Biologische und konventionelle Landwirtschaft fördern Bodenmikrobiome mit unterschiedlichem Stoffwechselpotenzial

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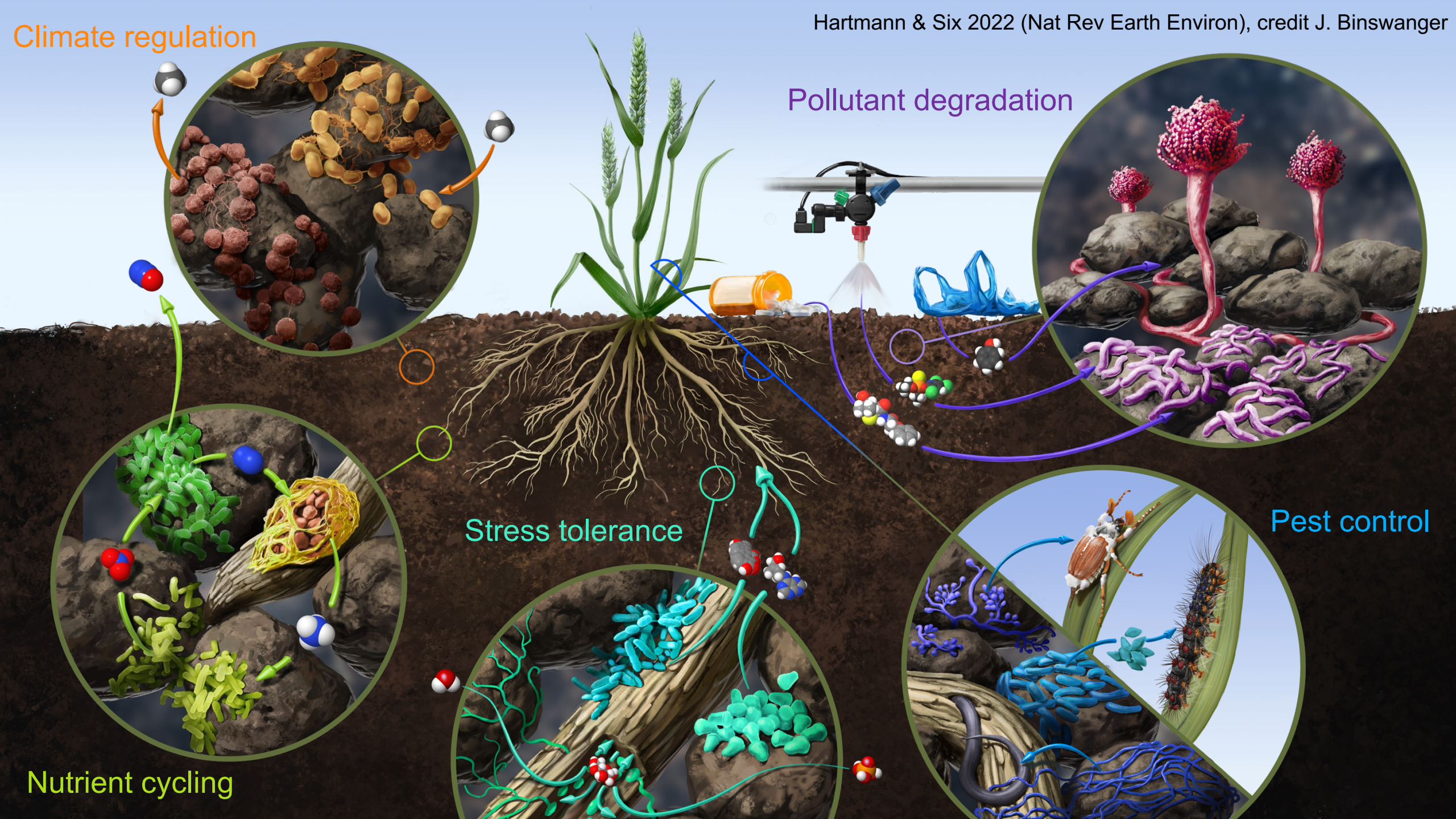
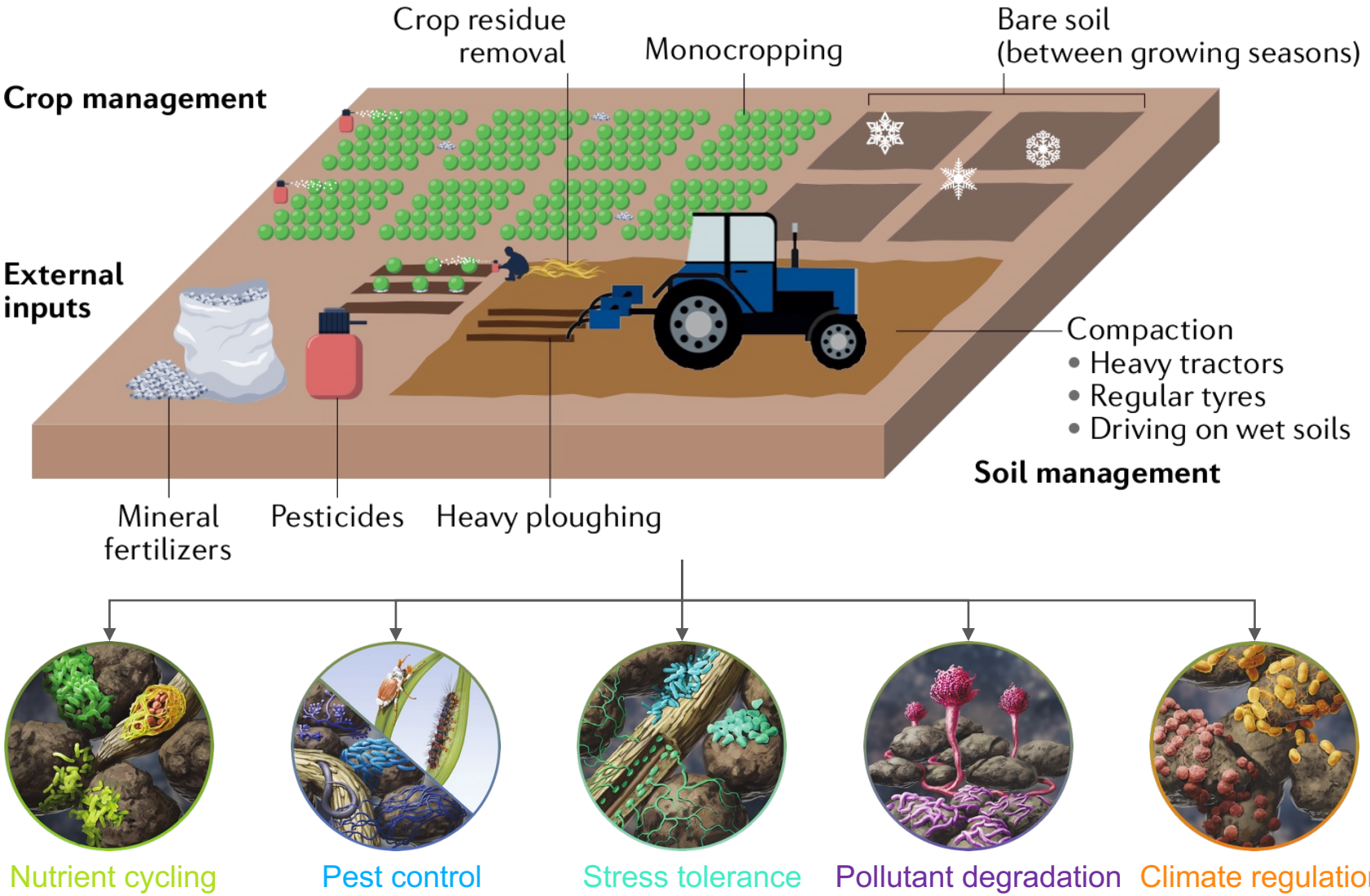


