Steering soil microbiomes for better crop quality: the holy grail to improve human health?

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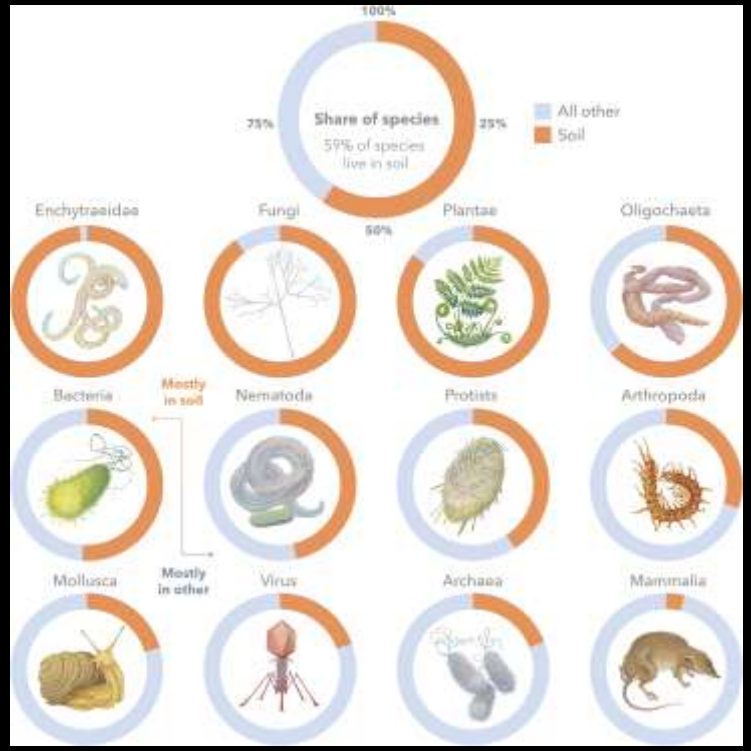
Soil are estimated to be home to 90% of world's fungi, 85% of plants and more than 50% of bacteria, making it the world's **most species-rich habitat**



Anthony et al. 2023 PNAS

2
ZERO
HUNGER

3
GOOD HEALTH
AND WELL-BEING

6
CLEAN WATER
AND SANITATION

12
RESPONSIBLE
CONSUMPTION
AND PRODUCTION

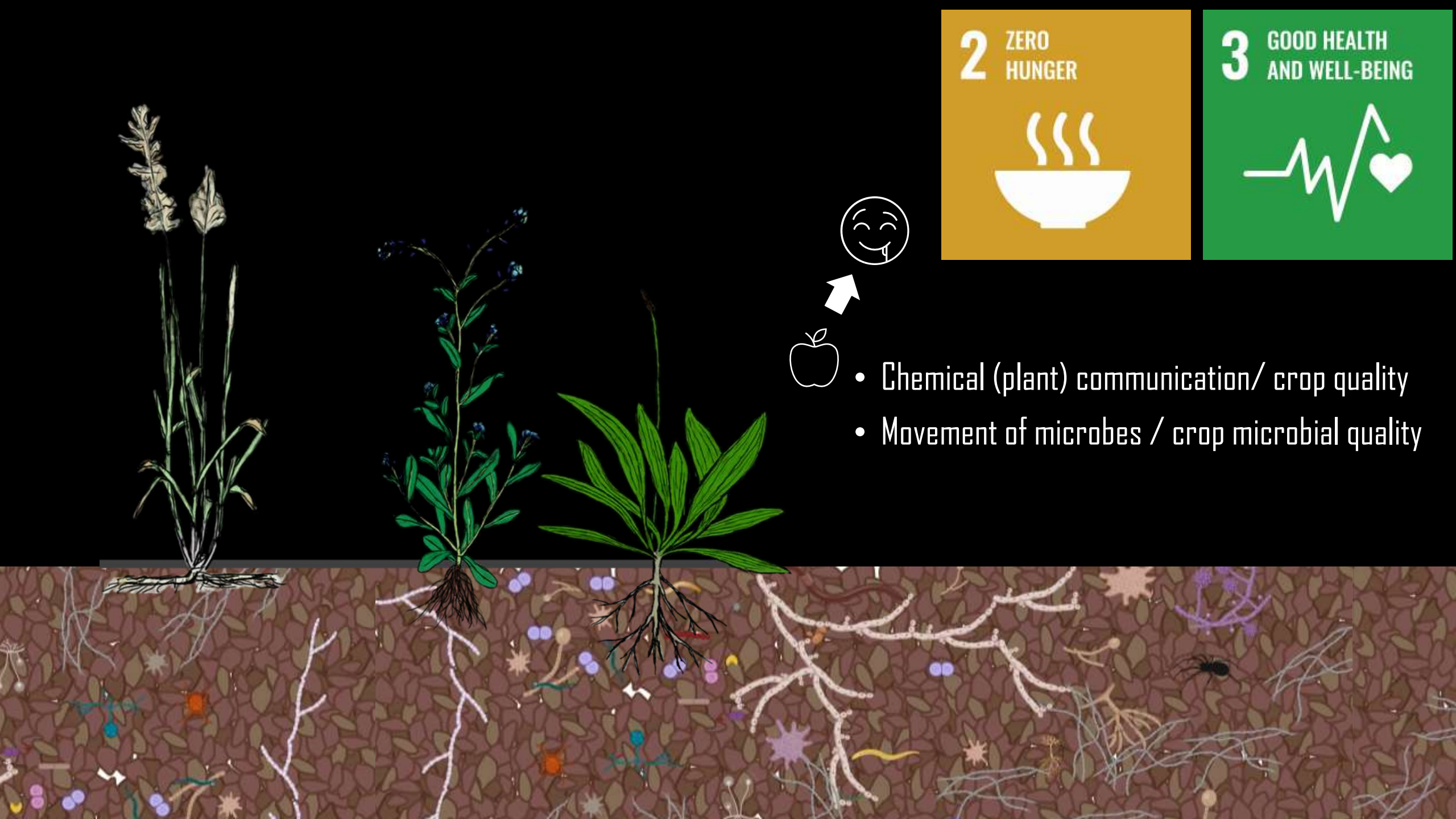
13
CLIMATE
ACTION

15
LIFE
ON LAND

Soils and us?

Besides direct transfer, we have food connecting us

- Chemical (plant) communication/ crop quality
- Movement of microbes / crop microbial quality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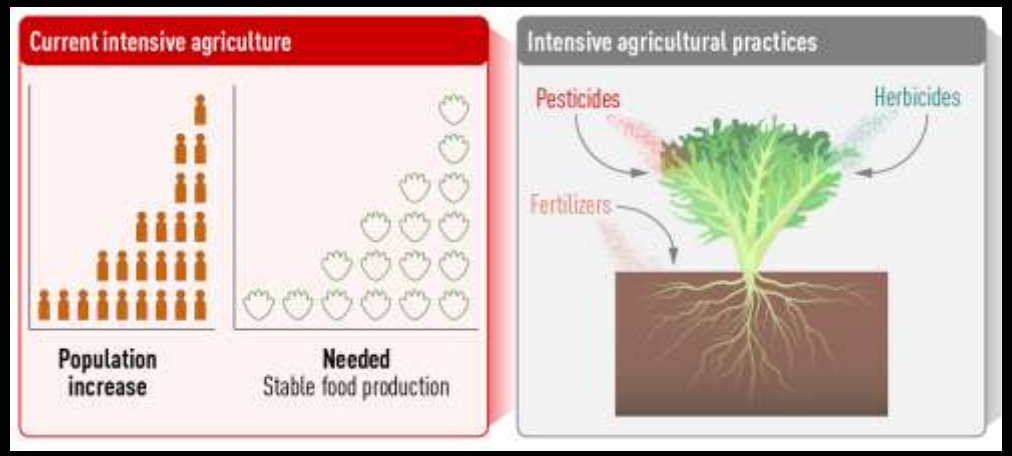
3 GOOD HEALTH AND WELL-BEING
• Chemical (plant) communication/ crop quality
• Movement of microbes / crop microbial quality


Current intensive agriculture
Population increase
Needed
Stable food production
Intensive agricultural practices
Pesticides
Herbicides
Fertilizers

