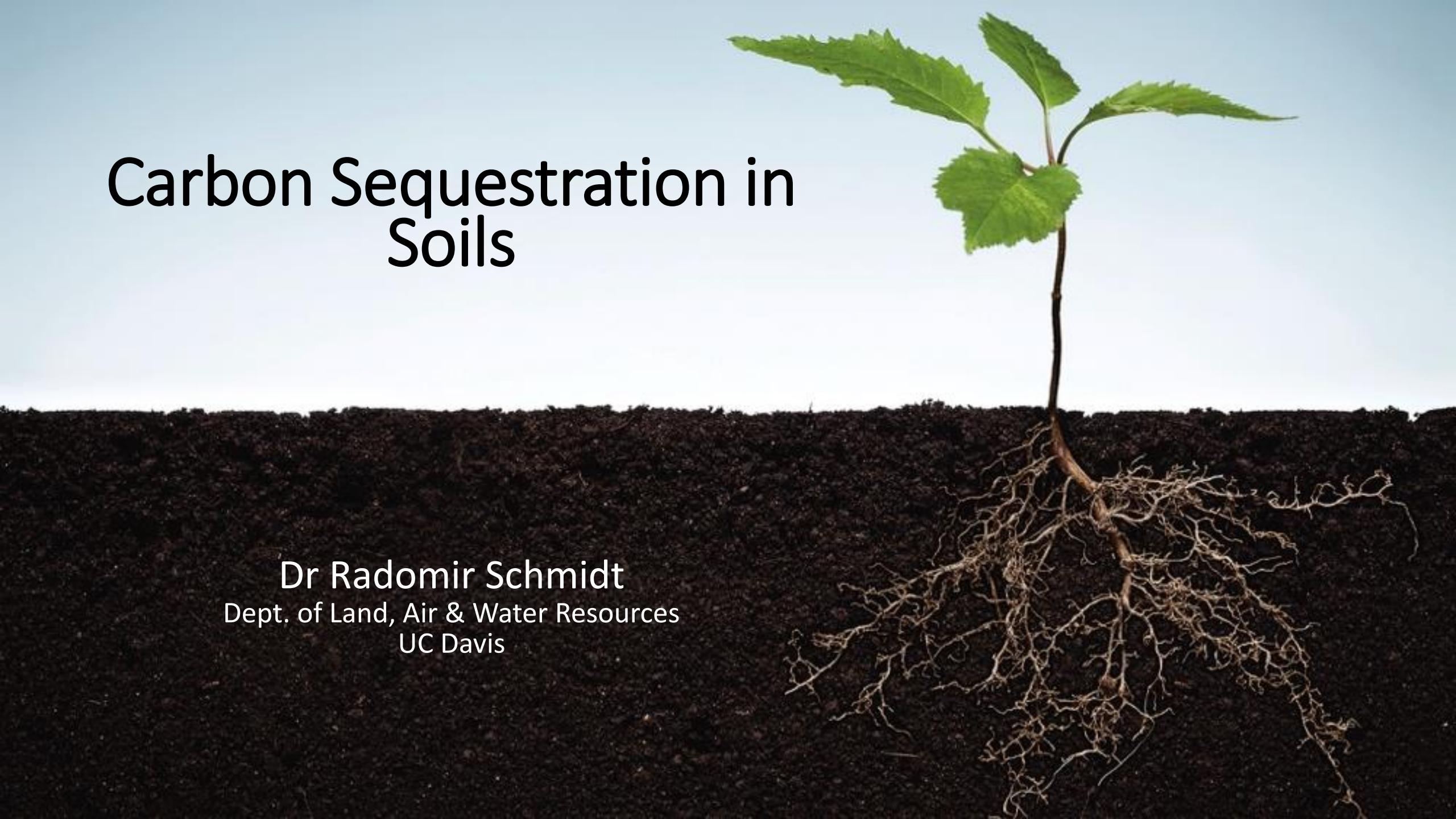
Carbon Sequestration in Soils



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Outline

- Soil is a living system
  - How does soil sequester C?
- A deeper look at soil
  - Where does the carbon go?
  - What are the microbes doing?
- What can we do to increase C sequestration?

Can soil solve all our carbon issues?

"If the global soil carbon level was increased by 0.4%, or 4‰ per year, in the top 30-40 cm of soils, the annual increase in carbon dioxide in the atmosphere would be stopped."

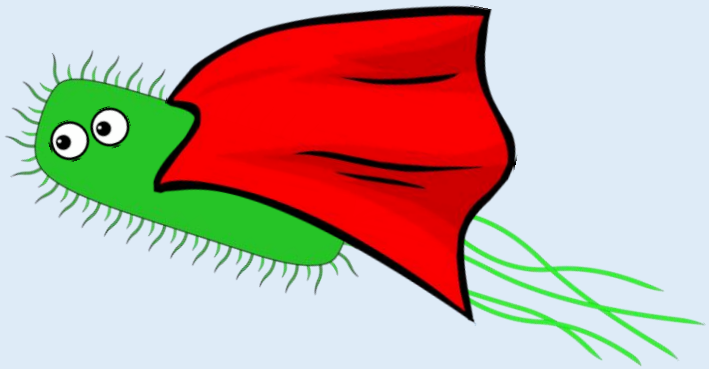
-- https://www.4p1000.org

How does soil sequester C?