Hartmann & Six 2022 (Nat Rev Earth Environ), credit J. Binswanger

Transforming agriculture to promote soil microbiomes



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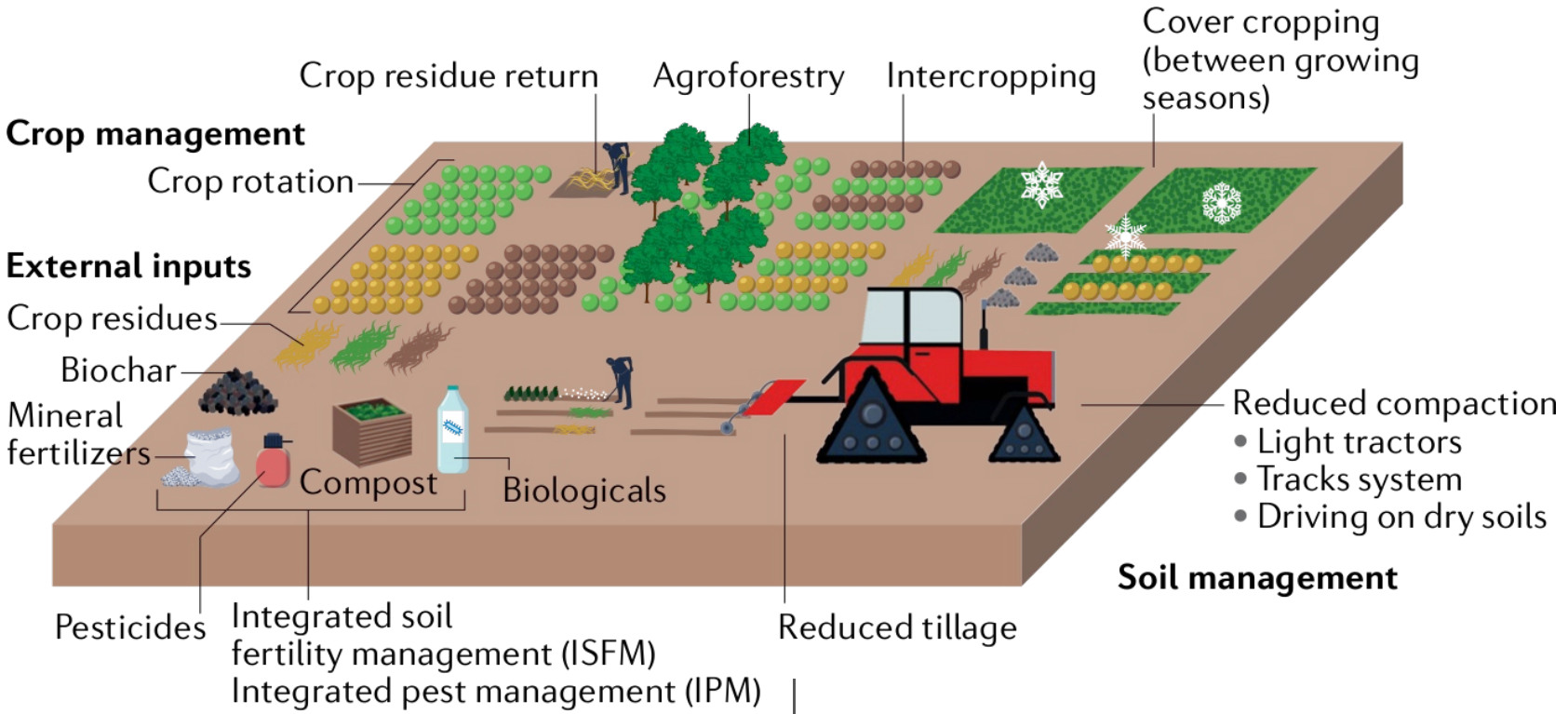
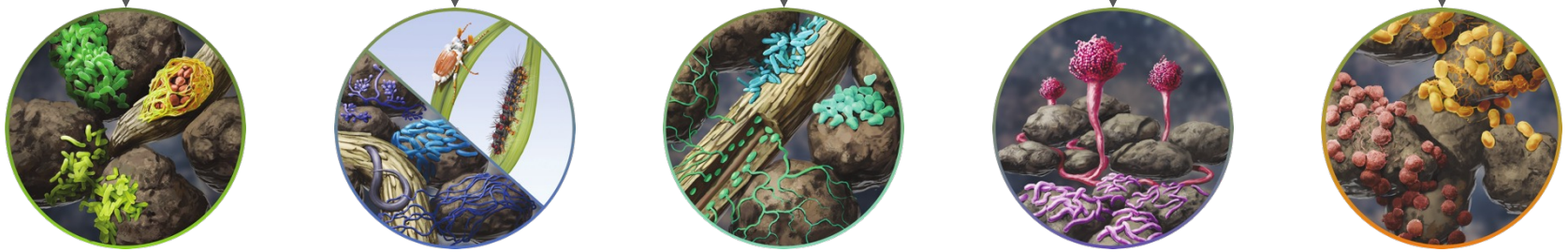




Nutrient cycling | Pest control | Stress tolerance | Pollutant degradation | Climate regulation

Hartmann & Six 2022 (Nature Reviews Earth & Environment)

The DOK experiment

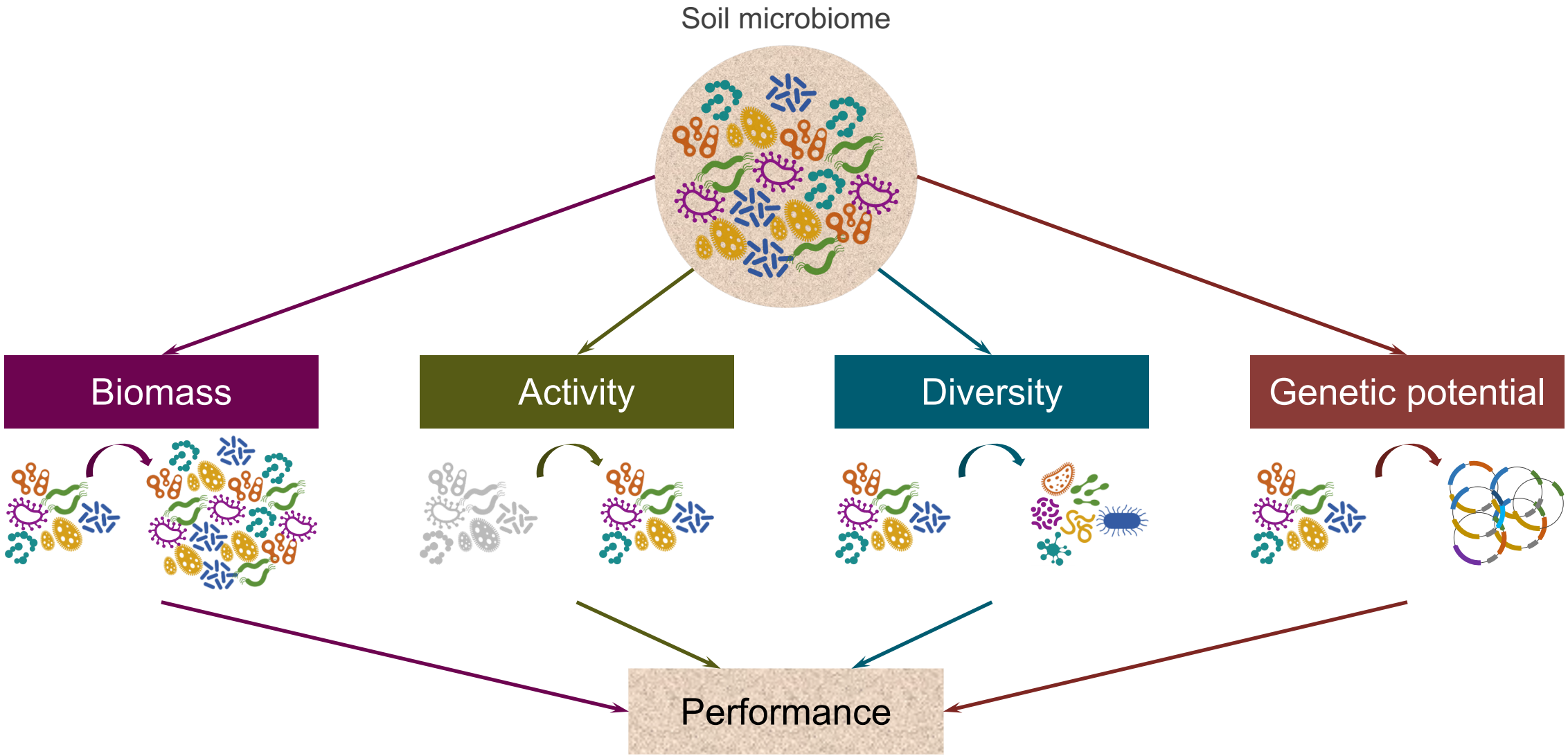
Factsheet

- Established in 1978
- Haplic Luvisol
- 791 mm MAP, 11°C MAT
- 5 systems, 4 replications
- 3 temporally shifted 7-yr crop rotations
- In 7th crop rotation (2020-2027)

