Forum for the Future of Agriculture®

From Soil Science to Policy

Harnessing the Biodiversity Beneath Our Feet for a Climate-Resilient Future

March 31st, 2025 11:00 - 17:00 Residence Palace

SOILGUARD ELO European Landowners' Organization IUCN

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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	Session 1	
11:00-11:05	Welcome Remarks Francesc Castro Cirac (Coordinator)	
11:05-11:15	Keynote Address by Sophie Helaine (DG AGRI)	
11:15-12:05	SOILGUARD Project Overview and Joint Results with the Microservices project.	Martin Hartmann (ETH Zurich) Pablo Sanchez Cueto (LEITAT) Salvador Lladó Fernández (UB)
12:05-12:25	The Valuation of Soil-mediated contributions to people.	Tobias Möllney (IÖW) Dr. Alexandra Dehnhardt (IÖW)
12:25-12:55	The SOILGUARDIANS App.	George Manassakis (WINGS) Laurence Jones (UKCEH) Els Dhiedt (UKCEH)
12:55-13:00	Closing Remarks by Salvador Lladó Fernández (UB)	

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	Session 2	
13:55-14:05	Opening Remarks	
14:05-14:25	SOILGUARD’s Soil biodiversity indicators	Pablo Sanchez Cueto (LEITAT) Giulia Bongiorno (WUR)
14:25-15:05	Expert Panel Discussion: Measuring Soil biodiversity, future strategies for harmonization and challenges	Diedrich De Ghellinck (AgriLand) Nataliya Zinych (John Deere) Tamás Krisztin (IIASA) Geert Magona van de Meer (reNature) moderated by Ana Rocha (ELO)
15:05-15:15	Q&A	
15:15-15:20	Closing Remarks	

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	Session 3	
15:35-15:50	Opening Remarks	Tassos Haniotis (ForumforAg & IIASA) & Salvador Lladó Fernández (UB)
15:50-16:30	Expert Panel Discussion: Linking Soil Monitoring and Resilience to Policy	Mirco Barbero (DG ENV), Ana Rocha (ELO), Maximilian Meister (NABU). Moderated by Elodie Champseix (IUCN)
16:30-16:45	Q&A	
16:45-16:55	Takeaways & Next Steps	
16:55-17:00	Final Closing by Gabriele Sacchettini (ELO)	

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SOILGUARD Project Overview

Salvador Lladó

31/03/2025

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SOILGUARD

General Information

<u>Project Title</u>:
Sustainable soil management to unleash soil biodiversity potential and increase environmental, economic and social wellbeing.

25 PARTNERS

17 COUNTRIES

4 YEARS PROJECT

9 WP

45 DELIVERABLES

Grant Amount

€6.999.161

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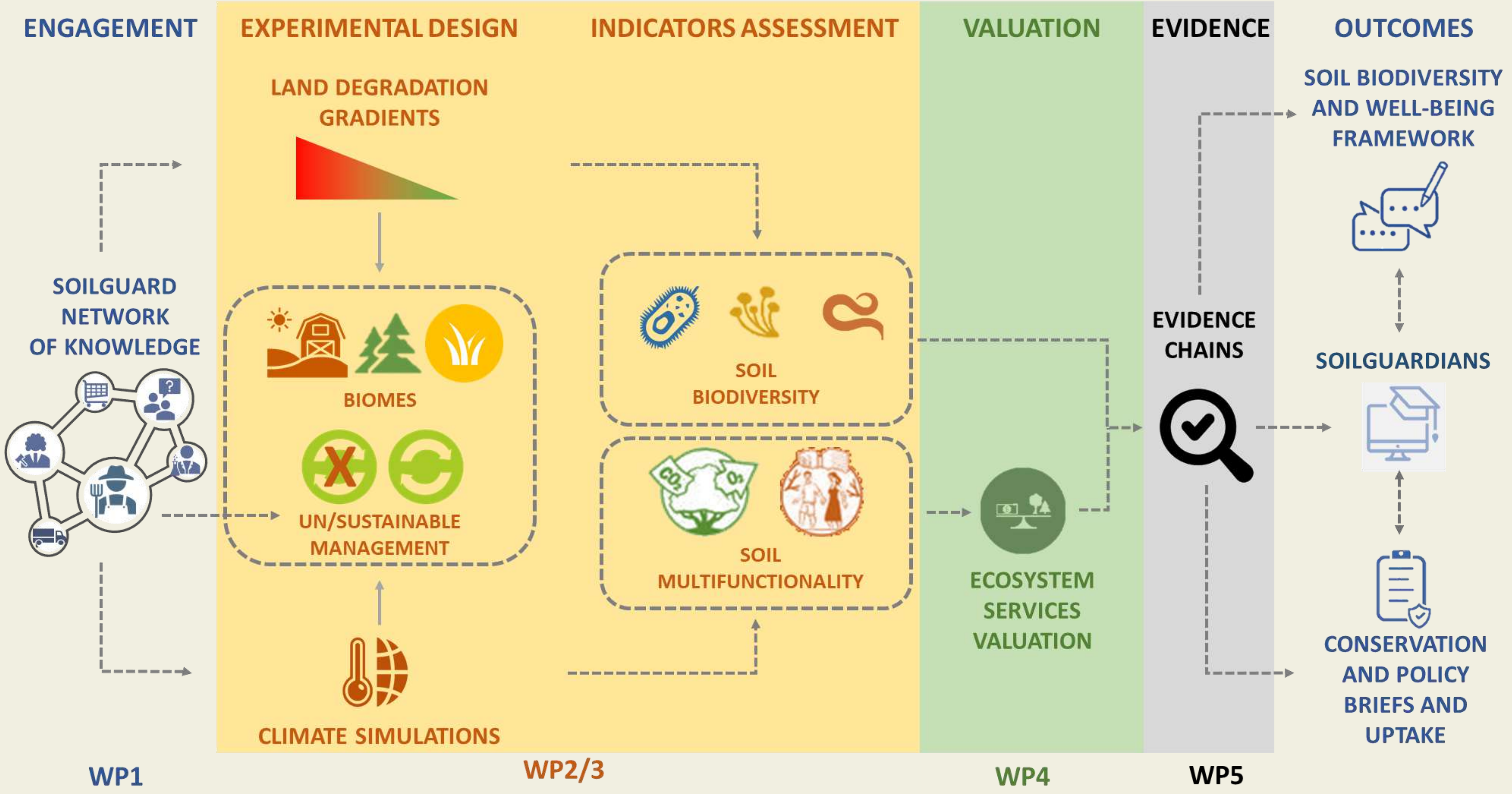

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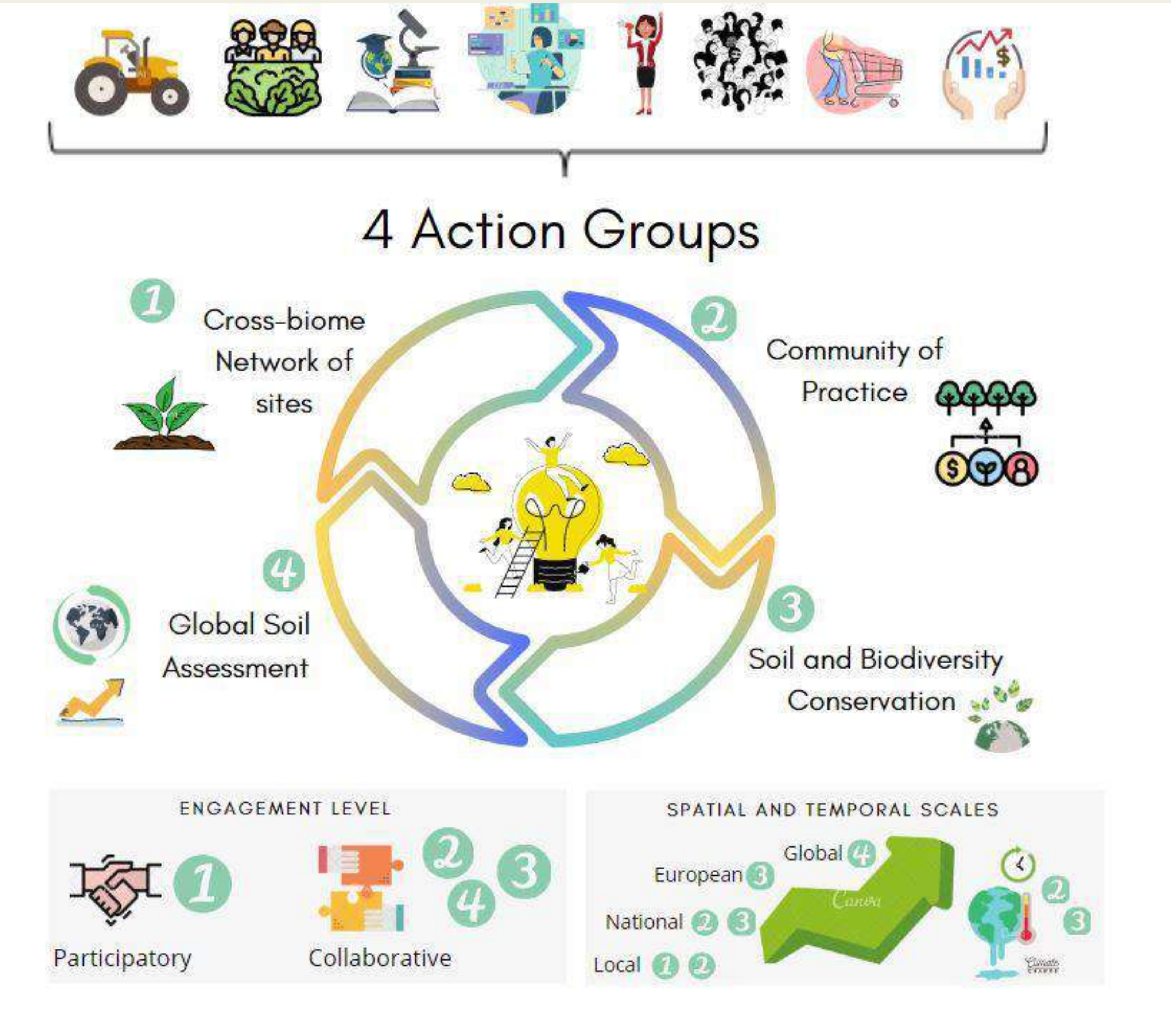
WP1: Co-creation in SOILGUARD



ENGAGE STAKEHOLDERS

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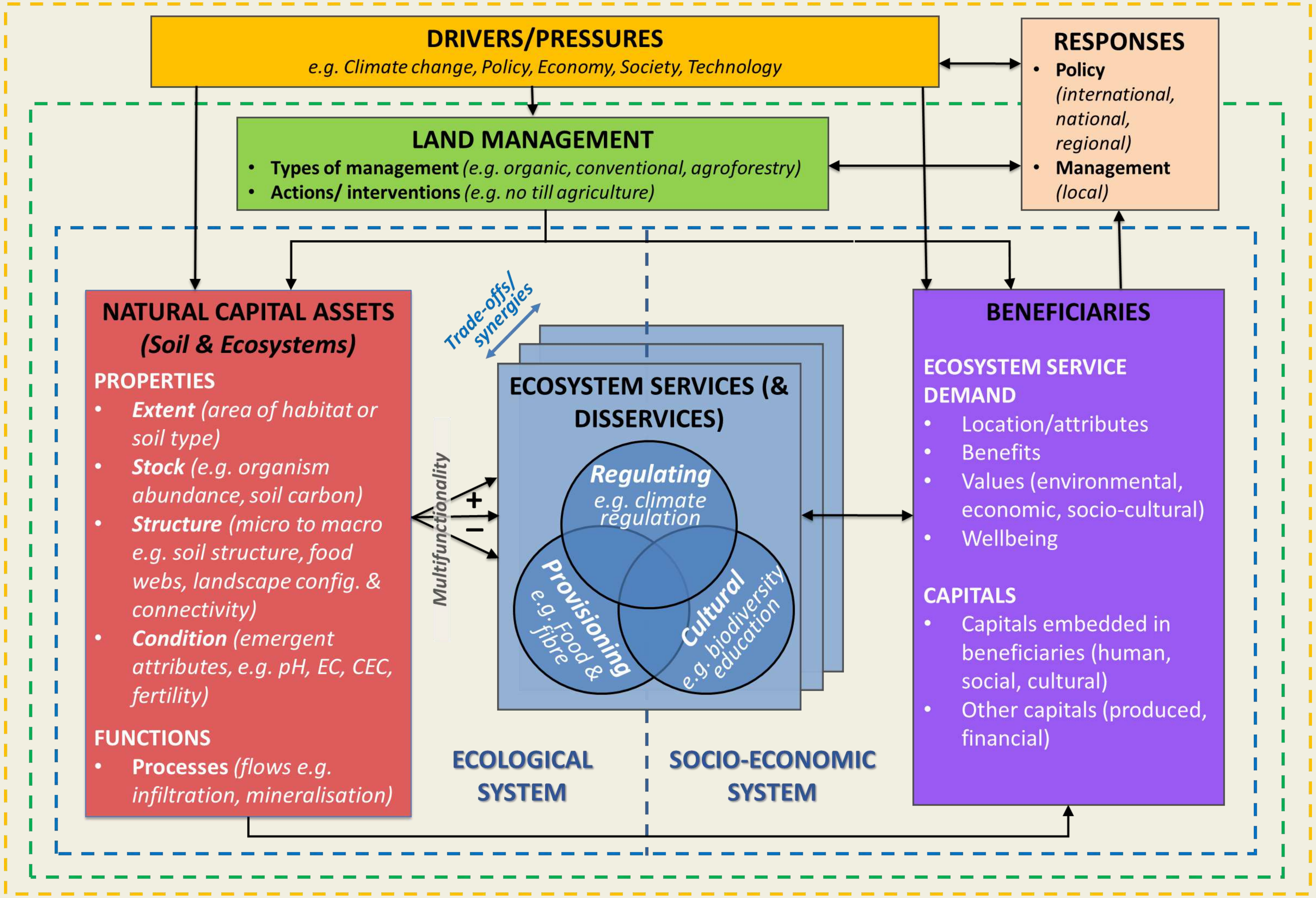
The soil biodiversity and well-being framework



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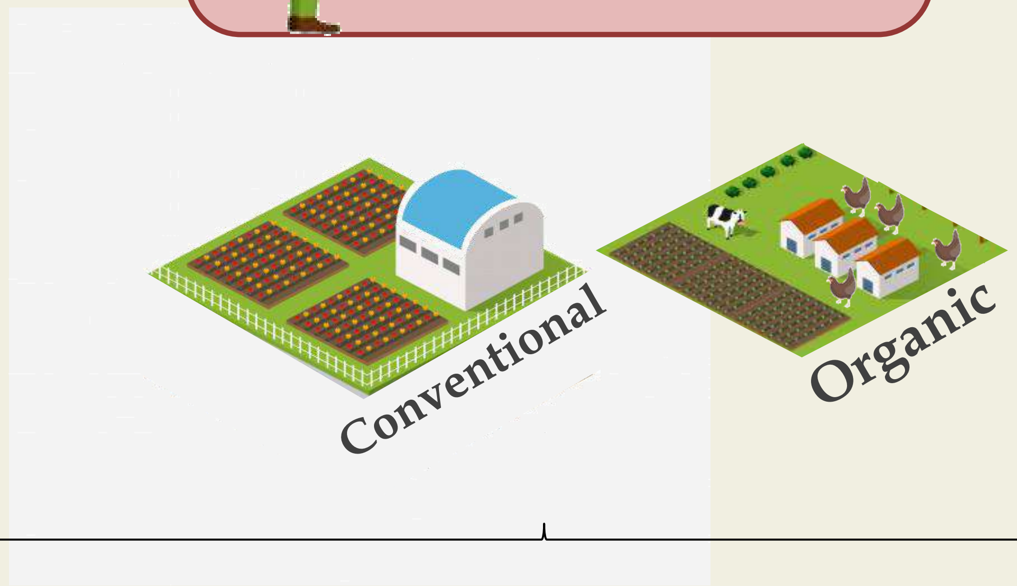
WP2: Impacts of unsustainable management and land degradation on soil biodiversity and multifunctionality

Benchmark Grassland (20 sites)


Grass monoculture


Grass-clover mixed

CROPLAND (169 sites)

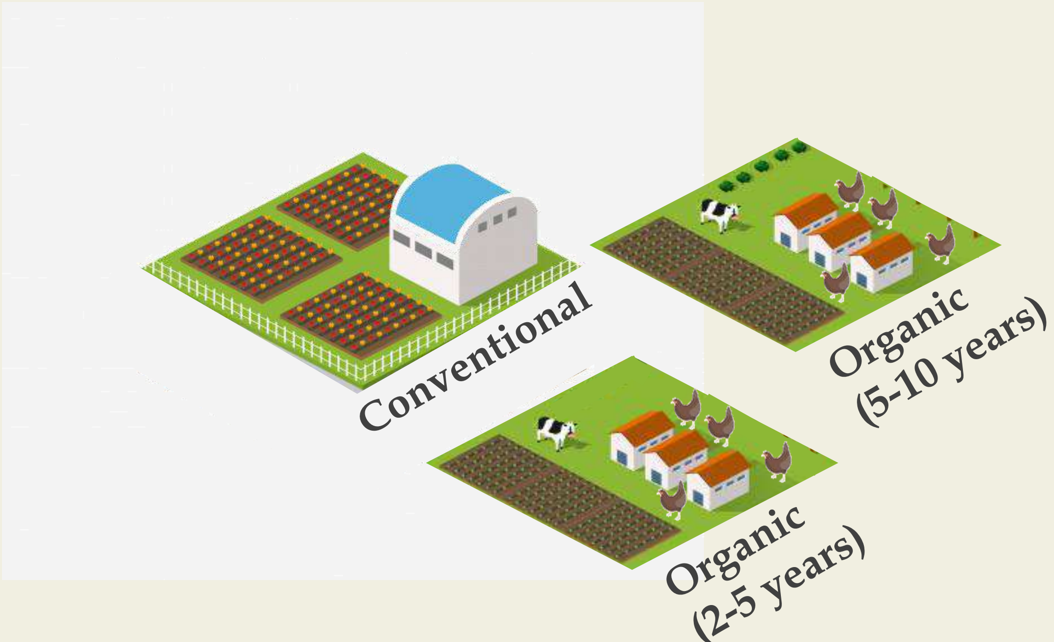


Benchmark Forestry (24 sites)

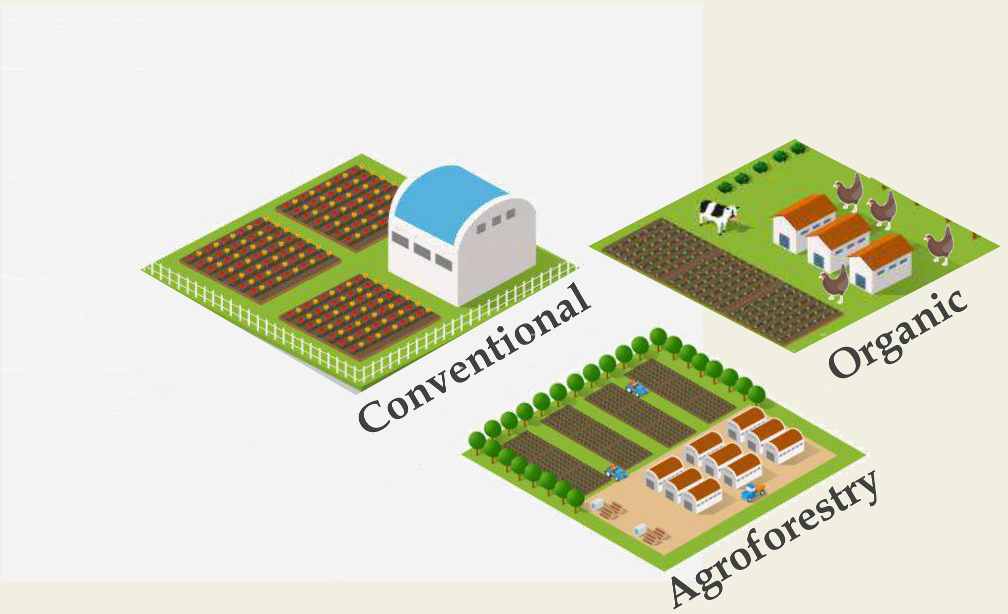

Clearcutting


Continuous cover

Benchmark Organic Transition (+10 sites)

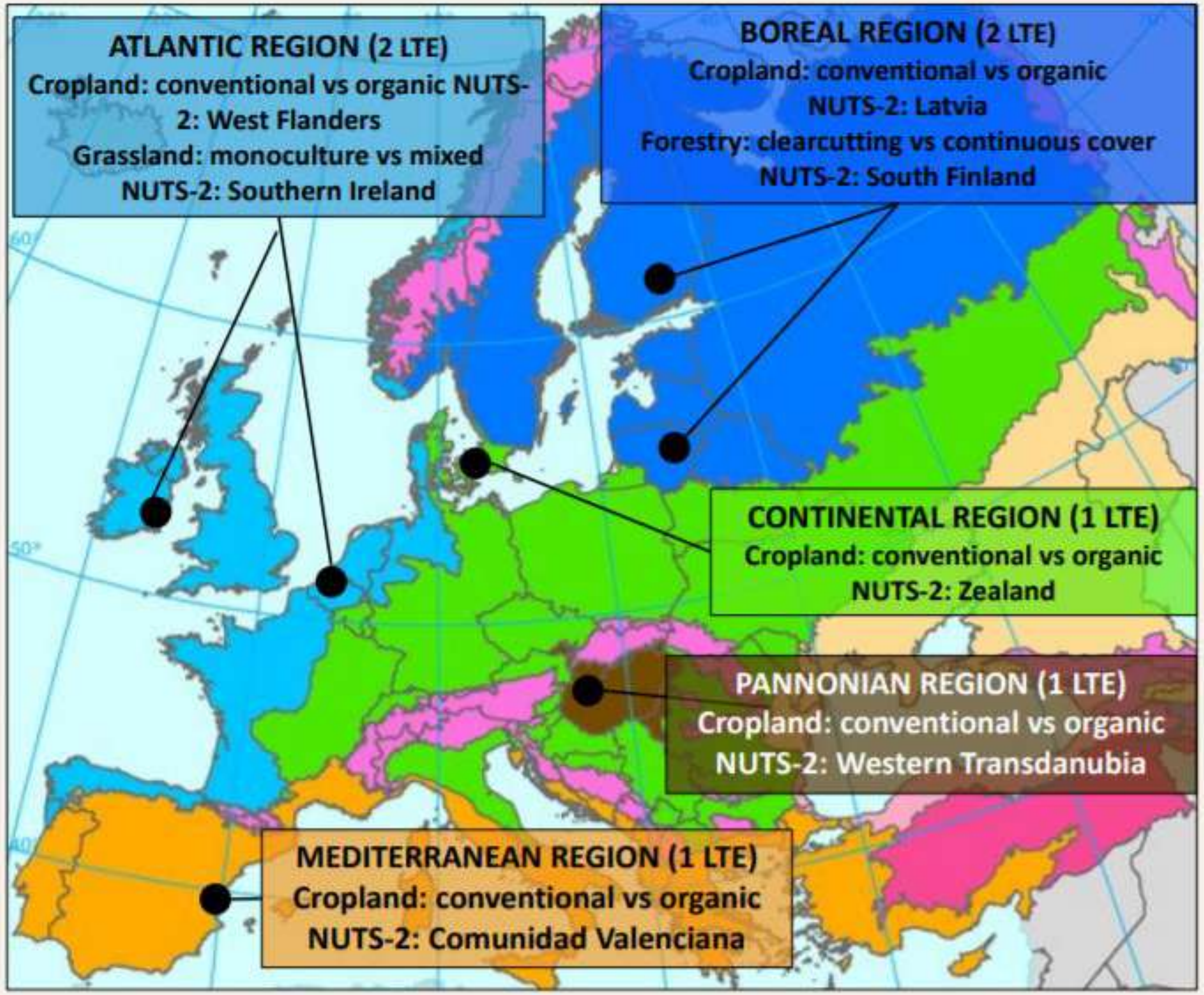


Benchmark Agroforestry (+10 sites)



- Each country: 1 NUTS- 2 region
- Each NUTS-2: land degradation gradient (high, medium, low)
- Each step of the gradient 2 or 3 management practices (triplicate sites)
- Assessment of soil biodiversity and soil multifunctionality indicators

WP3: Impacts of climate change on soil biodiversity and multifunctionality



Drought simulation in Latvia (Photo: Ina Alsina).

