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Food and Agriculture Organization of the United Nations (FAO)

GLOBAL SYMPOSIUM ON SOIL BIODIVERSITY | 20-22 February 2021

How crop production practices impact the soil microbiome – implications for ecosystem health, climate change and human well-being?

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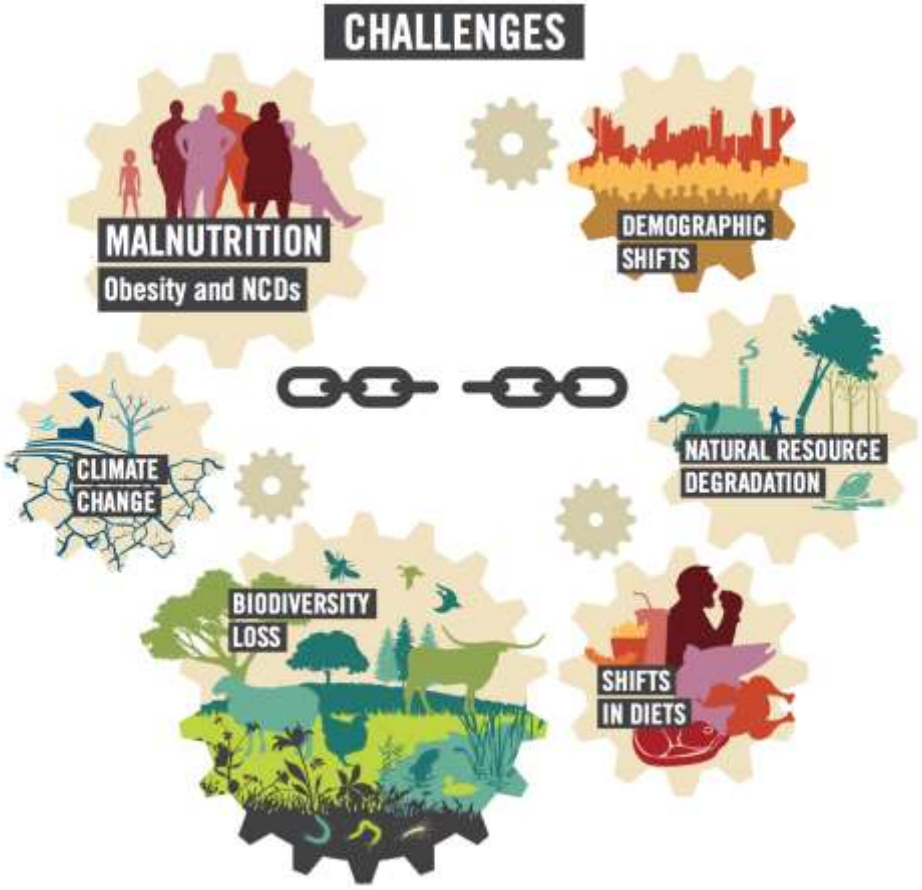
Microbiome: The Missing Link?