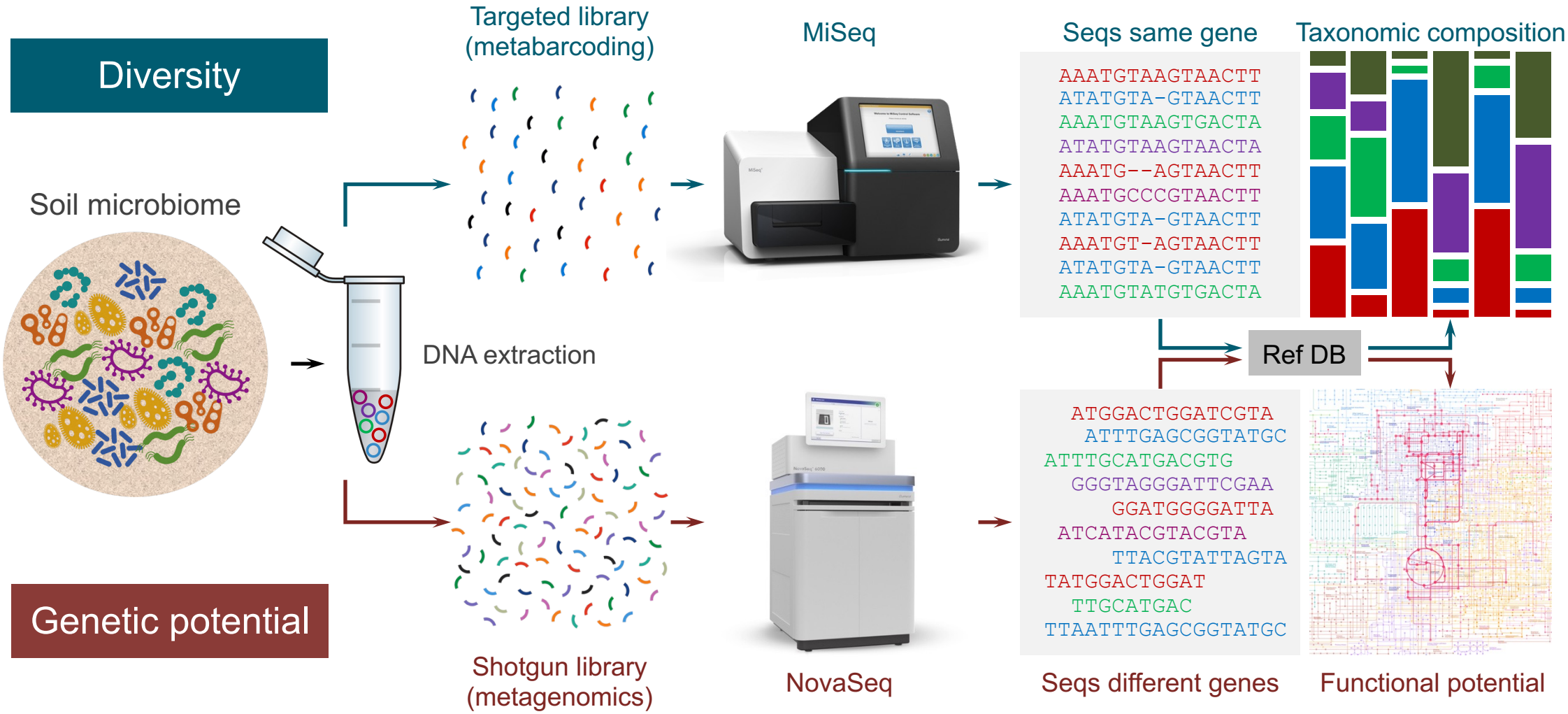
Cropping system	Unfertilized NOFERT	Bio-dynamic BIODYN	Bio-organic BIOORG	Conventional mixed CONFYM	Conventional mineral CONMIN
Fertilization	no fertilizer	composted manure	rotten manure	stacked manure & mineral fertilizer	mineral fertilizer
Crop protection	mechanical	mechanical, indirect, beneficials		insecticides, fungicides, herbicides (thresholds)	
		bio-dynamic preps	CuSO4		

Mäder et al. 2002 (Science)

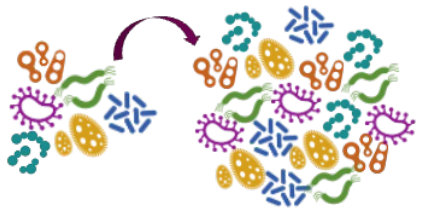
Measuring key properties for answering key questions