What we've known for a while

- Plant biomass is the driver for soil organic matter (SOM) formation
- Increasing SOM levels is slow and difficult
- Roots and root exudates contribute to SOM

How does soil sequester C?

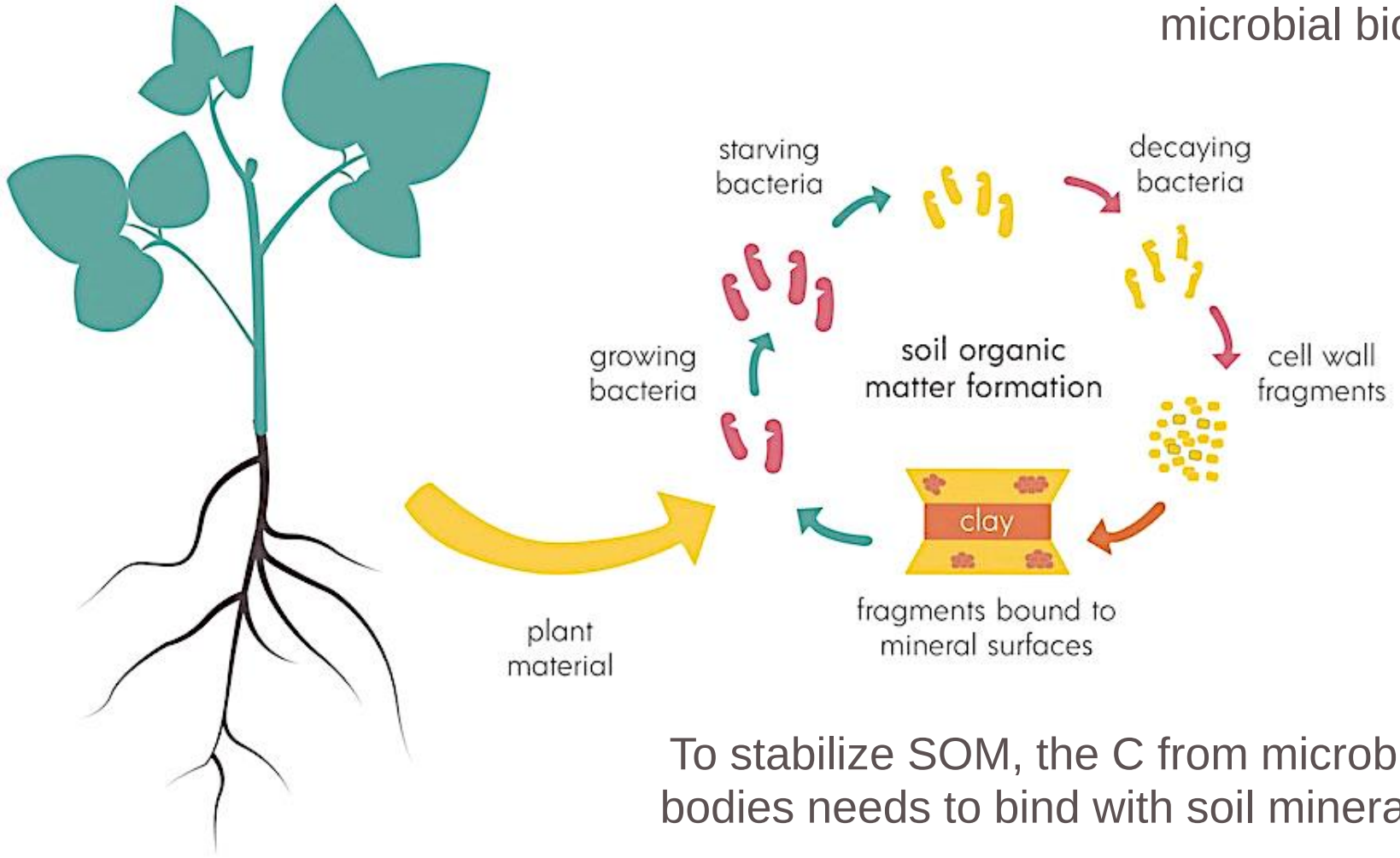


What's new

- Humus is probably artefact of analysis methods
- Microbes transform C inputs into SOM
  - microbial necromass important component of SOM
- SOM protected from degradation by:
  - attachment to silt and clay particles
  - aggregate formation
- Roots and root exudates are most important C sources
  - up to 5x more likely to become SOM than above-ground plant parts