Drought + Heatwave simulation in Denmark (Photo: Helle Hestbjerg).

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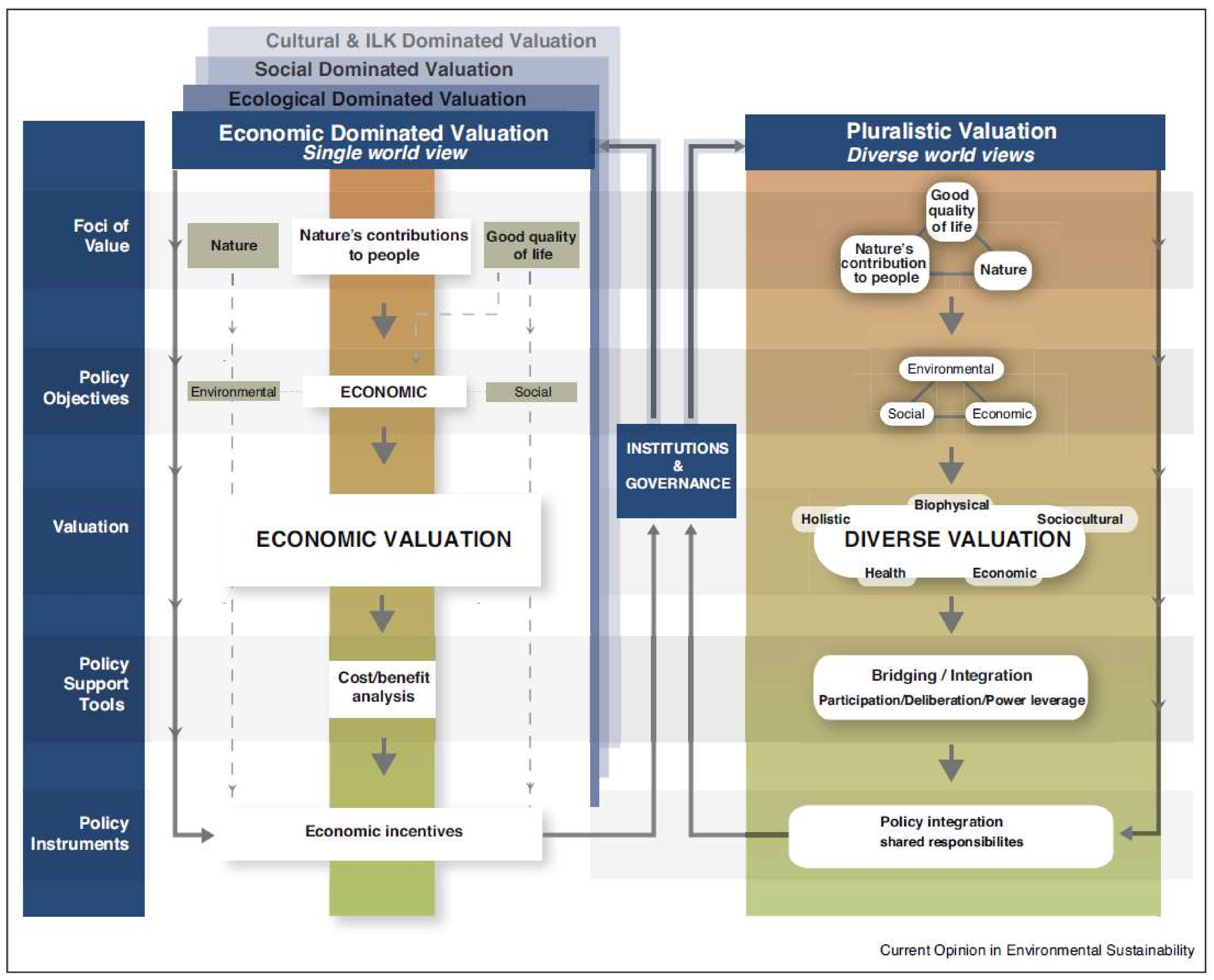
WP4: Economic and social consequences of unsustainable soil management



Source: Pascual et al. (2017): Valuing nature's contributions to people: the IPBES approach. In: Current Opinion in Environmental Sustainability 26-27, S. 7–16.

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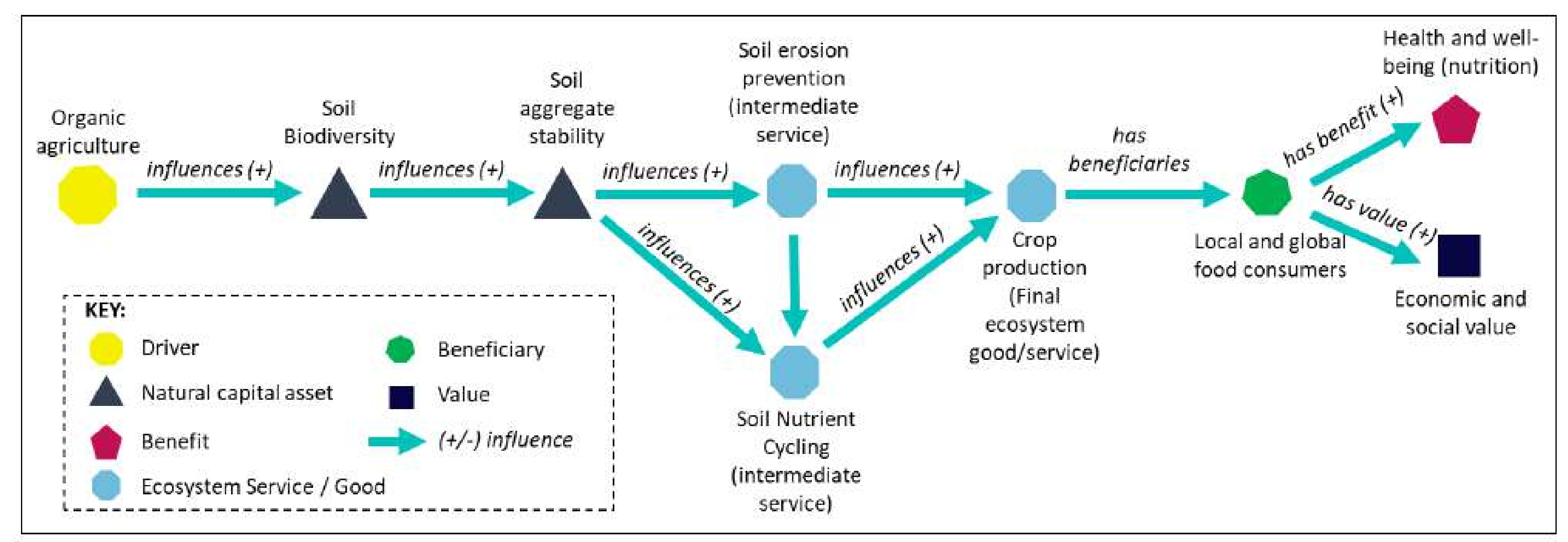
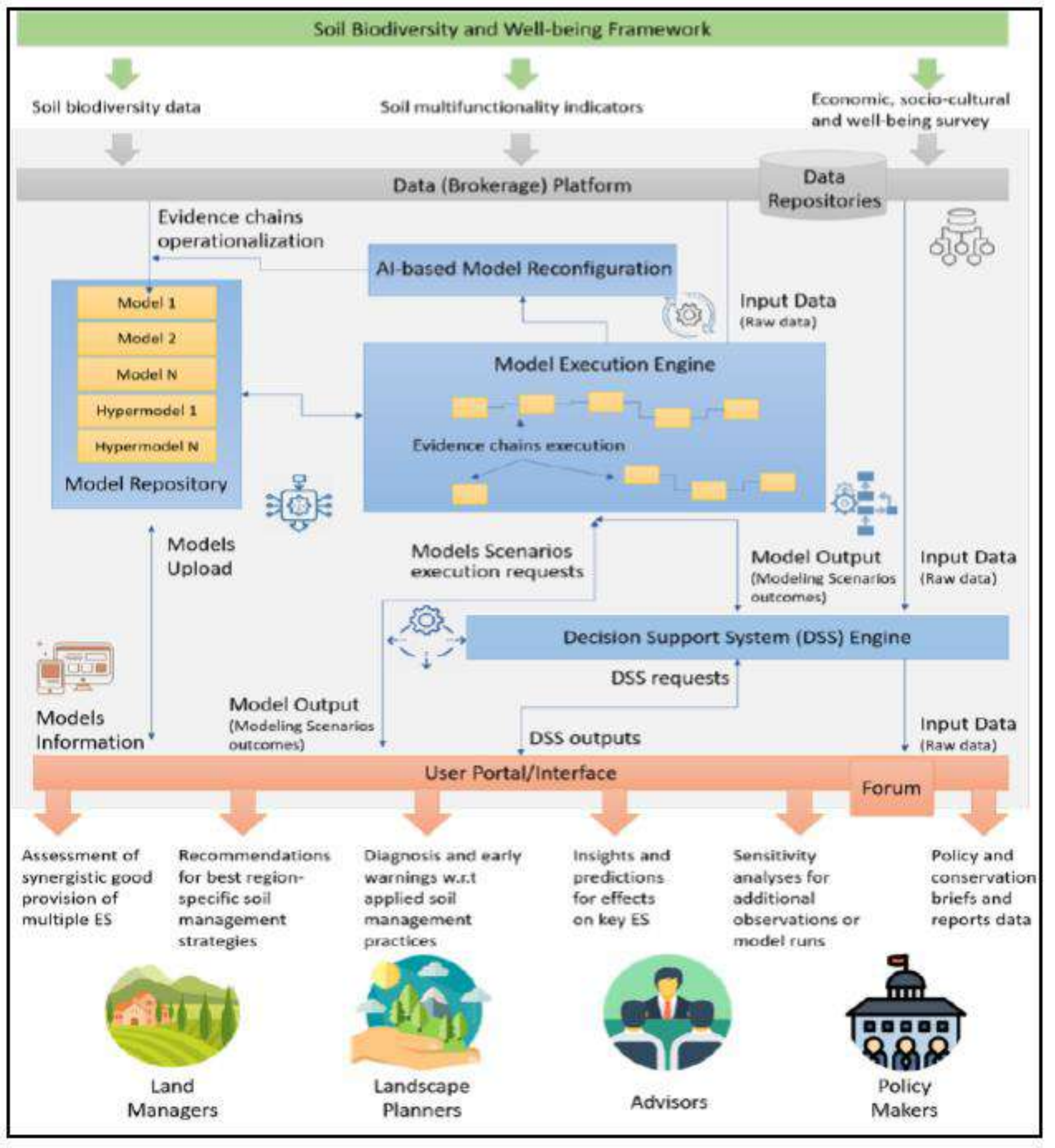
WP5: From evidence to the app





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WP6: conservation & policy recommendations

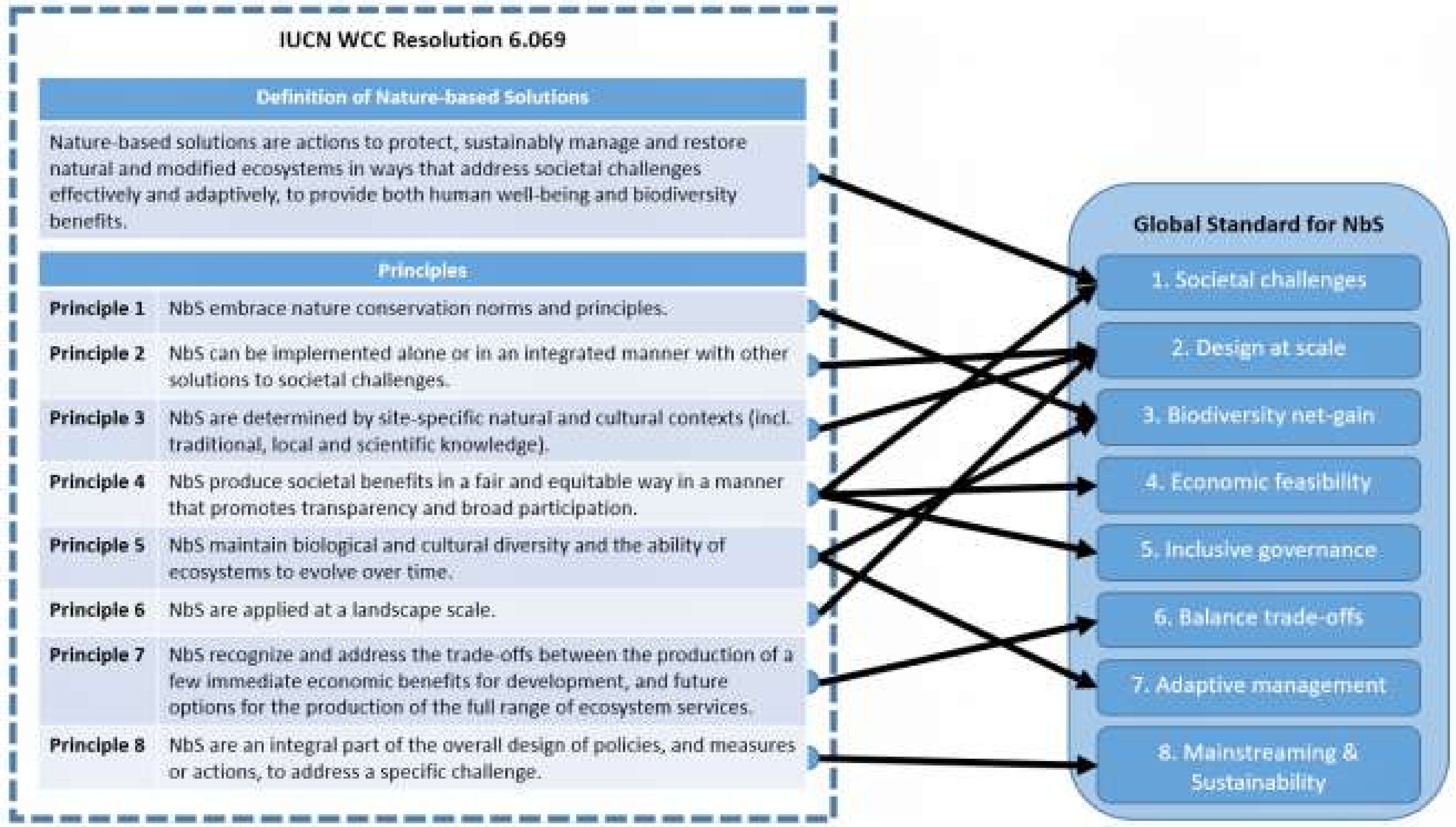

Figure 5: Link between the NbS Principles and the NbS Standard Criteria. (© IUCN)

GLOBAL SOIL PARTNERSHIP

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Thank you for your attention.

Salvador Lladó

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Region-specific impact of soil management and degradation on soil biodiversity and cascading effects on soil multifunctionality

Pablo Sánchez-Cueto, LEITAT
SOILGUARD TEAM

31/03/2025

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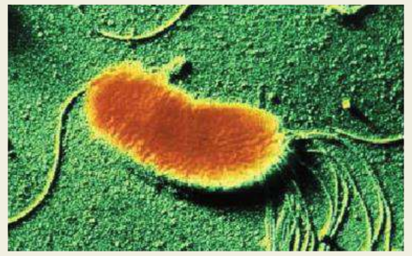
Introduction

Overview of soil biodiversity and functionality assessment

8 groups of soil biota

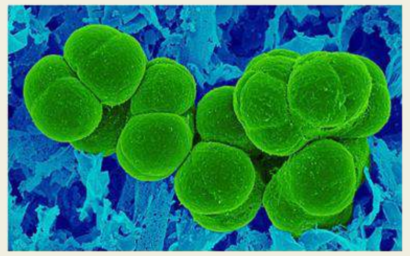
Prokaryotes

Bacteria
16S rRNA /PLFAs



Mcdonald & Rogers 2010

Archaea
16S rRNA /PLFAs



Dennis Kunkel

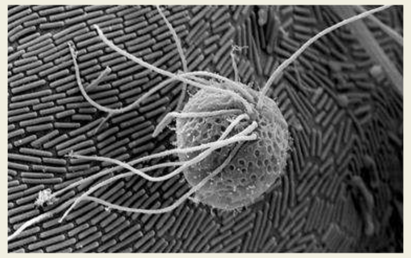
+ Viruses & ARGs
(under processing)
shotgun DNA sequencing

Eukaryotes

Fungi
ITS rrn / 18S rRNA / PLFAs

Joint Genome Institute

Protists
18S rRNA / PLFAs



Kevin Carpenter

Nematodes
18S rRNA / Morphotyping

Andy Murray

Micro-arthropods
18S rRNA / COI / Morphotyping

Felicity Crotty

Earthworms
18S rRNA / 16S rRNA mit

Goody Clairenstein

27 soil “functions” and 6 NCPs

- Basic properties: texture, pH, EC, bulk density
- Food production: crop yield, NDVI
- Soil formation & protection: nutrients, enzymes, litter decomposition, aggregate stability, N mineralization, N-genes, mycorrhizae, nitrate and phosphate leaching
- Climate regulation: soil C, methanotrophs
- Regulation of hazards and extreme events: water infiltration and holding capacity
- Regulation of detrimental organisms: leaf damage, root-feeding nematodes

1. What is the **soil biodiversity status** across biomes and regions?
2. How the **management** impact on **biodiversity** and **functionality**?
3. Assess the links between **biodiversity, multifunctionality and crop yield.**

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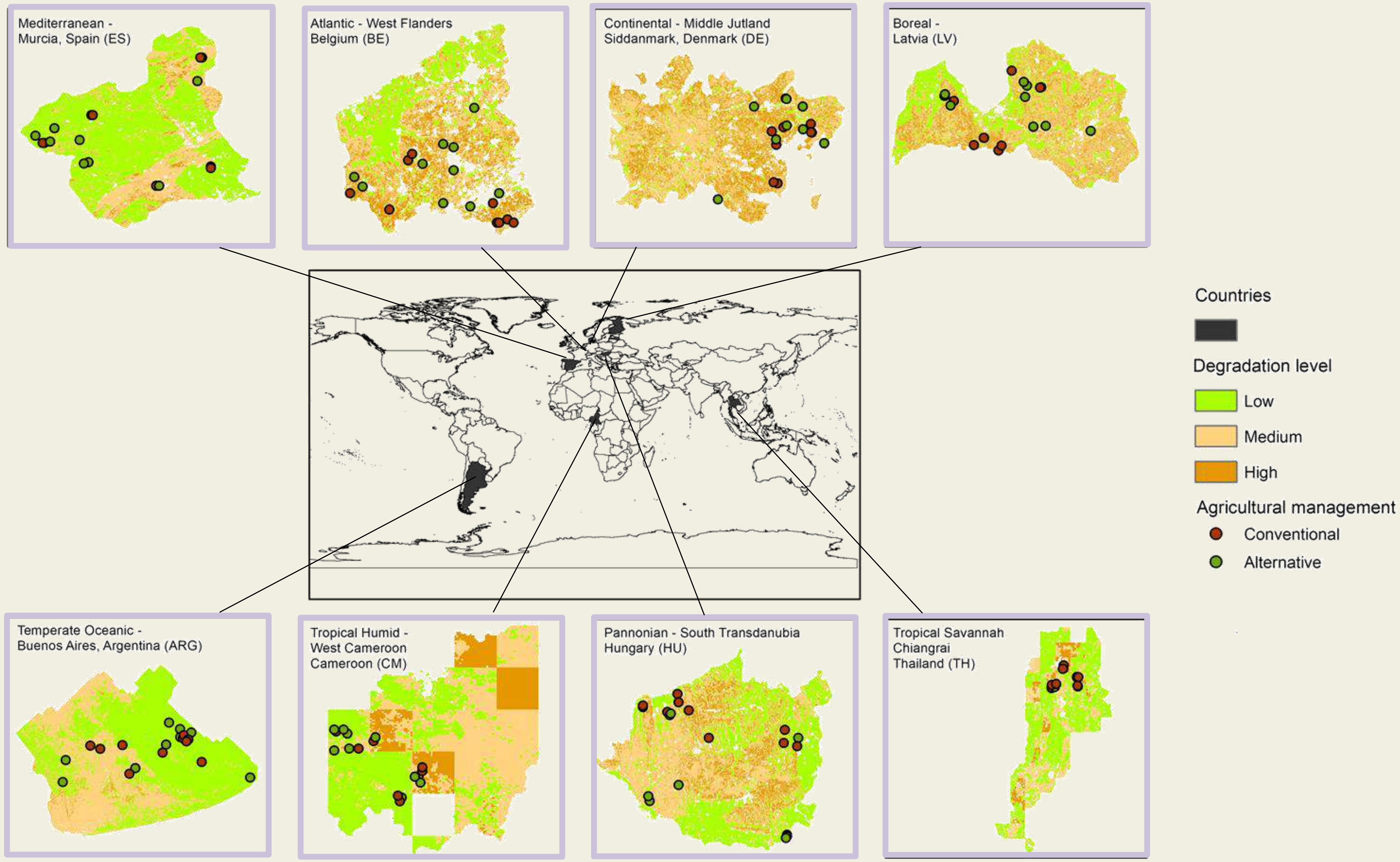
Experimental design



By María Paula Barral (IPADS – Balcarce; INTA-CONICET)

1.