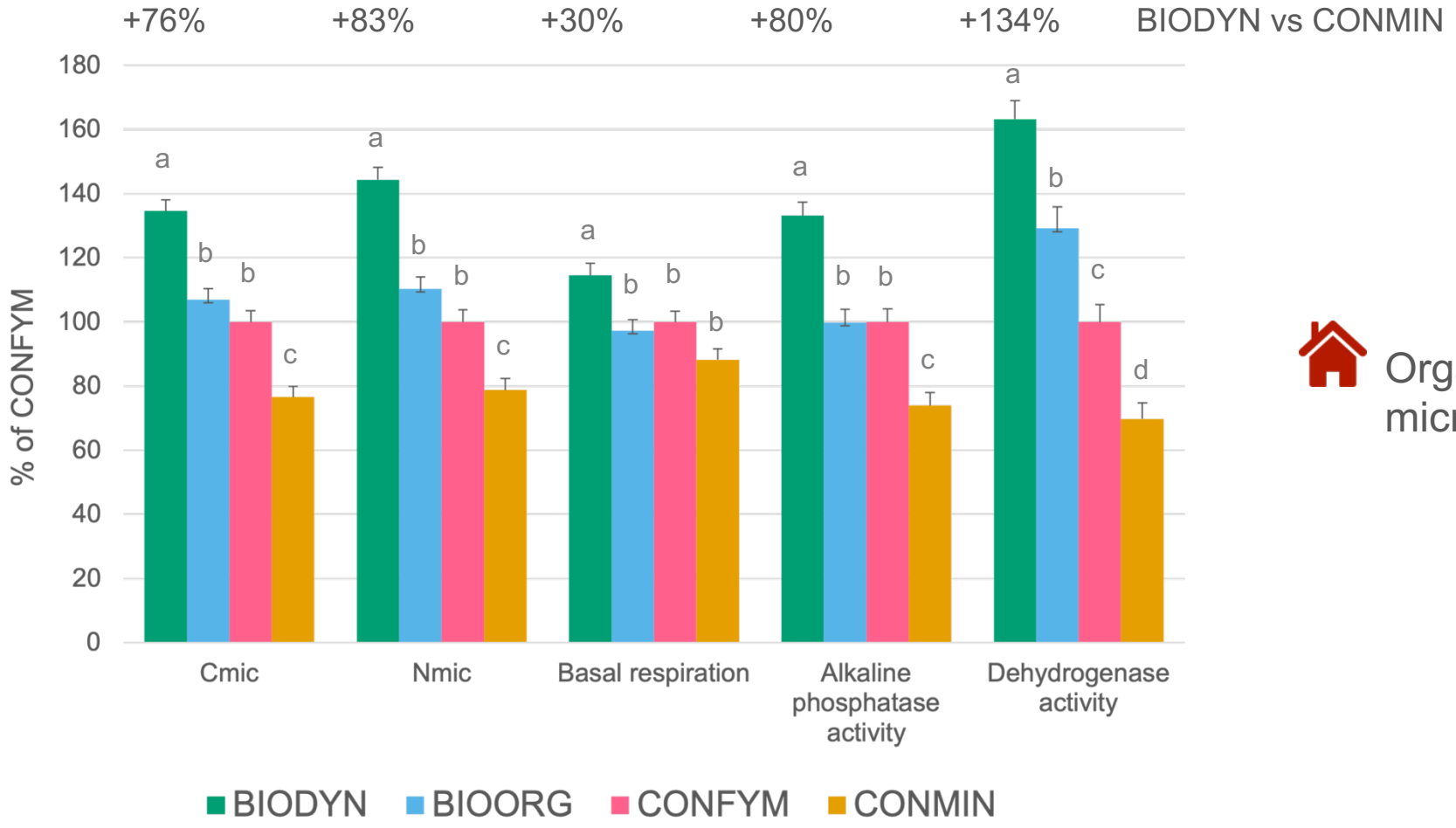


Molecular genetic toolbox



Soil microbial biomass and activity



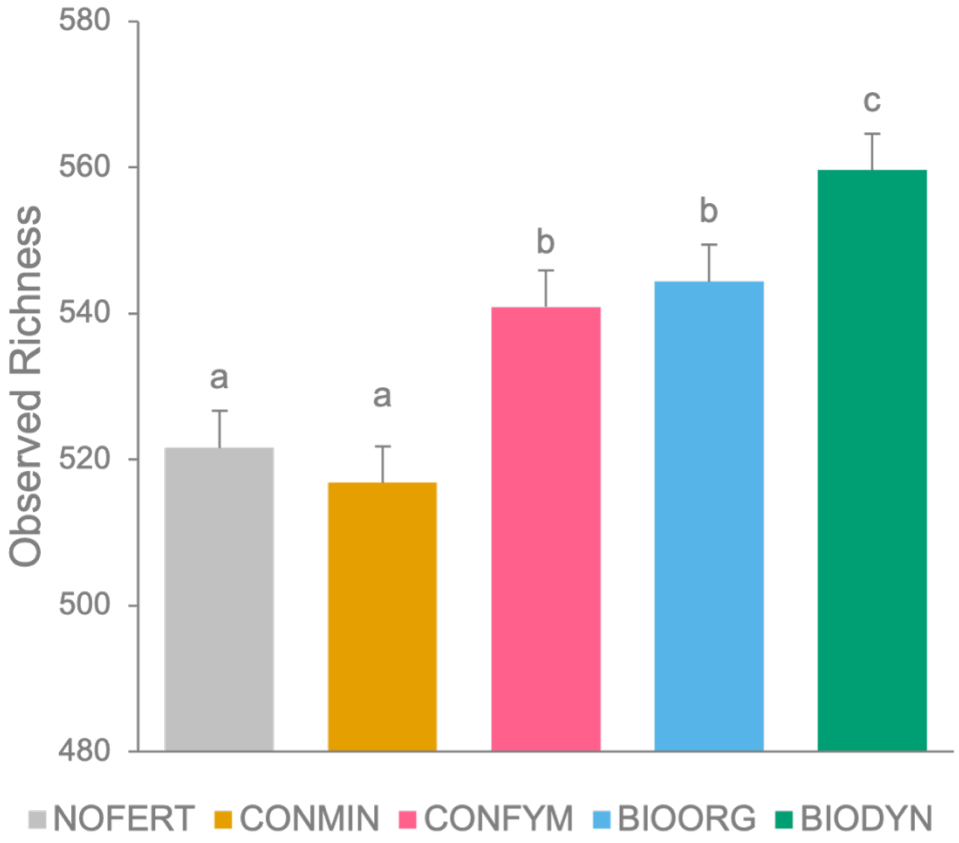


Organic systems increase soil microbial biomass and activity

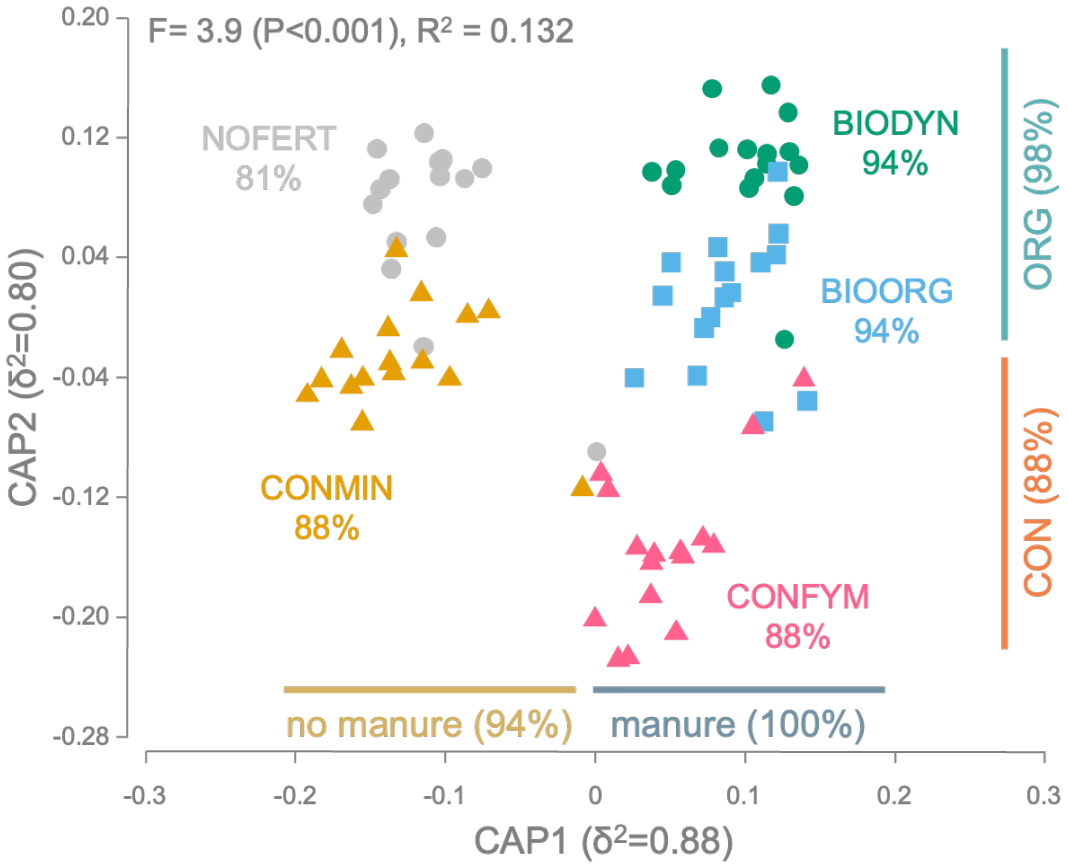
Krause et al. 2022 (Agronomy for Sustainable Development)

Soil microbial diversity

Alpha-diversity
(bacteria, archaea, fungi)



Beta-diversity
(bacteria, archaea, fungi)



ETH zürich Sustainable Agroecosystems

Hartmann et al. 2015 (The ISME Journal)

Soil microbial diversity

Each farming systems harbours a compositionally unique microbiome with distinct lifestyles