Building SOM

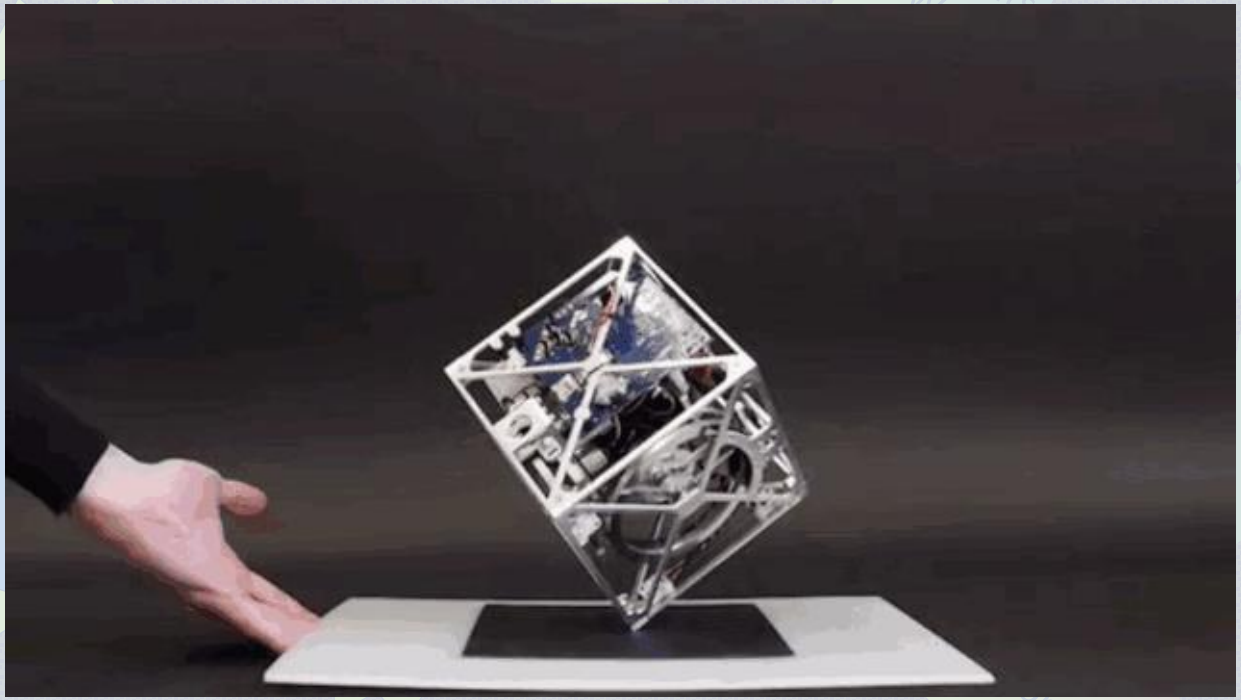
50-80% of SOM is simply dead microbial bodies. If you want to increase SOM, you must build microbial biomass.



To stabilize SOM, the C from microbial bodies needs to bind with soil minerals.

Soil as a dynamic system of biogeochemical cycles driven by carbon (energy) inputs

1. Need energy
2. Need nutrients
3. Balance is dynamic



“If the global soil carbon level was increased by 0.4%, or 4‰ per year, in the top 30-40 cm of soils, the annual increase in carbon dioxide in the atmosphere would be stopped.”

