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Eidgenössisches Departement für Wirtschaft,
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Agroscope



Universität
Zürich^{UZH}

Soil Health, Pesticides & Soil Ecological Engineering

Marcel van der Heijden et al.

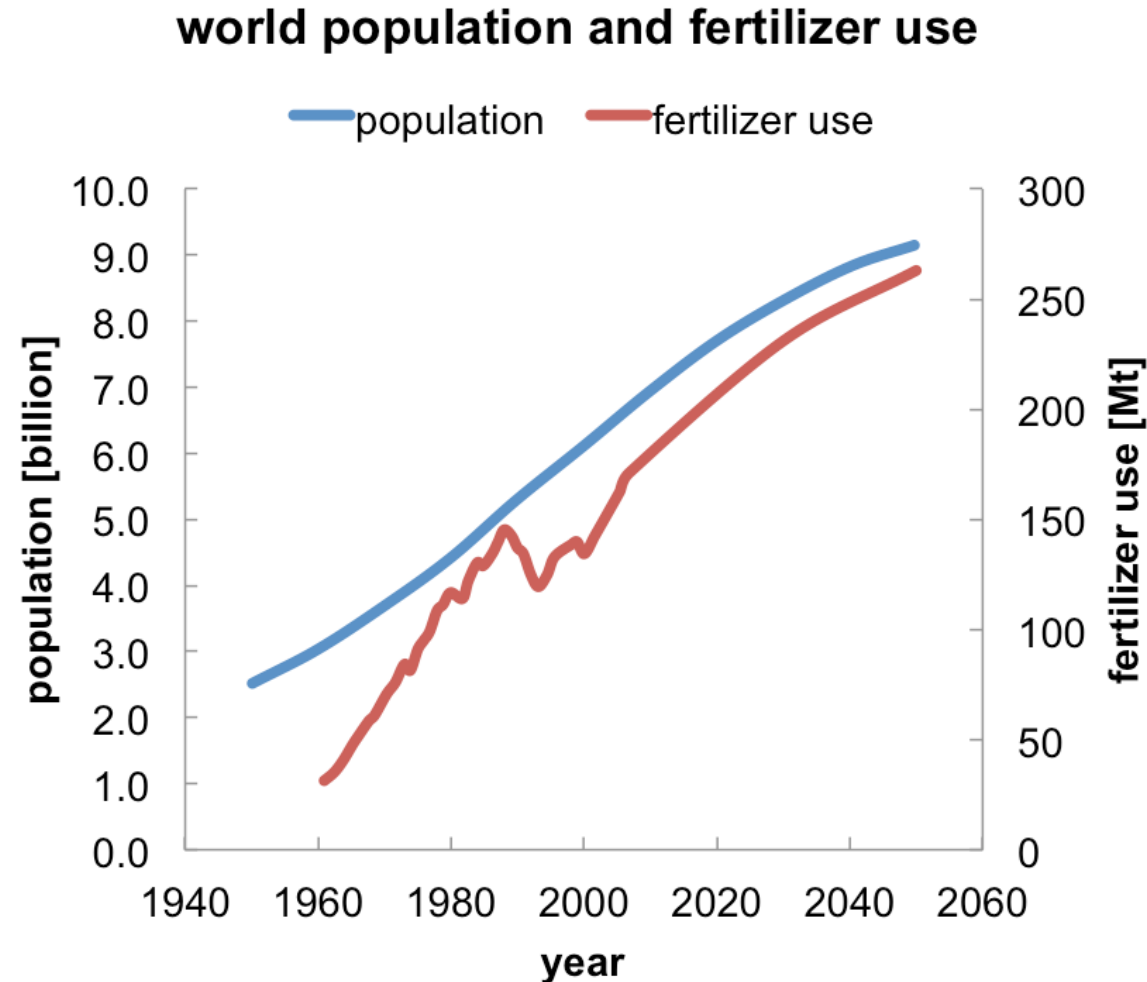
(marcel.vanderheijden@agroscope.admin.ch)

(marcel.vanderheijden@uzh.ch)



X: vandeHeijdenLab

Global demand for food will increase with 60% in the coming 35 years: we have to produce more, but also more sustainably –a role soil microbiomes and soil health?

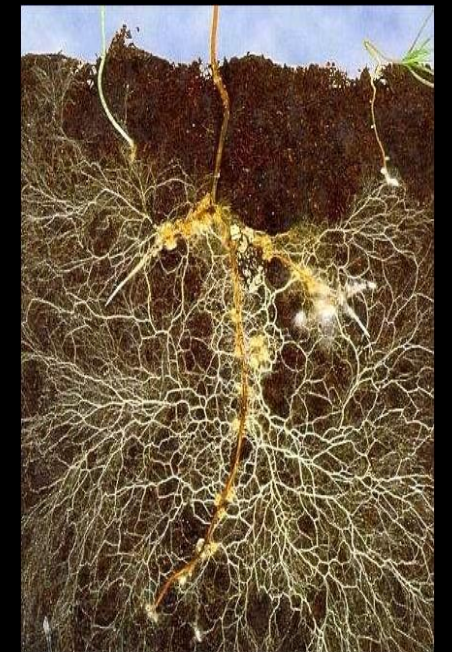
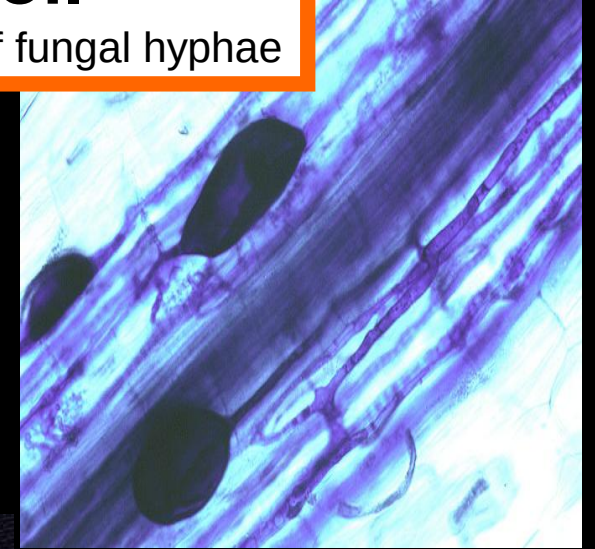