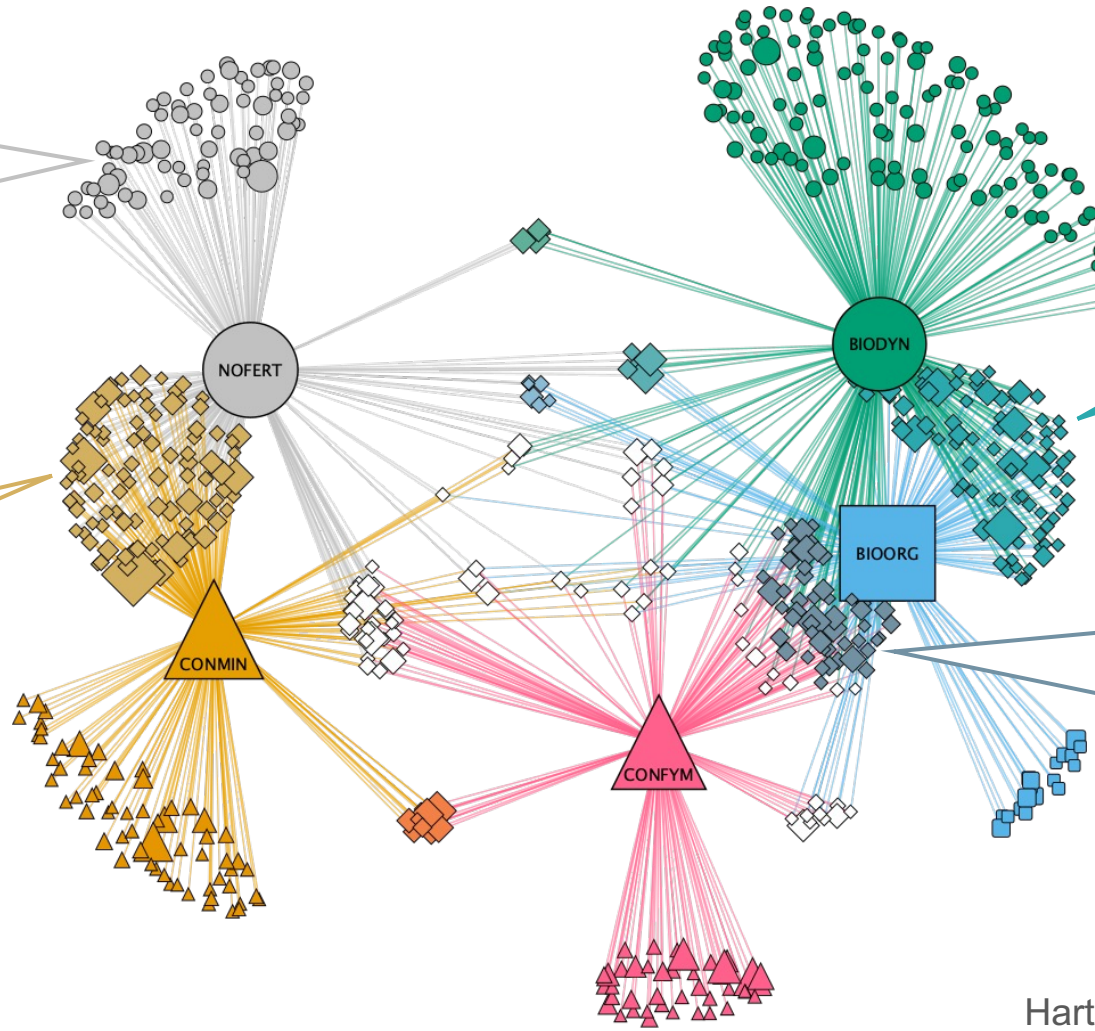
10% of the OTUs (= 50% of total sequences) responded (q<0.05) to management

Unfertilized system

Potential plant pathogens (Fusarium, Phoma, Ascochyta)

Organic systems

Potential biocontrols like Beauveria, Bionectria, Gliomastix, Stachybotrys, Myrothecium



Stockless systems

Dominated by oligotrophic groups adapted to resource-limited environments (Acidobacteria like C. Solibacter & C. Koribacter)

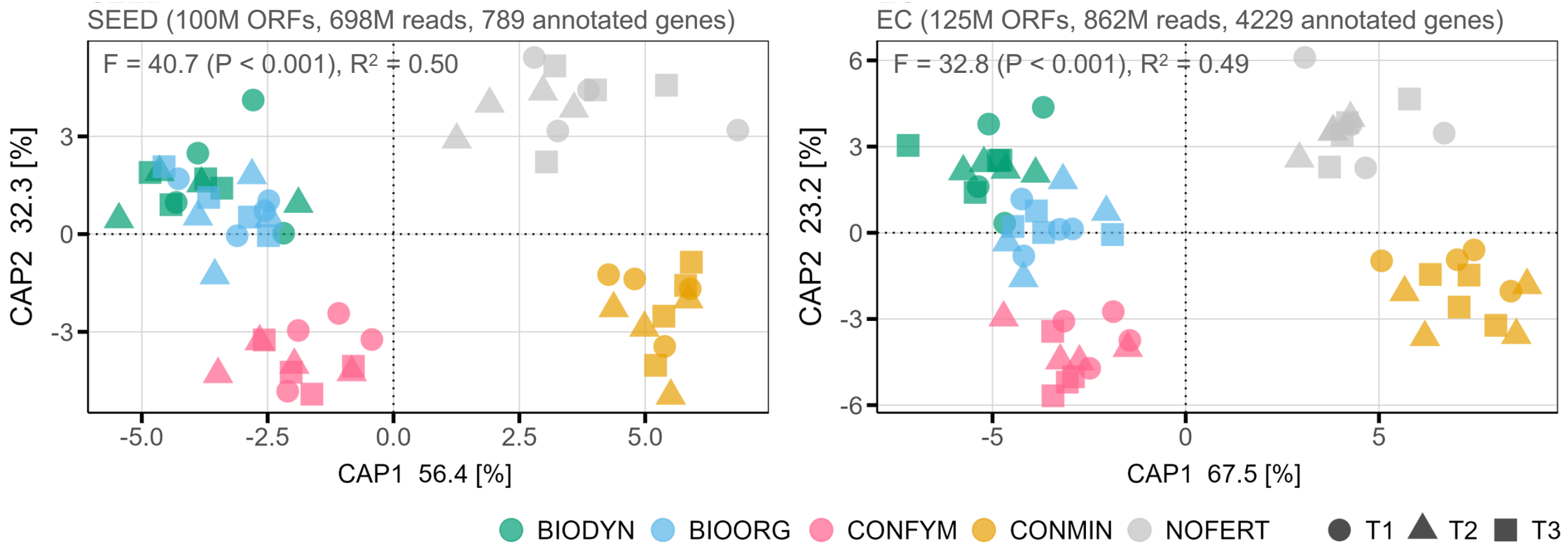
Manure-based systems

Dominated by groups commonly involved in degradation of organic matter (Firmicutes, Actinobacteria, coprophilous saprobic fungi like Lasiosphaeriaceae)

Hartmann et al. 2015 (The ISME Journal)

Soil functional potential

Shotgun metagenomes (5.7 billion reads, 347 million contigs, 422 million ORFs)



Differences in taxonomic composition translate into differences in the underlying genetic potential