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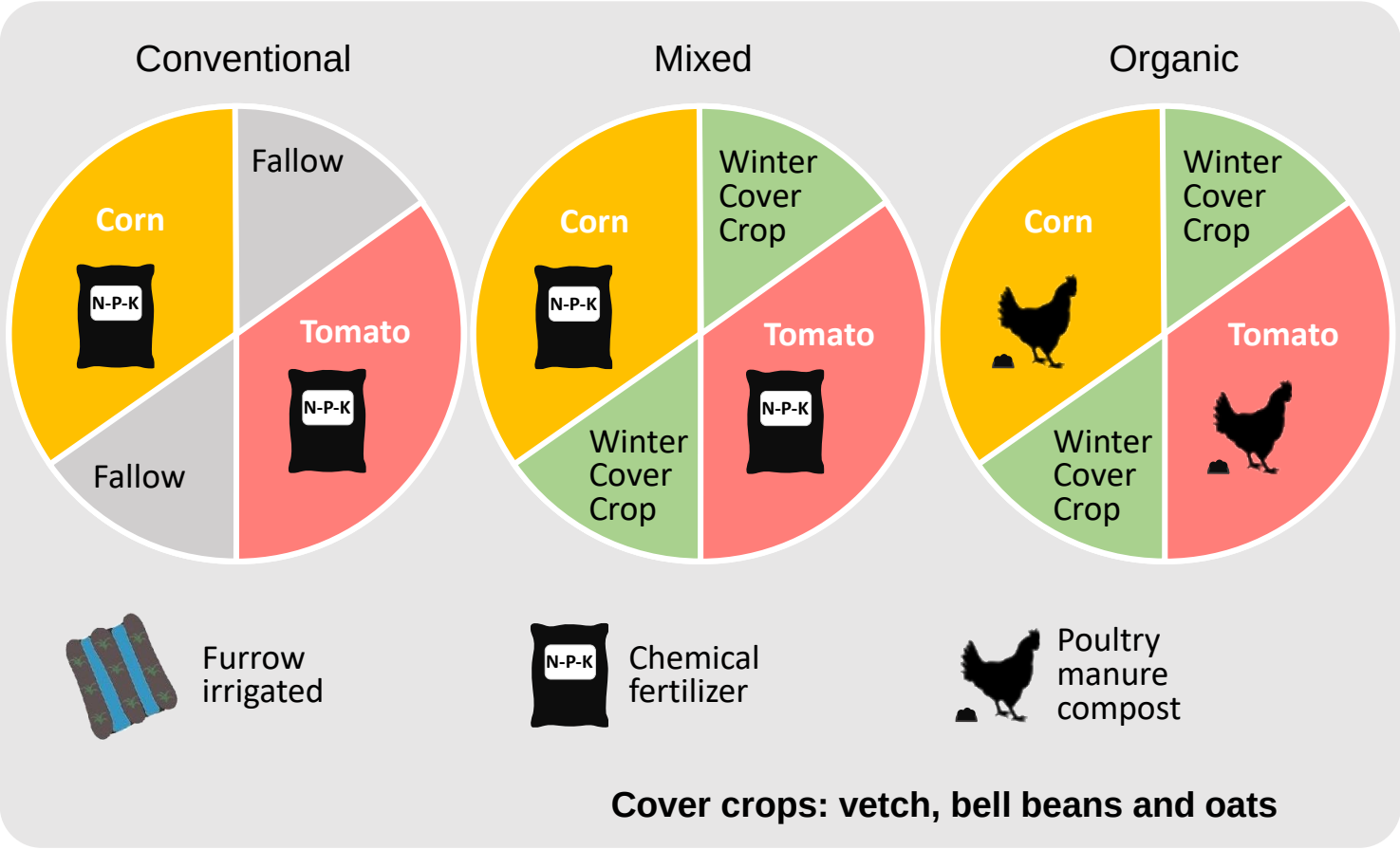
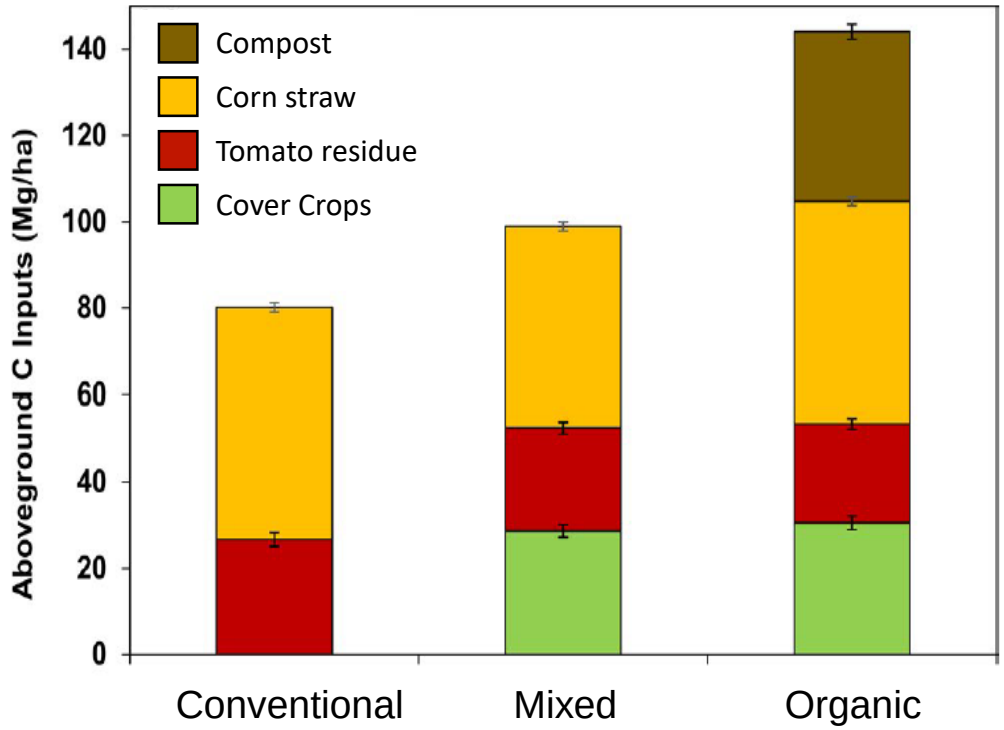
But is 30-40 cm deep enough, or do we need to look deeper?

Soil Carbon Sequestration after 19 years of management at Russell Ranch Sustainable Agriculture Facility