Soils are highly diverse: an estimated 59% of Earth's Biodiversity is linked to the soil

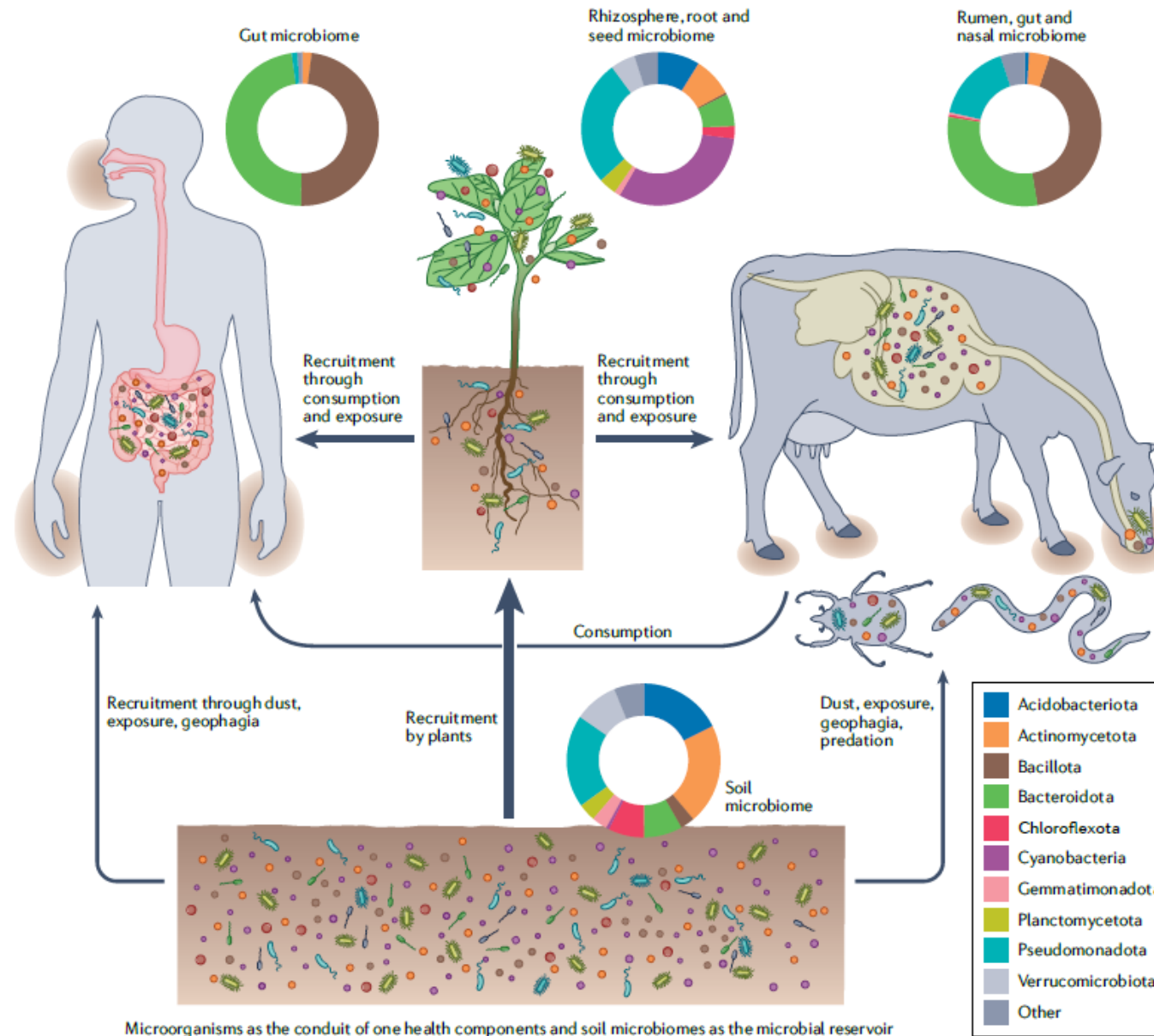
1 gram of soil contains up to 10^{10} bacteria, >10.000 taxa and up to 100 metre of fungal hyphae



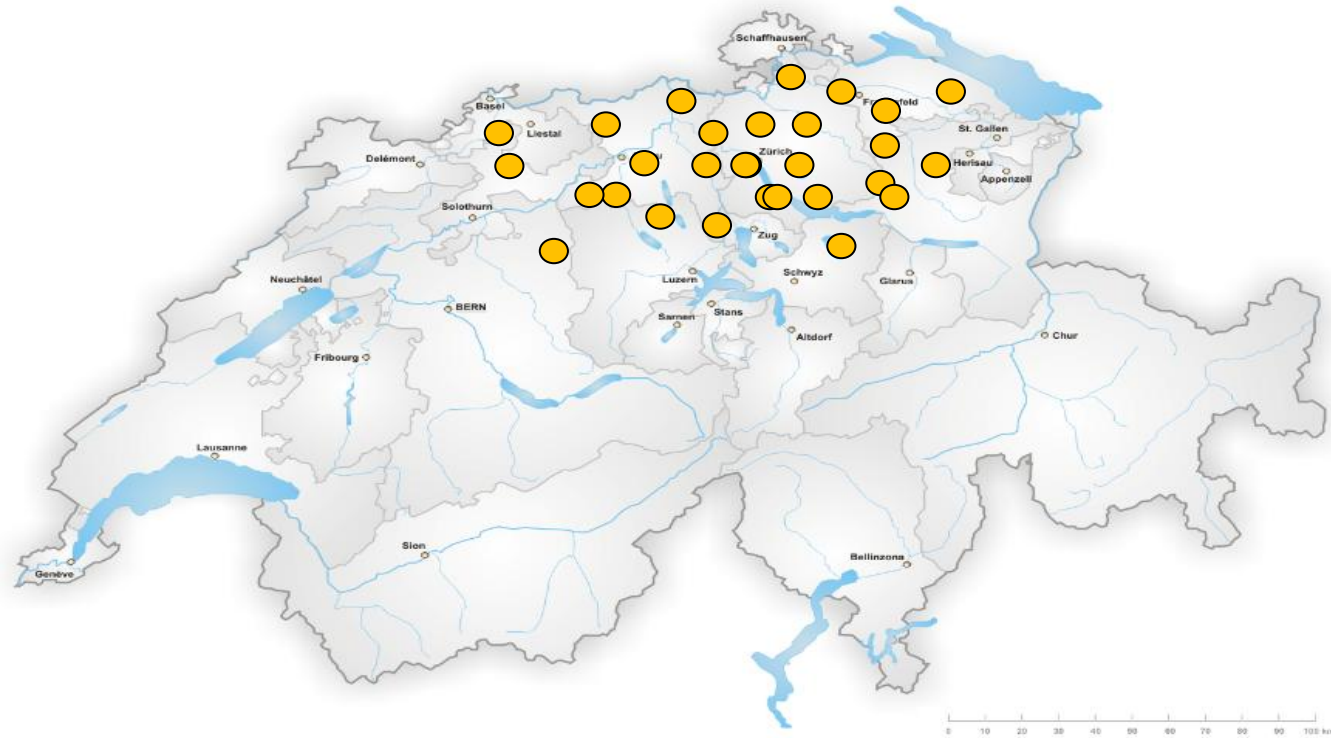
Anthony, Bender & van der Heijden (2023), PNAS: Enumerating soil biodiversity