FAO reviews on Microbiome

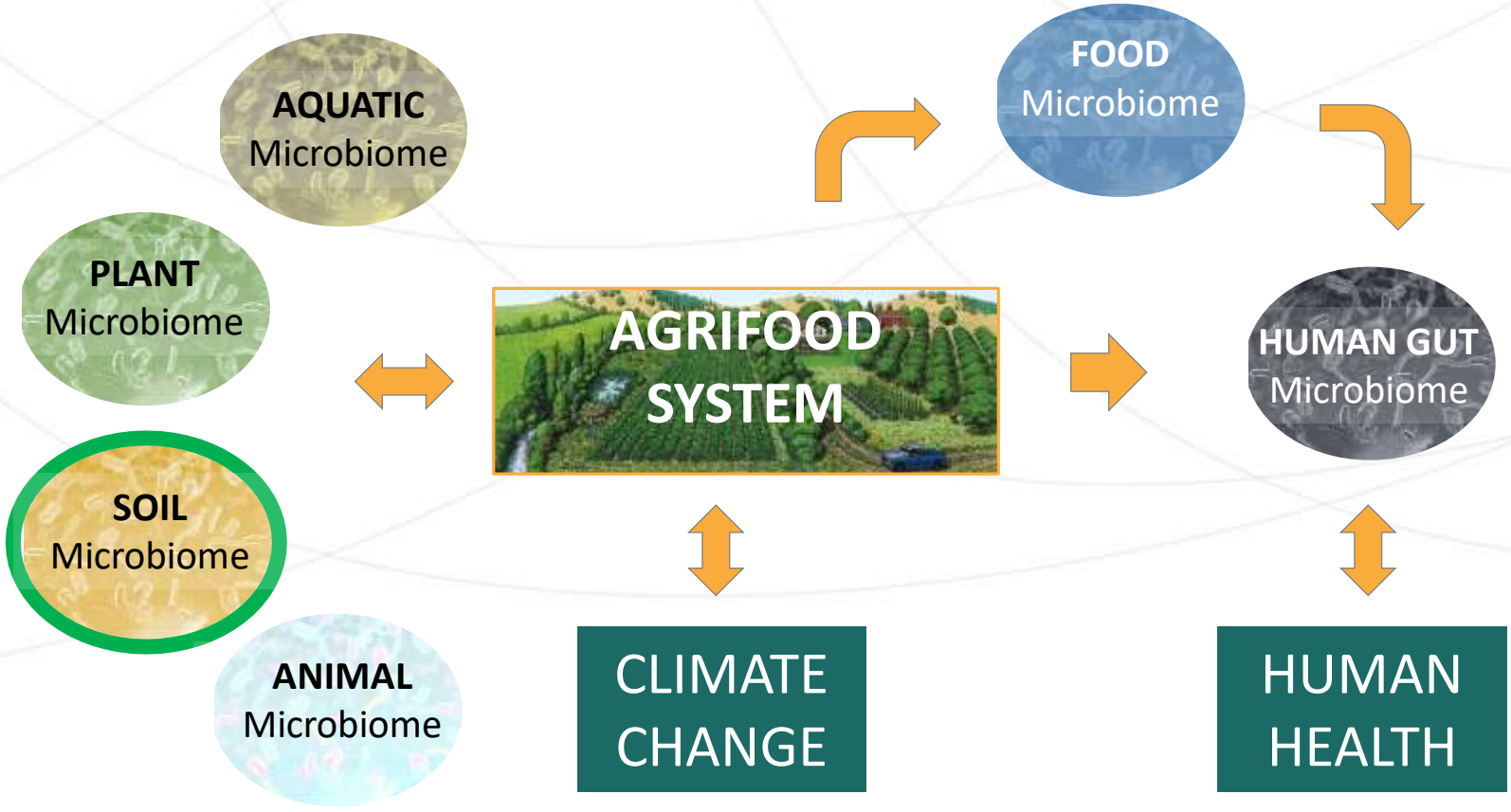


Image sources:

Examples of Diversified Farming Systems. UC Berkeley Food Institute. https://food.berkeley.edu/about-us/centers/dfs/examples-of-diversified-farming-systems/

Microbiome and SDGs

Sustainable Development Goals

Image sources:

Brtitish Veterinary Association https://www.bva.co.uk/news-and-blog/blog-article/covid-19-has-there-ever-been-a-more-critical-need-for-one-health/

SDG icons: https://sdgs.un.org/goals

Aims of the FAO microbiome working group and the work on soil

Build a process based on science to *promote debate to inform policy*

Explore connections between crop production systems, the climate system and human health from the perspective of the soil microbiome

Methodology

- **Narrative literature review**
  - Soil microbiome, ecosystem services and climate change
  - Farming practices ➔ soil microbiome
- **Systematic literature review, 2000 articles**
  - Farming practices ➔ soil microbiome ➔ climate change or human health

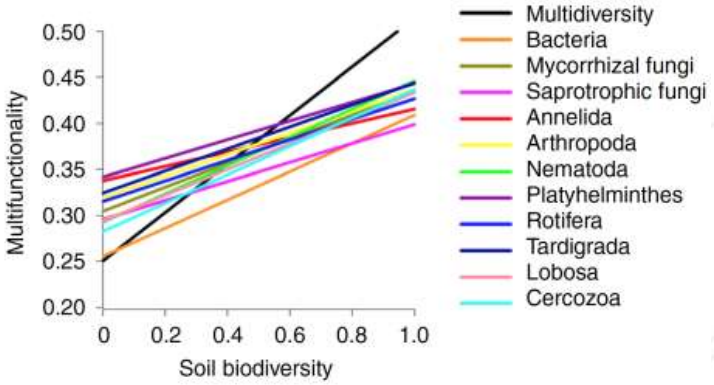
+ *Land use*
+ *Tillage*
+ *Agro-system diversification (plant diversity, crop rotations, cover crops)*
+ *Crop residue management*
+ *Selection of variety*
+ *Irrigation*
+ *Fertilization*
+ *Pest management*
+ *Microplastics*

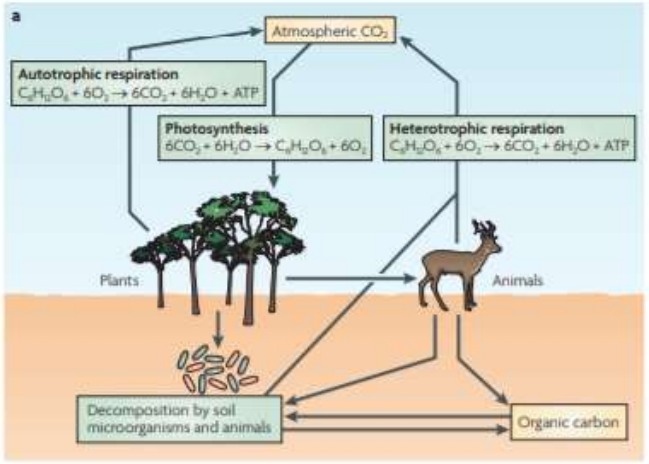
- **Focus groups : microbiome experts from research, industry and policy**
  - Research needs/opportunities
  - Opportunities and risks with using soil microbiome
  - Informing policy

Soil microbiome - Key messages (I)

- Soil microbiome plays **pivotal roles** in ecosystem health, agroecosystems, GHG emission and C storage

- **Strong connections** between some crop production practices, the soil microbiome, and their effects on GHG fluxes, C storage and soil functionality