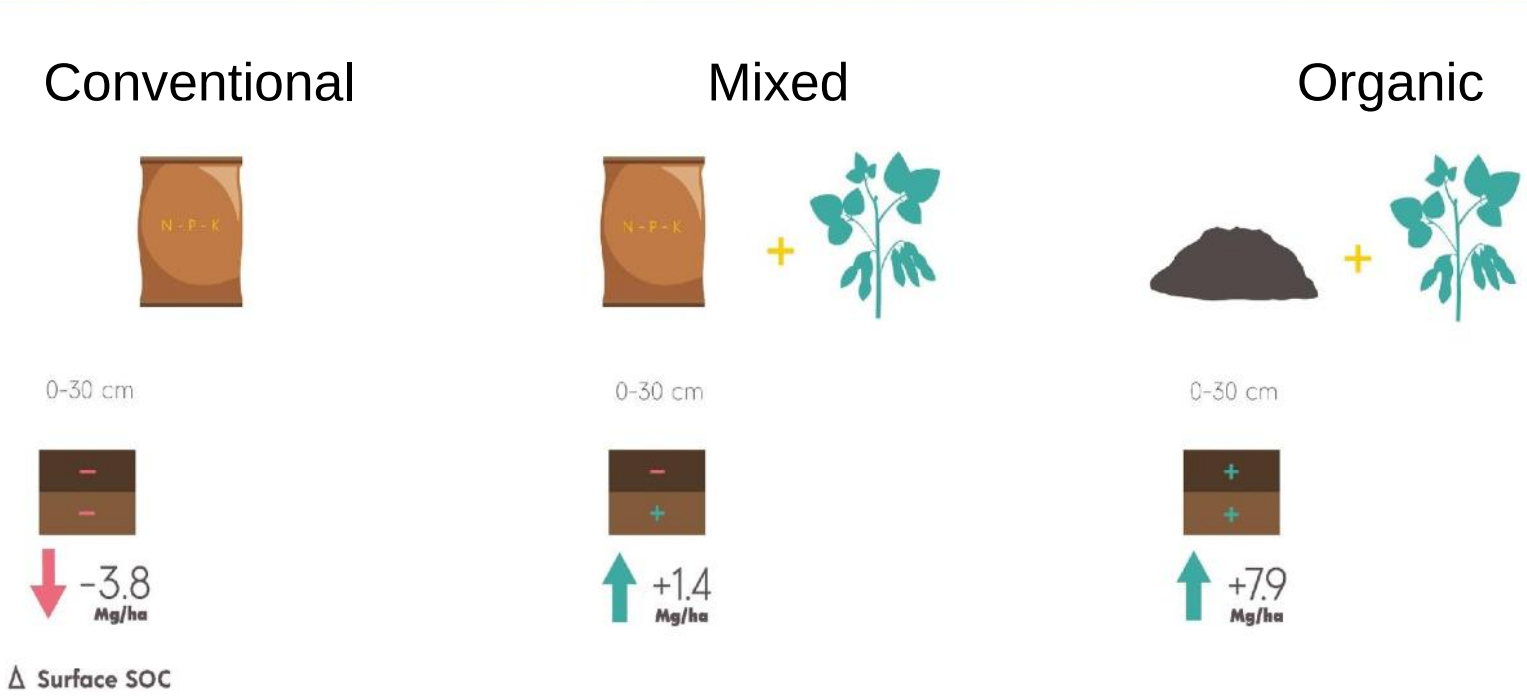
Farming Systems



Carbon inputs



Surface vs. Deep Soil Inventories of Carbon Sequestration



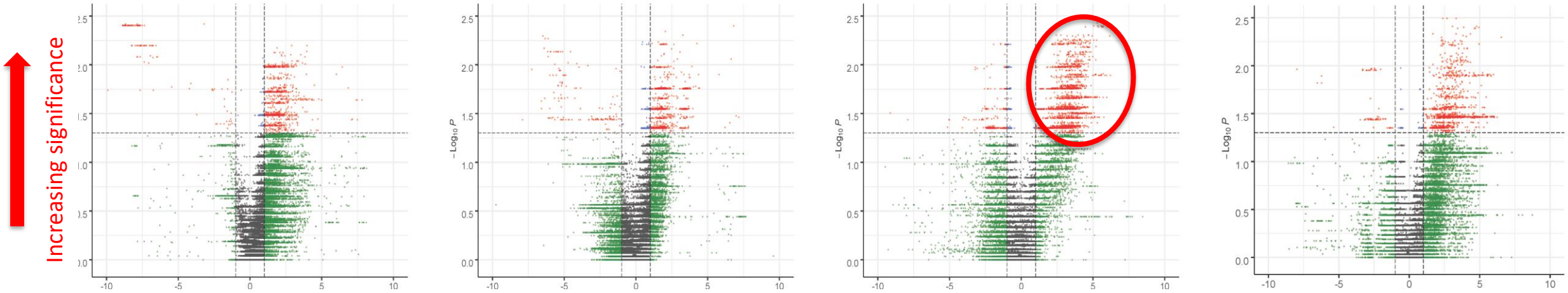
Surface vs. Deep Soil Inventories of Carbon Sequestration

So what about the soil microbial communities?

Metagenomic analysis: organic soils are significantly enriched in carbon cycling genes compared to conventional soils at all depths.

Soil depth

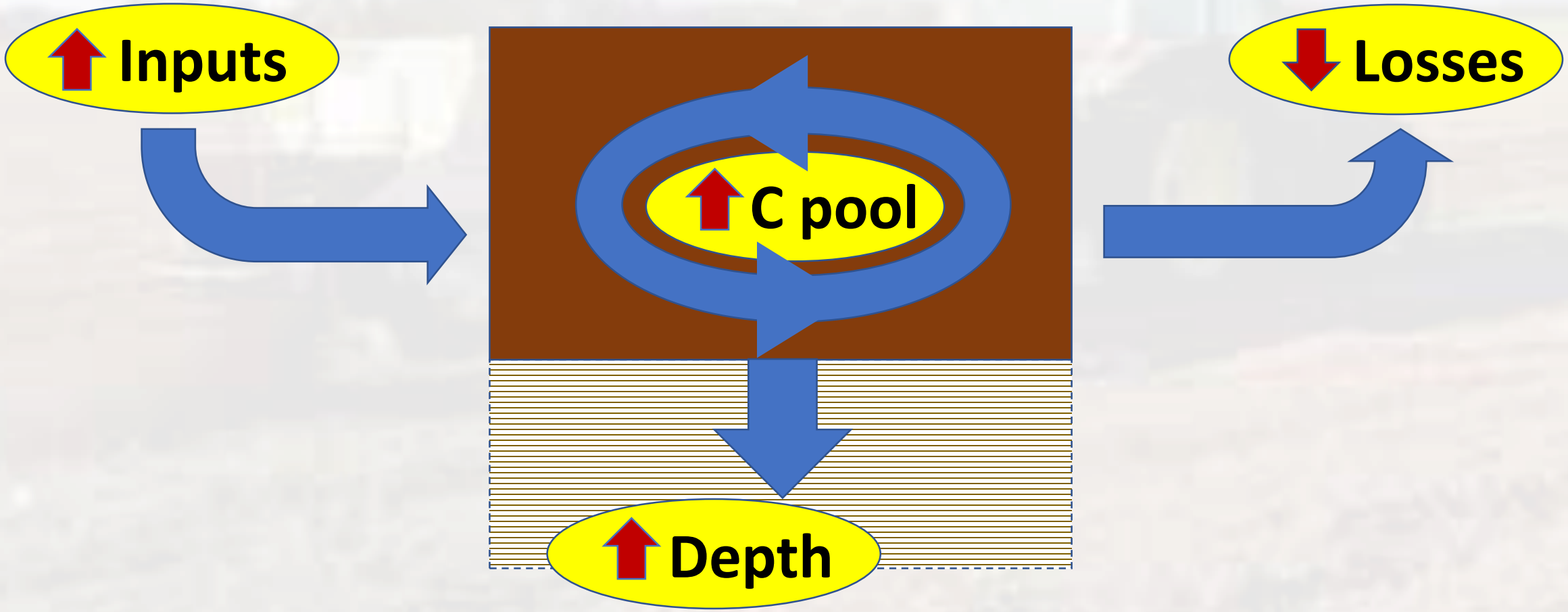
0-15 cm **15-30 cm** **30-60 cm** **60-100 cm**