Conventional croplands

Organic croplands

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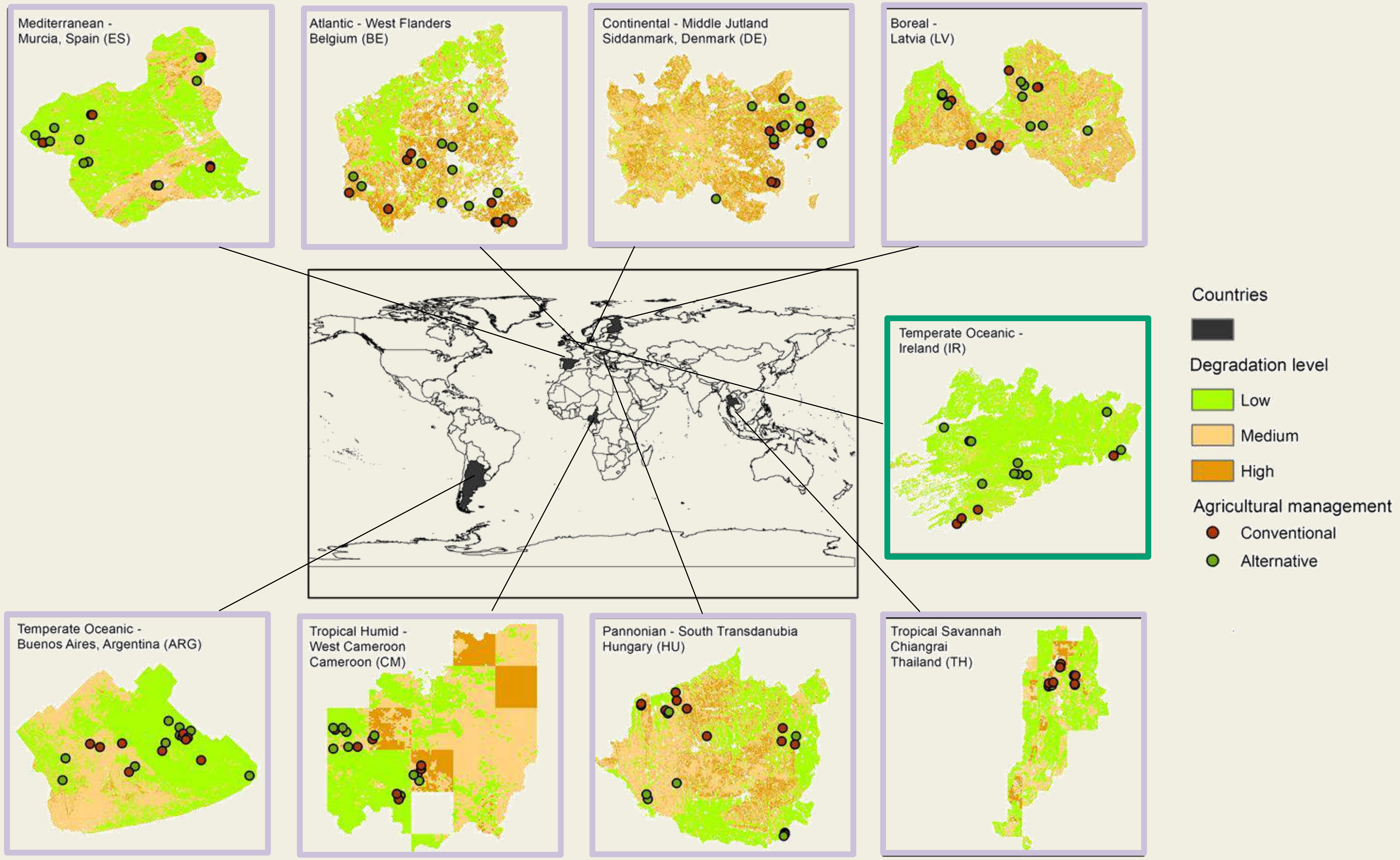
Experimental design



1.

Conventional croplands

Organic croplands

2.

Monoculture grasslands

Mixed species grasslands

By María Paula Barral (IPADS – Balcarce; INTA-CONICET)

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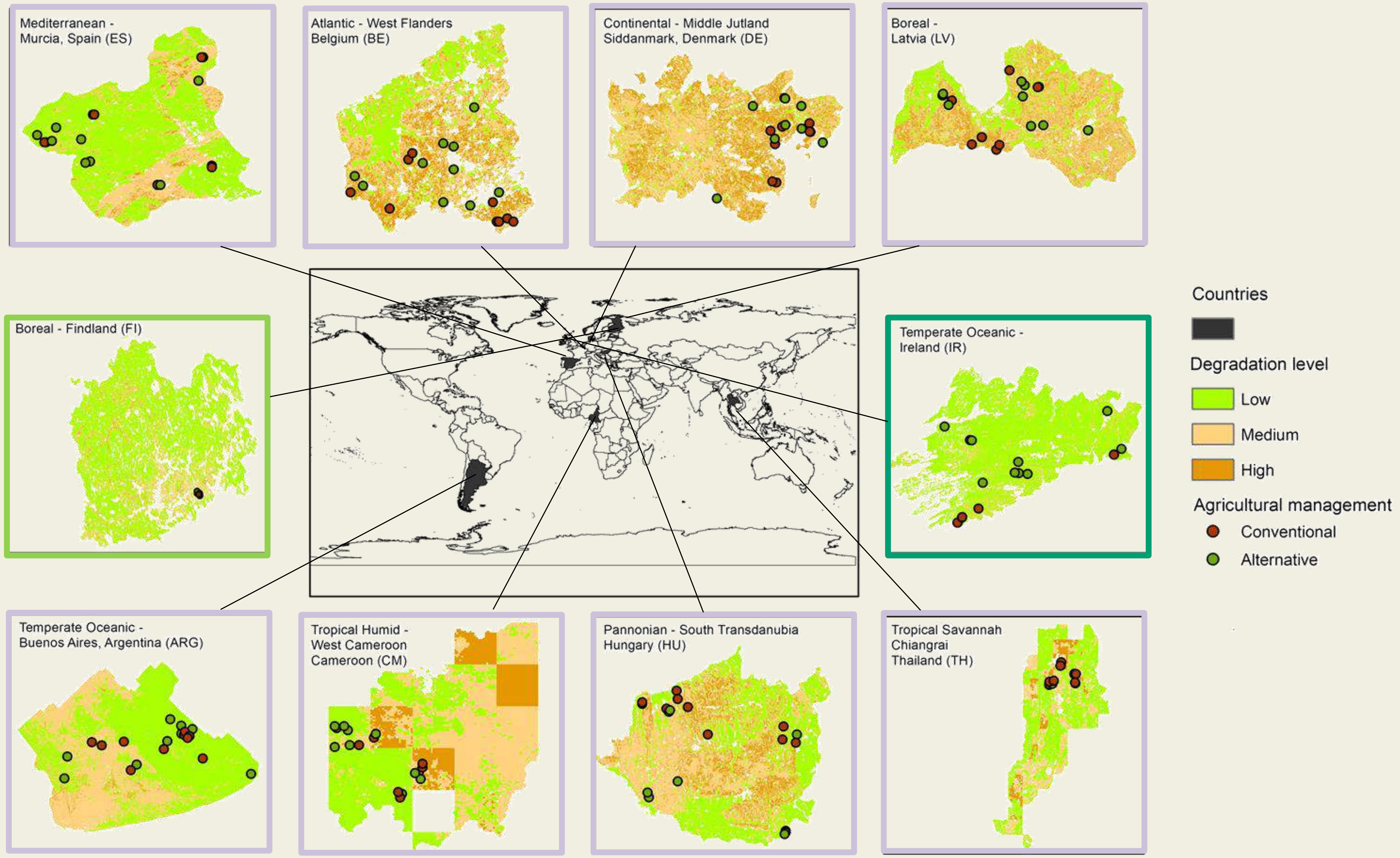

By María Paula Barral (IPADS – Balcarce; INTA-CONICET)

1.

Conventional croplands

Organic croplands

2.

Monoculture grasslands

Mixed species grasslands

3.

Clear-cut forestry

Continuos-cover forestry

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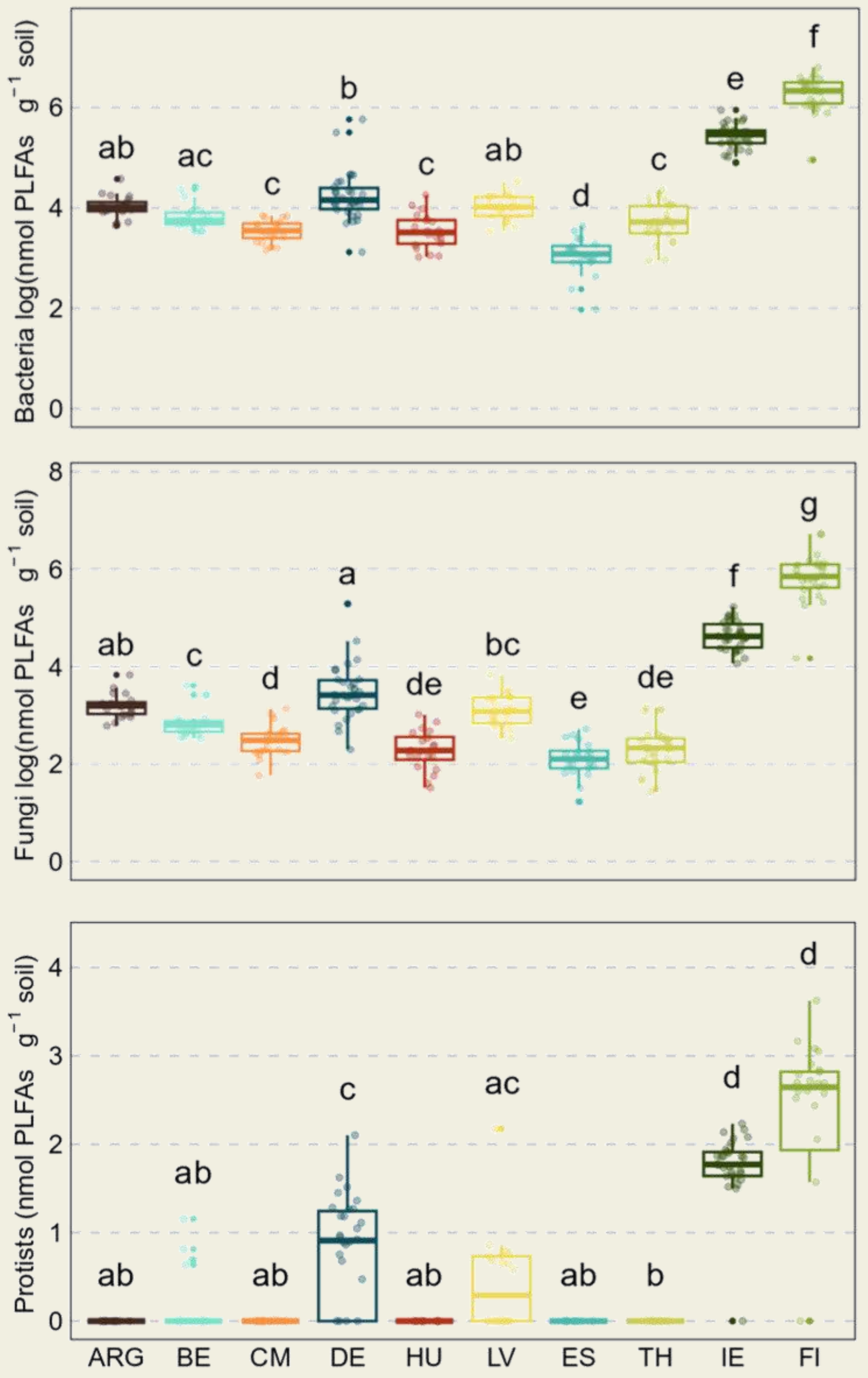
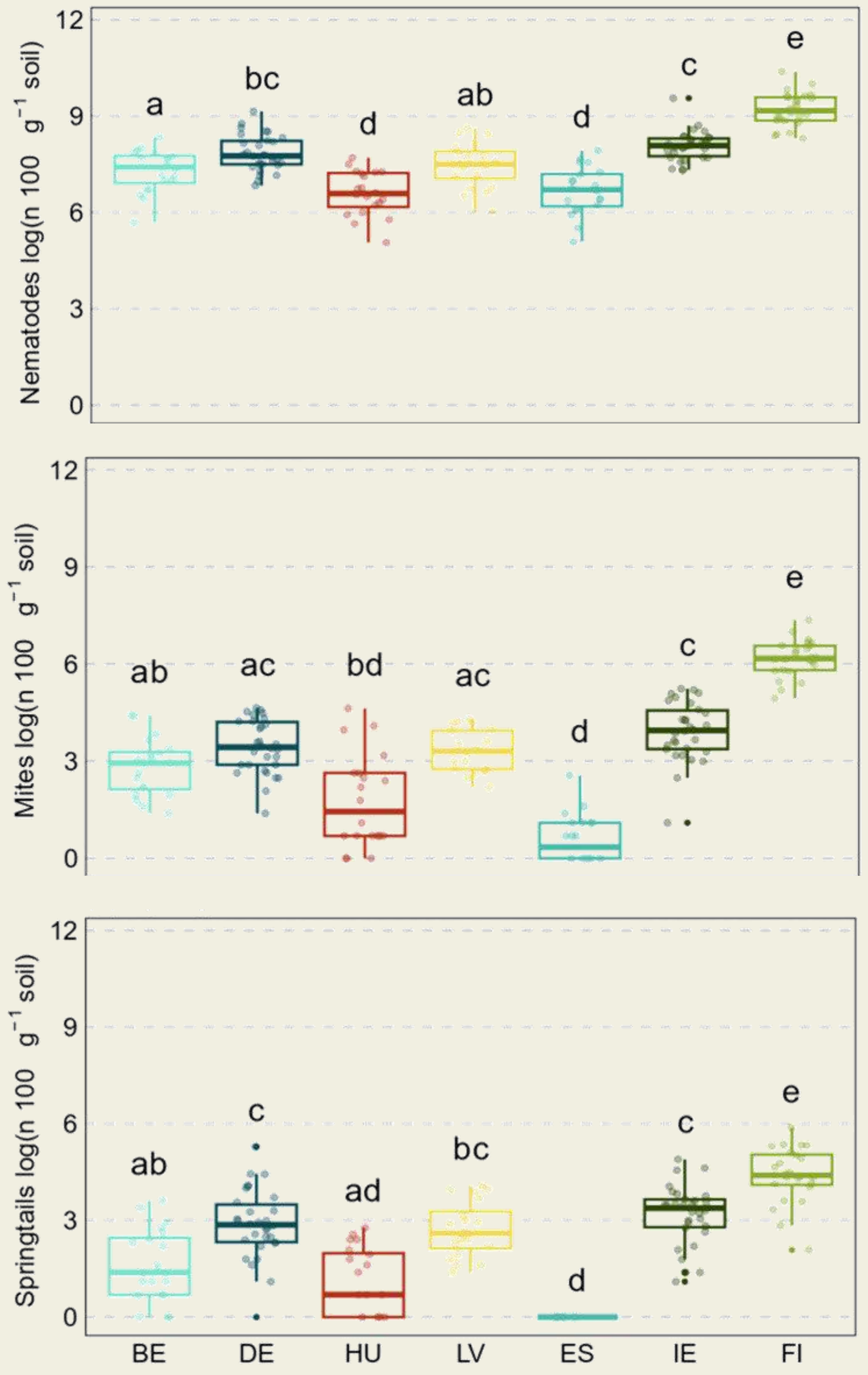
1. Biodiversity status

Microbial biomass (PLFAs)



Fauna abundance (microscope)



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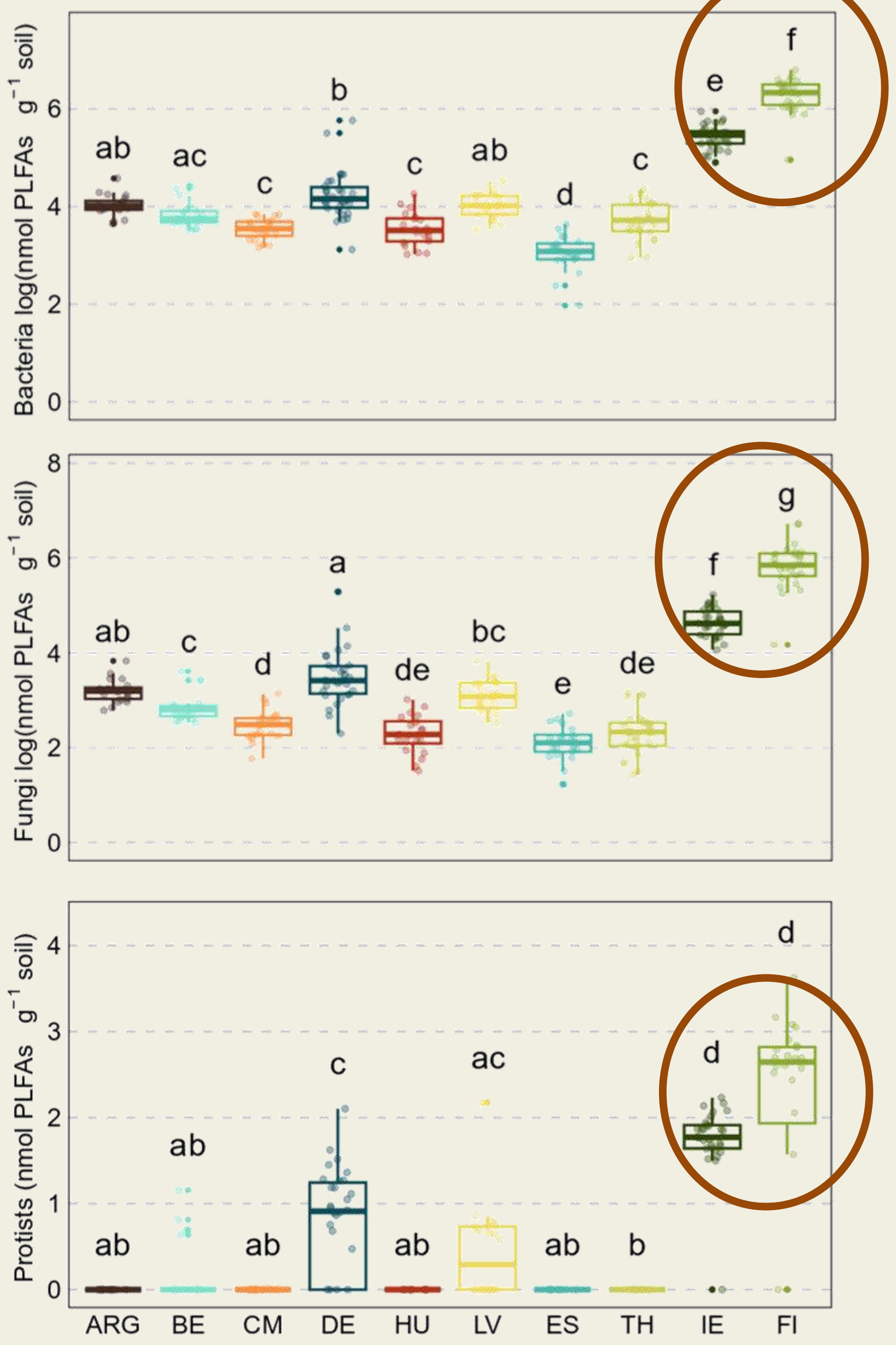
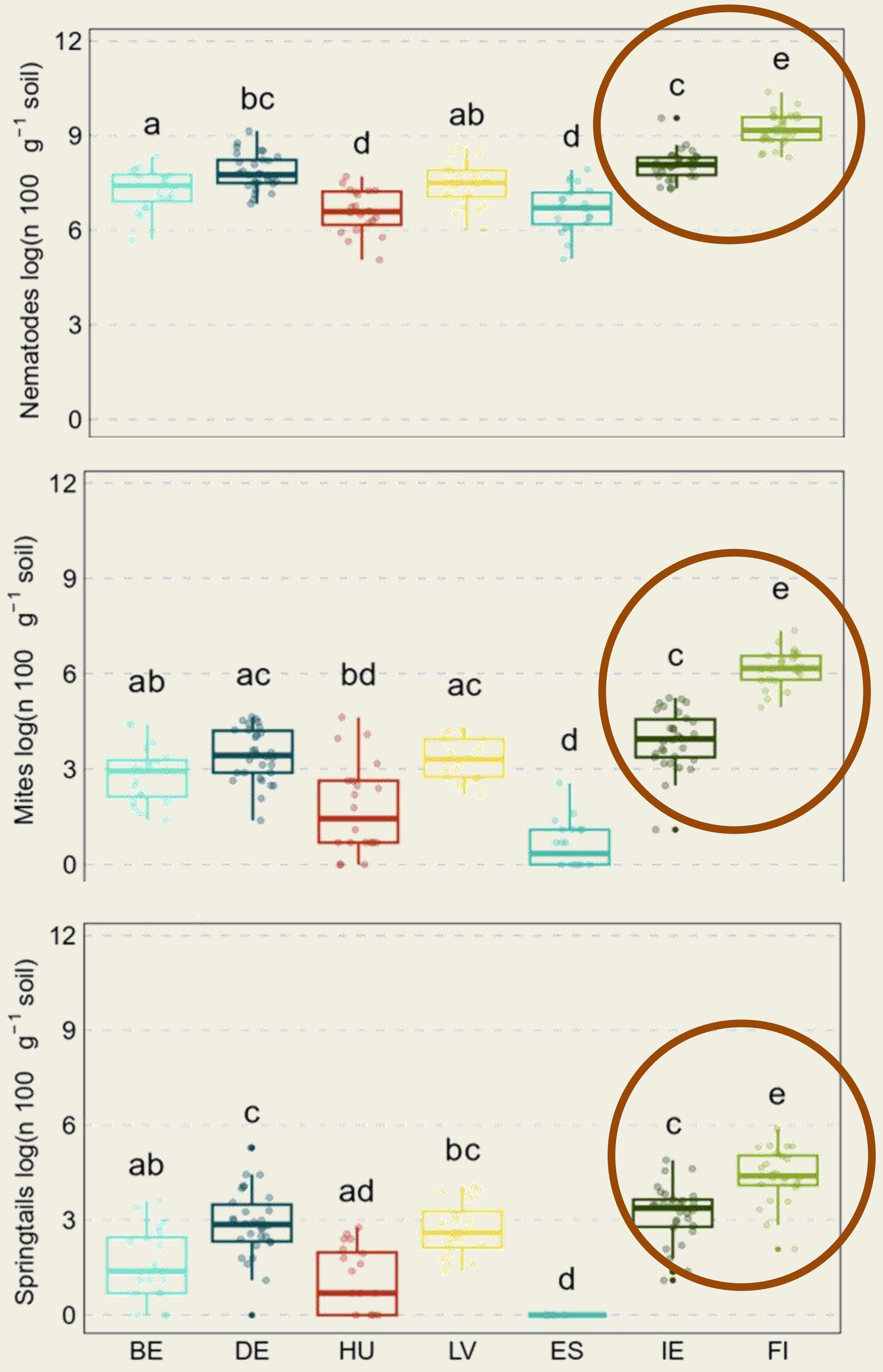


Fauna abundance (microscope)



Forest > Grassland > Croplands

Land-use intensity impact microbial biomass and fauna abundance.