The Food Security Dilemma

Agricultural Intensification

Increased use of fertilizers & pesticides

Heavy machinery & increased tillage

High-yielding crop varieties & long monocultures

The Food Security Dilemma

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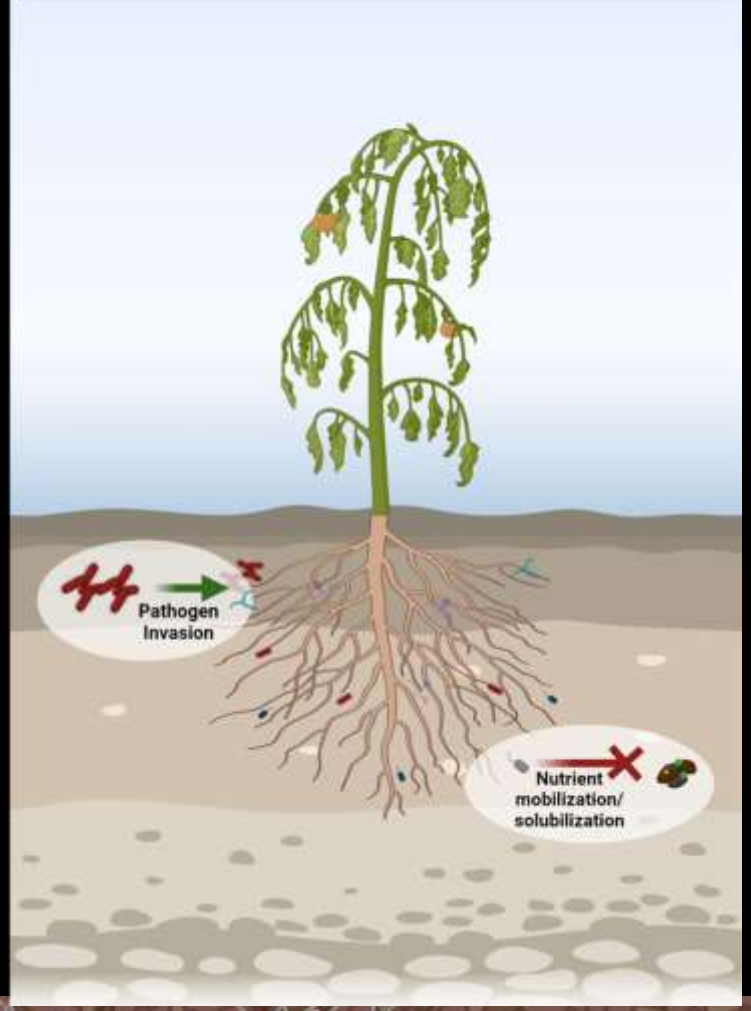
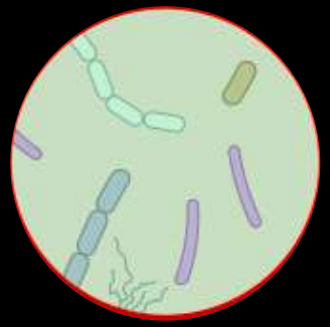
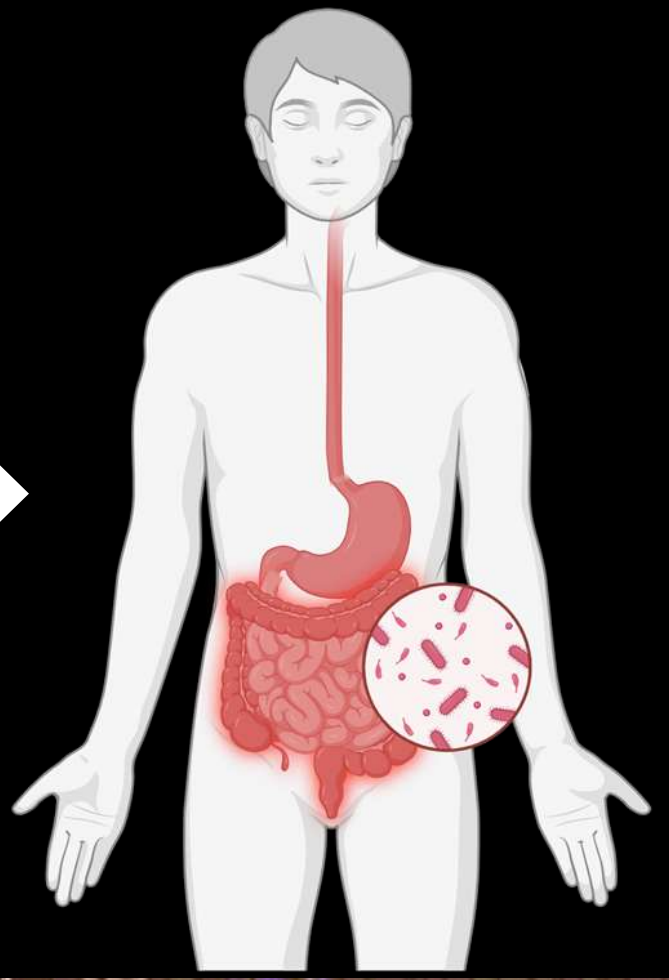
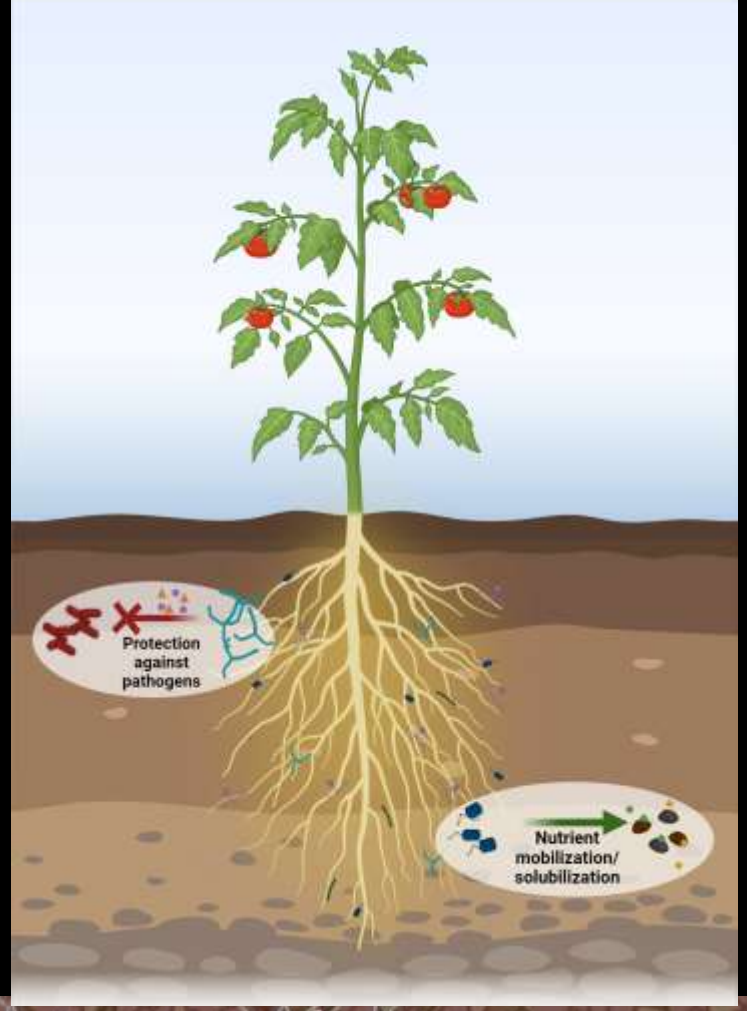
Quantity over quality