Photos: F. Ashwood, G.Brändle, H. Conrad, D. Müller, A Murray, D. Müller, D. Read

The soil microbiome as a conduit of one health

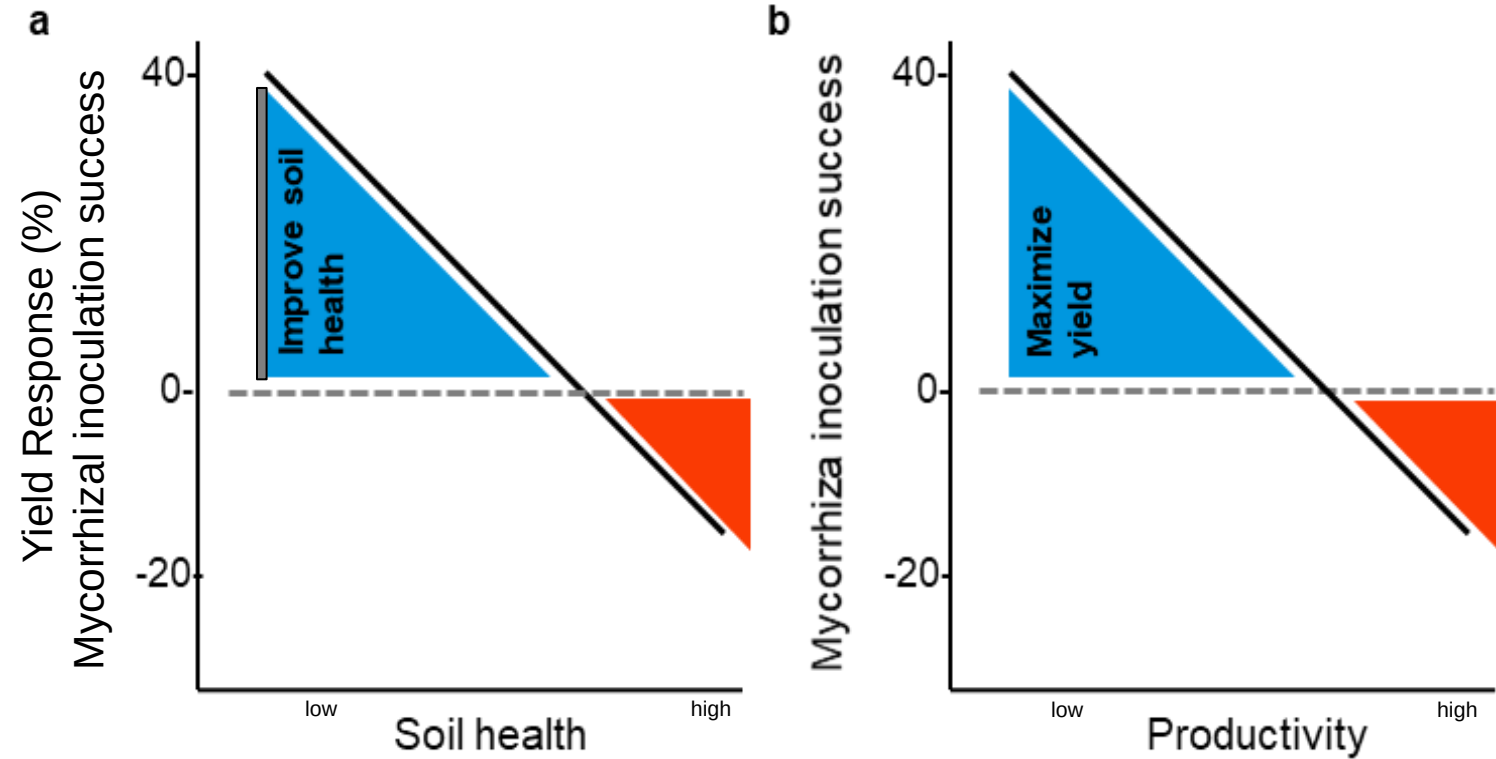


Soil Microbiome Engineering: Is it possible to enhance plant yield through inoculation with beneficial microbes (we focus on arbuscular mycorrhizal fungi)?



Soil Microbiome Engineering:

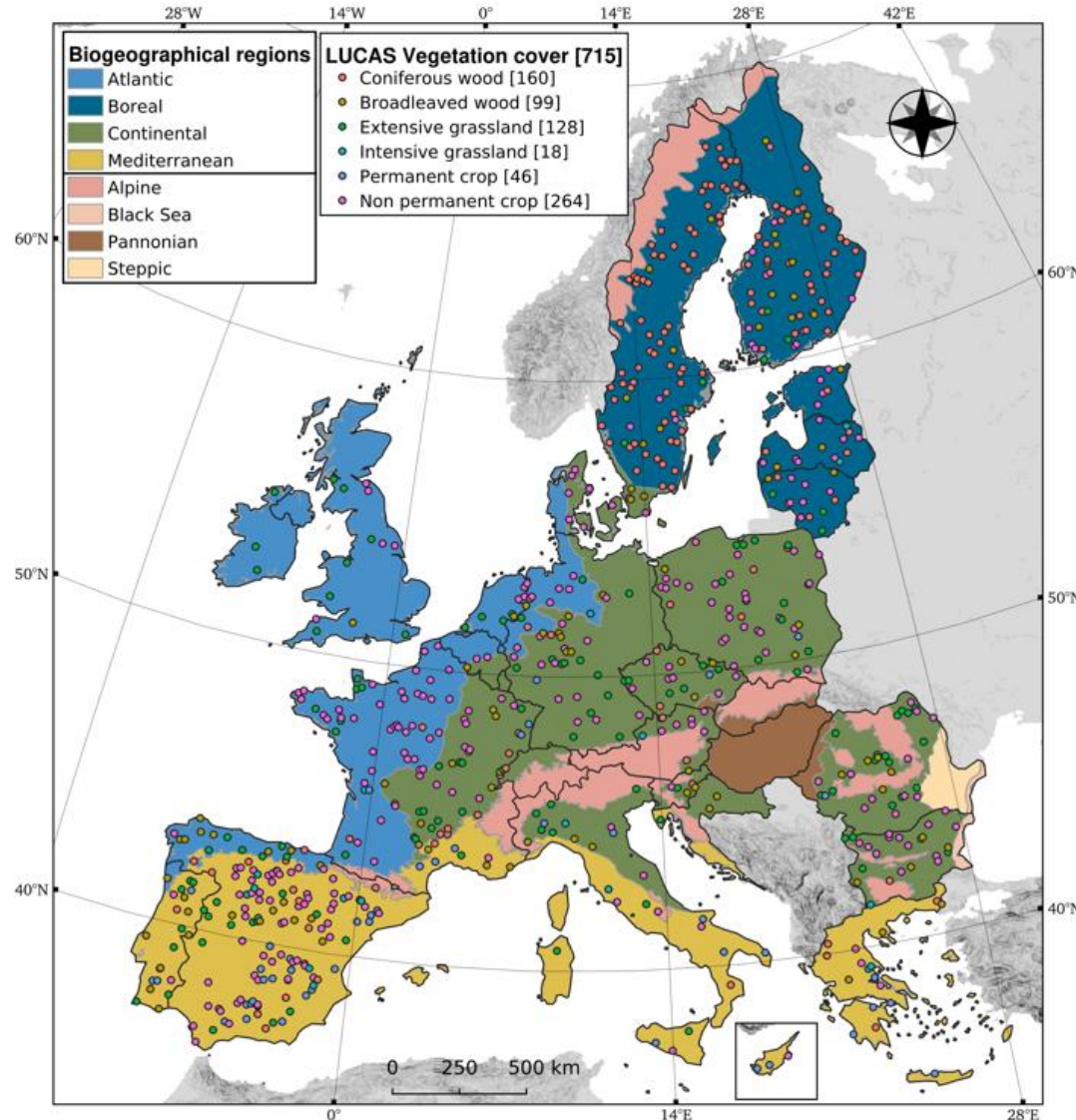
Large scale application of beneficial mycorrhizal fungi with the help of mycorrhizal granules (over 100 fields inoculated now)



Rog, van der Heijden..... Lutz (2025), *FEMS Letters*

Lutz, Bodenhausen..... Schläppi, van der Heijden (2023), *Nature Microbiology*. 8

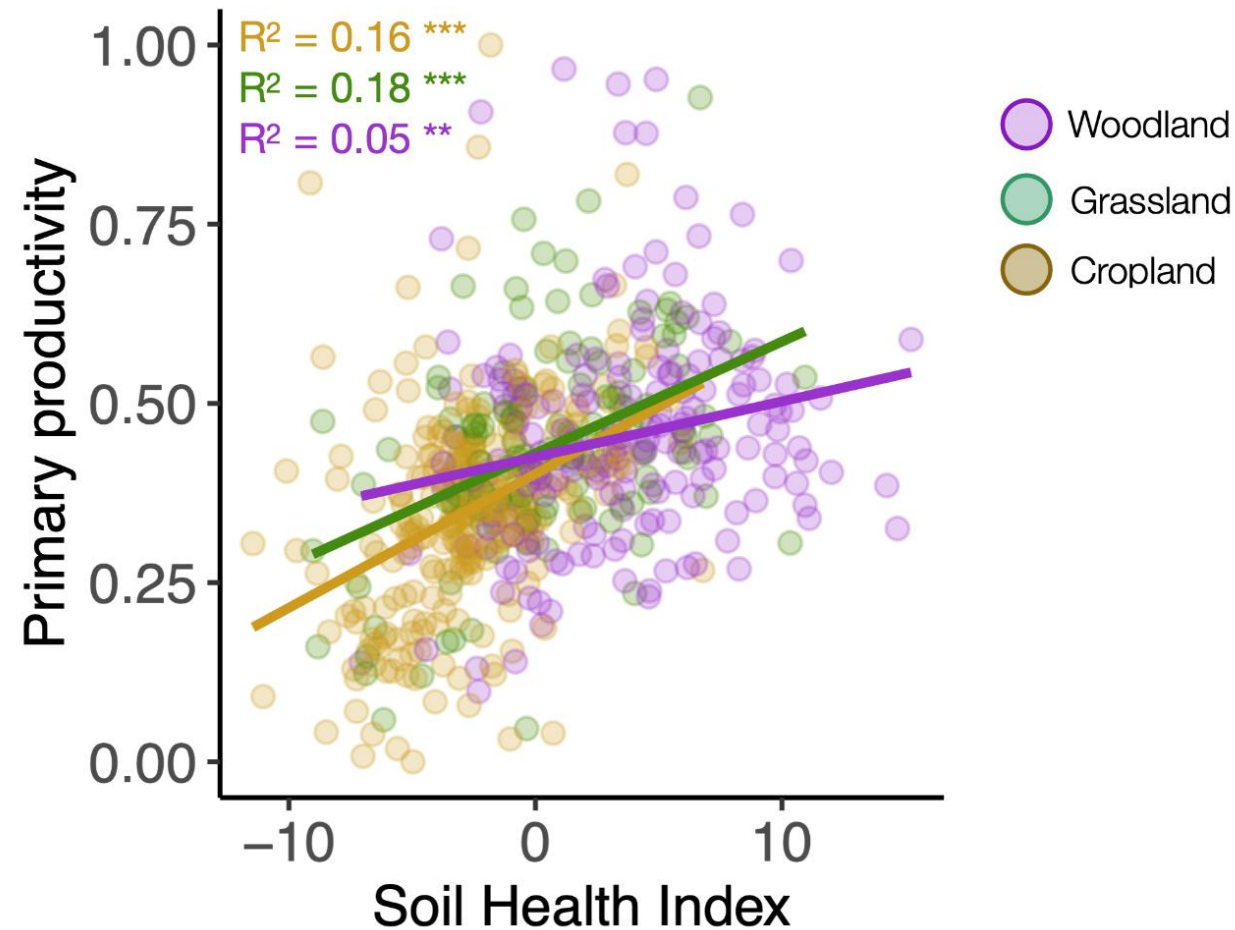
LUCAS Soil Monitoring



LUCAS Soil Biodiversity

- Largest European soil survey
- 715 sampling points
- 3 land cover types (cropland, grassland, woodland)
- 4 biogeographical regions
- Microbial (bacteria & fungi) community (DNA metabarcoding)
- Labouyrie et al. 2023, *Nature Communications*