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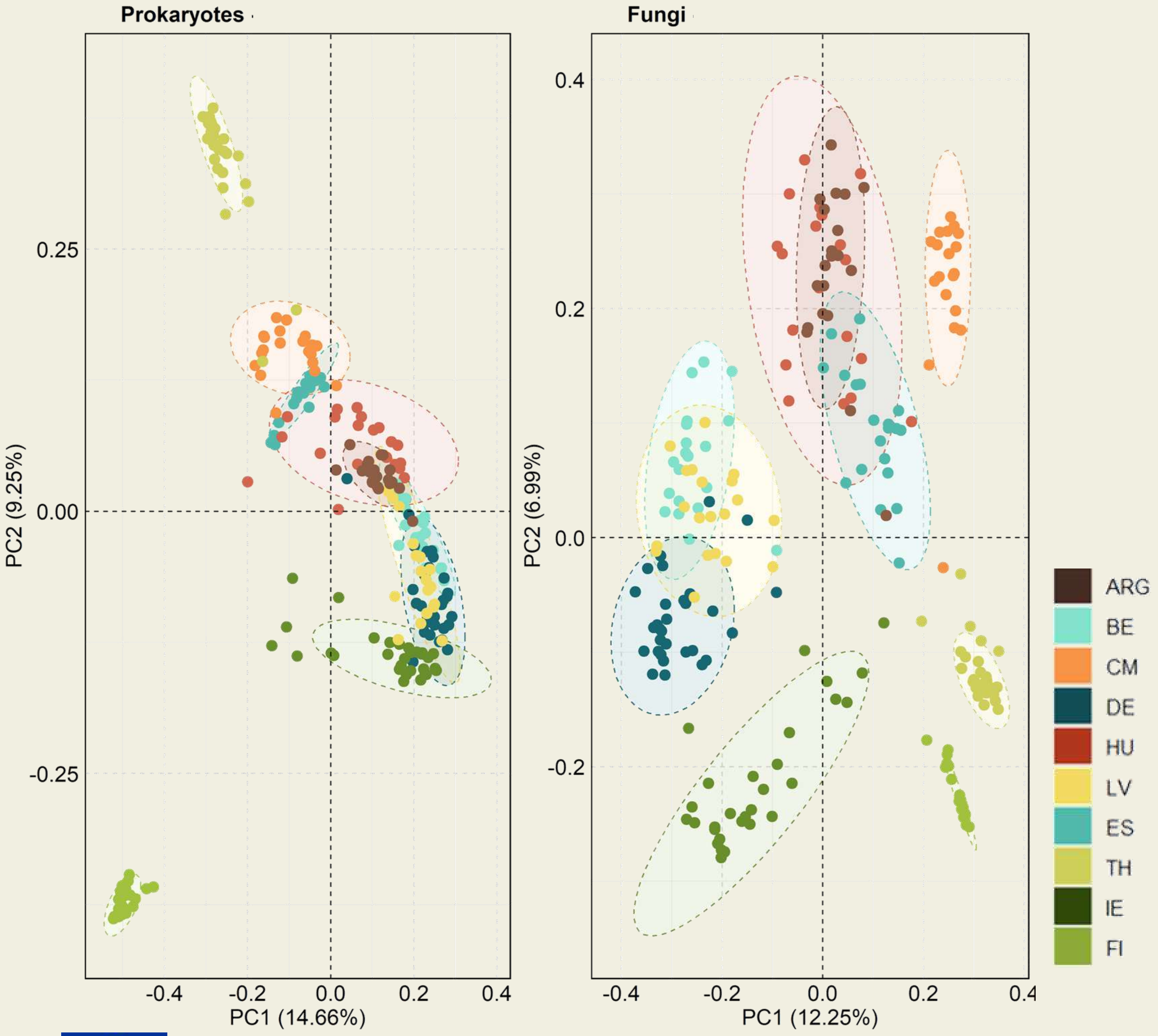
1. Biodiversity status

Soil taxa diversity (DNA metabarcoding)



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1. Biodiversity status



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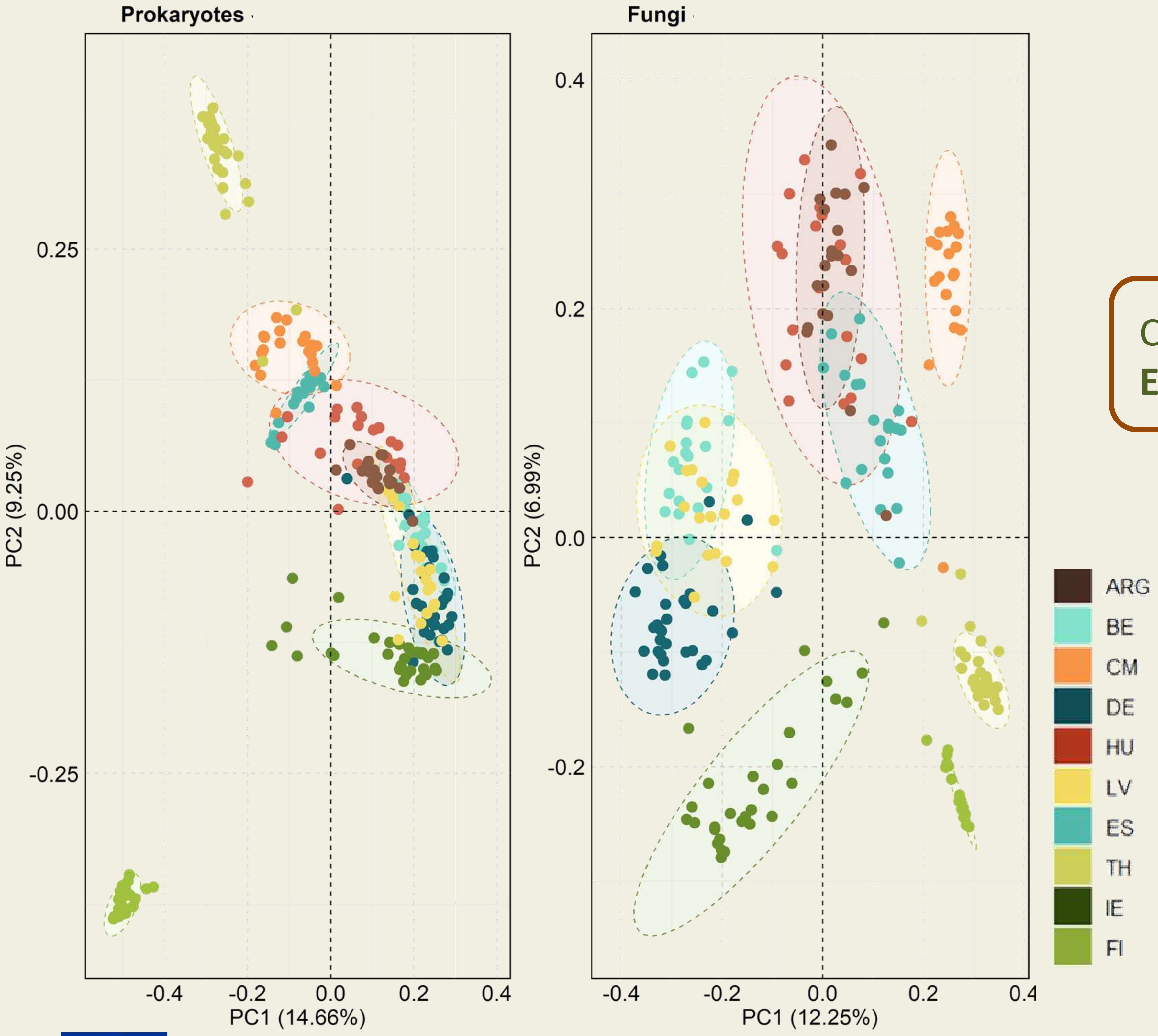

Country explain large variation of soil biodiversity (25-60%) →
Each ecosystem has a unique biome composition.

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1. Biodiversity status

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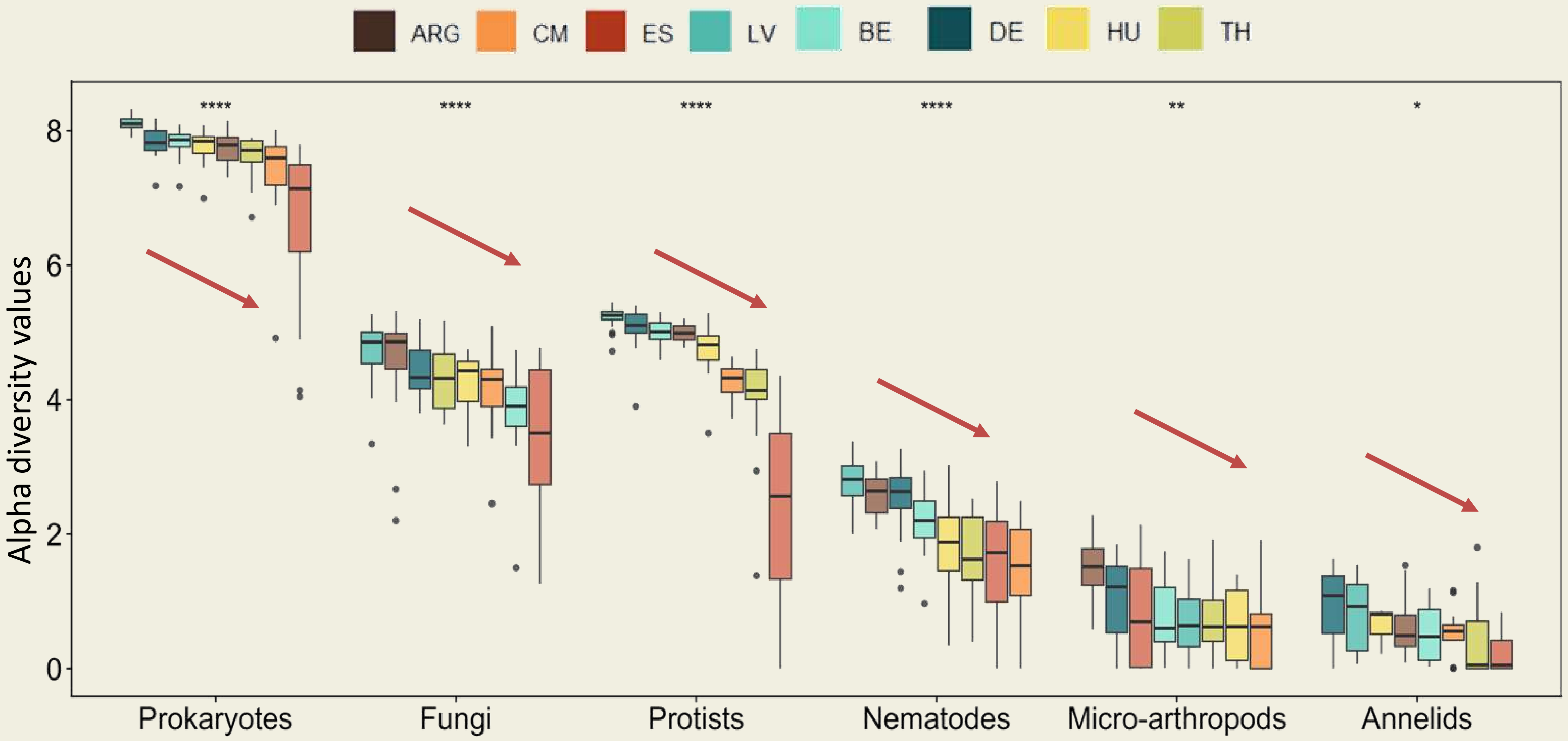

Croplands

DE > ARG > LV > TH = BE > HU > CM > ES

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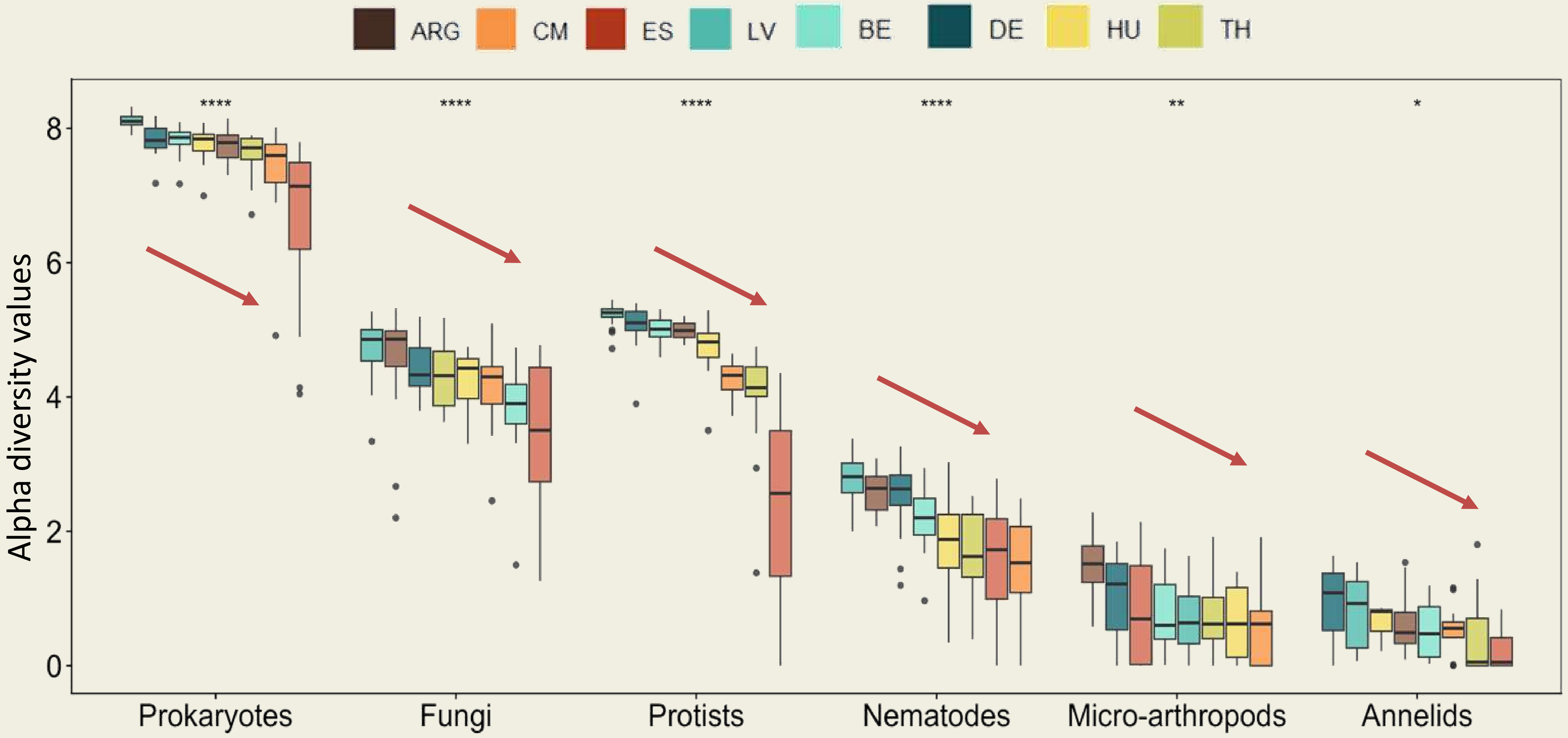

Croplands

DE > ARG > LV > TH = BE > HU > CM > ES

Soils with **higher temperatures in warmest seasons, clay content and aridity** present **lower biodiversity** values. Particularly prokaryotes and protists.

This can be related to processes of **biodiversity loss** that should be further studied.

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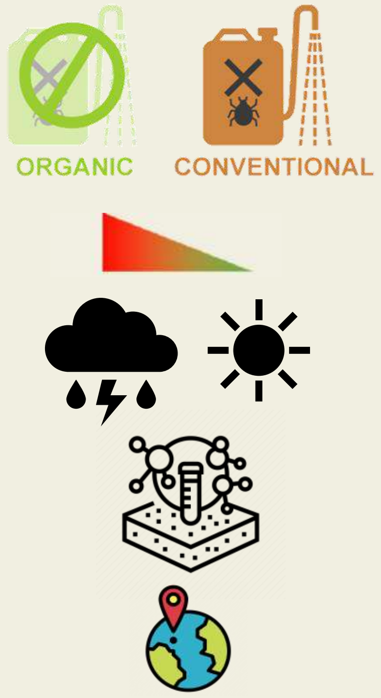
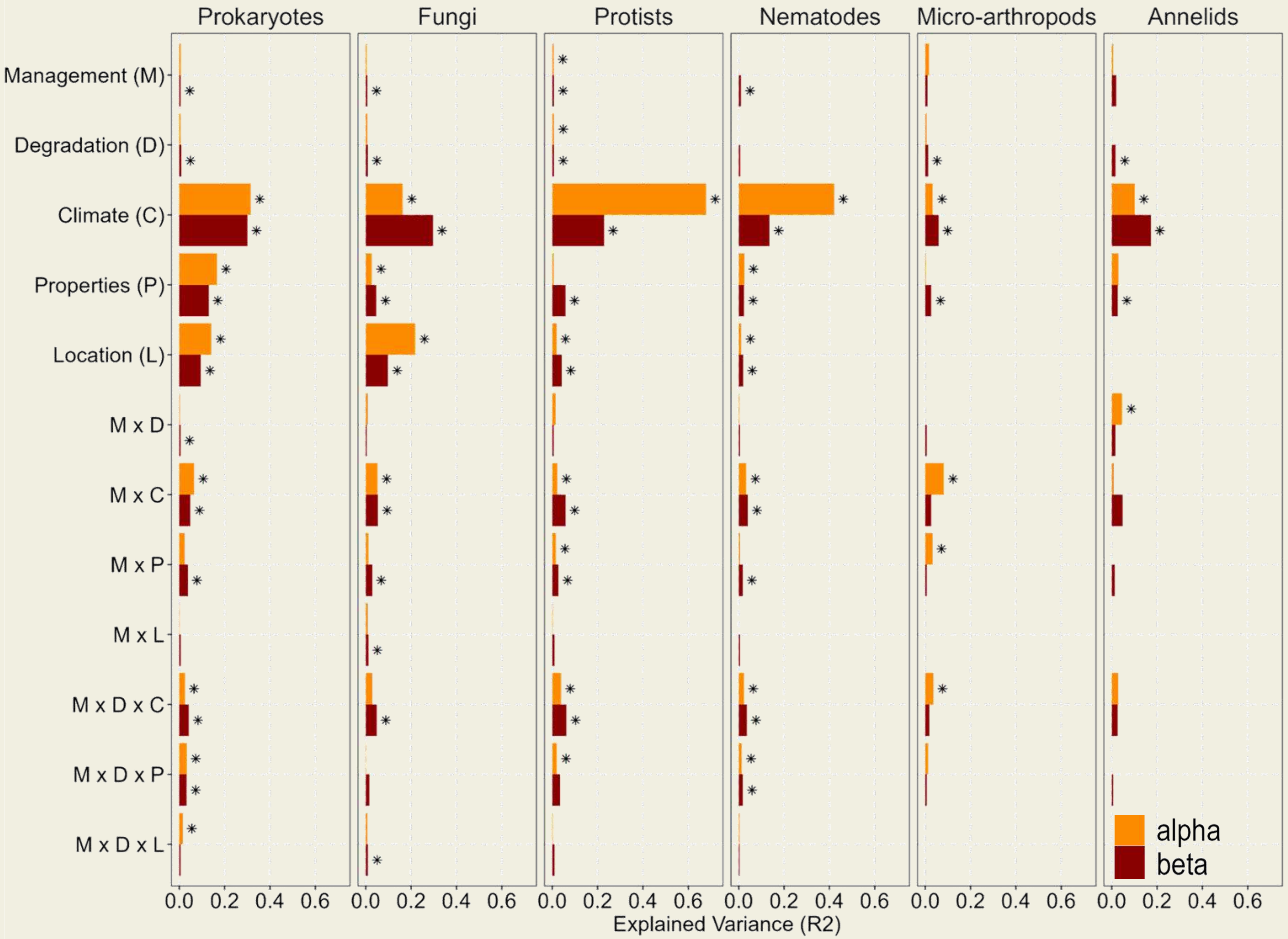
2. Management & Biodiversity