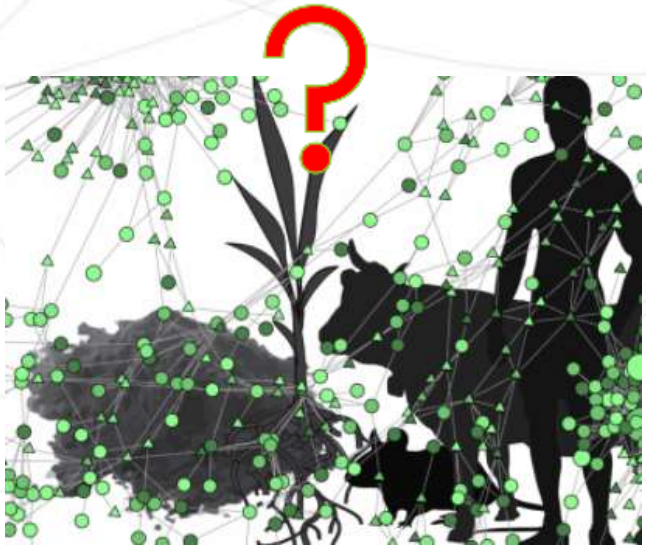


Graph source: Delgado-Baquerizo, M., Reich, P.B., Trivedi, C., Eldridge, D.J., Abades, S., Alfaro, F.D., Bastida, F., Berhe, A.A., Cutler, N.A., Gallardo, A., García-Velázquez, L., Hart, S.C., Hayes, P.E., He, J.-Z., Hseu, Z.-Y., Hu, H.-W., Kirchmair, M., Neuhauser, S., Pérez, C.A., Reed, S.C., Santos, F., Sullivan, B.W., Trivedi, P., Wang, J.-T., Weber-Grullon, L., Williams, M.A. & Singh, B.K. 2020. Multiple elements of soil biodiversity drive ecosystem functions across biomes. *Nature Ecology & Evolution*, 4(2): 210–220.

Singh, B.K., Bardgett, R.D., Smith, P. & Reay, D.S. 2010. Microorganisms and climate change: Terrestrial feedbacks and mitigation options. Nature Reviews Microbiology, 8(11): 779–790. https://doi.org/10.1038/nrmicro2439

Soil microbiome - Key messages (II)

- **Underexplored areas:**
  - Role of certain microorganisms in soil interactions (e.g. protists)
  - Soil microbial necromass contributions to soil C storage and sequestration
  - Plant variety and rhizosphere microorganisms in breeding programs
  - Effect of microplastics on soil microbiome



- **Strong conceptual frameworks** for relationship between crop production, soil microbiome and **human health**

- Need for **interdisciplinary collaboration** across ecosystems

Innovation opportunities for a sustainable bioeconomy

- **Diversity** of genes and functions in the soil microbiome = **opportunities**

<u>Soil microbial innovation market figures</u>

- Microbial segment of biologicals: **USD 4.3 billion in 2020 → USD 12 billion by 2027**
- Biosequestration and bioremediation microbial innovations: potential impact of **USD 15 to 30 billion** over next 20 years

What do these innovative solutions look like in the world of crop production?

Nurturing a healthy soil microbiome requires

multiple and complementary approaches:

Agricultural management practices

Inoculates + in situ microbiome engineering (probiotics, prebiotics)

Role of FAO: Helping bridge the gap between science, innovation and policy

Recommendation areas for policy related to (soil) microbiome:

- Public support for research, development and innovation (participatory approaches)
- Education and communication
- Commercialization and demand of microbiome innovations (practices, products, services)
- Regulatory framework

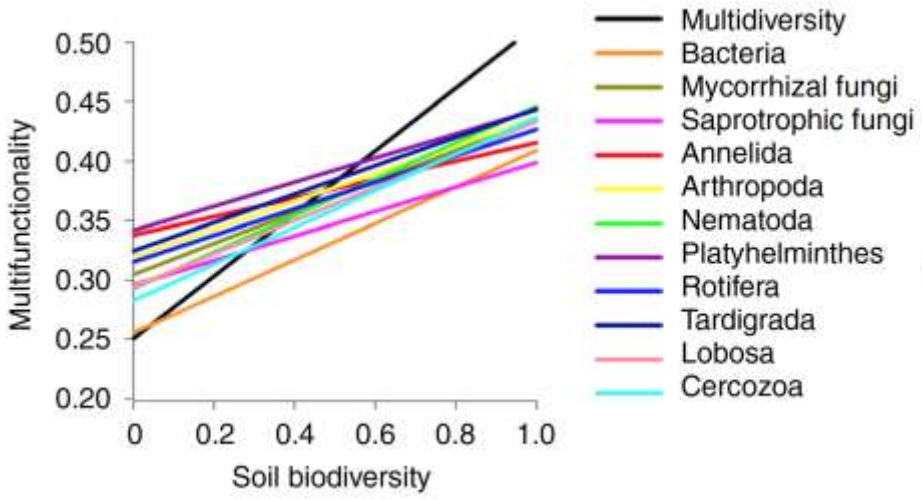
FAO can act as a dependable intermediary between the scientific community and policy makers worldwide to identify and share innovative ideas and solutions