Soil Health is positively linked to plant productivity across Europe

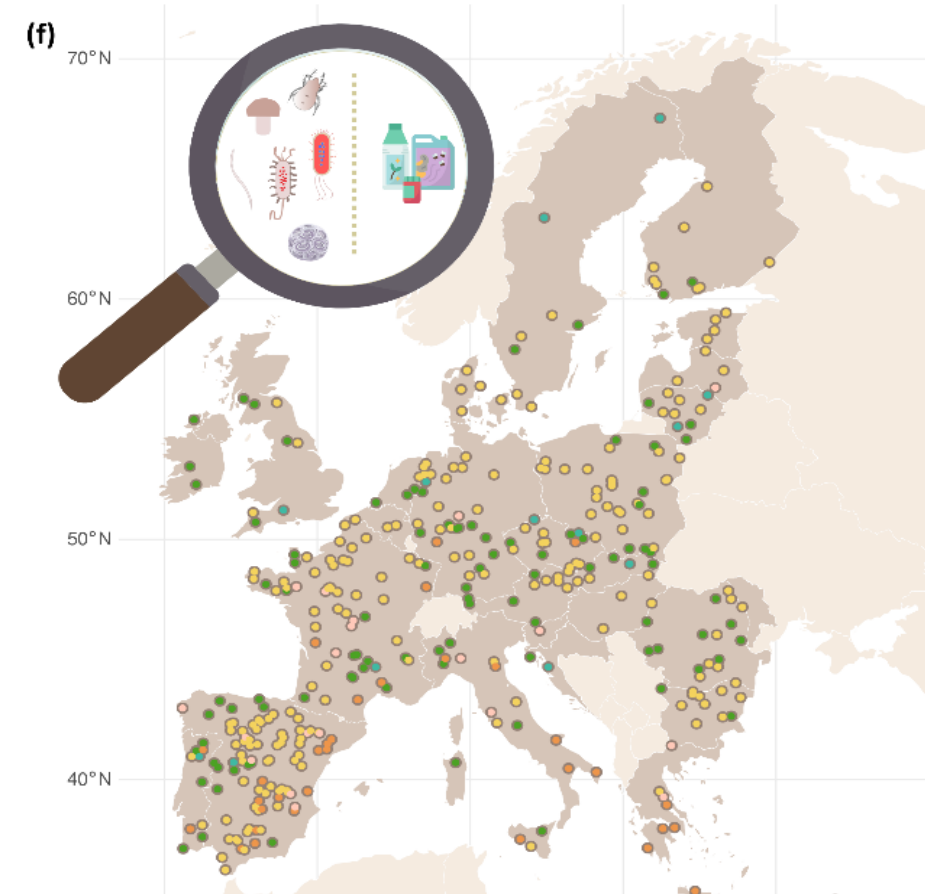
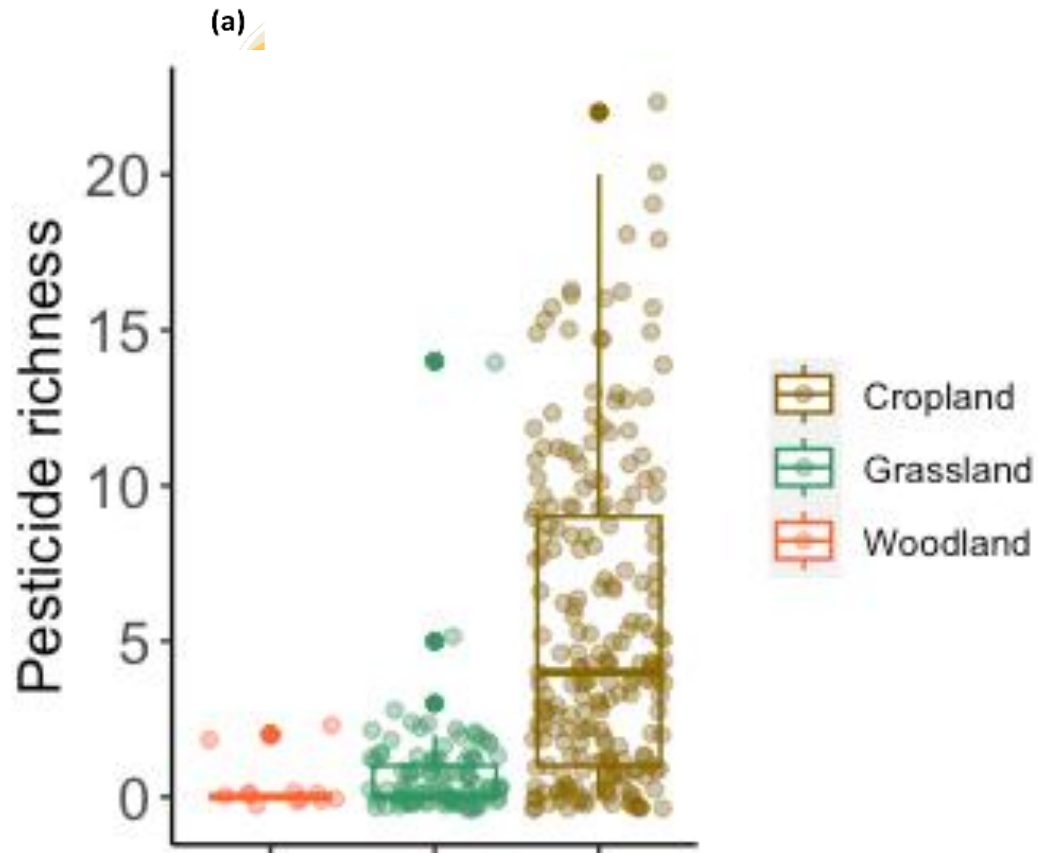


Romero et al...van der Heijden (2024), *Nature Ecology & Evolution*

Soil Health: SOC, N content, P content, microbial biomass, soil density, mycorrhizal fungal abundance, nitrogen fixing bacteria abundance, inverse of pathogen richness.