Soil taxa diversity (DNA metabarcoding)



Soil diversity (DNA metabarcoding)

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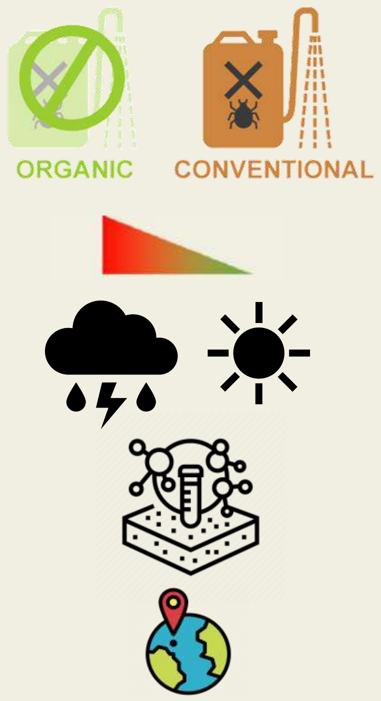

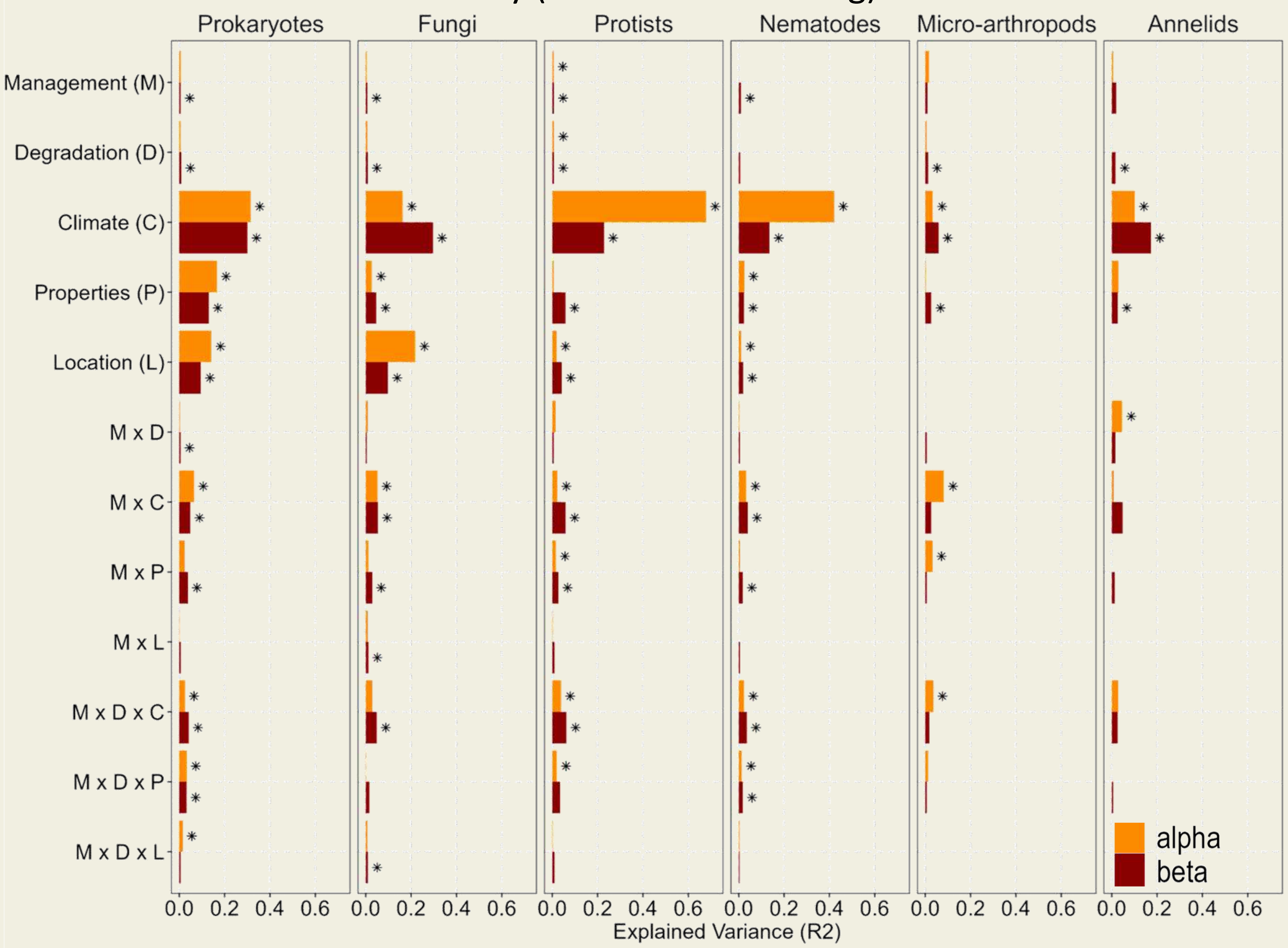

Global drivers in soil biodiversity are: climate > soil properties > location.

Overall soil management and degradation status impacts on soil biodiversity are smaller compared to the other drivers.

There are **significant effects of management dependent on the context – climate, soil properties and degradation**

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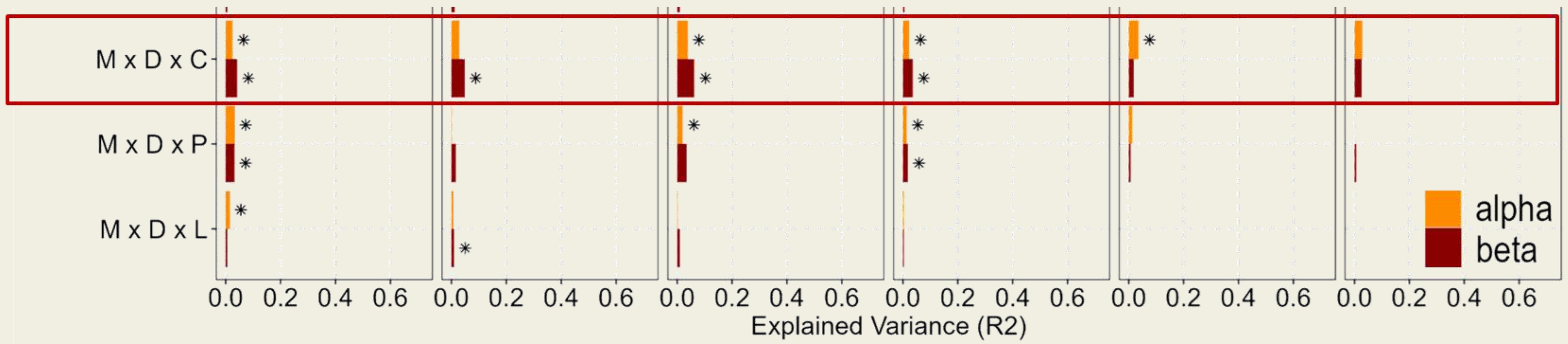
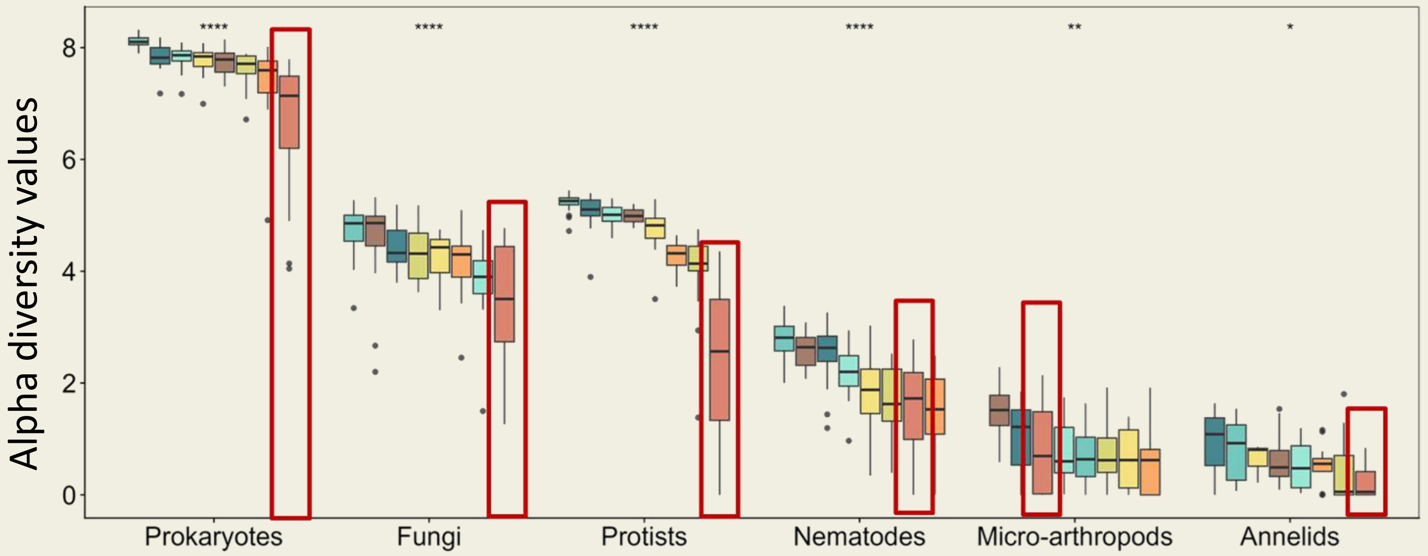
2. Management & Biodiversity

Soil taxa diversity (DNA metabarcoding)





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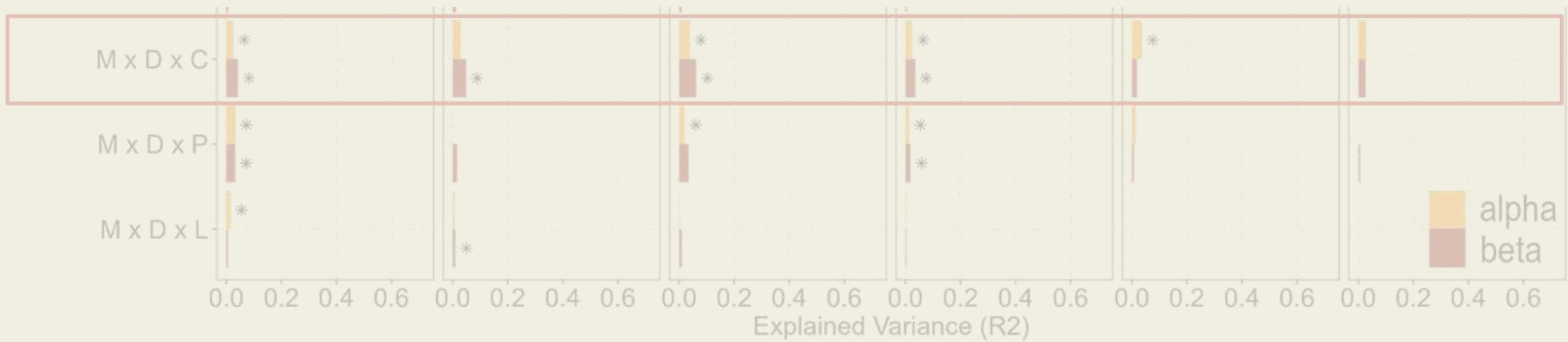
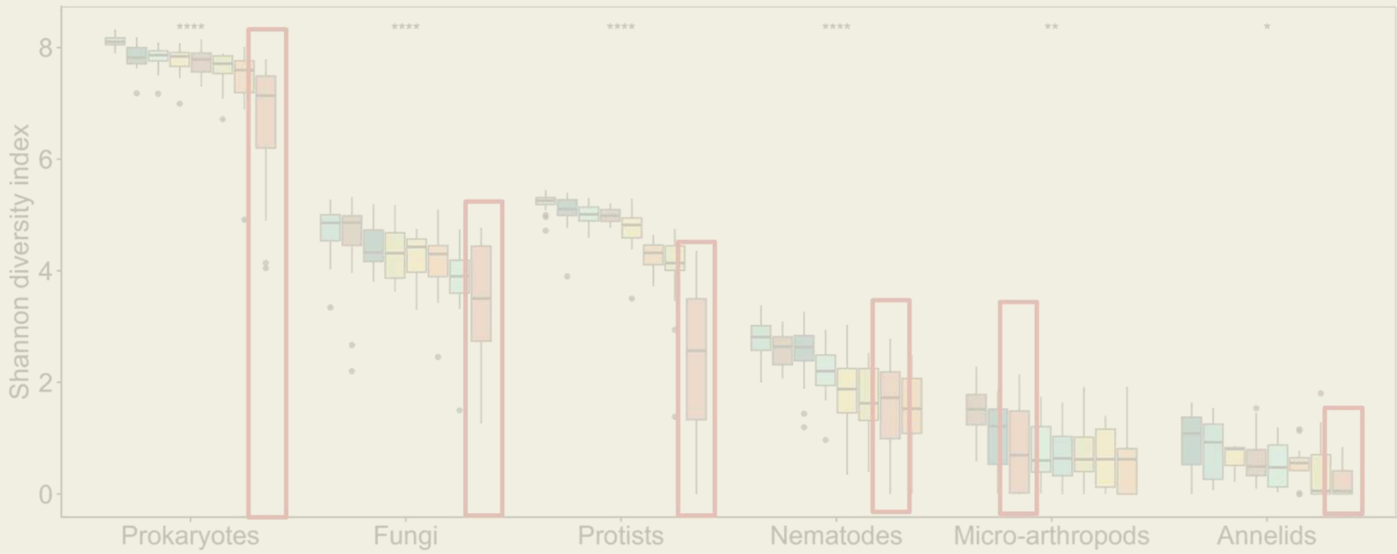
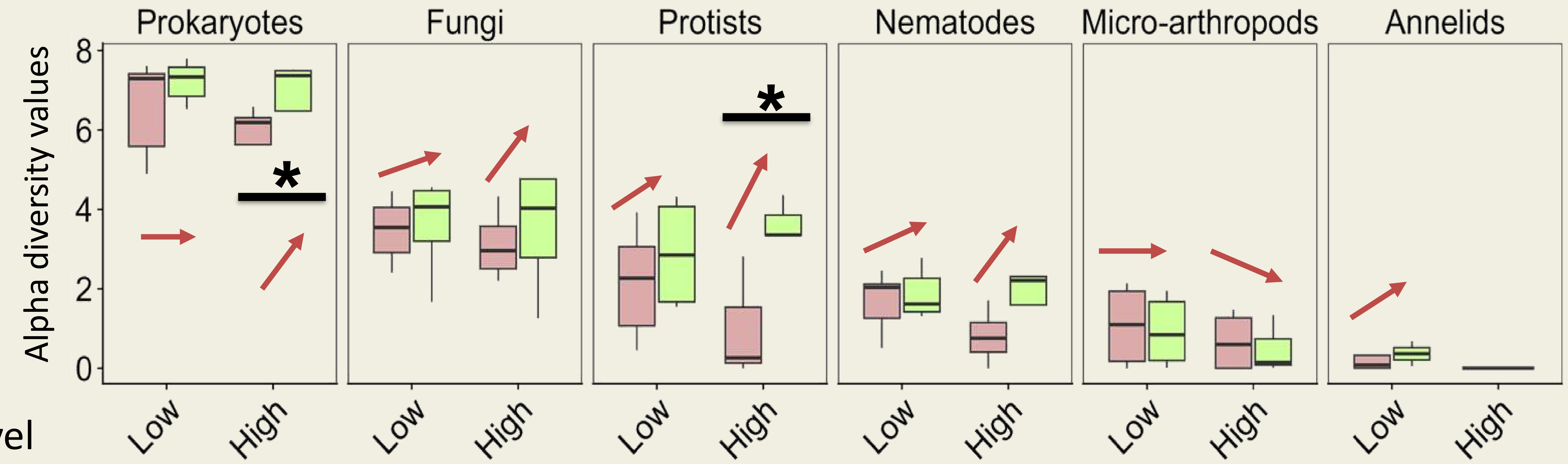
2. Management & Biodiversity

Soil taxa diversity (DNA metabarcoding)







Mediterranean – Murcia, Spain (ES)

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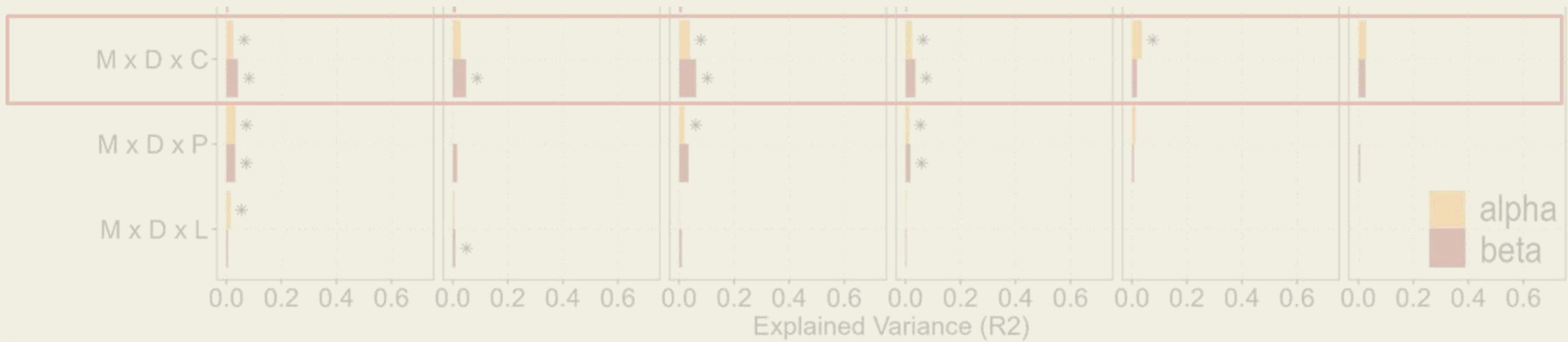
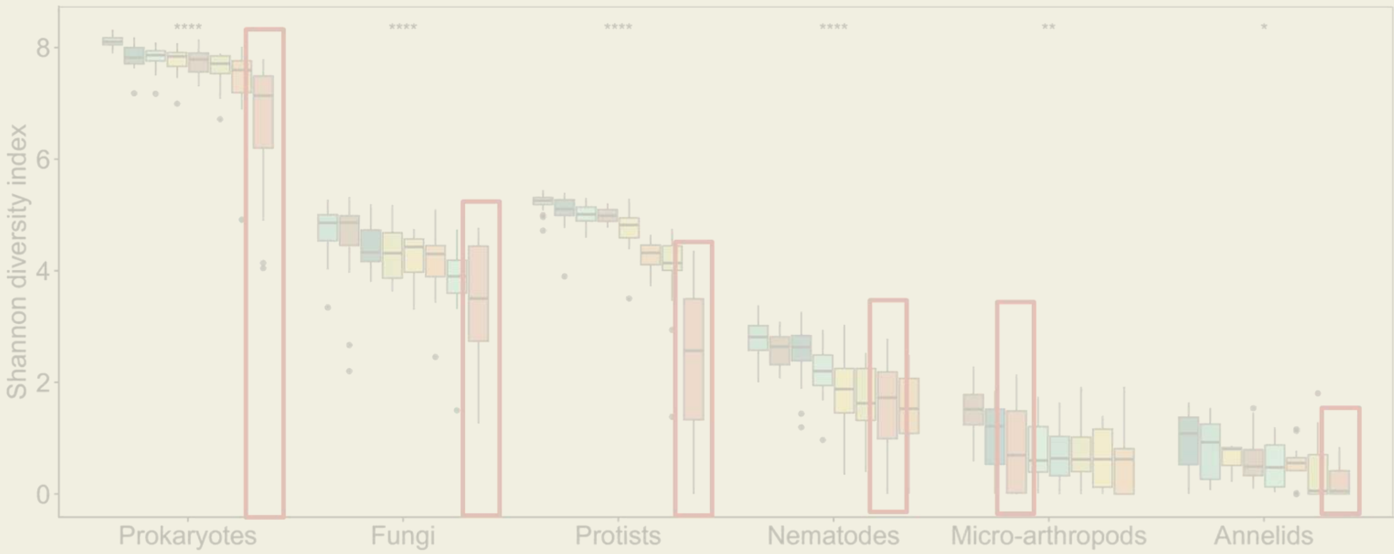
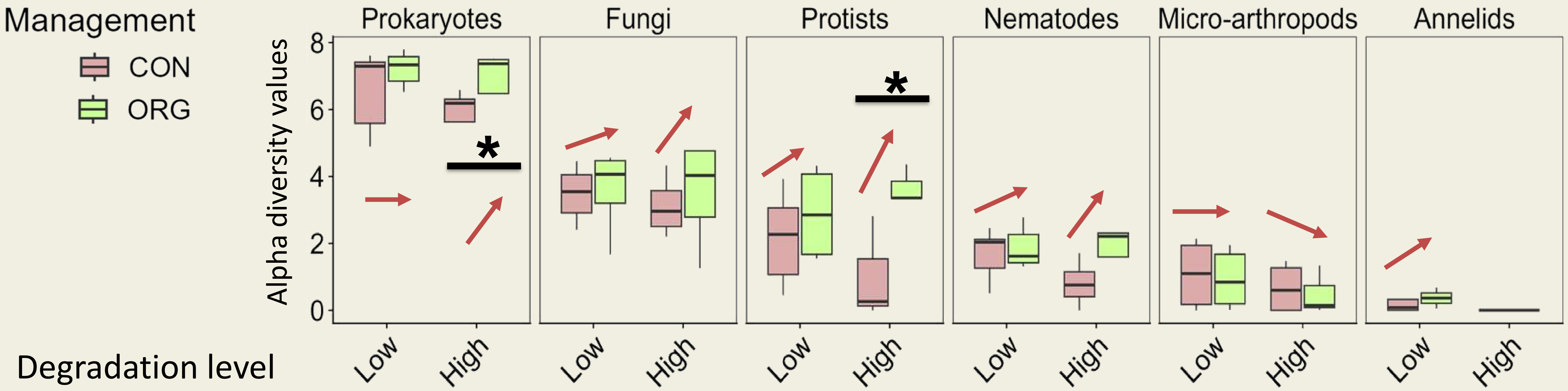
2. Management & Biodiversity

Soil taxa diversity (DNA metabarcoding)







Mediterranean – Murcia, Spain (ES)

Organic farming helps to buffer the biodiversity loss in arid and degraded soils.