Thank you for your attention

Why the soil microbiome matters for a healthy planet and ecosystem services

- The soil microbiome carries out fundamental ecosystem functions

Multifunctionality and Ecosystem Services



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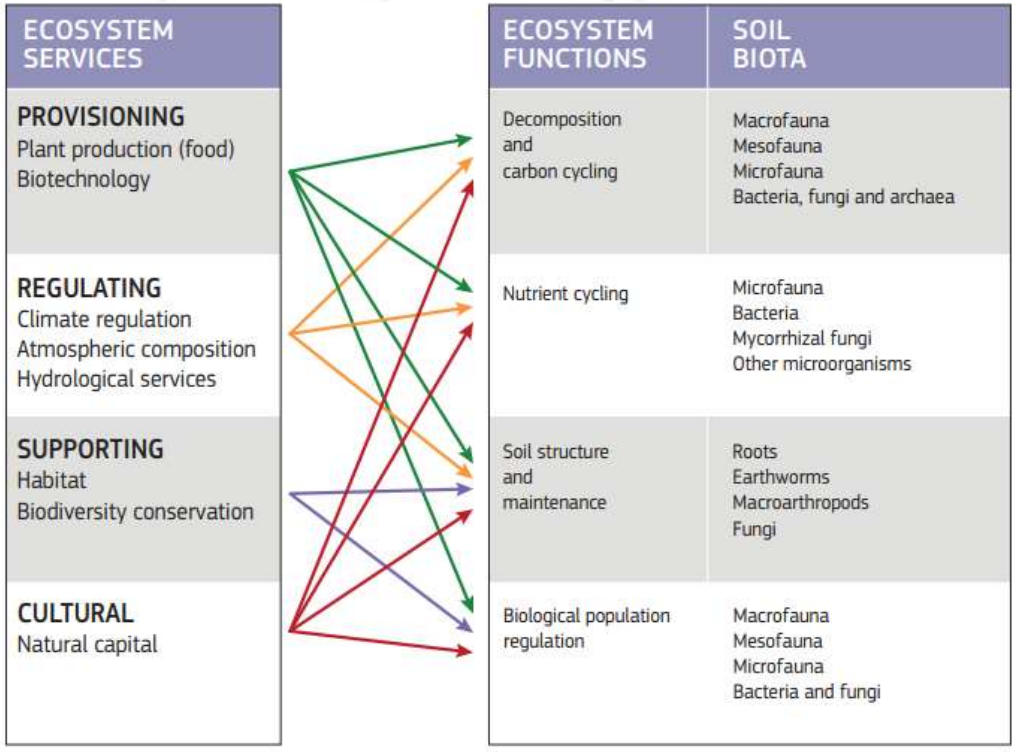
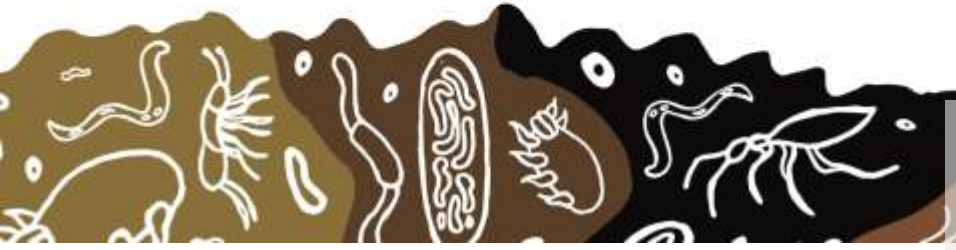
Multifunctionality and Ecosystem Services





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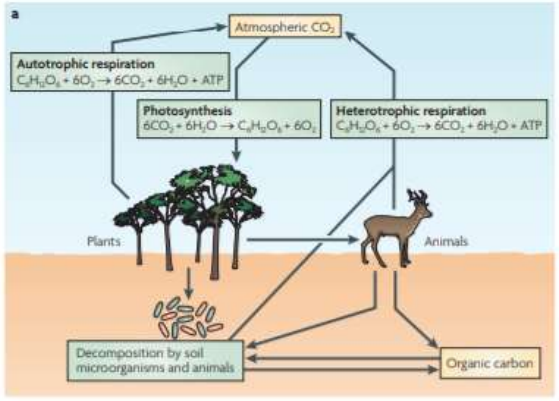
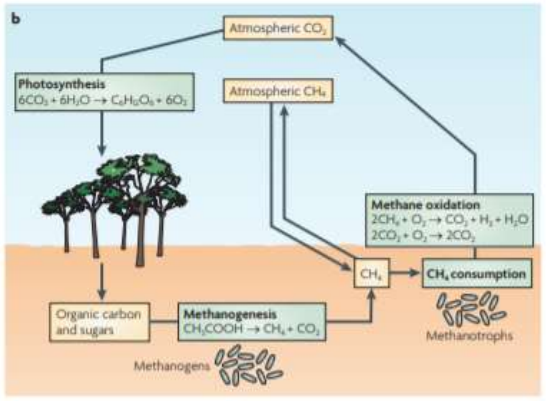
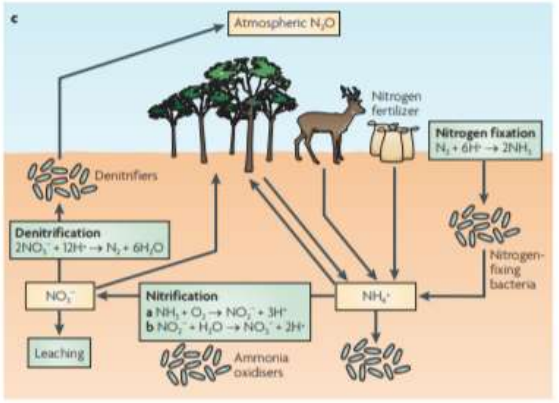
Why the soil microbiome matters for a healthy planet and ecosystem services