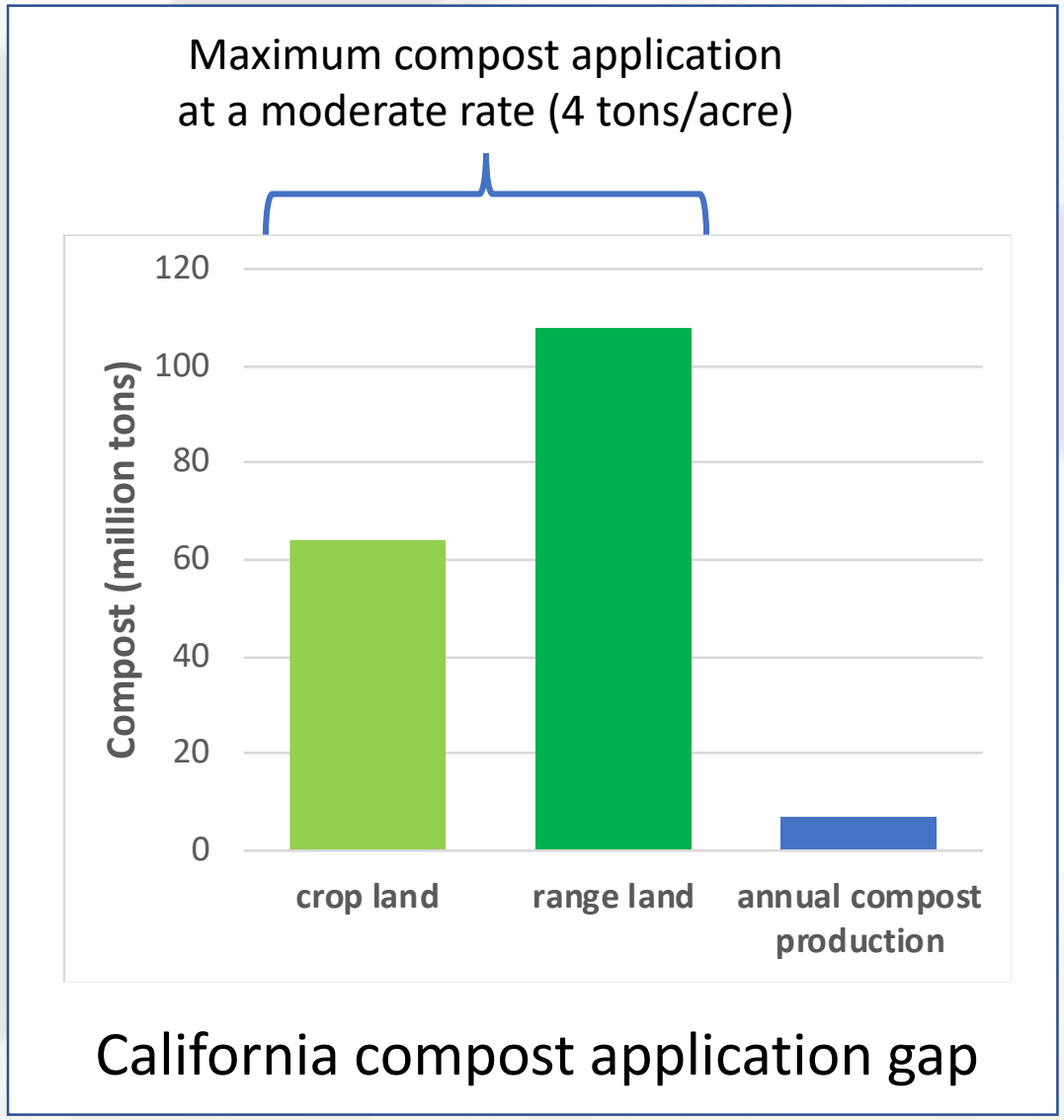
Log_2 fold change

(Relative abundance of assembled scaffolds)