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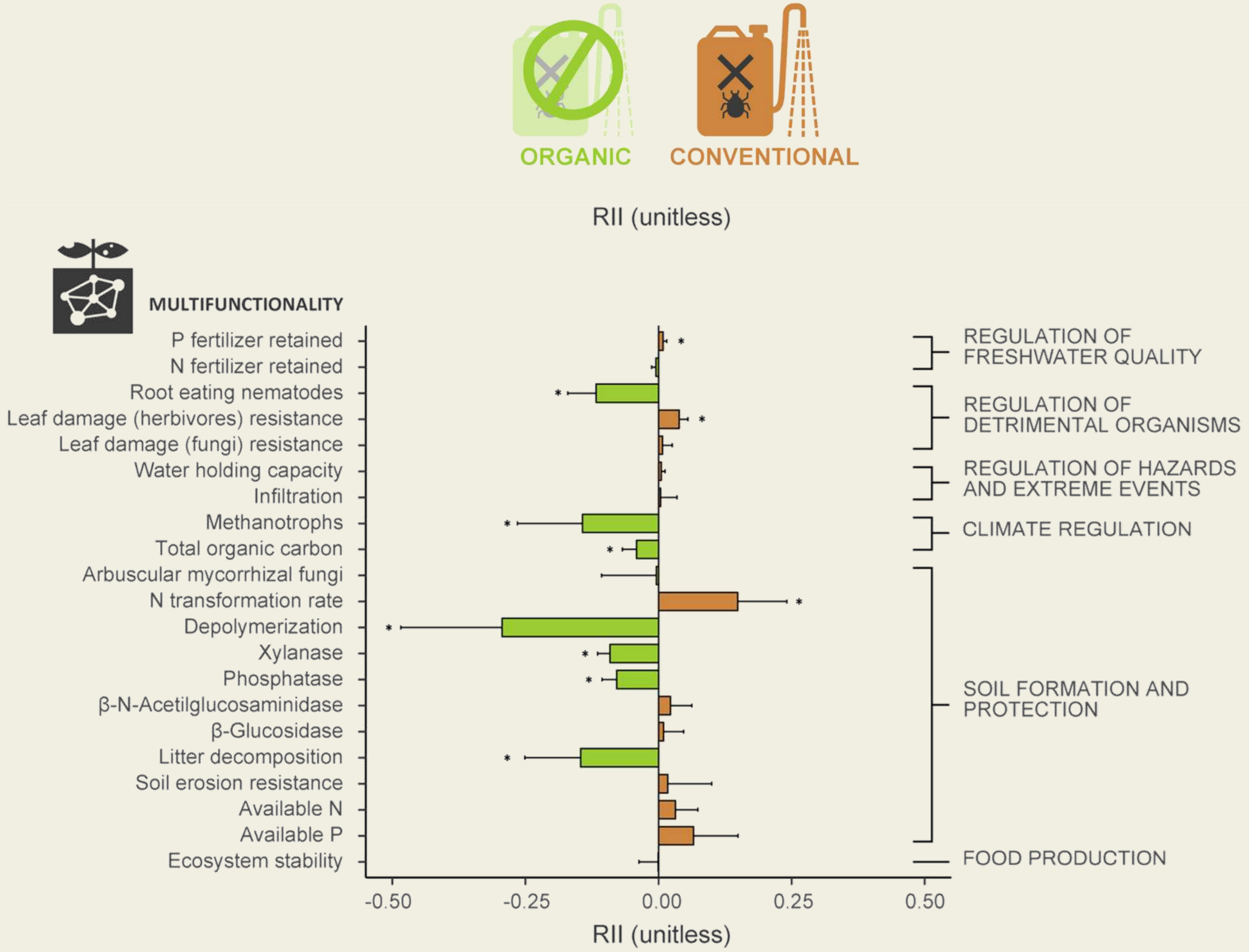
2. Management & Functions



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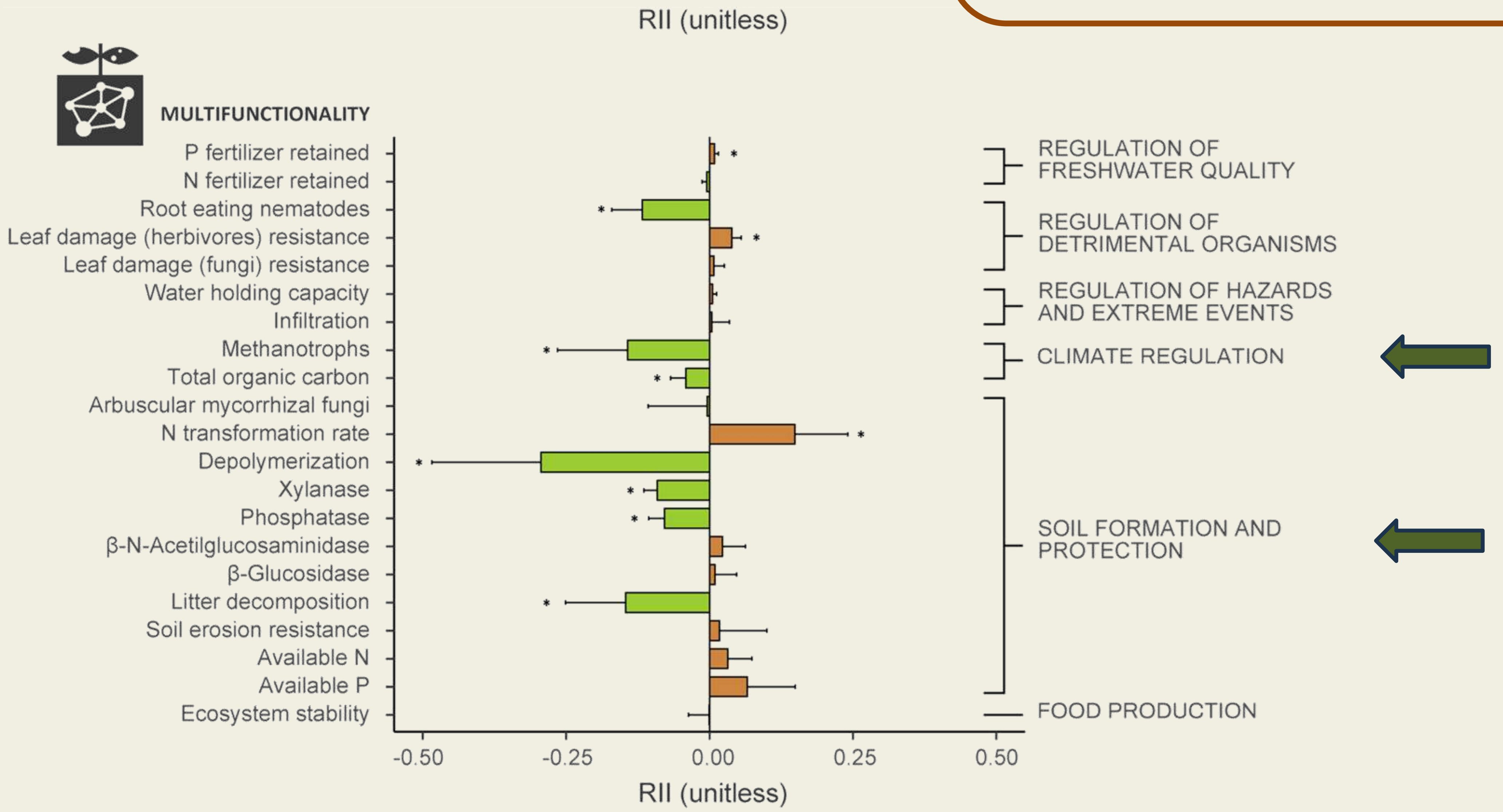
2. Management & Functions

Organic farming have positive effects on key aspects of soil functioning (e.g. OM decomposition, enzymatic activity, potential CH_4 consumption & N inmobilization).



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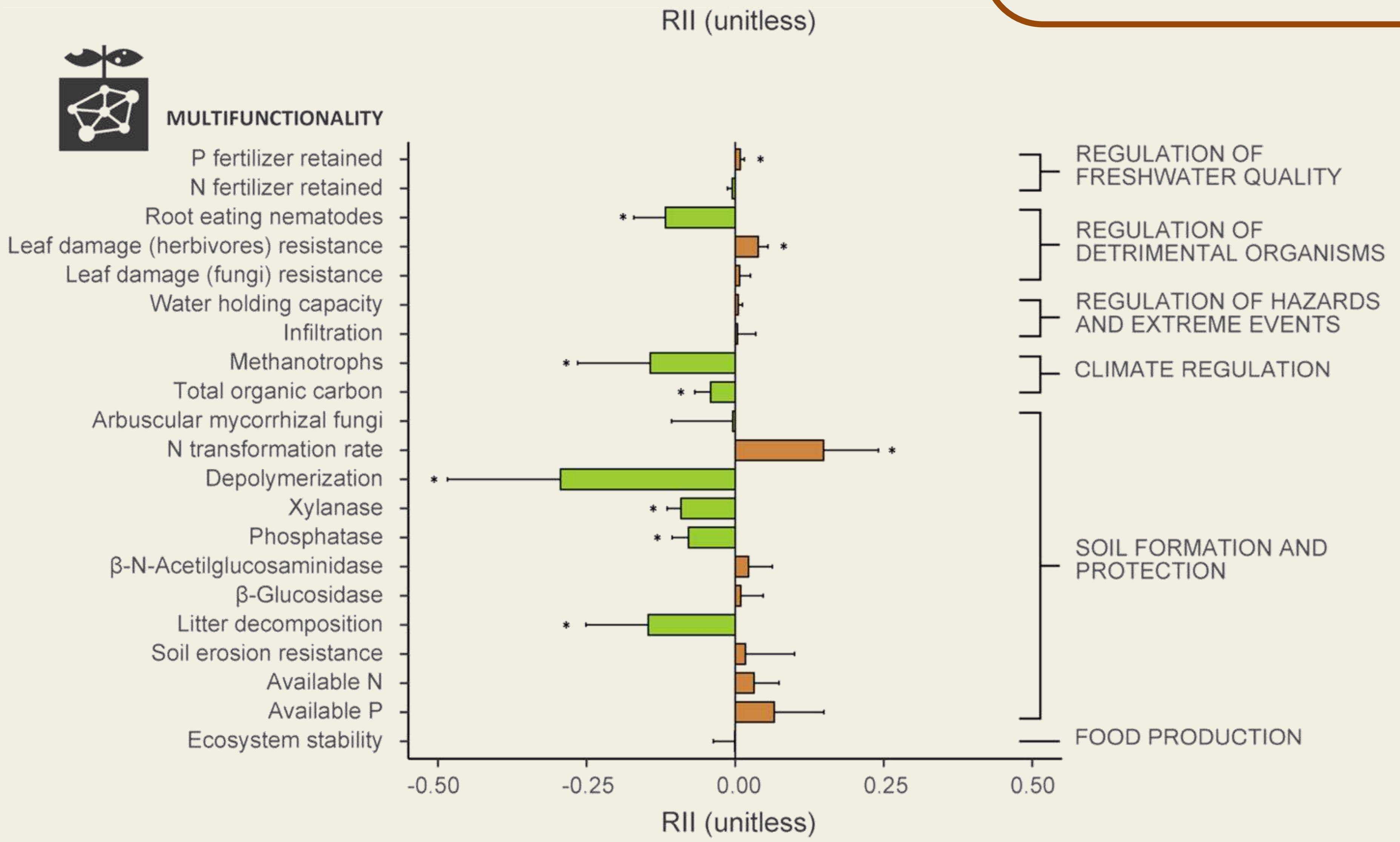
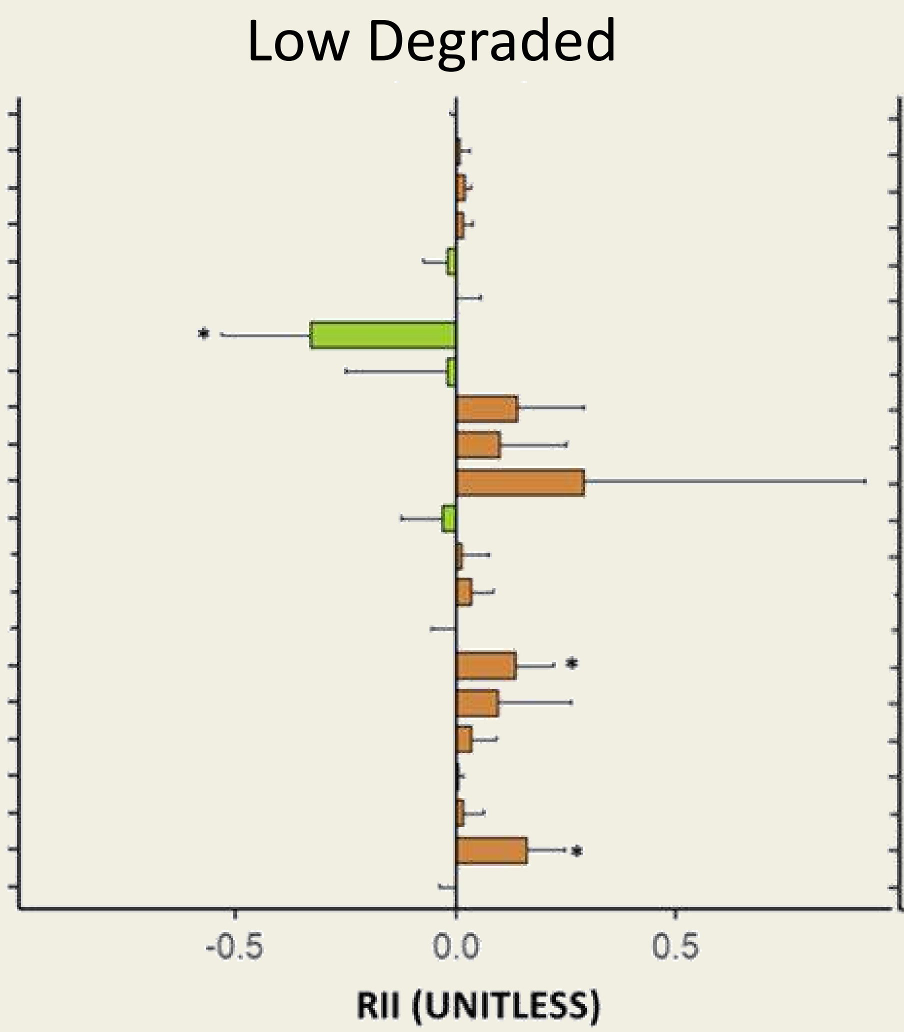
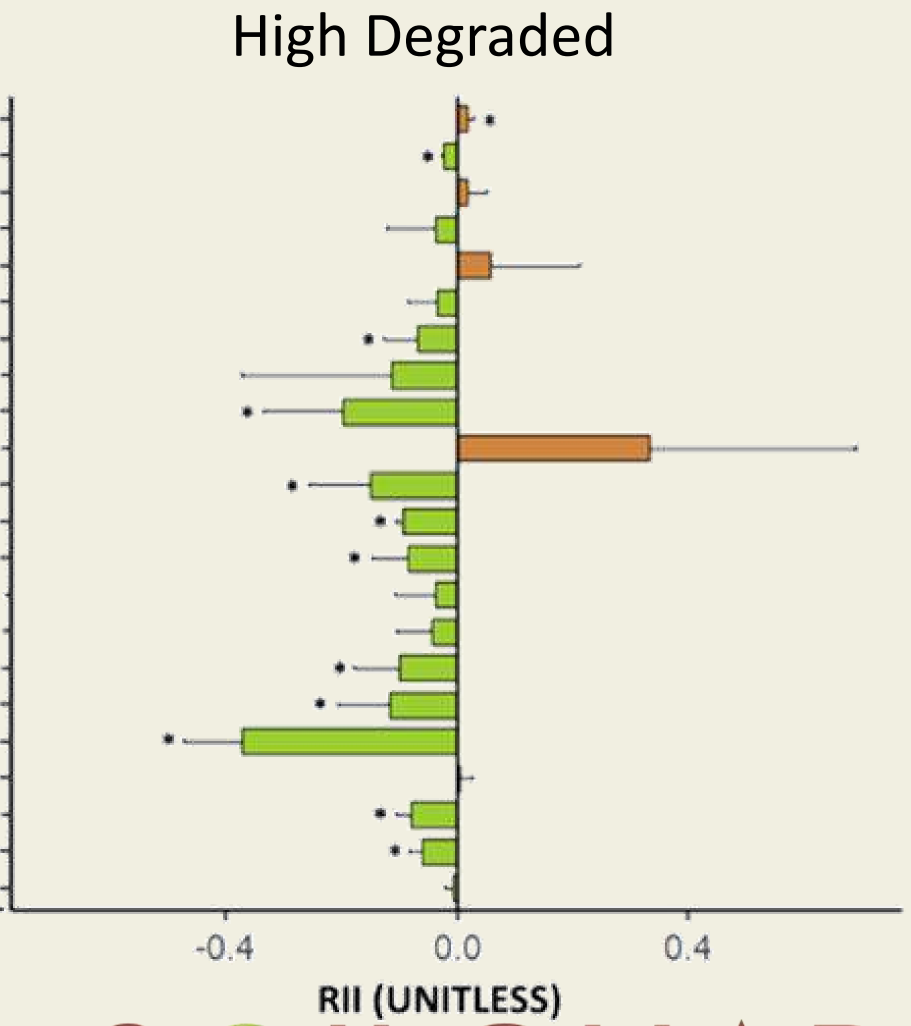
2. Management & Functions

Organic farming have positive effects on key aspects of soil functioning (e.g. OM decomposition, enzymatic activity, potential CH_4 consumption & N inmobilization).

Moreover, the **benefits** in terms of functionality are also **higher under high degraded soils.**







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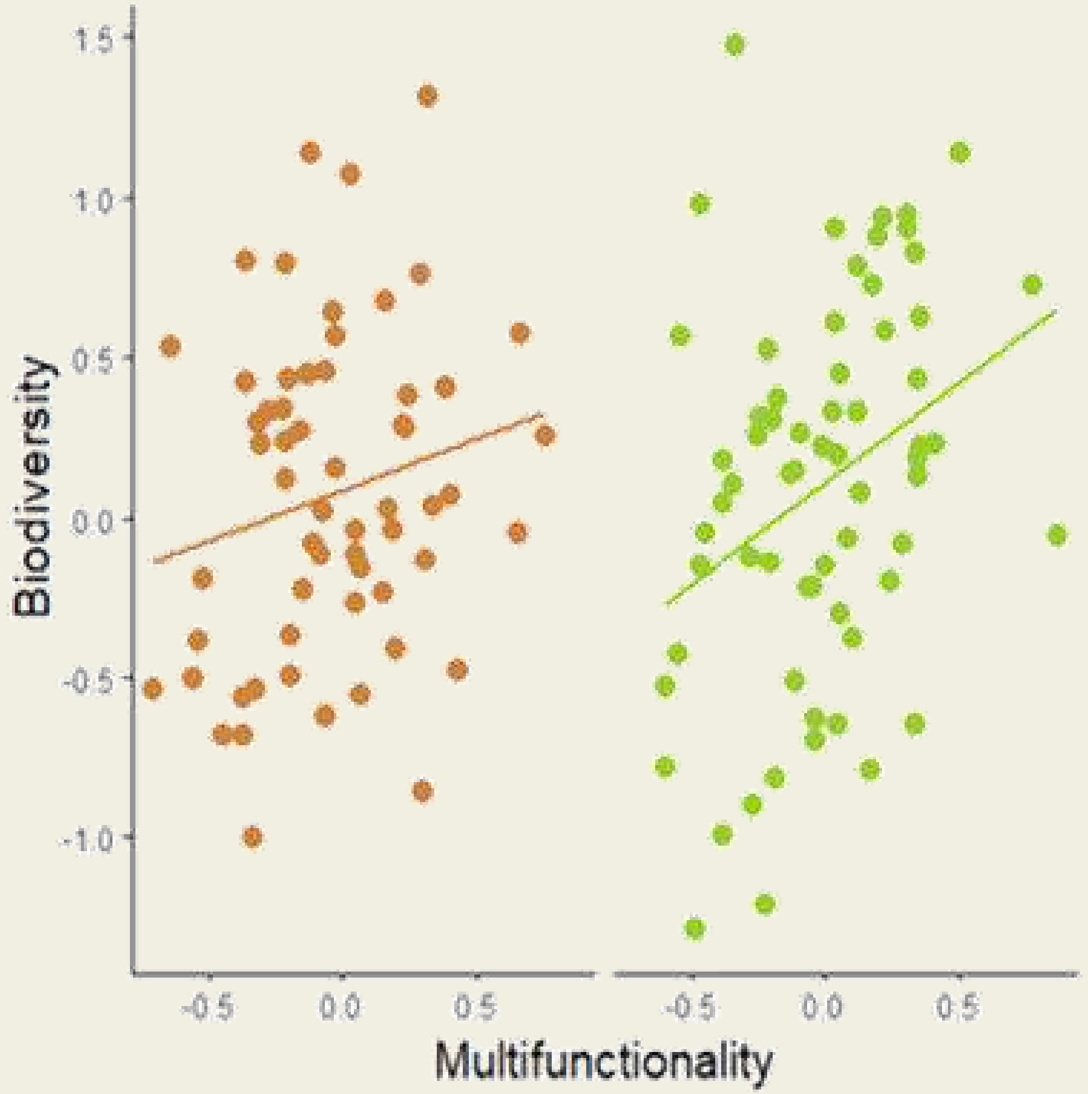
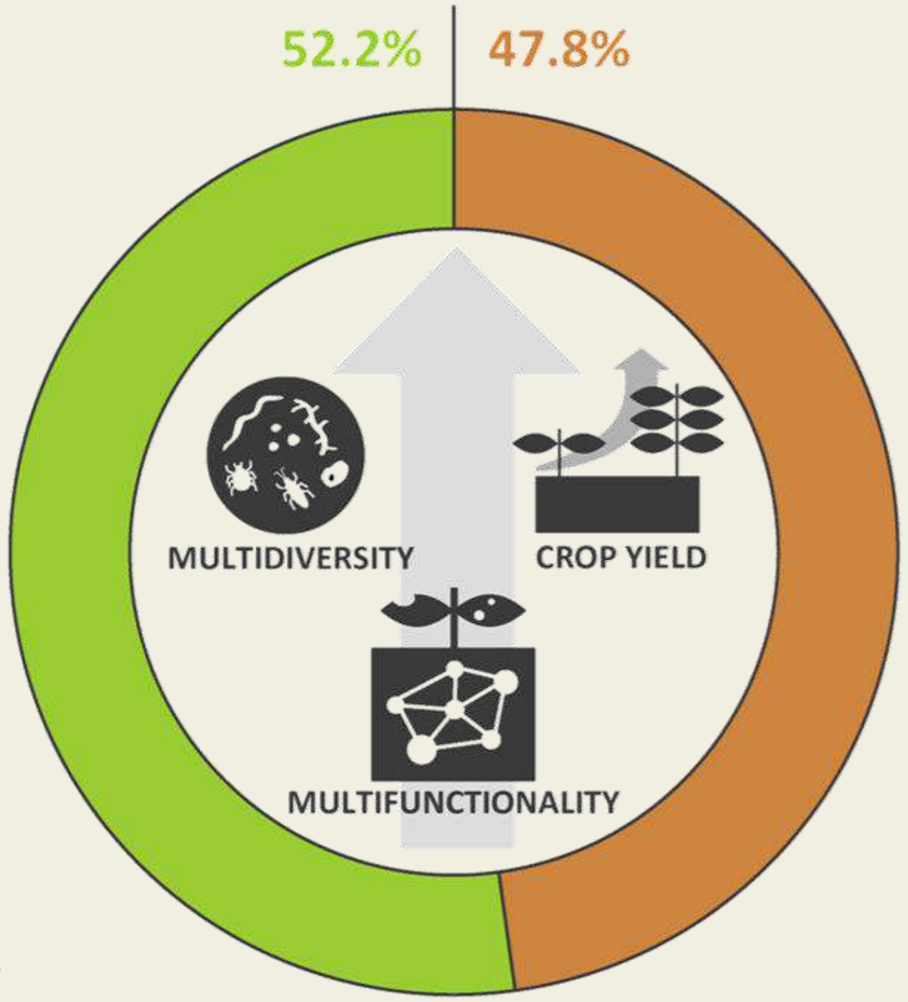
3. Biodiversity, Multifunctionality & Crop Yield