Note: although soil health can be beneficial for various ecosystem services (e.g. soil carbon storage), there are also various reports where no link to plant yield is reported (e.g. Edlinger et al. (2025), *Journal of Sustainable Agriculture and Environment* 4 (1), 11.)

Pesticide residues in EU cropland soils are widespread

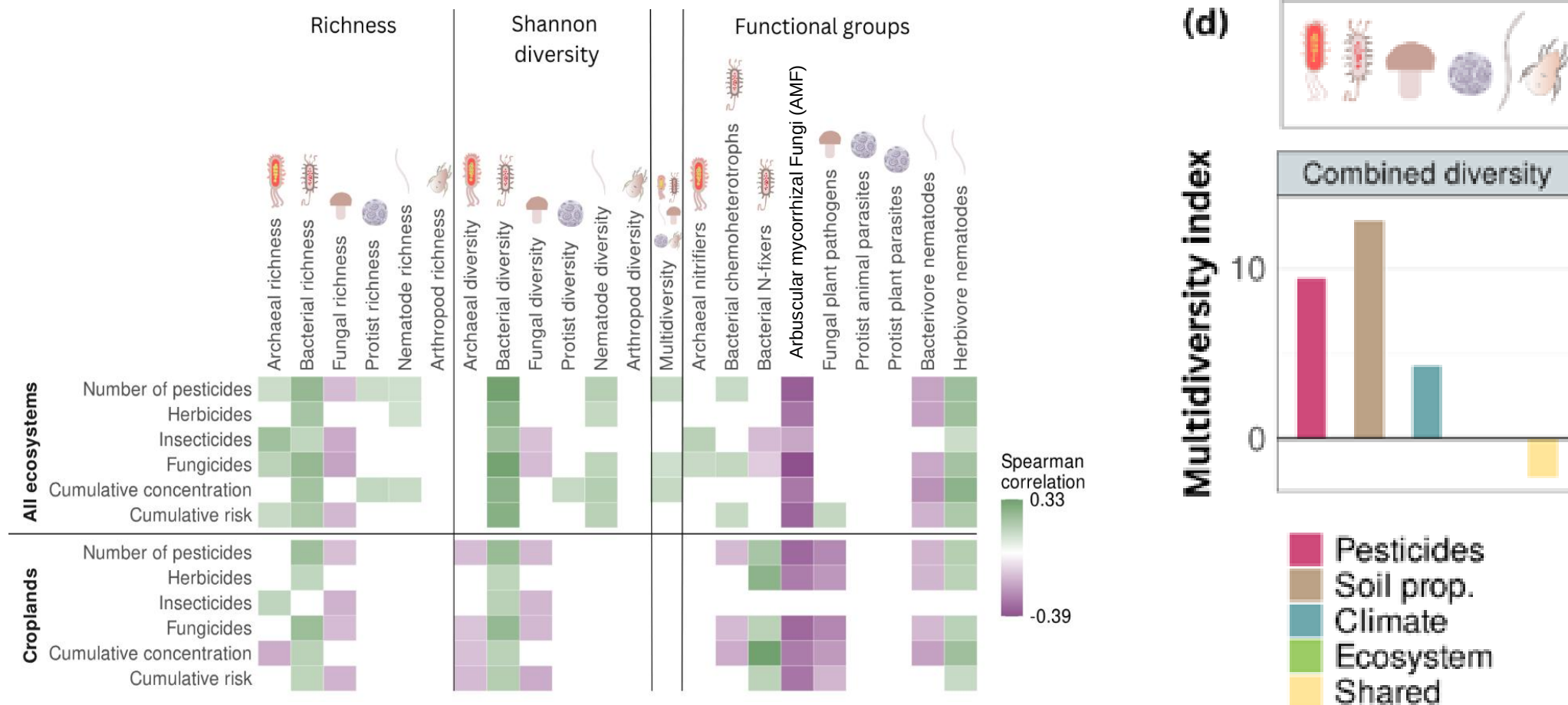


Köninger, Labouyrie, Ballabio, Romero, Franco, Bahram, Dulya, Mikryukov, Panagos, Jones, Tedersoo, Orgiazzi, Briones, & van der Heijden, unpublished results.

*In a Swiss monitoring program with more sensitive pesticide detection methods, we find pesticides in every agricultural soil analysed.

*Up to 16 different pesticides residues were detected after 20 years of organic management: see Riedo et al. 2021; *Environmental science & technology* 55 (5), 2919-2928.

Pesticides have a large impact on soil biodiversity



Köninger, Labouyrie, Ballabio, Romero, Franco, Bahram, Dulya, Mikryukov, Panagos, Jones, Tedersoo, Orgiazzi, Briones, & van der Heijden, unpublished results.

- The negative impact on AMF was also found in Riedo et al. (2021). *Environmental science & technology*; and Edlinger et al. (2022), *Nature Ecology & Evolution*
- A 30% decrease in soil fauna diversity and abundance has been shown in a review by Beaumelle et al. 2023, *Journal of Applied Ecology*:

Conclusions

- Soil Ecological Engineering: Field inoculation with beneficial microbes (Arbucular Mycorrhizal Fungi) has clear potential to enhance plant yield and improve agricultural sustainability. Further research for practical application is needed.
- Soil Ecological Engineering and Soil Health Improvement is also possible through altered management practices (e.g. enhanced crop rotation, reduced tillage, leys, compost application or cover cropping)
- Pesticides are widespread in agricultural soils and our results indicate that they are a major determinant of soil microbial diversity and the niche of a wide range of soil microbes.



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Thomas Bucheli, Katie Mackie-Haas, Judith Riedo, Elias Barmettler, Florian Walder, Pierre-Henri Dubuis et al.

Ferran Romero, Maeva Labouyrie, Alberto Orgiazzi, Cristiano, Panos Panagos, Arwyn Jones, Julia Koniger, Maria Briones, Leho Tedersoo, et al.