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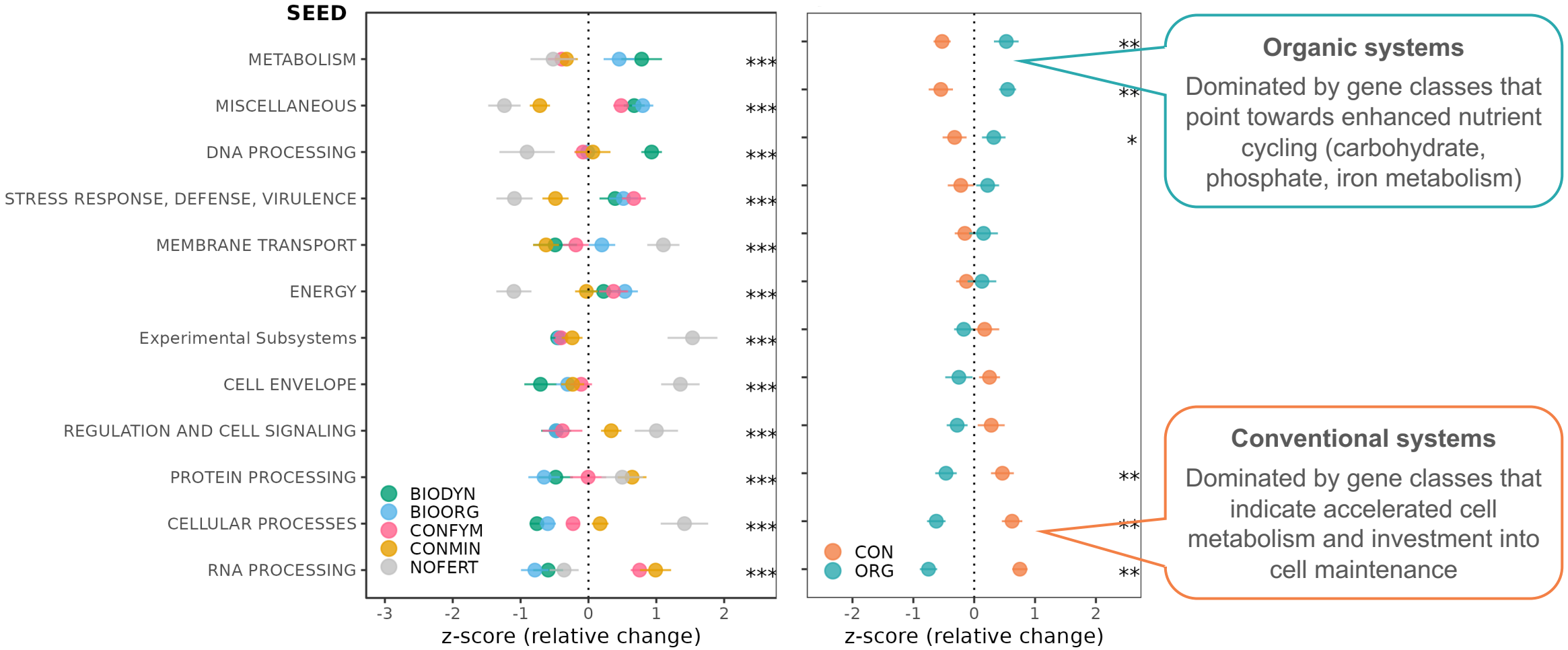
Krause, Hartmann et al. (in preparation)

Soil functional potential



Organic systems

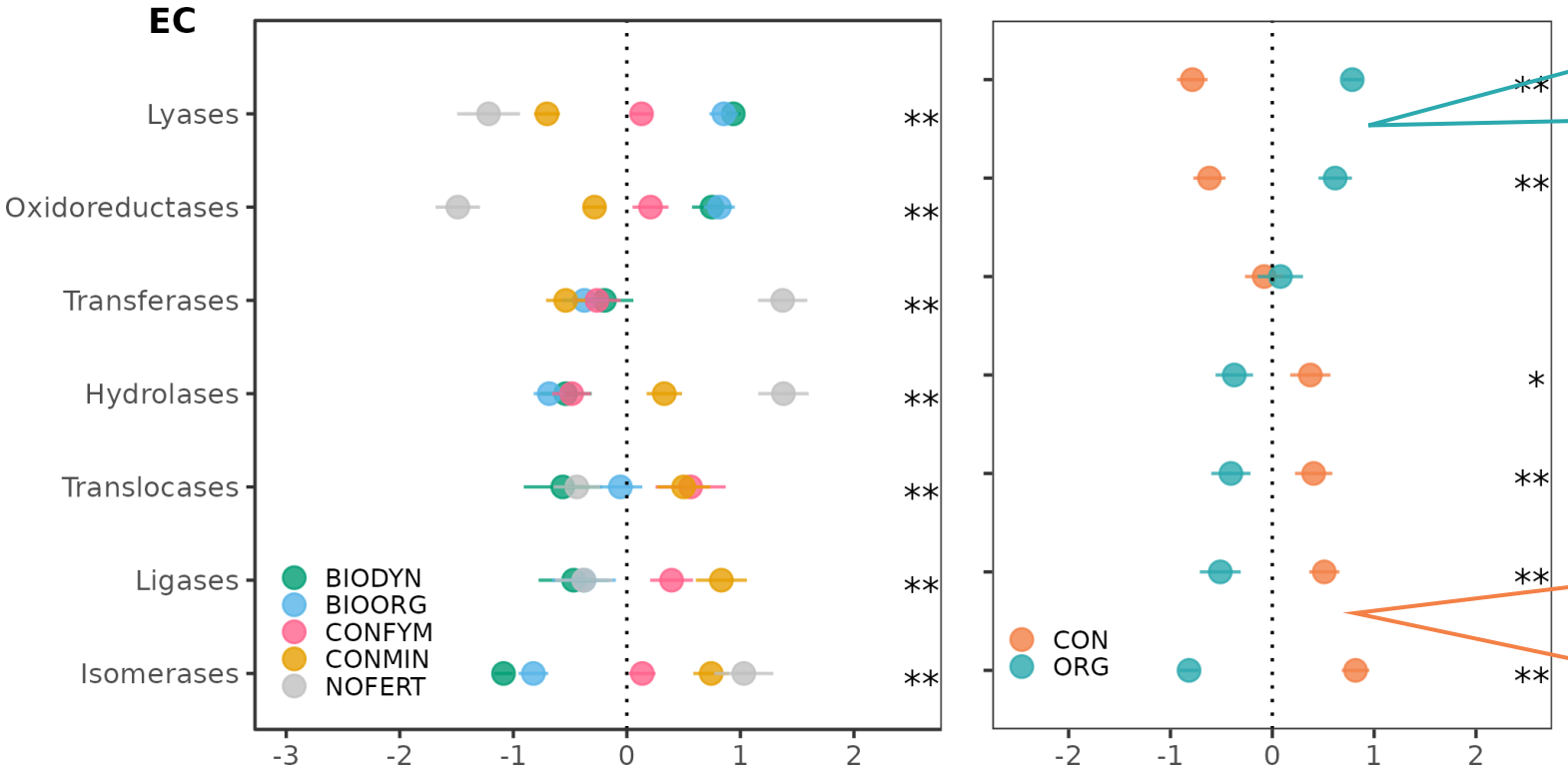
Dominated by gene classes that point towards enhanced nutrient cycling (carbohydrate, phosphate, iron metabolism)

Conventional systems

Dominated by gene classes that indicate accelerated cell metabolism and investment into cell maintenance

Krause, Hartmann et al. (in preparation)

Soil functional potential



Organic systems

Enrichment of lyases and oxidoreductases indicate a higher demand for breakdown of complex OM