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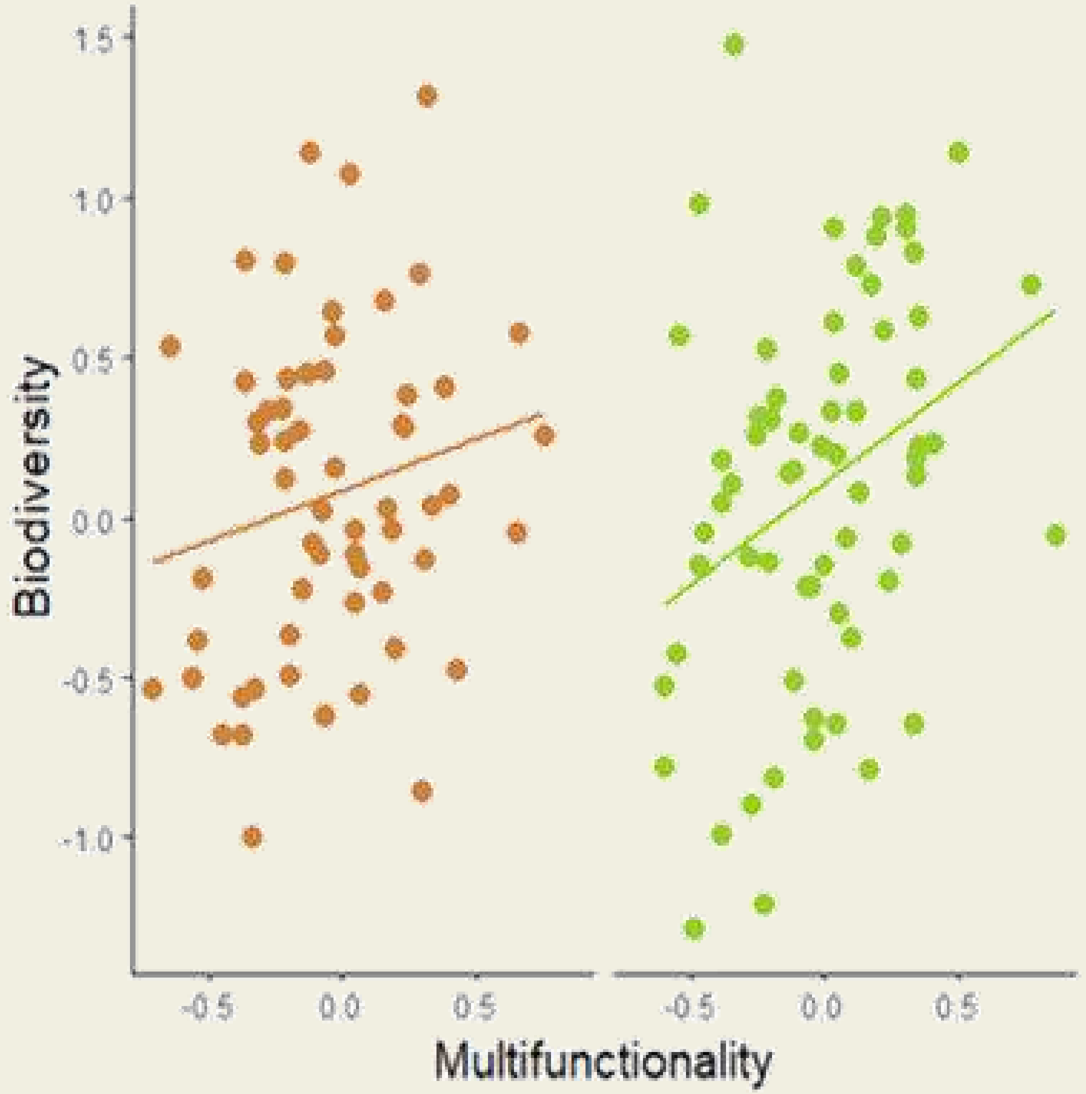
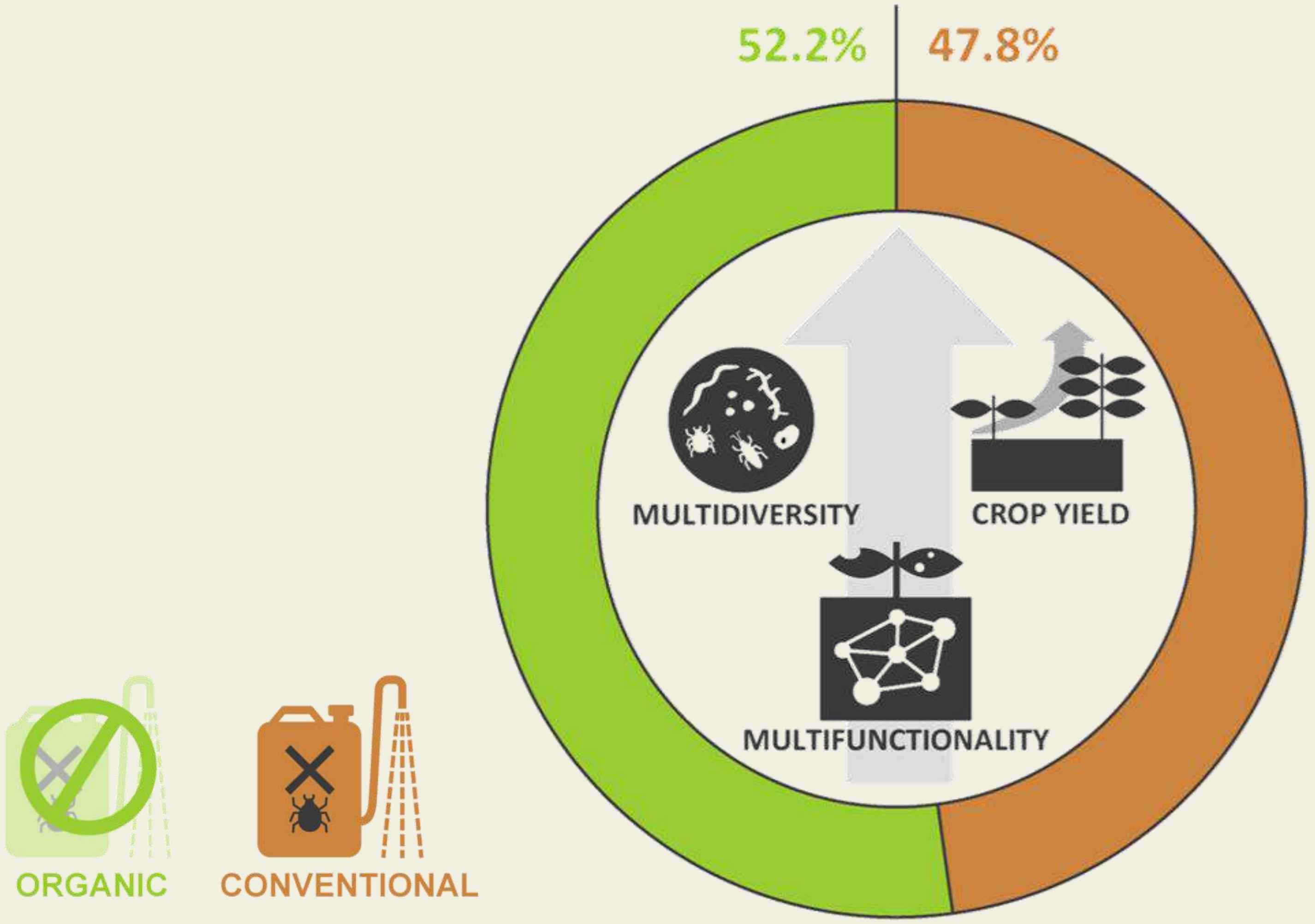
3. Biodiversity, Multifunctionality & Crop Yield

Global positive relationship between biodiversity and multifunctionality, under both types of management.





The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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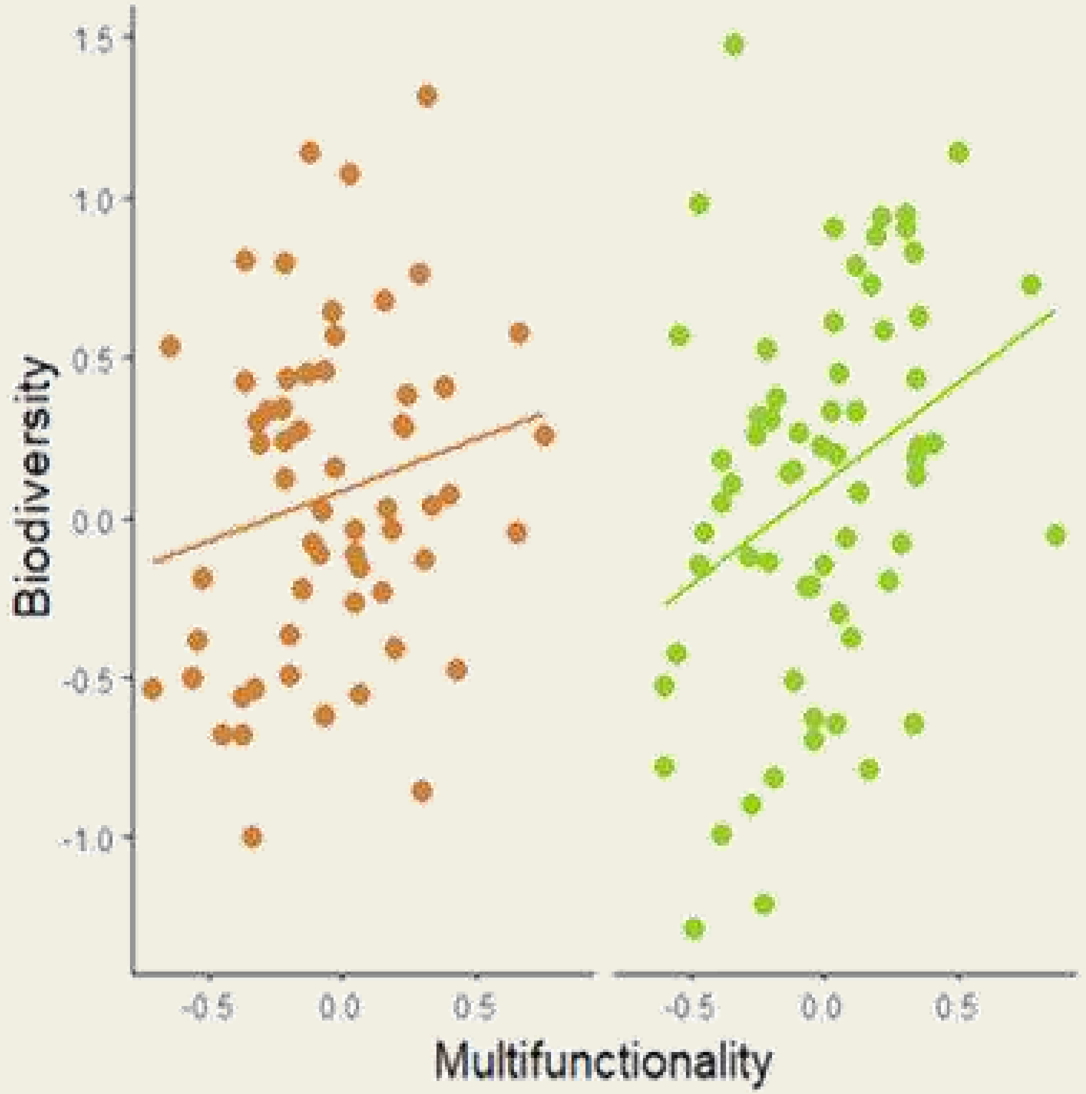
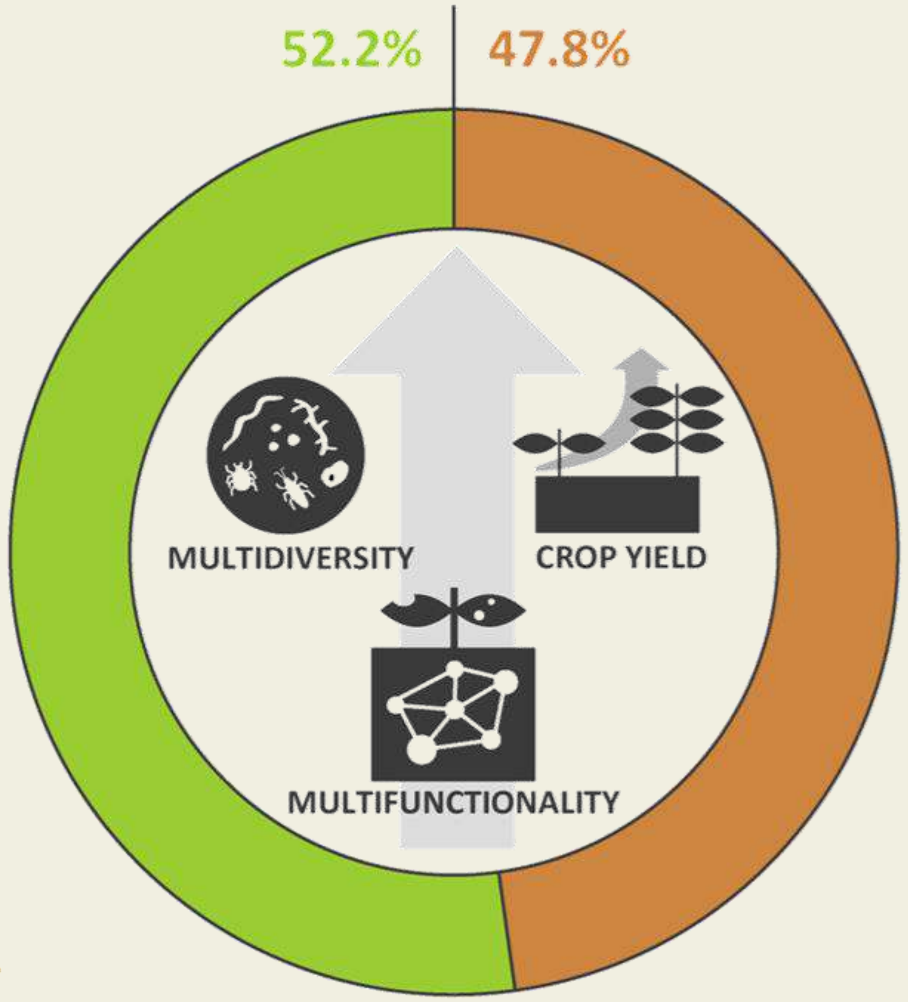
3. Biodiversity, Multifunctionality & Crop Yield

Global positive relationship between biodiversity and multifunctionality, under both types of management.

Our results show that **organic but also conventional farming can promote healthy soils** (biodiversity and multifunctionality) **without compromising crop yield**





The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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Take home messages

1. Each ecosystem has unique soil biodiversity. Less land use intensity (grasslands and forests) showing higher microbial and faunal biomass and abundance than croplands.

2. Climate is the main driver of croplands biodiversity, with high temperatures in warm seasons and aridity potentially linked to biodiversity loss.

3. The overall effect of management on biodiversity is small compared to other drivers, but it increases when considering the soil context. In this regard, organic farming can help to buffer biodiversity loss in arid and degraded soils. Further studies exploring these interactions are needed.

4. Organic farming has a generally positive effect on soil functionality, especially in high degraded soils.

5. Considering our agricultural fields as system boundaries, there are no relevant intrinsic trade-offs between soil biodiversity, ecosystem multifunctionality and crop yield. There is potential to refine site-specific crop managements systems that can be sustainable, profitable and biodiversity-friendly.

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Region- and management-specific impact of climate stressors on soil biodiversity and cascading effects on soil multifunctionality

Martin Hartmann, ETH Zürich
SOILGUARD TEAM & MICROSERVICES TEAM

31/03/2025

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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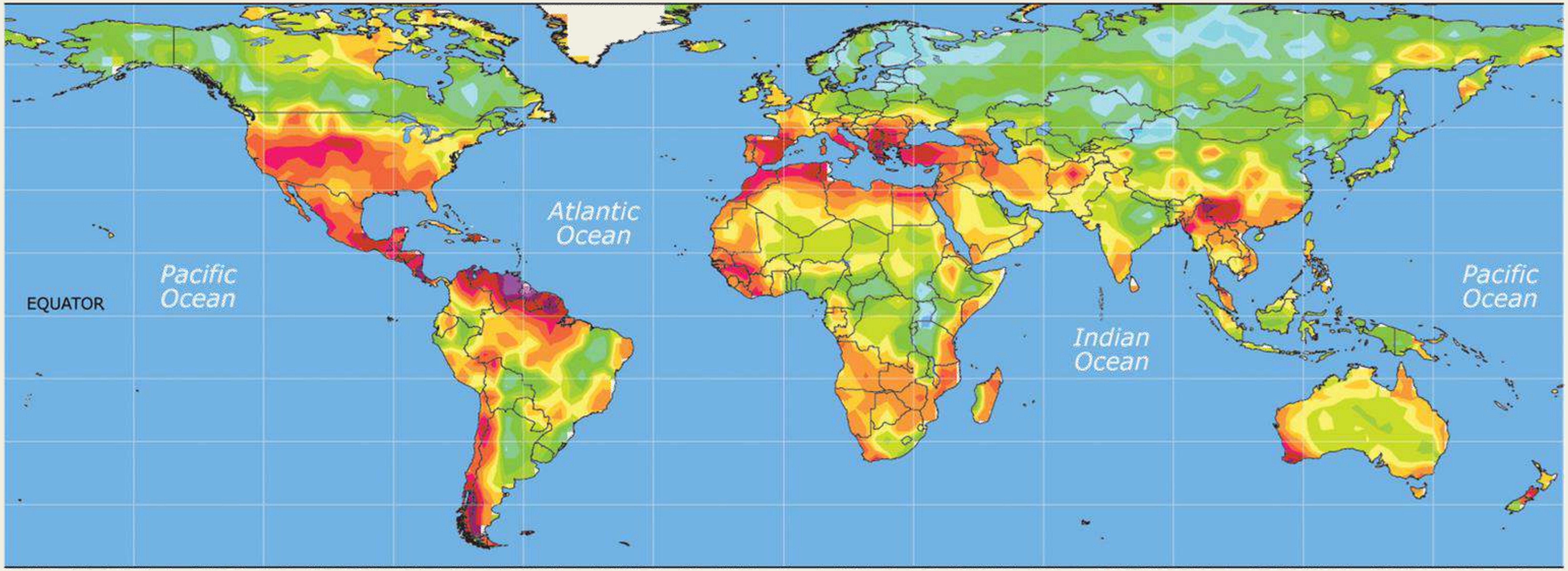
2000–2009



DRY **CONDITION** WET

−20 −15 −10 −8 −6 −4 −3 −2 −1 −0.5 0 0.5 1 2 3 4 6 8 10 15 20

Dai et al. 2010 (Wiley Interdisciplinary Reviews)
Image: University Corporation for Atmospheric Research