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Research Group Plant-Soil Interactions AGS & Team Agroecology and Plant-Microbiome Interactions UZH

Participating farmers, scientists

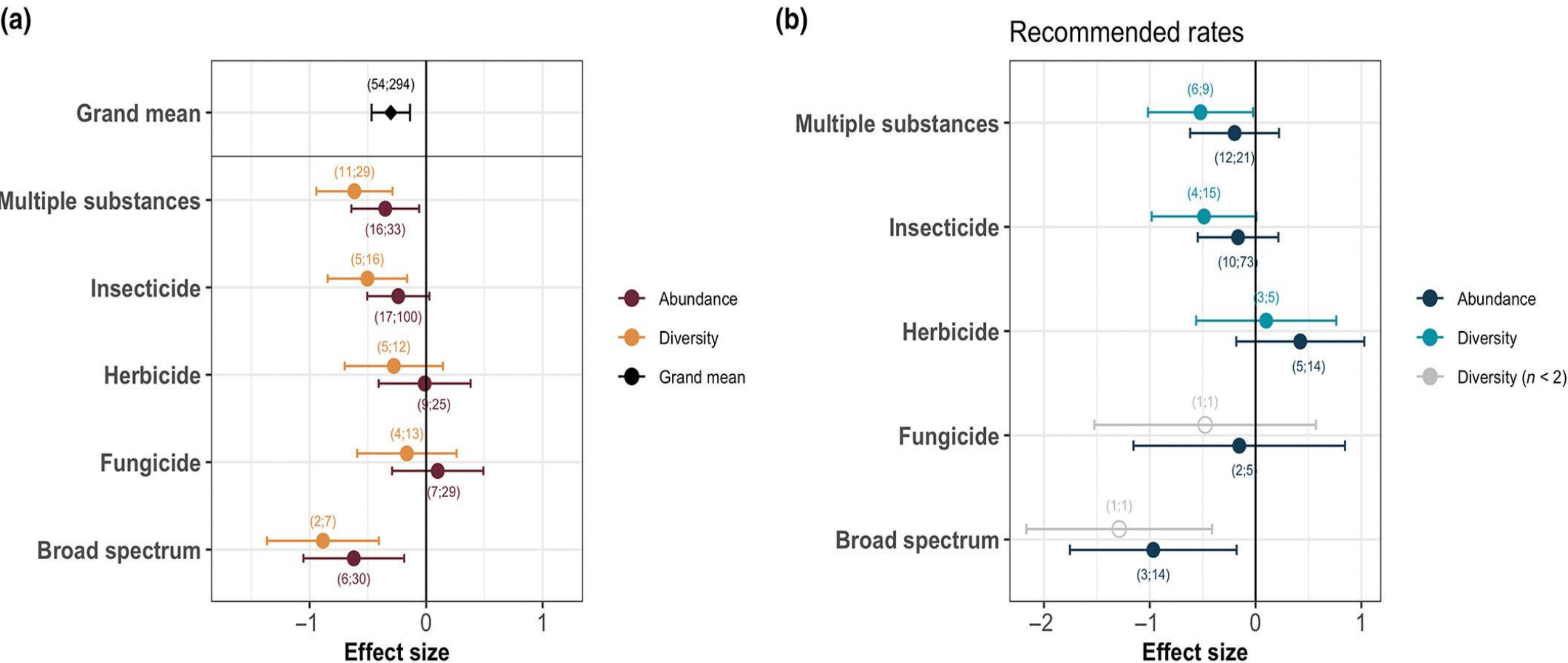
Many other scientists for exchange and collaboration



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Pesticide application has a negative effect on soil fauna (on average a 30% reduction in abundance and richness)





Soil Processes:

Plant Nutrition & Cycling

Biodiversity Reservoir

Carbon Storage

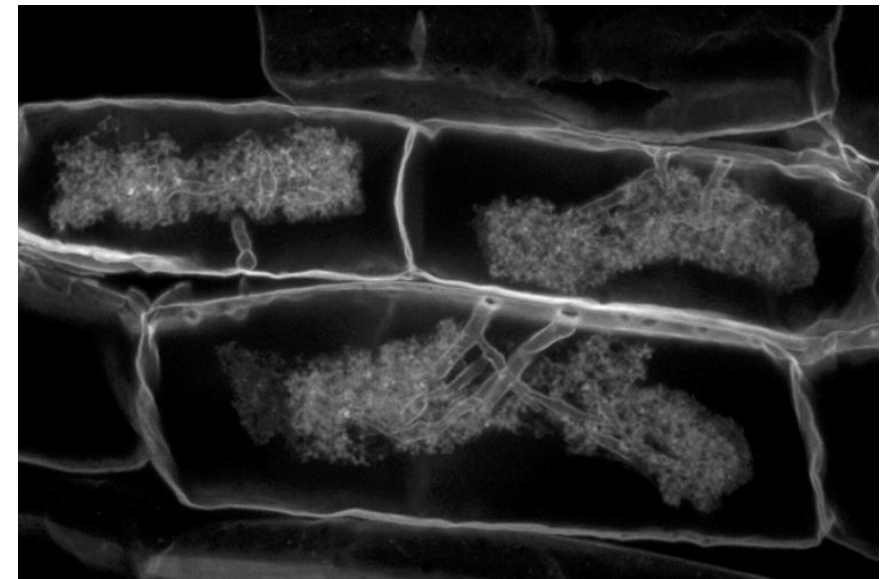
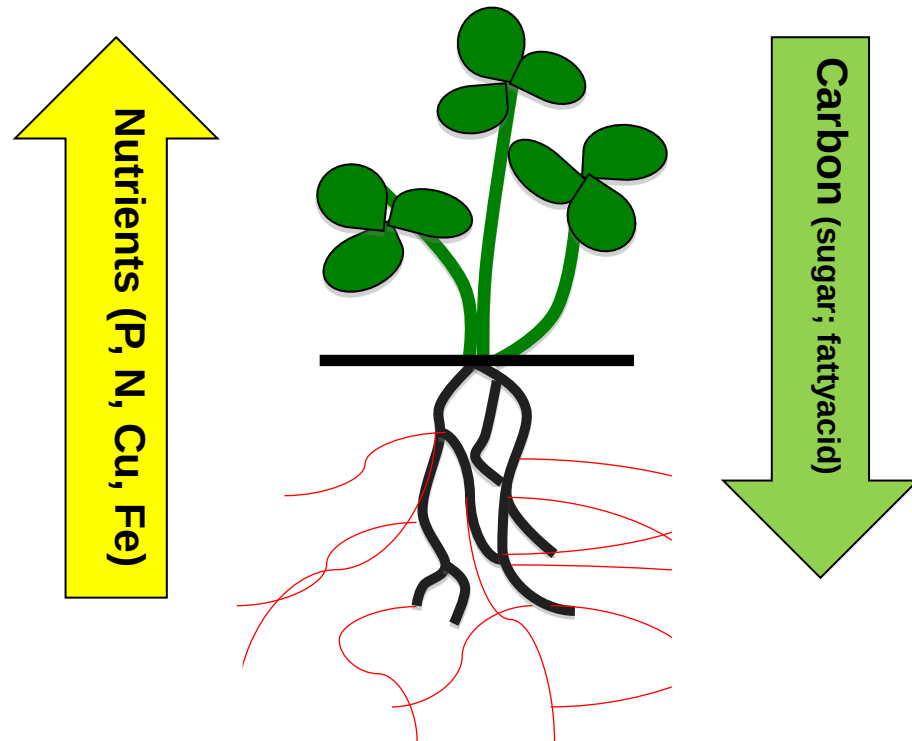
Water Storage