- Biogeochemical processing

Terrestrial greenhouse gas fluxes and soil C storage







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Impacts of farming practices on the soil microbiome (highlights)

Agrosystem diversification - plant diversity

Increased plant diversity:

- Higher soil C input
- Enhanced soil microbial biomass → necromass
- Enhanced activities (e.g. turnover rate of root litter and exudates)
- Enhanced community diversity

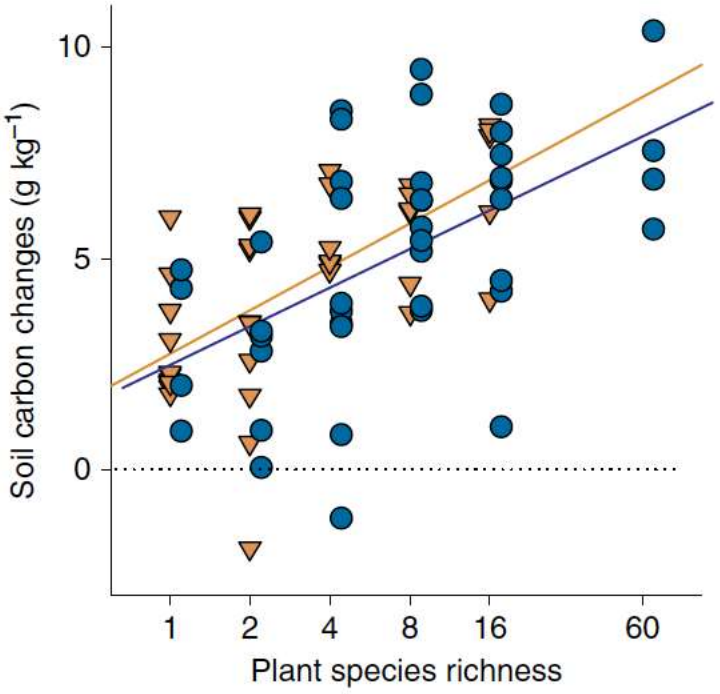

Figure sources: Lange, M., Eisenhauer, N., Sierra, C.A., Bessler, H., Engels, C., Griffiths, R.I., Mellado-Vázquez, P.G., Malik, A.A., Roy, J., Scheu, S., Steinbeiss, S., Thomson, B.C., Trumbore, S.E. & Gleixner, G. 2015. Plant diversity increases soil microbial activity and soil carbon storage. *Nature Communications*, 6: 6707.

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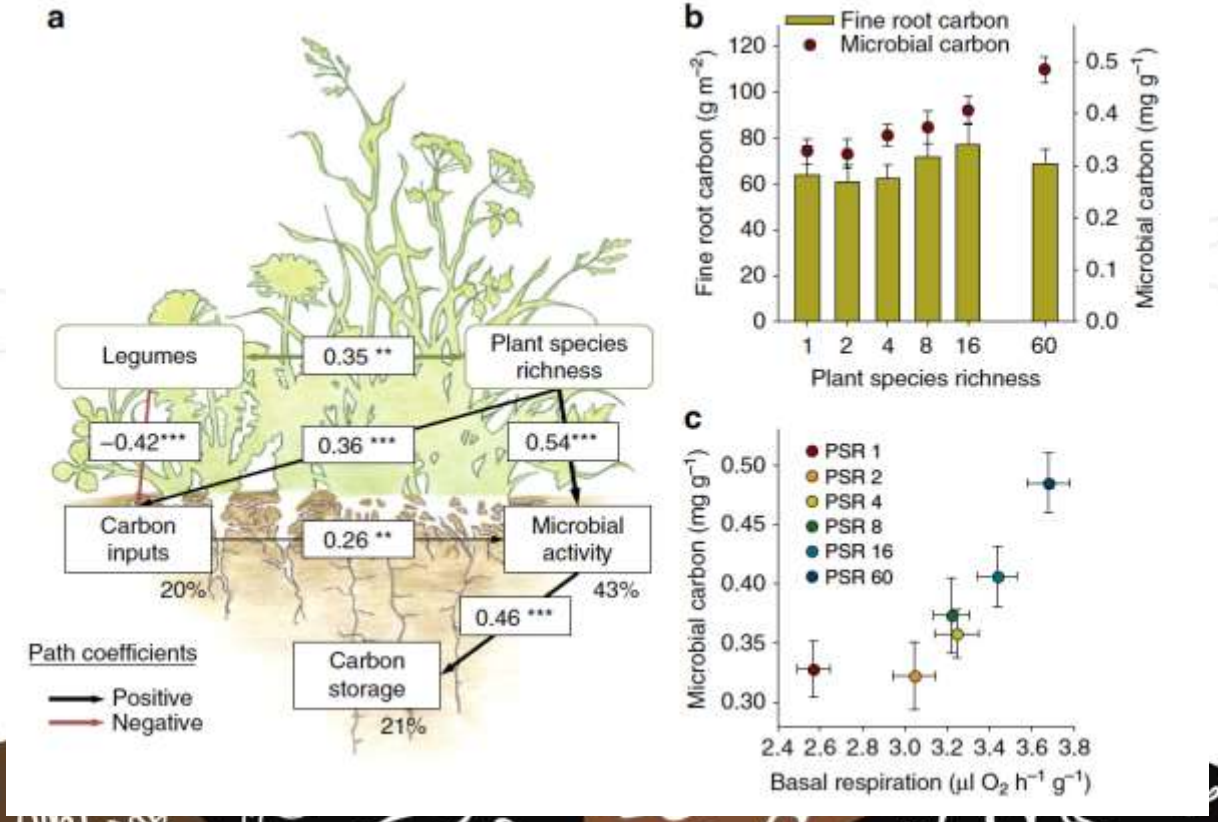