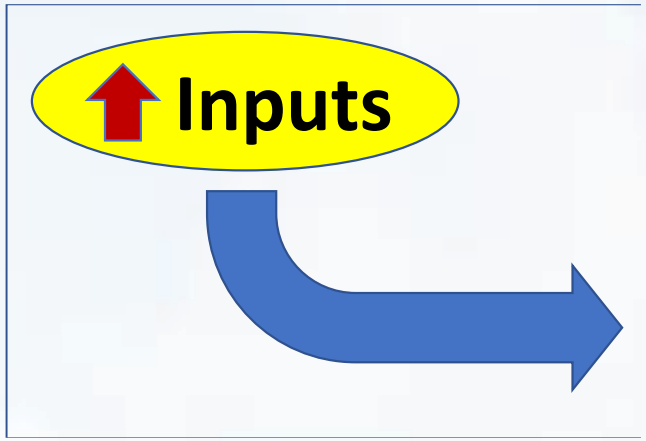
What can we do to increase C sequestration?



Add organic amendments

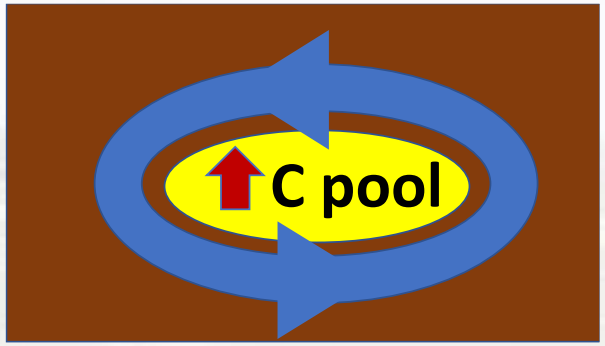


California compost application gap



- Slow release of nutrients over the course of the year
  - steady food supply for microbes
- Variety of organic compounds
  - promote metabolic diversity
  - feed range of soil cycles

Increase plant cover



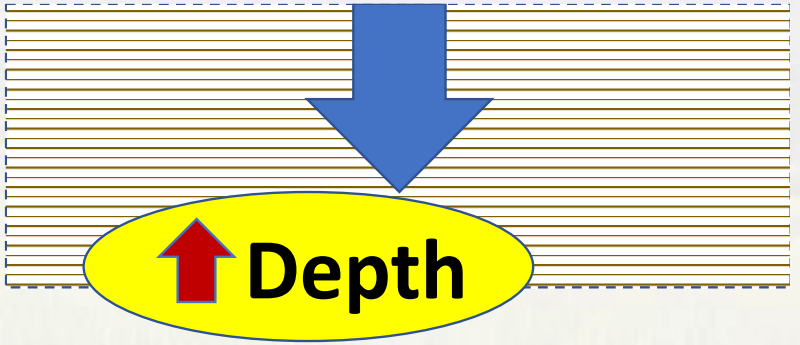
- Soil cover for more of year
  - steady food supply
- Variety of exudates/dead roots
  - promote metabolic diversity
  - feed range of soil cycles
- Legumes
  - N inputs
- Plant repellents (e.g mustard)
  - reduce pests/pathogens