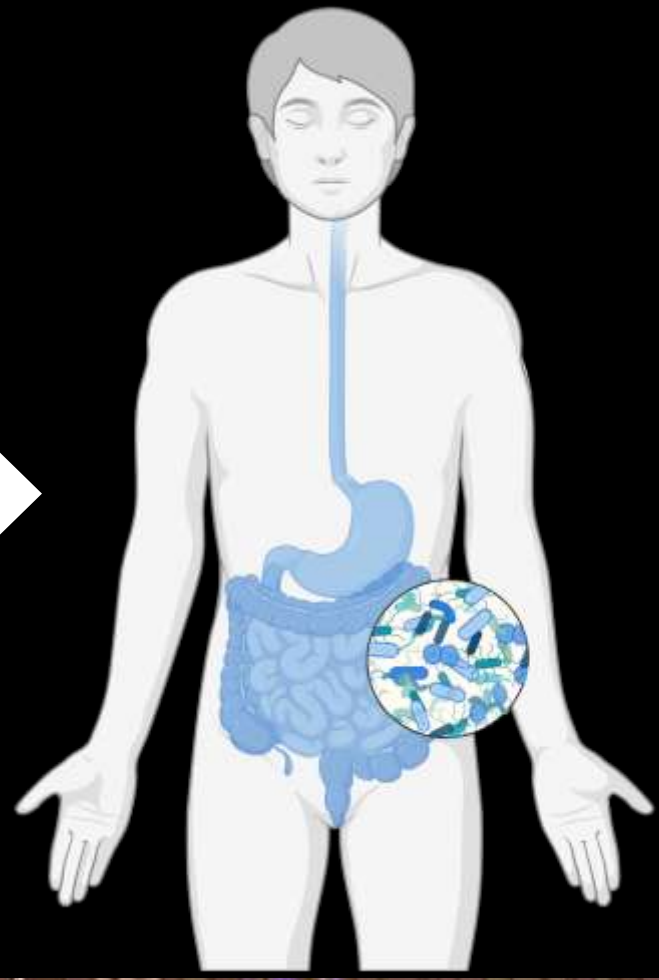
Reduced nutritional composition





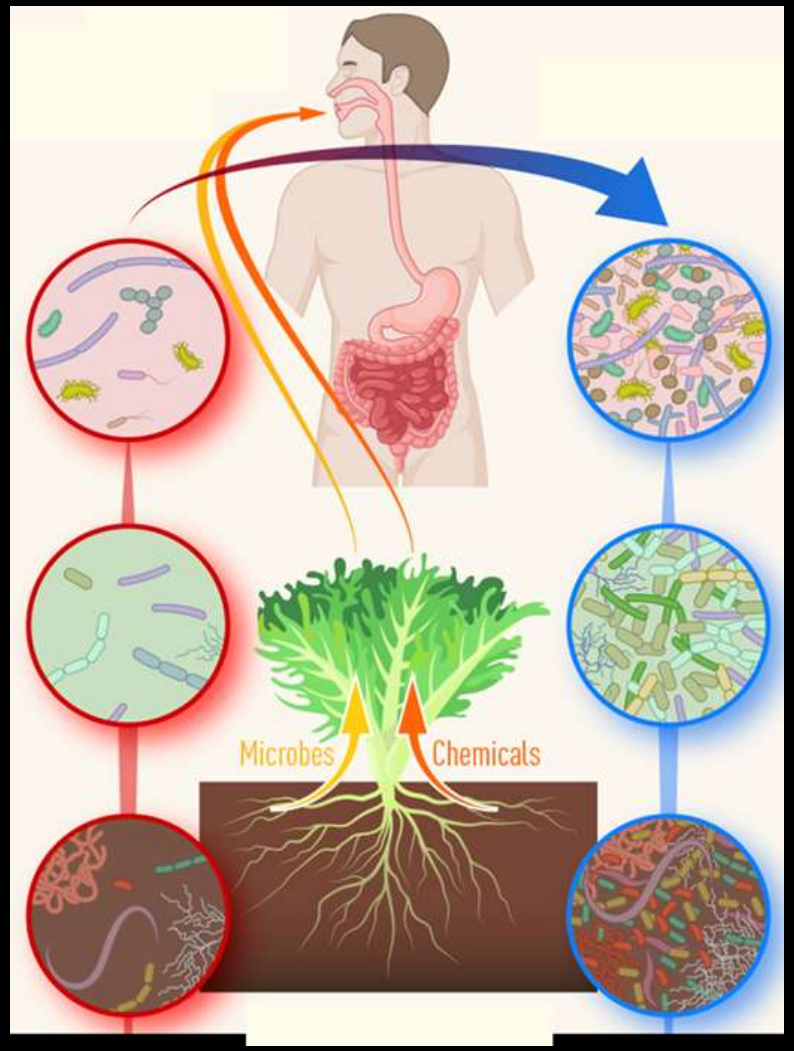


Adequate nutritional composition



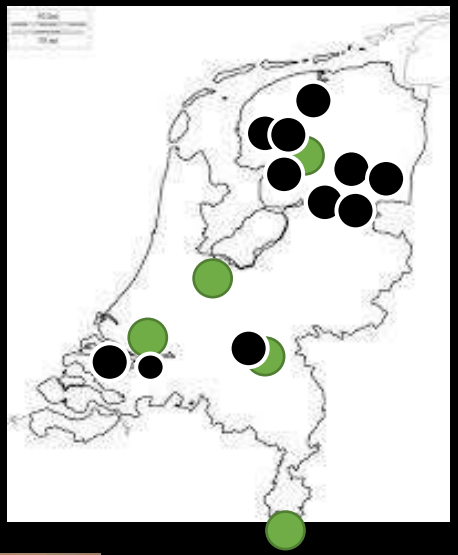
Soil scientists cannot change the world alone…

Interdisciplinary team of scientists Soils2guts



Scientific partners

Farmers and stakeholders



https://soils2guts.org/ https://www.linkedin.com/company/soils2guts/

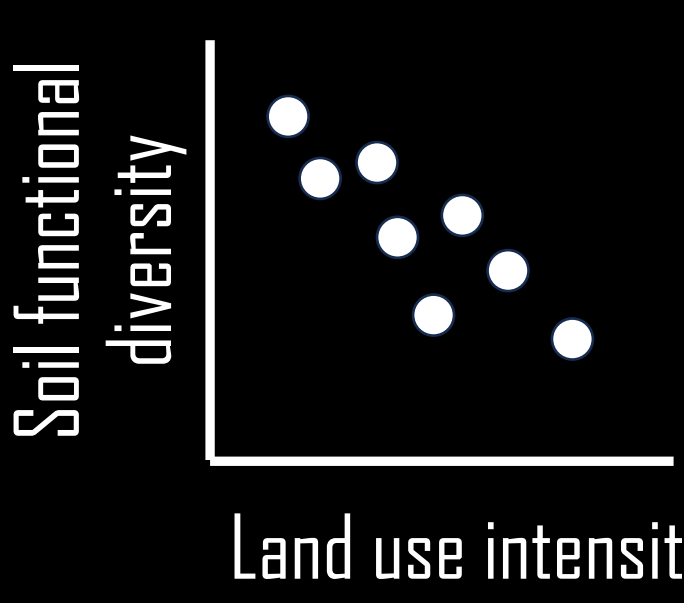
Task 1: Establishing baseline of crop microbiomes and quality

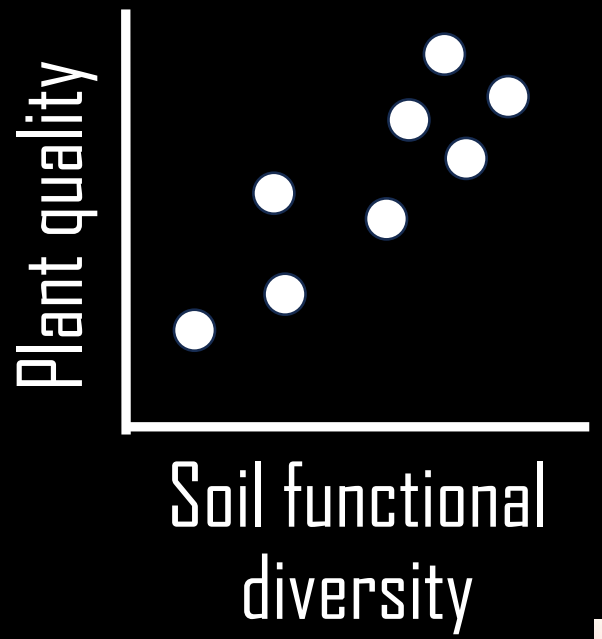
31 farms (ranging in land use intensity)

-19 carrot farms
-15 potatoes
-14 lettuce

→ Measure soil and plant quality and microbiomes
→ Test the effects of plant homogenates on synthetic (gut) communities and in ex-vivo gut models
→ Using selected fields, feed crops with contrasting quality to people and investigate health outcomes

Expectations





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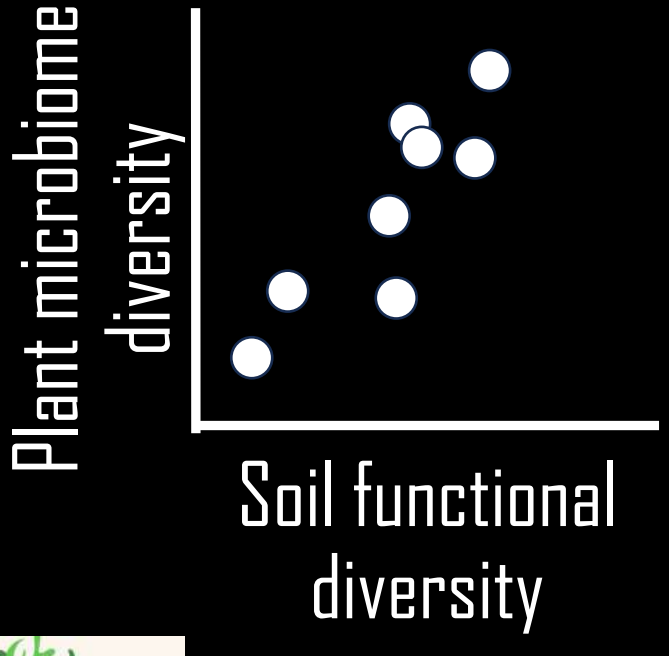