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Impacts of farming practices on the soil microbiome (highlights)

Agrosystem diversification – cover crops

- Can increase fungal species diversity
- Associated with positive effects on AMF

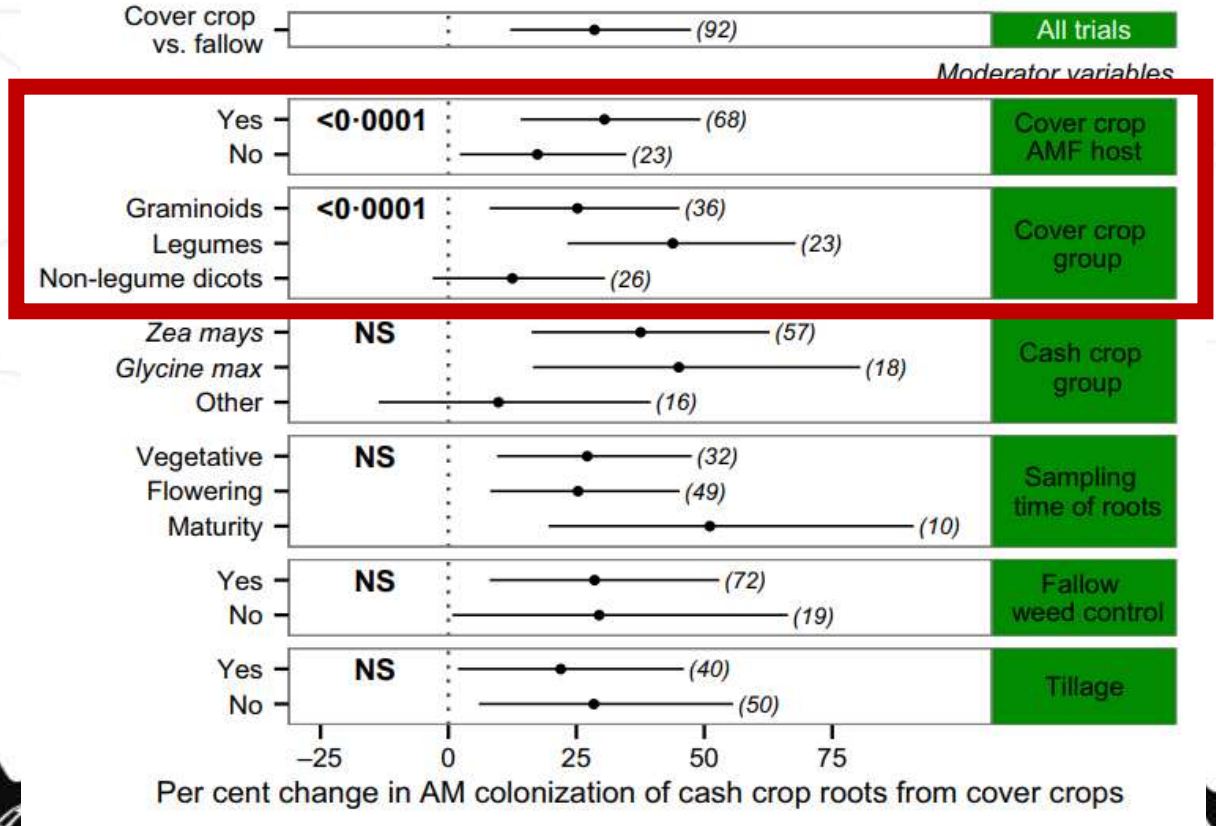


Figure sources: Bowles, T.M., Jackson, L.E., Loeher, M. & Cavagnaro, T.R. 2017. Ecological intensification and arbuscular mycorrhizas: a meta-analysis of tillage and cover crop effects. *Journal of Applied Ecology*, 54(6): 1785–1793. https://doi.org/10.1111/1365-2664.12815

Impacts of farming practices on the soil microbiome (highlights)

Selection of plant variety

- Genotypes influence root exudate composition and architecture
- “Missing microbes”