Conventional systems

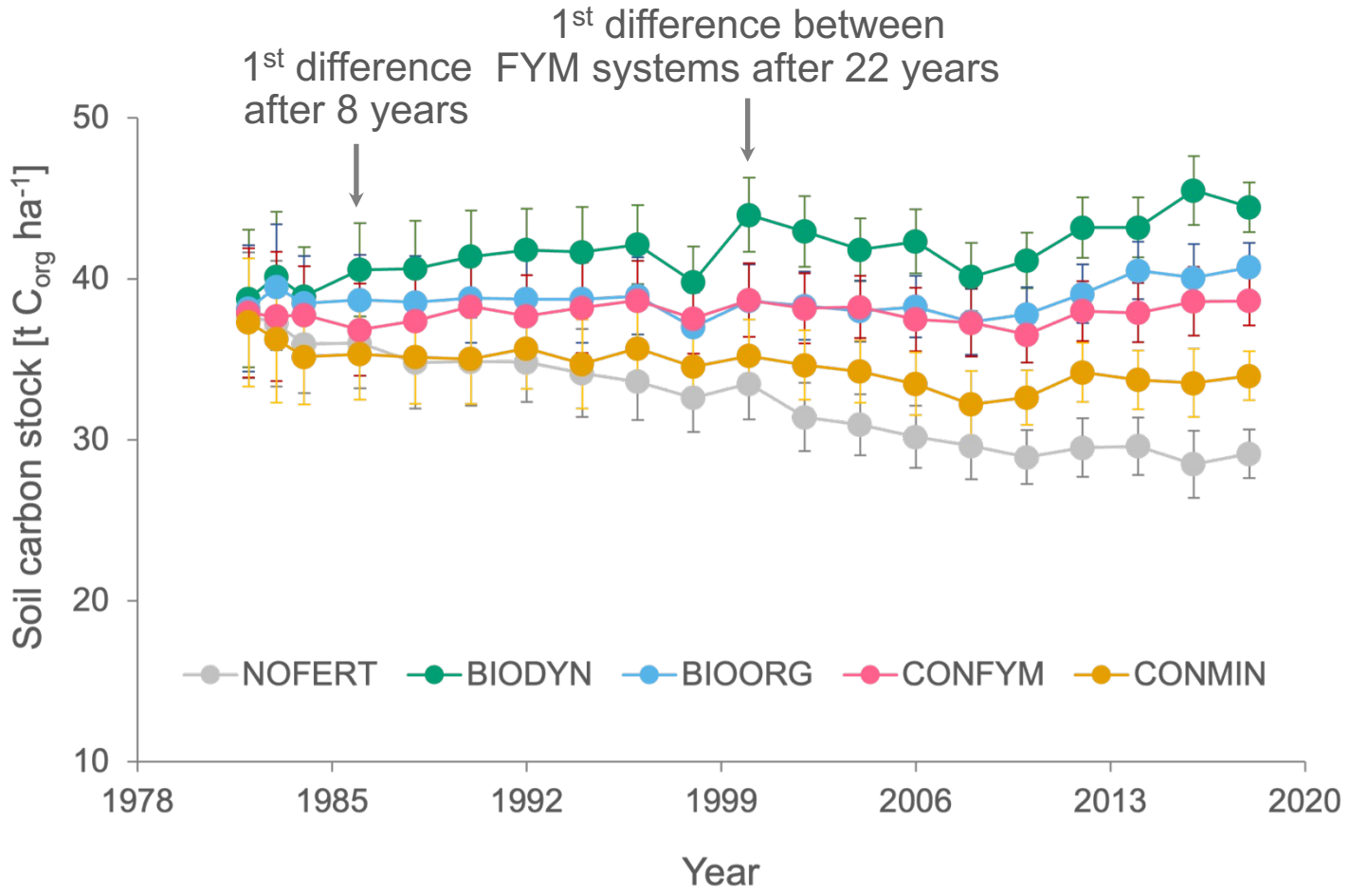
Enrichment in isomerases, ligases and translocases point towards metabolic adaptation to alternative energy sources and enhanced transmembrane molecule transport

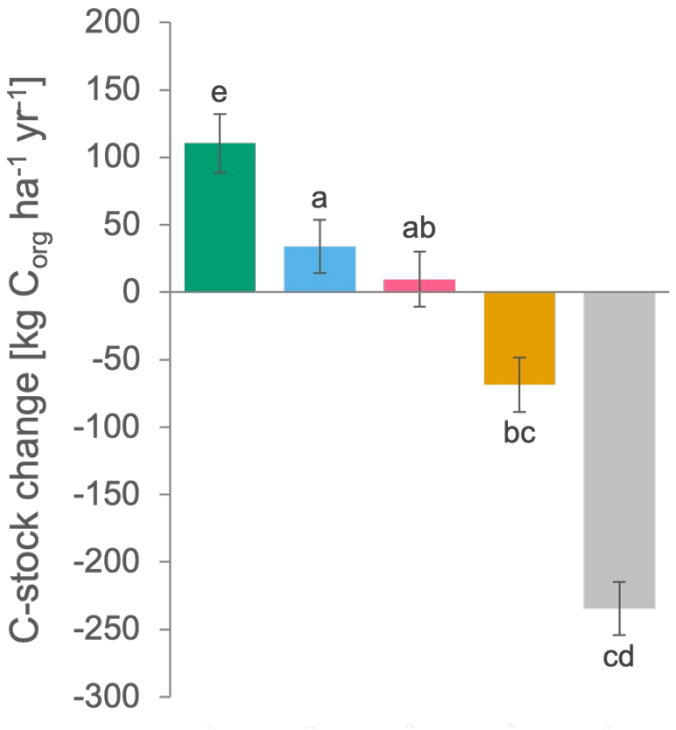
Overall, the soil microbiome in the organic systems appears to prioritize energy generation through the breakdown of available organic matter (C-rich environment), while the soil microbiome in the conventional systems seems to invest more into nutrient uptake and biosynthesis.

Krause, Hartmann et al. (in preparation)

Soil organic carbon (SOC)