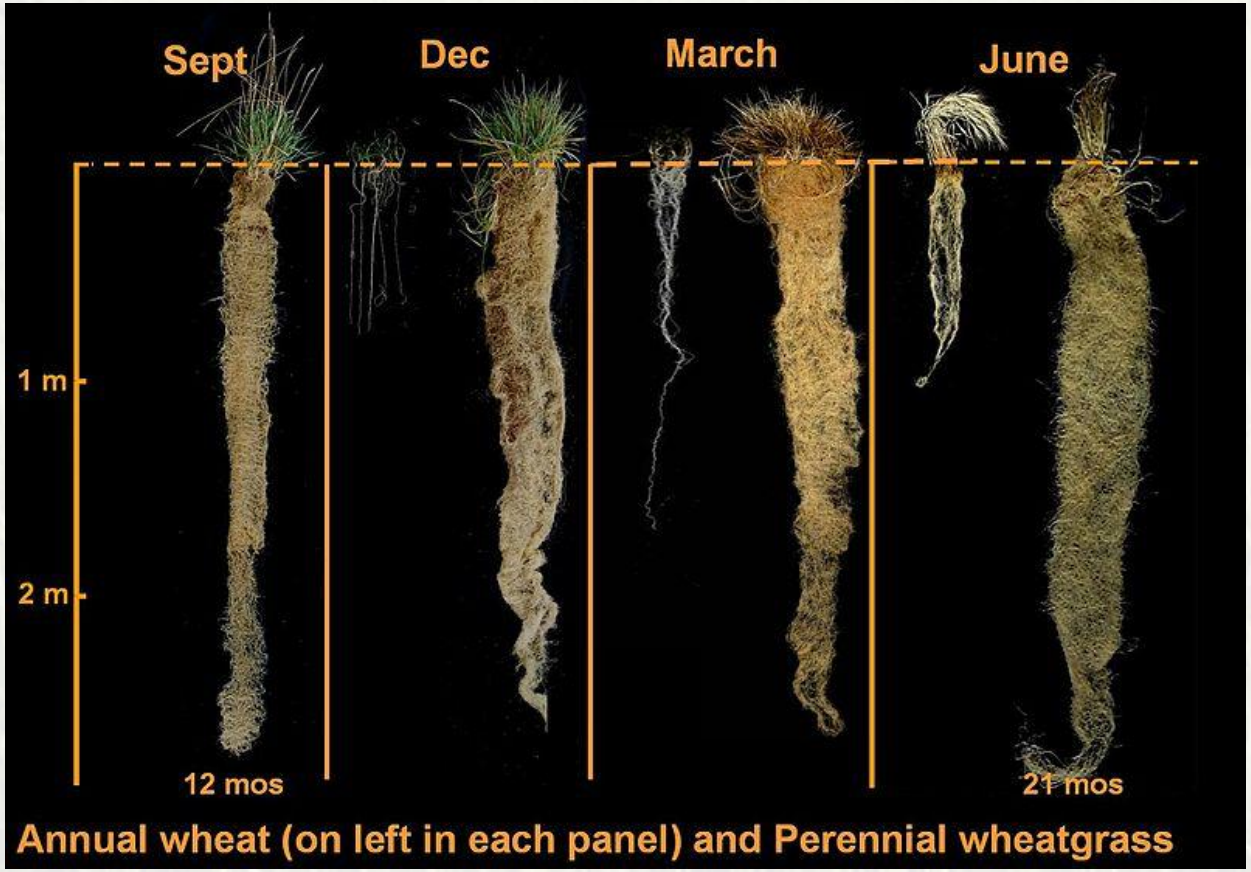
Intercropping

Cover crops

Crop rotations

Improve root systems

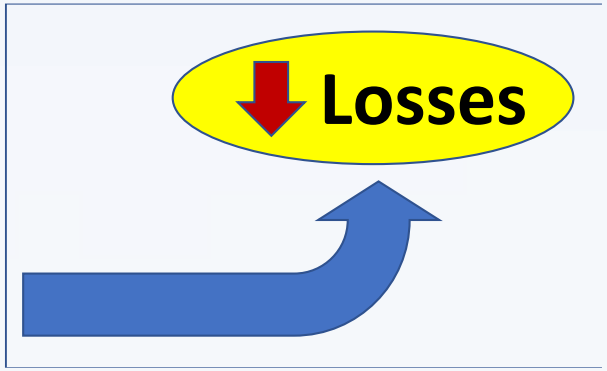




Annual crop varieties have been bred for systems that provide water and mineral fertilizers.

- Maximized
  - above-ground biomass (fruits, leaves etc)
- Reduced
  - root system extent
  - root colonization by beneficial organisms
  - root exudates
  - organic mass when plants die

Reduce disturbance



Benefits

- Stalk incorporation
- Weed suppression

Issues

- Loss of soil C
- Fungal symbiont network disturbance
- Compaction

Benefits

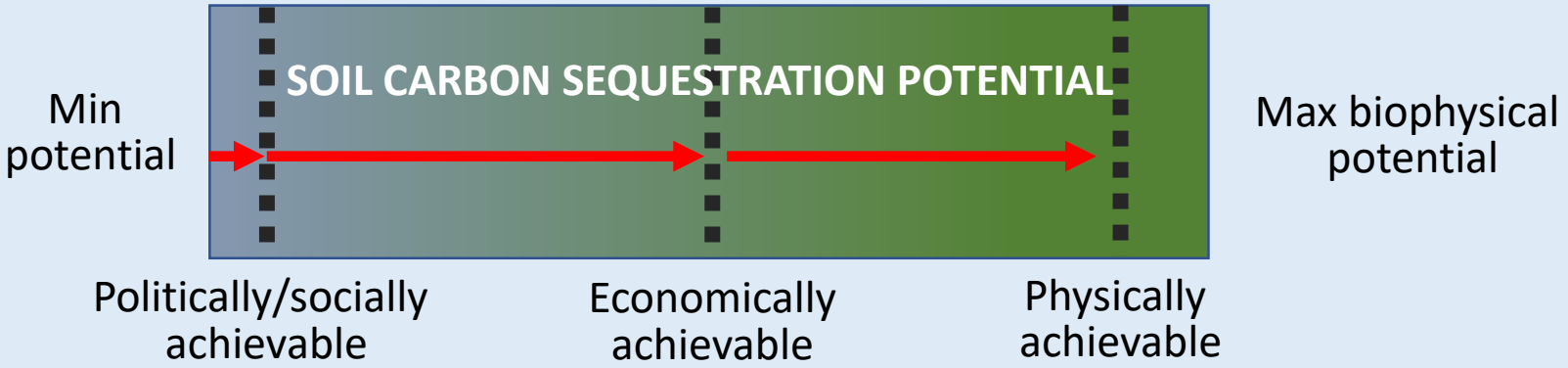
- Increased soil C near surface
- Improved soil structure

Issues

- Decreased soil C deeper?
- Herbicide use

How much C can soils sequester globally?

- 4‰ physically unrealistic
  - need too much N, P, K etc (close to double current fertilizer production)
- Other economical, political, social barriers



adapted from PNAS November 13, 2018 115 (46) 11652-11656

- 1-10% of current global CO_2 emission equivalents possible?

Take home messages

- Soil is a dynamic living system
- Need to consider deeper soil profiles when accounting for soil C
- To maximize C sequestration:
  - Add organic amendments
  - Increase plant cover
  - Improve root systems
  - Reduce disturbance

Acknowledgments

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