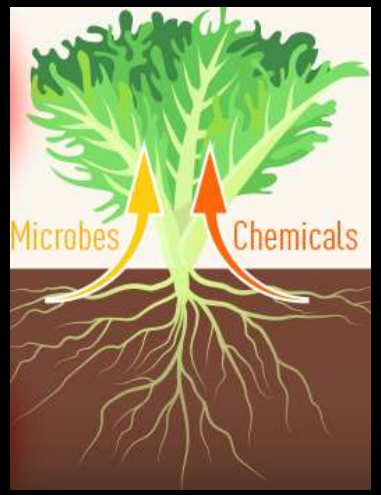

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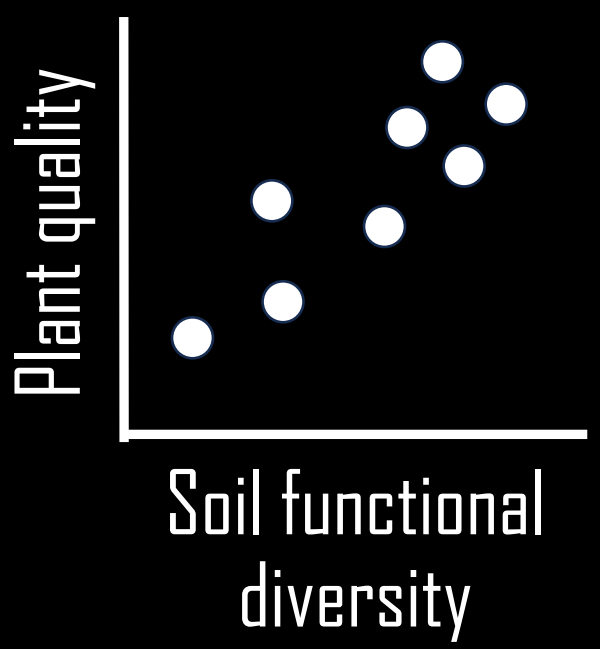

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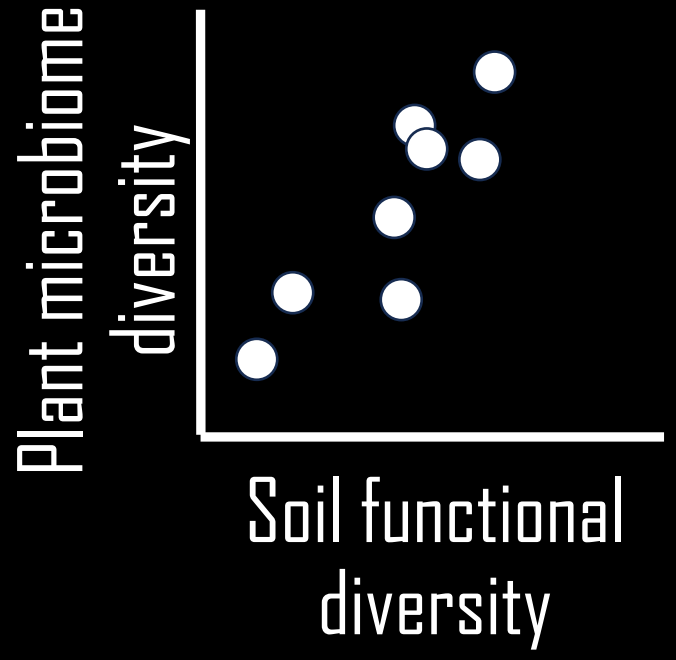
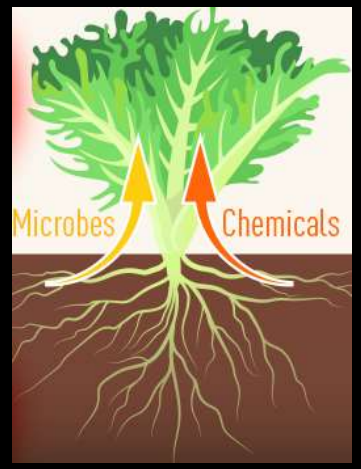
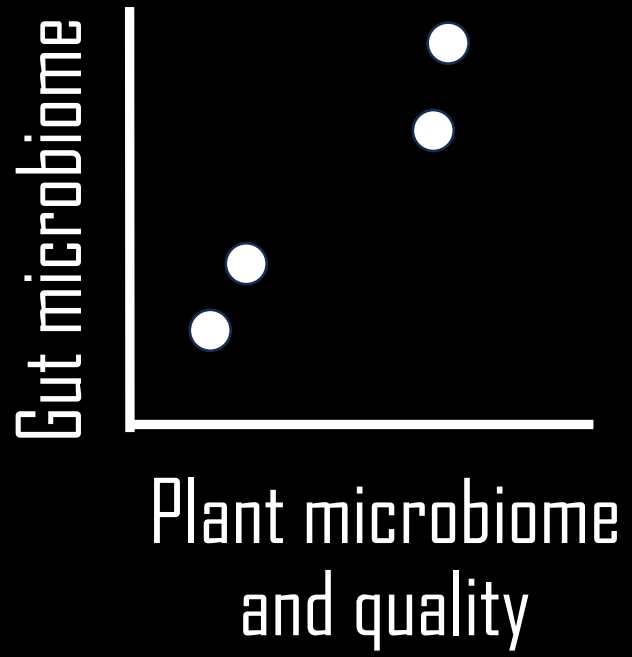
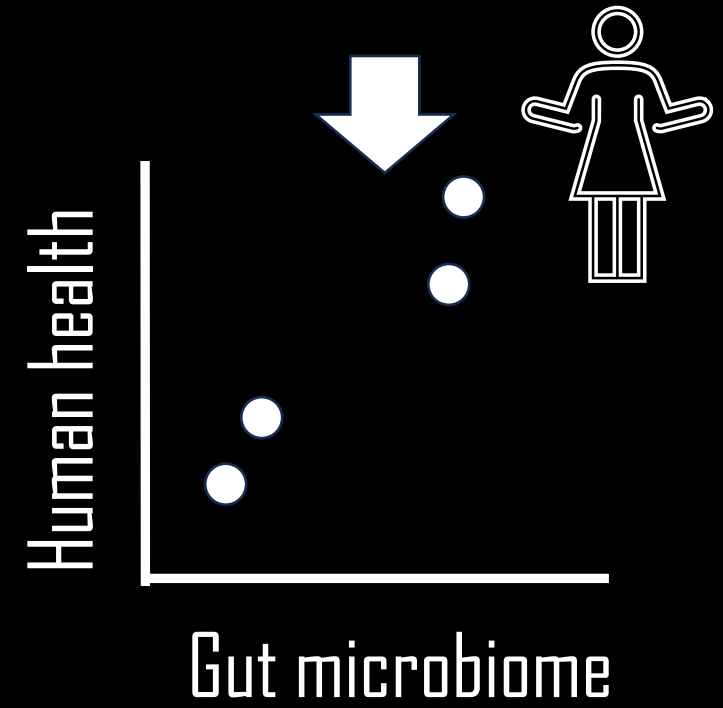
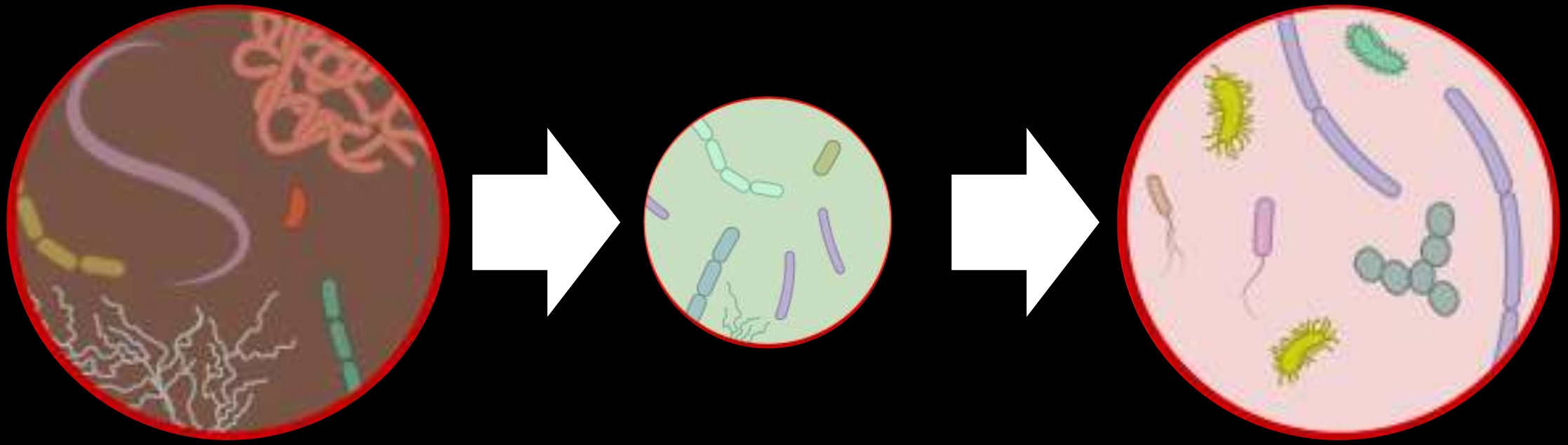