The organic systems increase SOC, stockless systems loose SOC

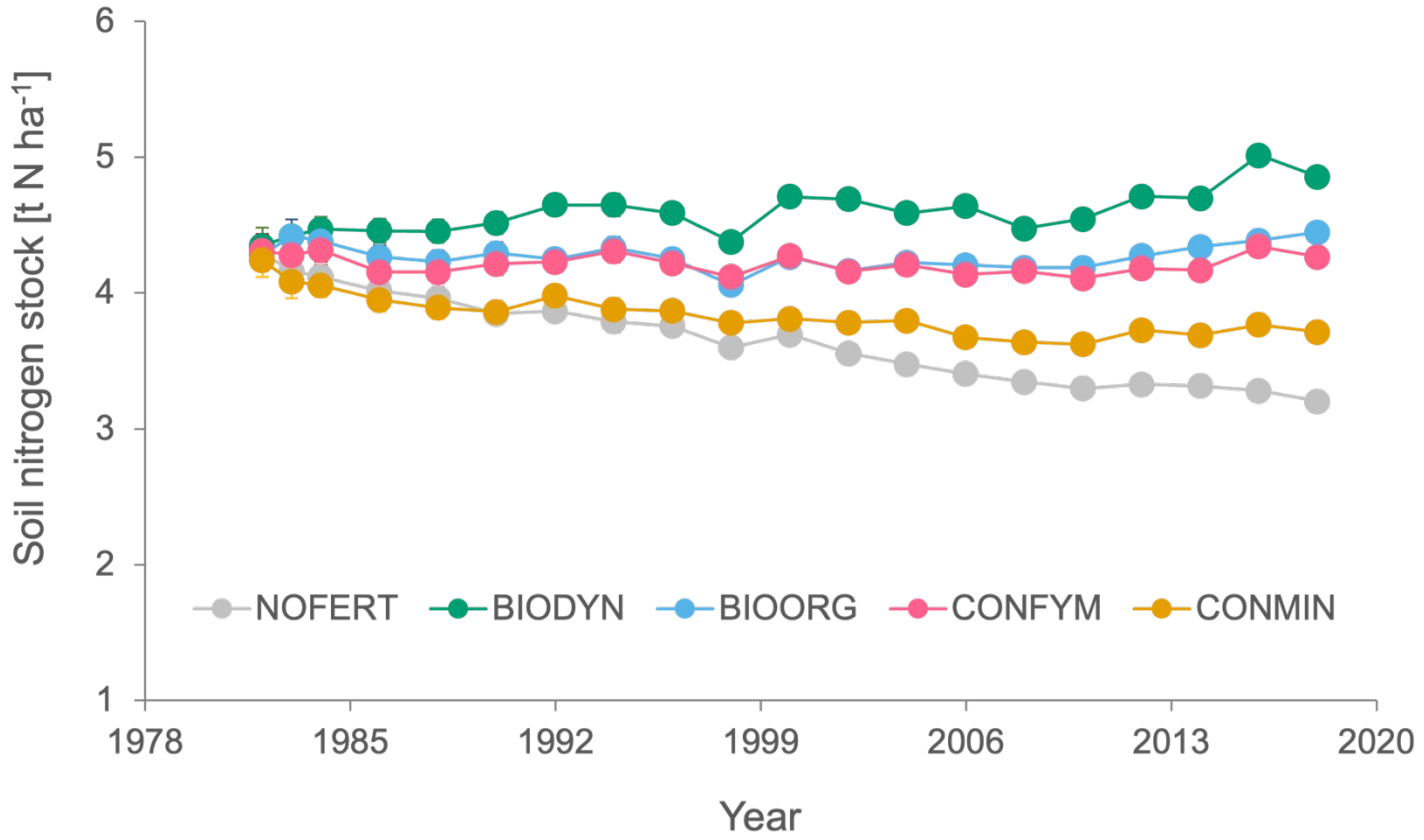


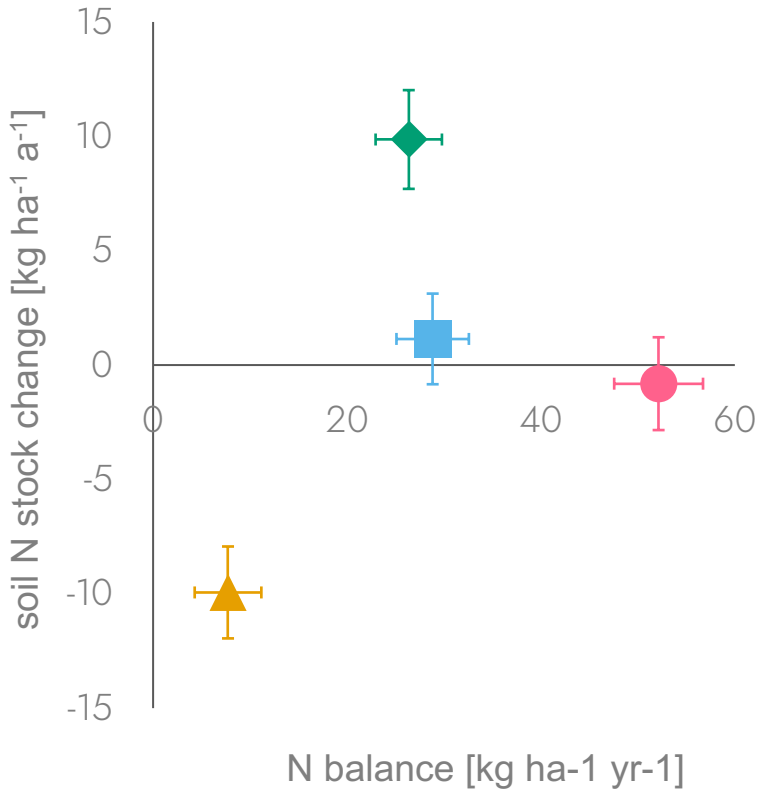


Krause et al. 2022 (Agronomy for Sustainable Development)

Soil nitrogen

Mixed system requires excess N to maintain soil N stocks, stockless system loses soil N despite positive N balance



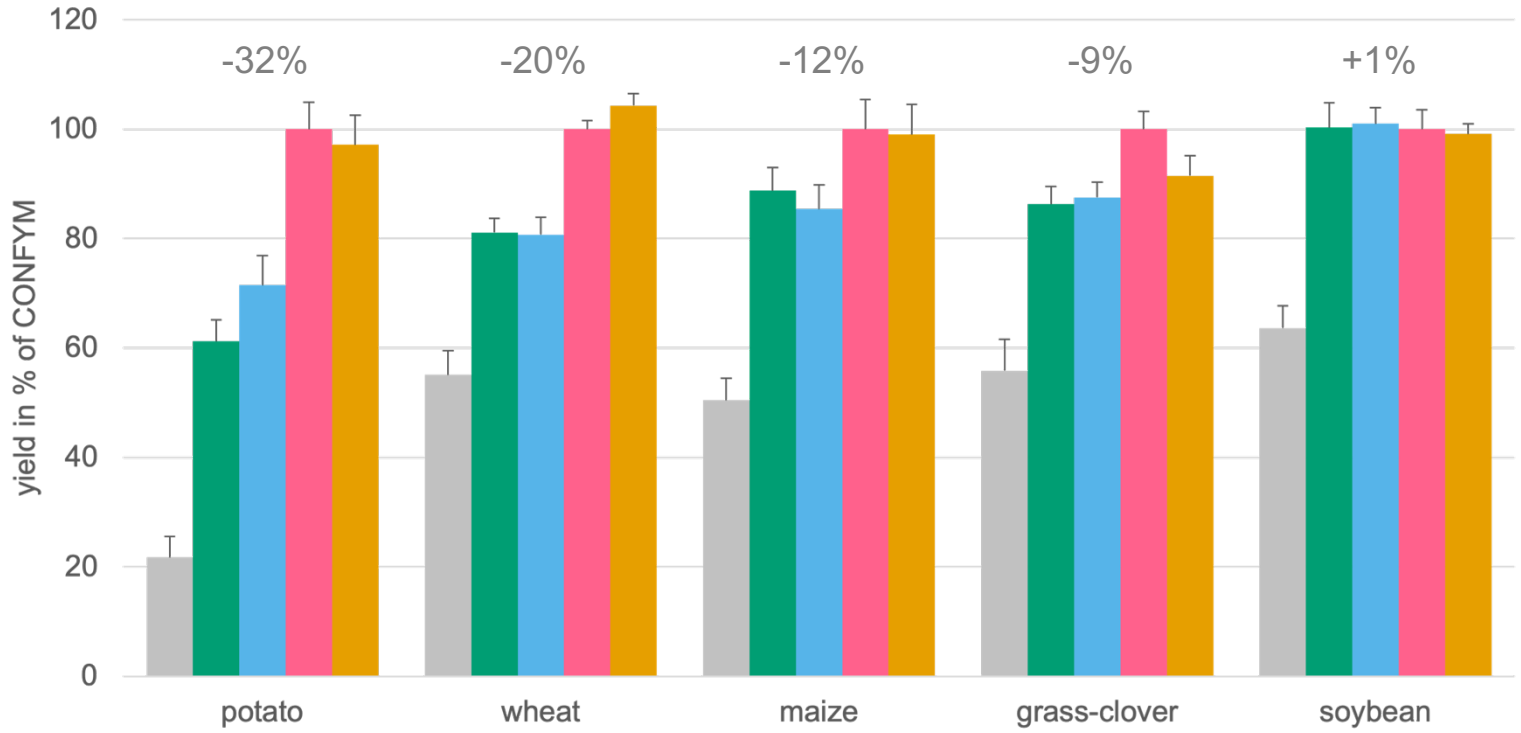


includes inputs via fertilization, deposition, seeds, and N fixation; outputs via harvest

Oberson et al. 2024 (Agriculture, Ecosystems and Environment)

Crop yields

Mean yields of crop rotations 1-6 (grass clover, wheat, potato) and 4-6 (soya, maize)



Average yield gap of 15% between organic and conventional systems, but highly crop-dependent

… in agreement with meta-analysis by de la Cruz et al. 2023 (Agricultural Systems)

Knapp et al. 2023 (Field Crops Research)

Conclusions

1) Organic and conventional farming systems harbor different soil microbiomes carrying distinct functions that are likely relevant for crop yield and health.
   - Microbiome composition and metabolic potential are largely driven by fertilization. Pesticide application seemed to play a subordinate role.
   - Organic fertilization promoted diverse microbial communities involved in decomposition and nutrient cycling, whereas stockless systems harbored more oligotrophic communities adapted to resource-limited environments and enriched for genes associated with cell maintenance.

2) Organic, lower-input farming systems showed an average yield gap of 15% but had positive effects on soil biodiversity (e.g., biocontrol species), metabolic potential to cycle nutrients, and soil carbon and nitrogen stocks. This suggests positive long-term trajectories for crop yield and health.

Acknowledgments

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