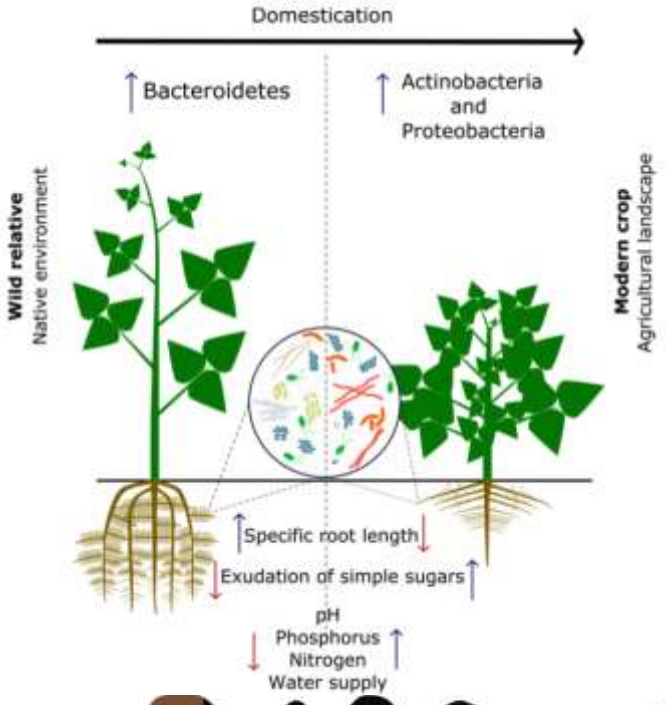
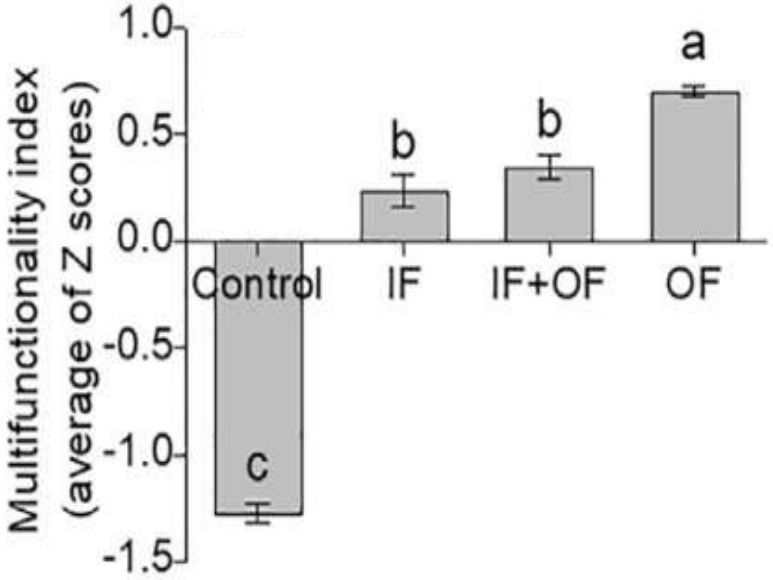


Image source: Pérez-Jaramillo, J.E., Carrión, V.J., de Hollander, M. & Raaijmakers, J.M. 2018. The wild side of plant microbiomes. *Microbiome*, 6(1).

Impacts of farming practices on the soil microbiome (highlights)

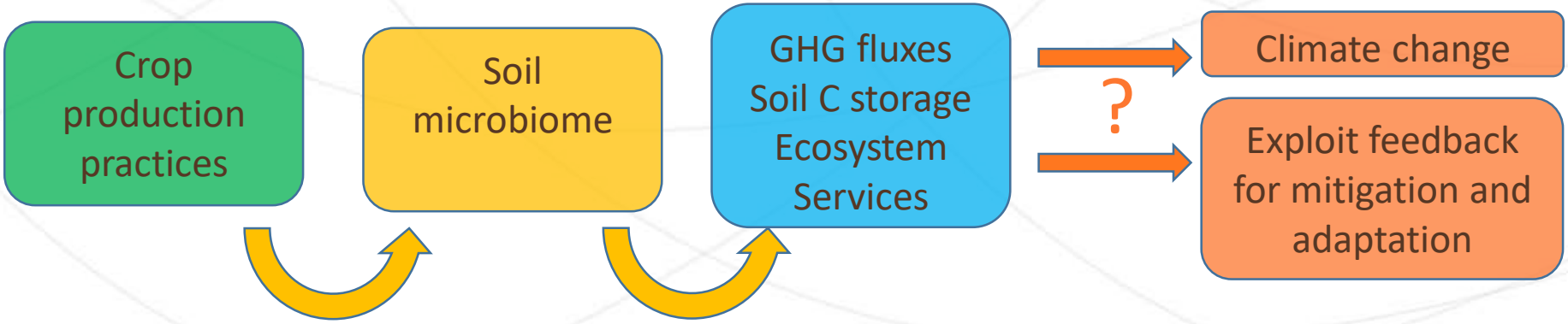
Fertilizers

Combination of organic and synthetic fertilizers increases multifunctionality



Sources: Chen, L., Redmile-Gordon, M., Li, J., Zhang, J., Xin, X., Zhang, C., Ma, D. & Zhou, Y. 2019. Linking cropland ecosystem services to microbiome taxonomic composition and functional composition in a sandy loam soil with 28-year organic and inorganic fertilizer regimes. *Applied Soil Ecology*, 139: 1–9. https://doi.org/10.1016/j.apsoil.2019.03.011

Limitations of this study



Also must consider

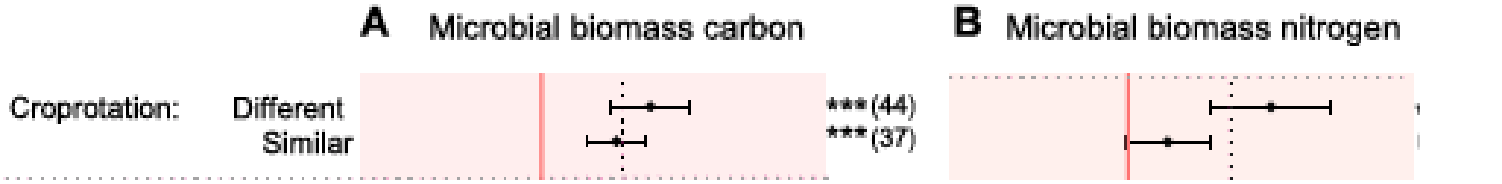
- Trade-offs
- Short- vs long-term effects
- Complexity of farm management and interactions across practices.