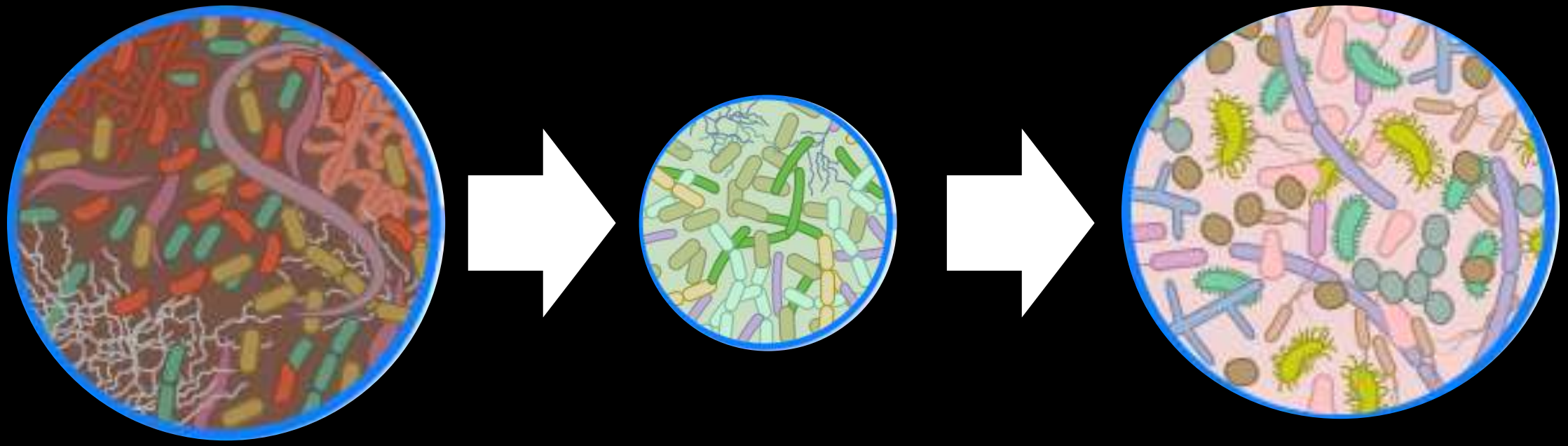


Low soil functional diversity leads to simple plant microbiomes and reduced plant quality



Which leads to perturbated gut microbiome and impaired gut health

High soil functional diversity leads to improved plant microbiomes and high plant quality



Which leads to balanced gut microbiome and adequate gut health

Results:

Fungal diversity negatively affected by intensive land-use across plant species

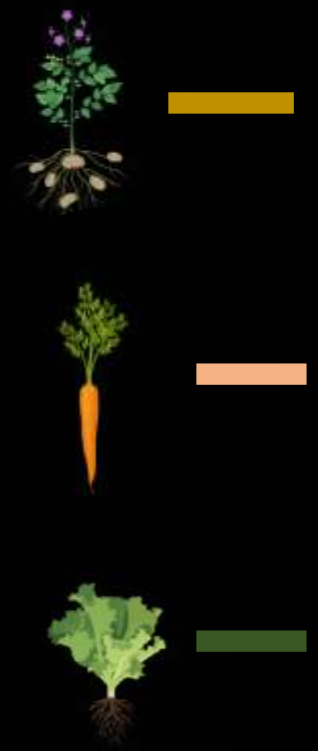
Soil fungal diversity

Land use intensity

Diversity of bacteria not affected

Soil bacterial diversity

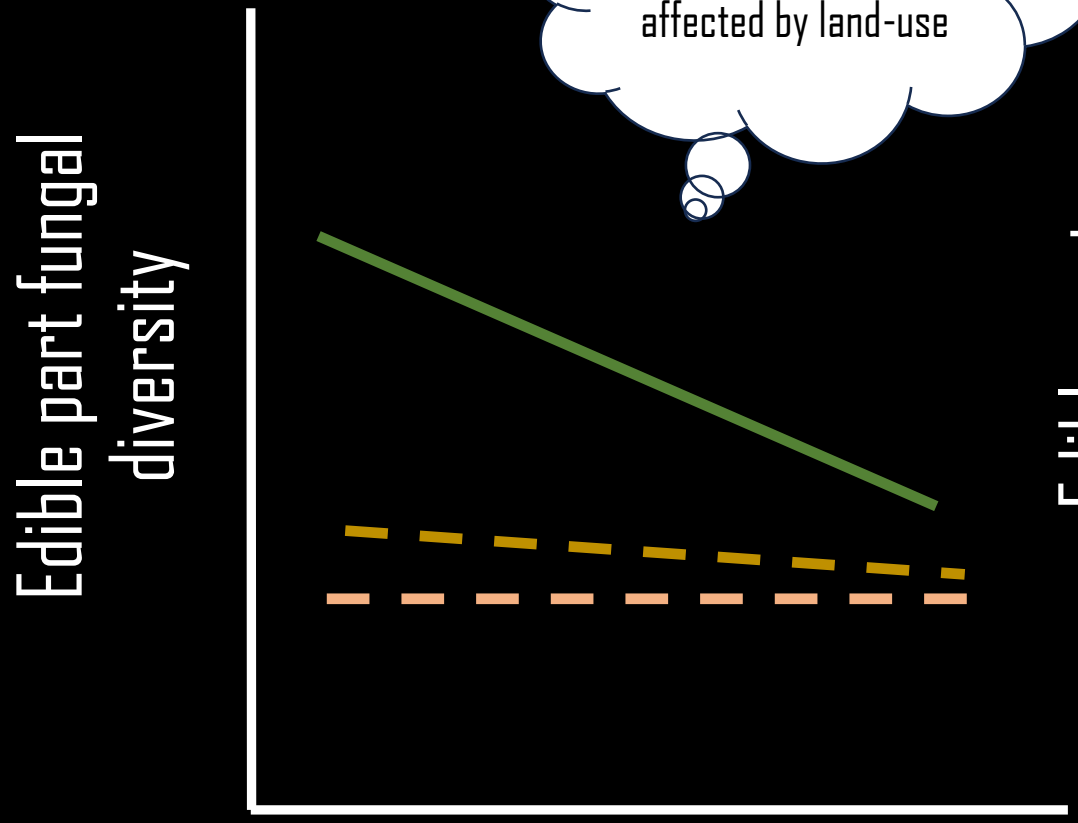
Land use intensity



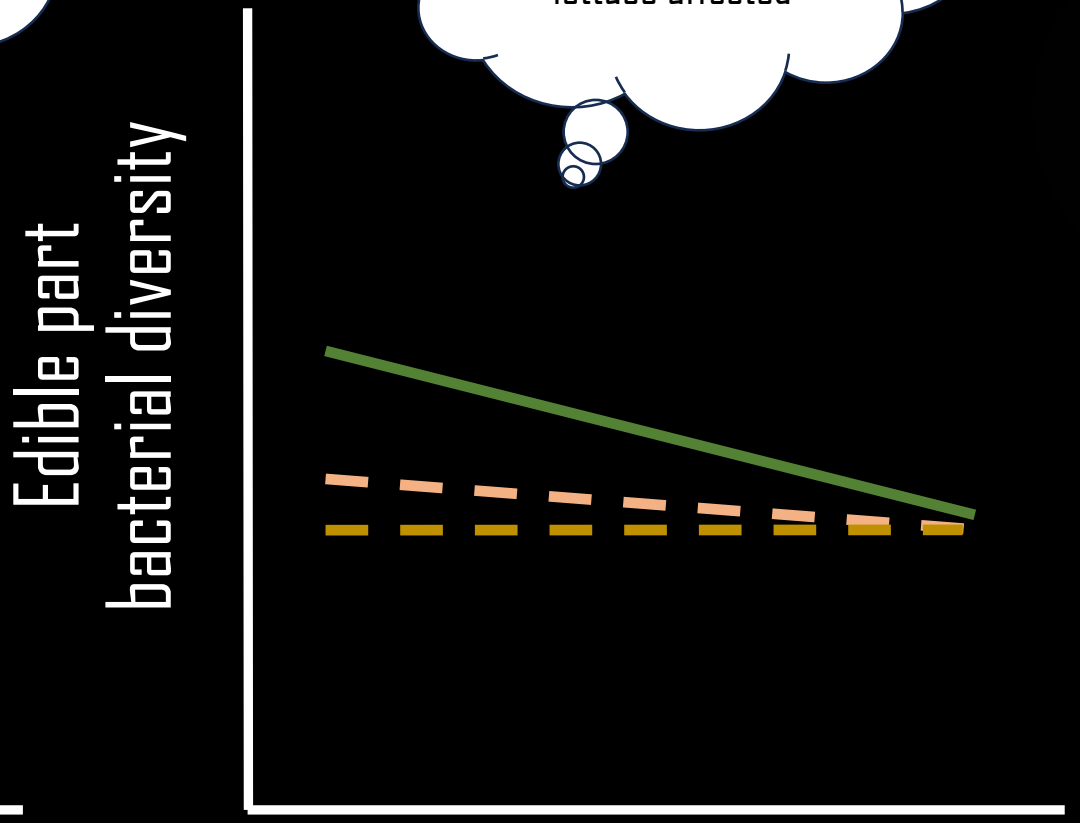
Siles-Asaff et al. in prep

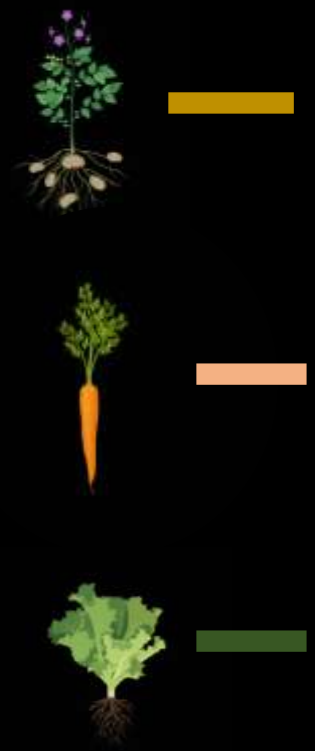
Results:

Fungi in the edible part of only lettuce affected by land-use



Same for bacteria; only bacteria in lettuce affected





Siles-Asaff et al. in prep

Results:

Edible part

Common **fungi** and **bacteria** between soils and edible part

Bulk soil

Rhizosphere soil

Edible part

Some common **bacteria** between soils and edible part but less than in lettuce

Bulk soil

Rhizosphere soil

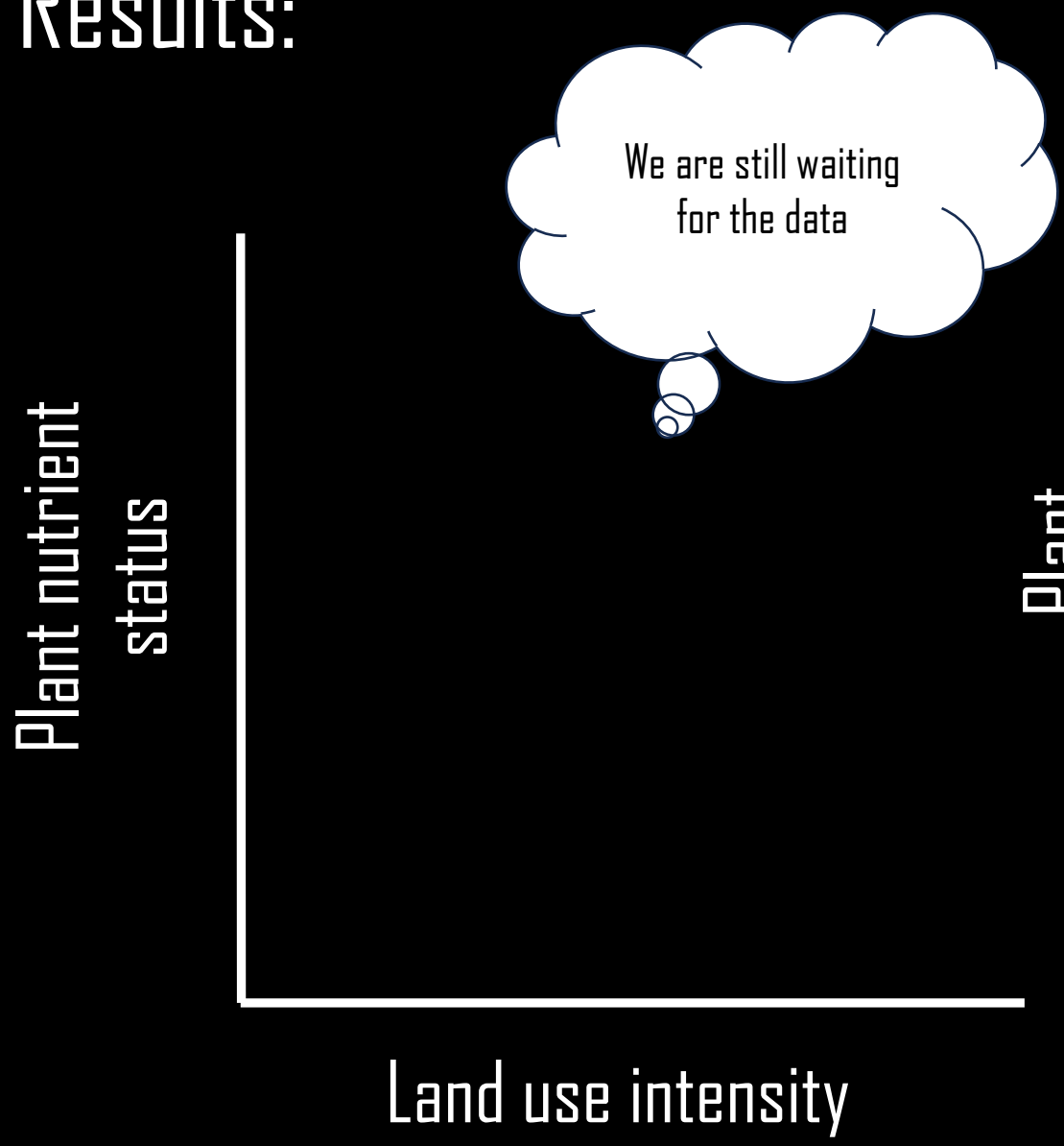
Siles-Asaff et al. in prep

Recap so far:

- Land use intensity affects (rhizosphere) soil fungal diversity across crop species
- Microbial diversity in edible part of lettuce affected by land use intensity
- More microbes transferred from soil to edible parts in lettuce than in potatoes and carrots

Siles-Asaff et al. in prep

Results:

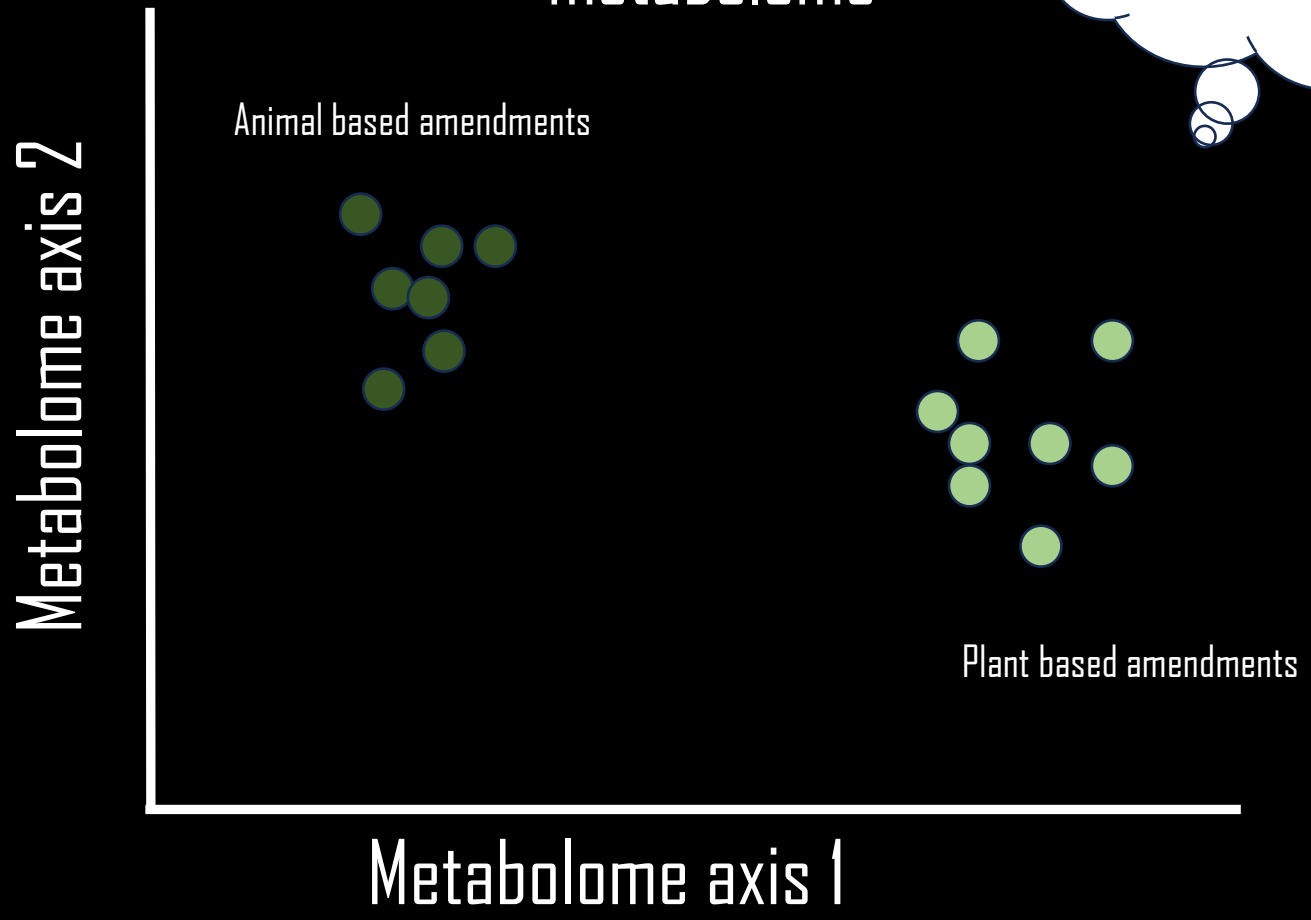


Elfferich et al. in prep

Results:

Plant metabolome

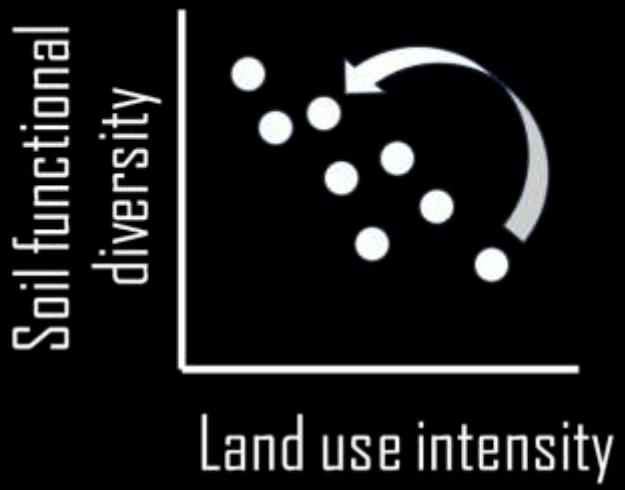
Lettuce metabolome is affected by amendment type



Elfferich et al. in prep

Steering for functional change

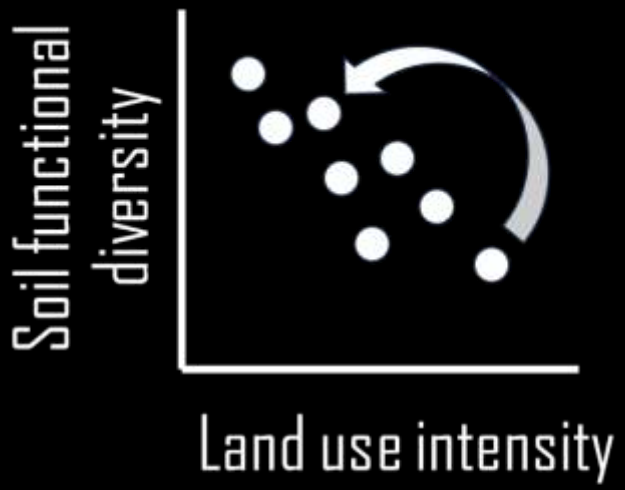
Systems change



Steering functionality

Steering for functional change

Systems change



Steering functionality

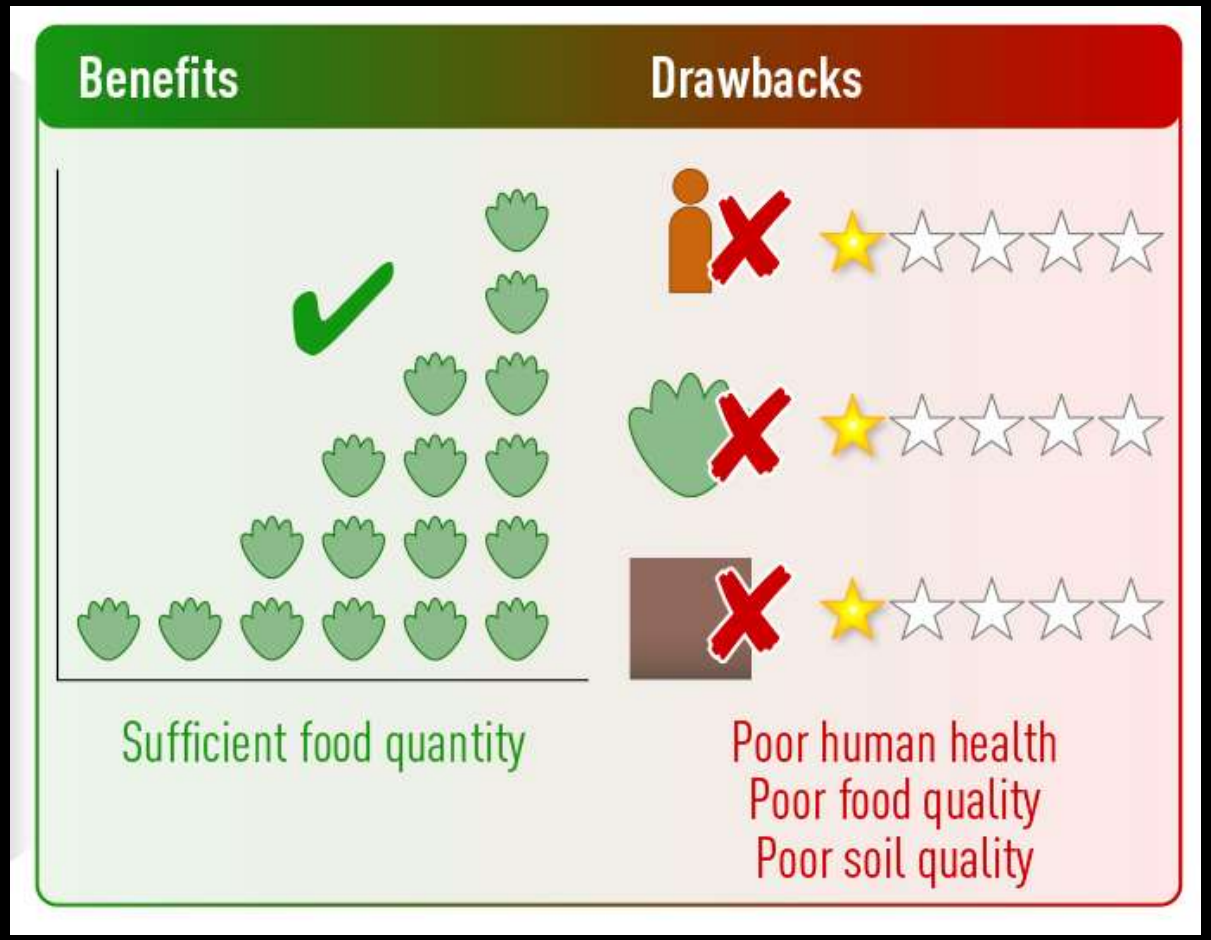
Systems change

Intensive agriculture:

Extensive agriculture

Systems change

Current intensive agriculture:



Future of agriculture:

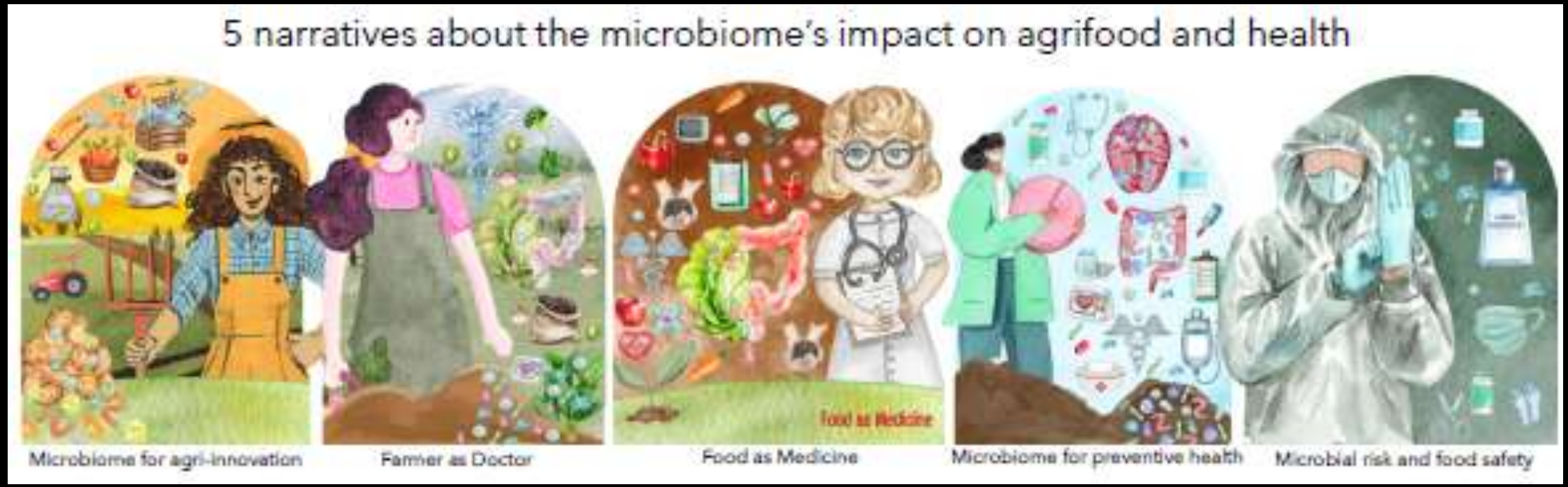
Systems change

-Needs **political will** to change

-Dutch farmers are interested in producing better quality food (if paid for it) & healthcare professionals are interested in the effects of food quality

-Obstacle is lack of **common efforts** and even terminology ('food', 'nutrition', 'produce')

Hepping et al., 2025, Sustainability Science

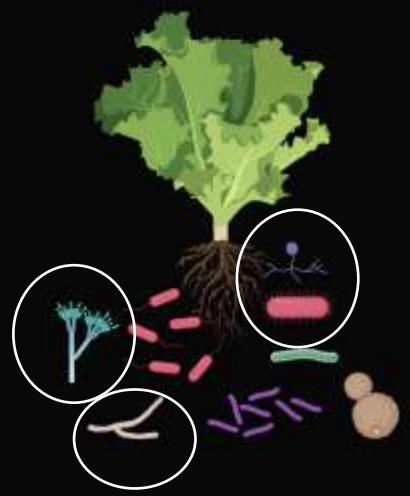


- Microbiome is an emerging bridge between agrifood and healthcare
- Stakeholders increasingly use narratives like Food as Medicine and Farmer as Doctor
- Unlocking integrative potential requires shared narratives and cross-sector collaboration, reframing health through an ecosystemic lens that connects soil, food, and human well-being.

Hepping et al., 2025, Sustainability Science

Steering for functionality – i.e. what can we do?

Good quality plant



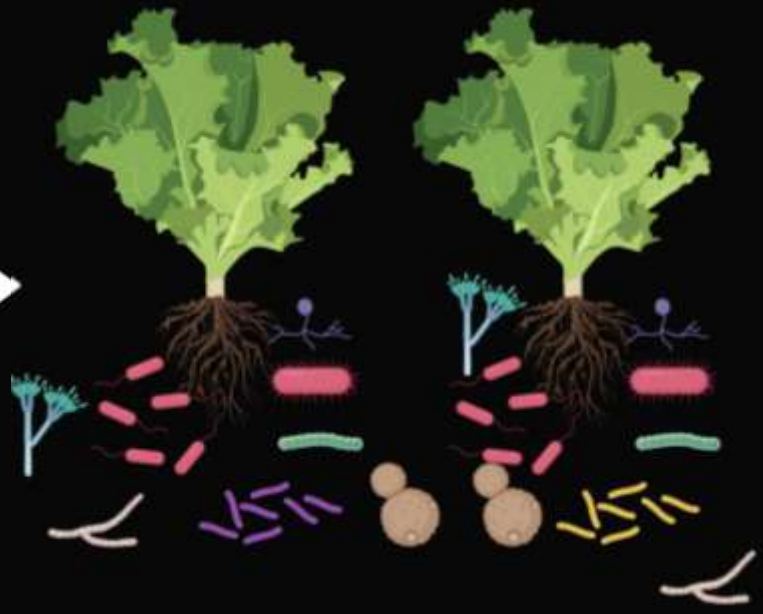
Bad quality plant

Identify microbiome members differing

Direct manipulation

Steering

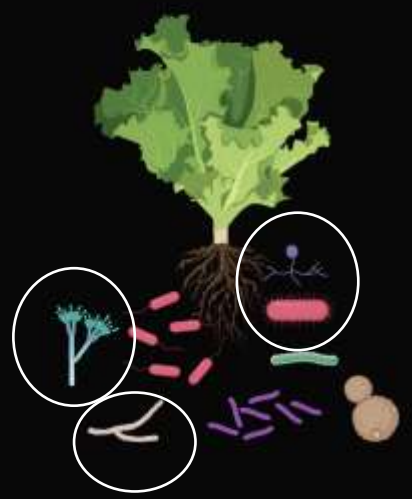
Good quality plants



Classified as Internal Unterm

Steering for functionality – i.e. what can we do?

Good quality plant



Bad quality plant

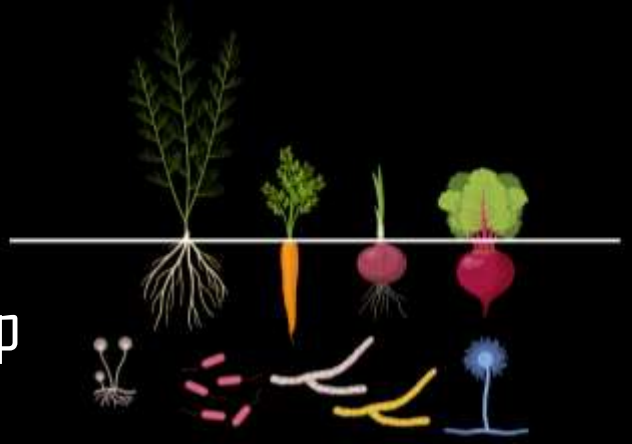
Identify microbiome members differing

- *Mortiriellales*, *Streptomycetes* and *Cercozoa* associated with 'good' soil and sugar, fatty acid, and amino acid content of the vegetables (own data)
- *Enterobacterales*, *Burkholderiales*, *Actinomycetales* and *Lactobacillales* shown to be shared between vegetable and human gut microbiomes (Wicaksono et al. 2023 Gut microbes).

Classified as Internal Unters

Steering functionality (inspiration)

+ C rich cover crop



Control

+ N rich cover crop

More: *Bacillales, Enterobacterales (*asparagus) and *Mortiriellales*

Liu, Hannula et al. 2021 Soil Biology and Biochemistry

+ wood chips

More: *Bacteoidota, Rhizobiales,* Fungi *(Sordariomycetes)*

Clocchiatti, Hannula et al. 2020 Applied soil ecology
Clocchiatti, Hannula et al. 2021 Environmental Microbiology

Recap

-Soils and humans are connected directly and through plants (i.e. food)
-Effects of plant quality and plant microbiome on human gut microbiome
-We can either steer the soil (and plant) functionality or change the system

→ We need to work together in an inter- (and trans-) disciplinary way!

https://soils2guts.org/ https://www.linkedin.com/company/soils2guts/

Tak!

Netherlands Organisation for Scientific Research

Soils 2Guts