Filtration & Cleaning



Arbuscular mycorrhizal fungi (AMF)

- ▮ Probably the most ancient and abundant plant symbionts on Earth.
- Up to 90% of plant P and plant N is acquired by mycorrhizal fungi
- Arbuscular mycorrhizal fungi associate with most major crops including arable crops (potato, cereals) and vegetables (e.g. salad, tomato, carrot)



van der Heijden et al. Sanders 1998, *Nature*
Smith & Read 2008, *Mycorrhizal Symbiosis*
van der Heijden et al. 2015, *New Phytologist*
Martin & van der Heijden 2024, *New Phytologist*



half of the plots inoculated with AMF
(*Rhizogloinus irregulare*)
half with a control inoculum



Field Inoculation has a lot of potential, but not always...



Steffi Lutz



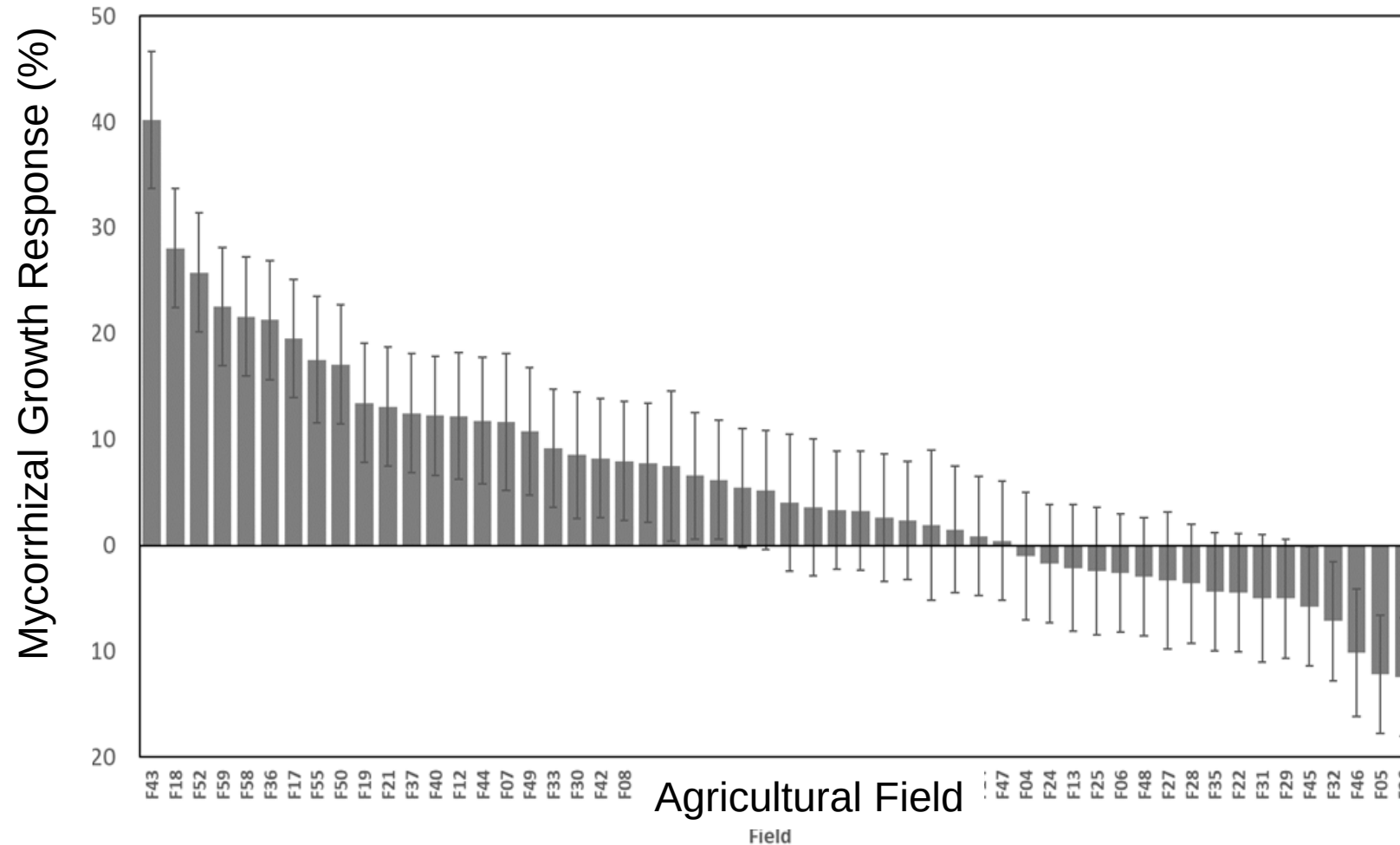
Natacha Bodenhausen



Klaus Schläppi



Julia Hess



Lutz, Bodenhausen..... Schläppi, van der Heijden (2023), *Nature Microbiology*.

Inoculation success is linked to Soil Health and Plant productivity