Impacts of farming practices on the soil microbiome (highlights)

Agrosystem diversification – crop rotations

- Long-term crop rotations can improve soil health via microbiome effects
- Inclusion of legumes enhances microbial biomass N
- Soil memory hypothesis

Global meta-analysis 56 studies 149 paired comparisons



RR Microbial carbon response to crop rotation

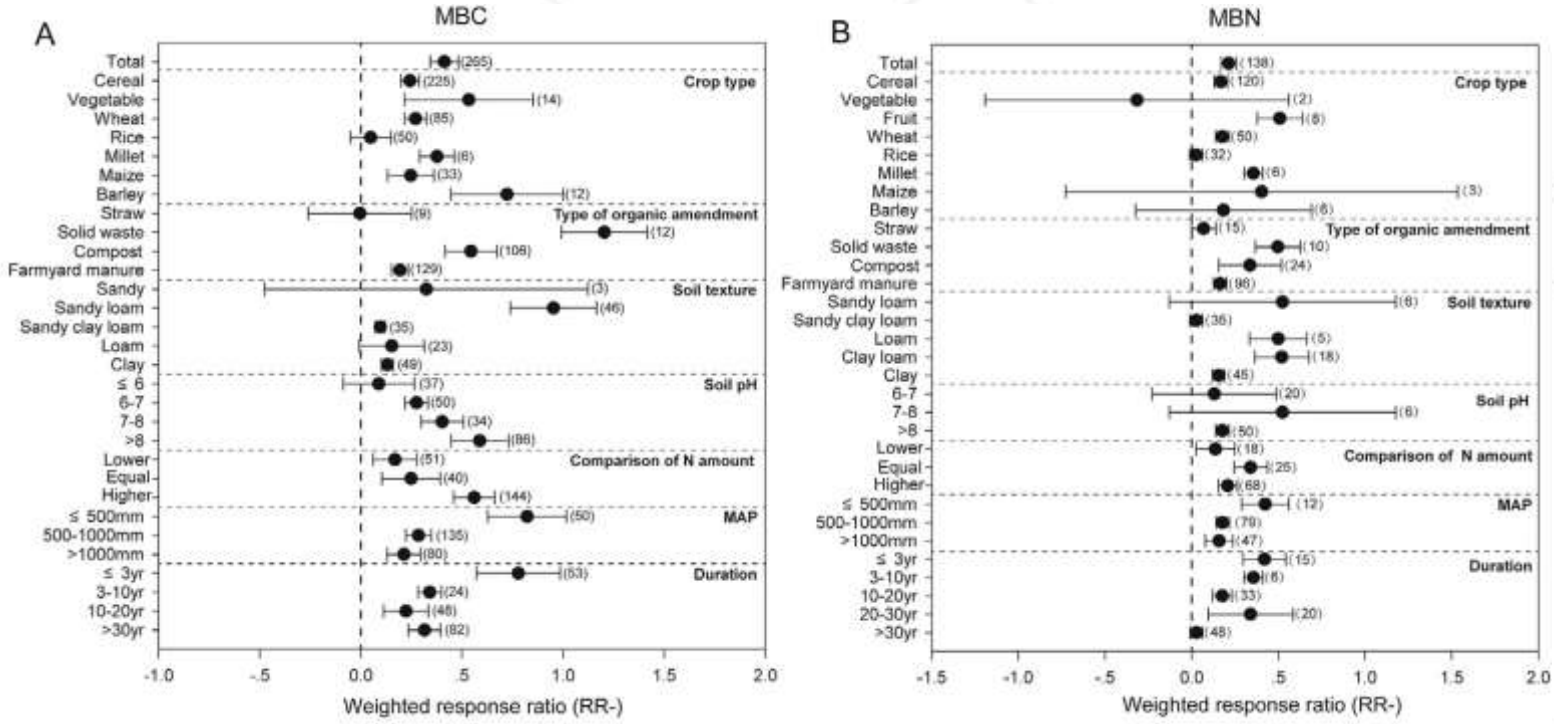
RR Microbial biomass N response to crop rotation

Figure sources: **Lori, M., Symnaczik, S., Mäder, P., De Deyn, G. & Gattinger, A.** 2017. Organic farming enhances soil microbial abundance and activity—A meta-analysis and meta-regression. *PLOS ONE*, 12(7): e0180442. https://doi.org/10.1371/journal.pone.0180442

Impacts of farming practices on the soil microbiome (highlights)

Fertilizers

Mineral and organic fertilization impact the soil microbiome



Sources: Luo, G., Li, L., Friman, V.-P., Guo, J., Guo, S., Shen, Q. & Ling, N. 2018. Organic amendments increase crop yields by improving microbe-mediated soil functioning of agroecosystems: A meta-analysis. *Soil Biology and Biochemistry*, 124: 105–115. https://doi.org/10.1016/j.soilbio.2018.06.002