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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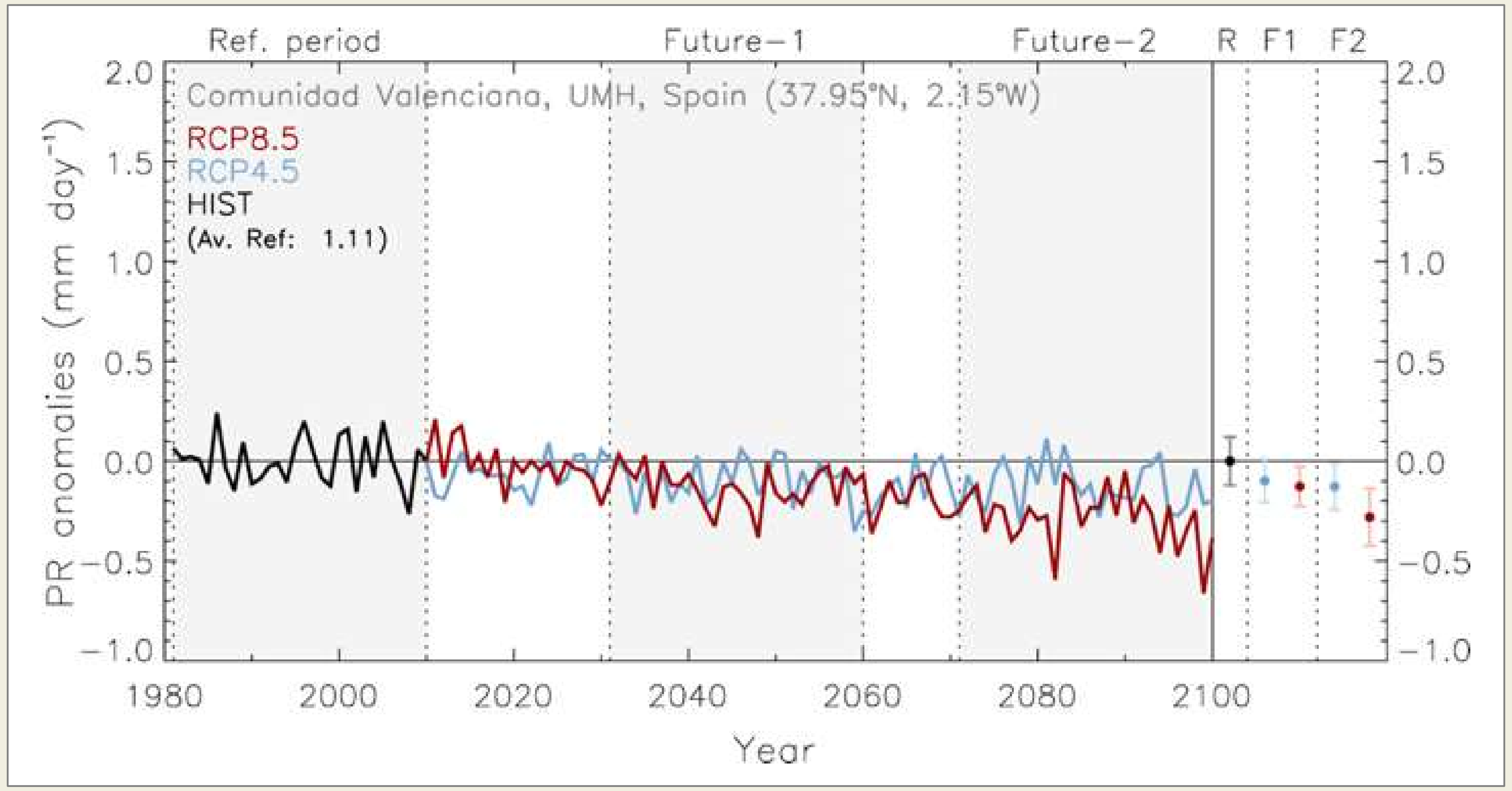
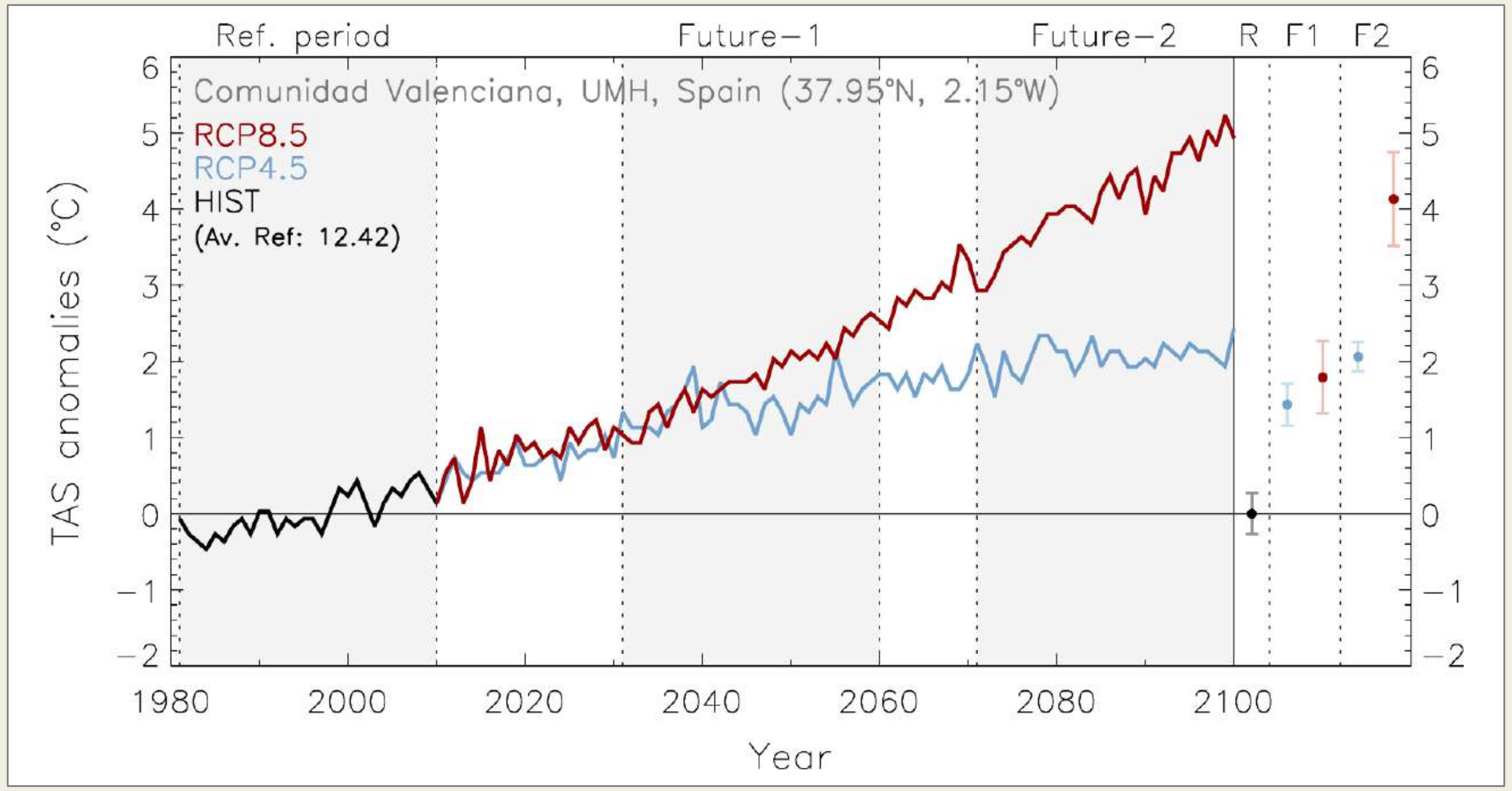
Projected precipitation anomalies



Projected temperature anomalies



Representative Concentration Pathway

RCP 4.5 (intermediate scenario): Emissions peak around 2040 and decline to around half between 2050 and 2100

RCP 8.5 (business as usual): Emissions continue to rise throughout the 21st century.

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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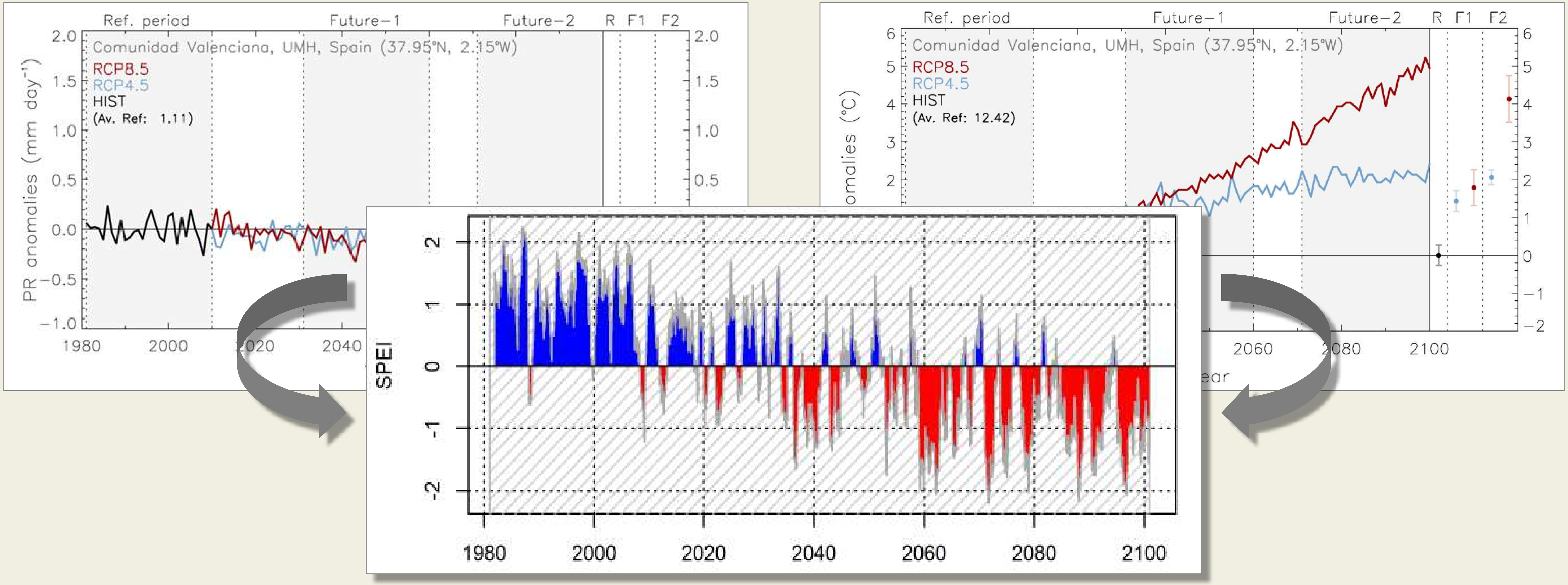
Projected precipitation anomalies

Projected temperature anomalies



The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

SOILGUARD

Photo courtesy of Ina Alsina, LLU

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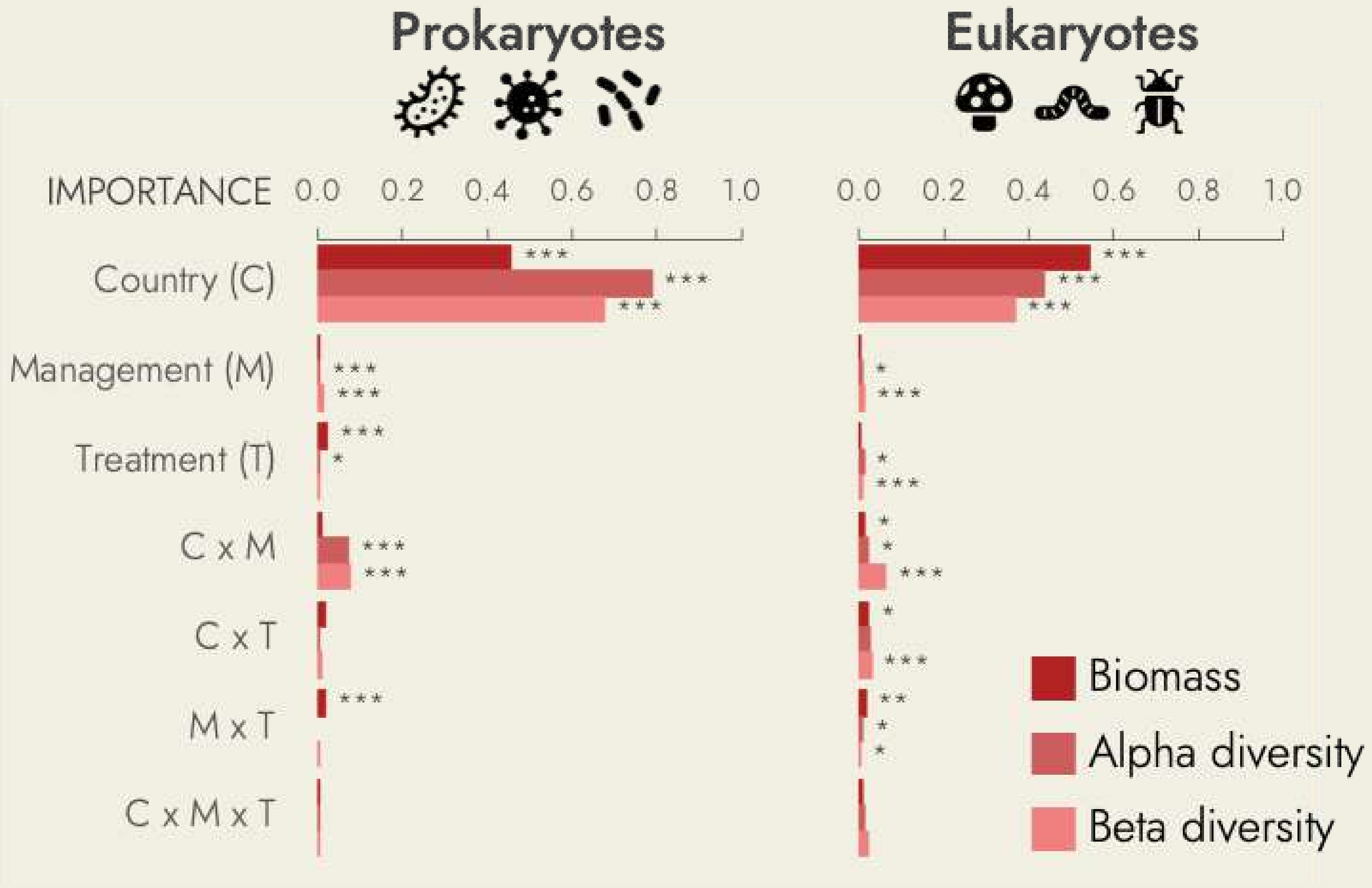
Soil biodiversity



TAKE HOME

- **Country was the overriding driver of soil biodiversity,** highlighting the importance of the local context. Prokaryotes were more site-specific than eukaryotes.
- **Management effects were considerably smaller** than those of site, **but consistently detectable** and showing a strong site-dependency. This highlights the context-dependency of the effects of agricultural practices.
- **Drought effects were small, partially site- and management-dependent**, and more pronounced for eukaryotes than prokaryotes. However, these management-dependent drought effects became **more pronounced in close proximity to plant roots**.

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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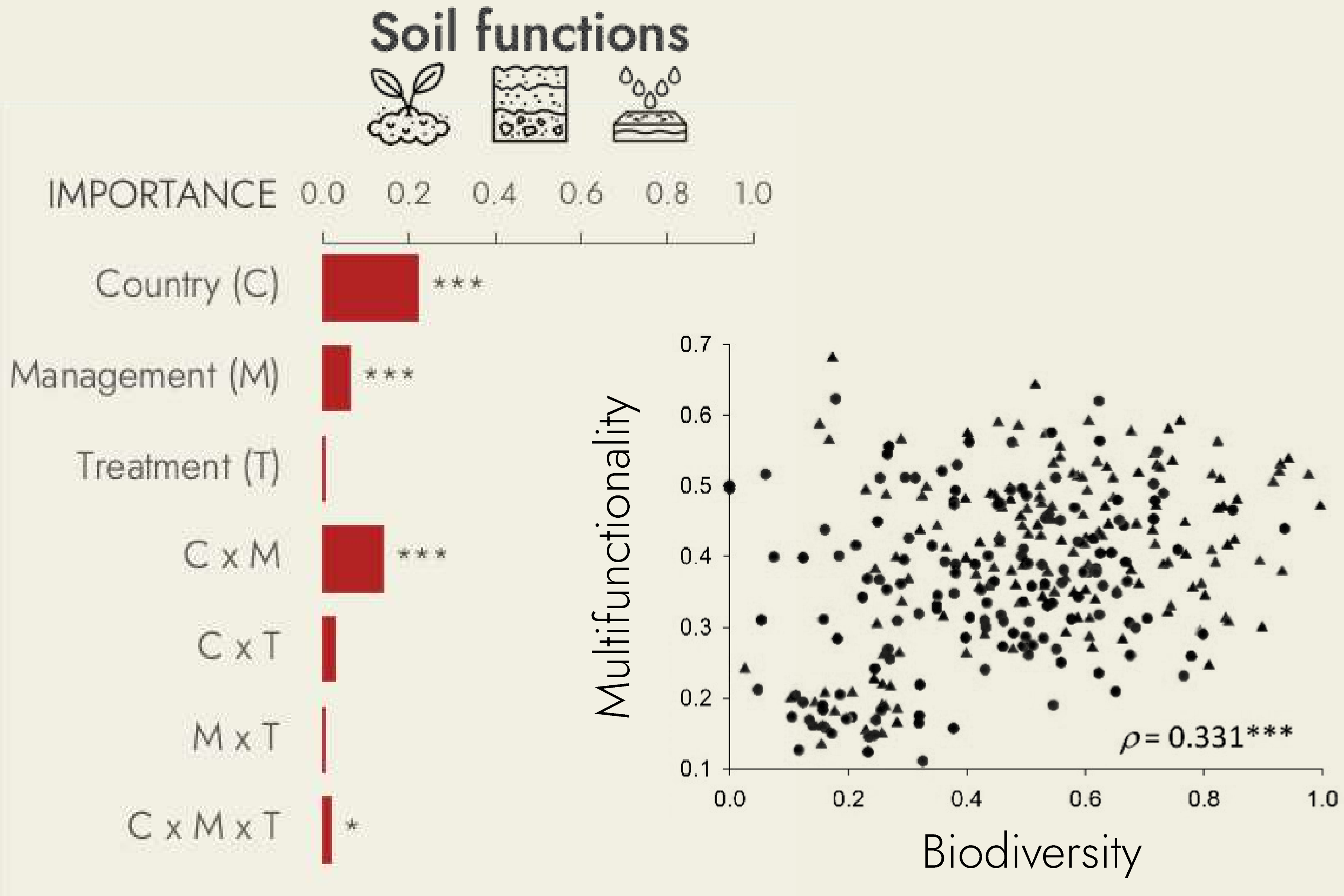
Soil Multifunctionality



TAKE HOME

- **Country was the strongest determinant of soil multifunctionality**, but less decisive than for soil biodiversity.
- **Management effects were substantial**, seemingly more pronounced than effects on soil biodiversity. These effects were **strongly site-dependent**.
- **Drought effects were small and not significant but showed a dependency on site and management.** This context-dependency could not be explained by the measured soil properties.
- A **positive relationship between soil biodiversity and multifunctionality** was observed.

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

MICROSERVICES

Organic system

- Fertilization with farmyard manure without synthetic fertilizer
- Crop protection with mechanical methods and biocontrol

Integrated system

- Fertilization with farmyard manure and synthetic fertilizer (NPK)
- Crop protection with insecticides, fungicides, herbicides

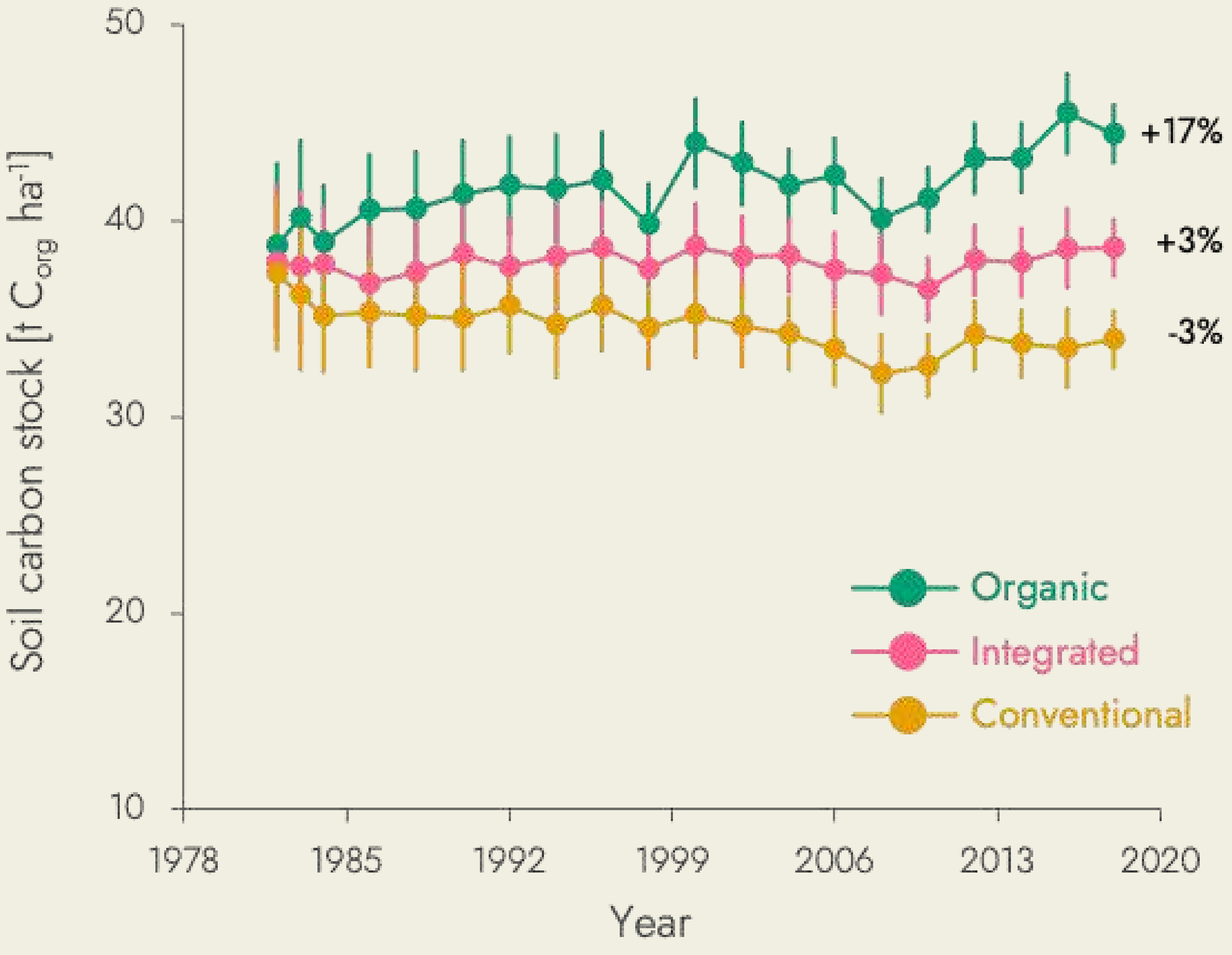
Conventional system

- Fertilization with synthetic fertilizer only
- Crop protection with insecticides, fungicides, herbicides

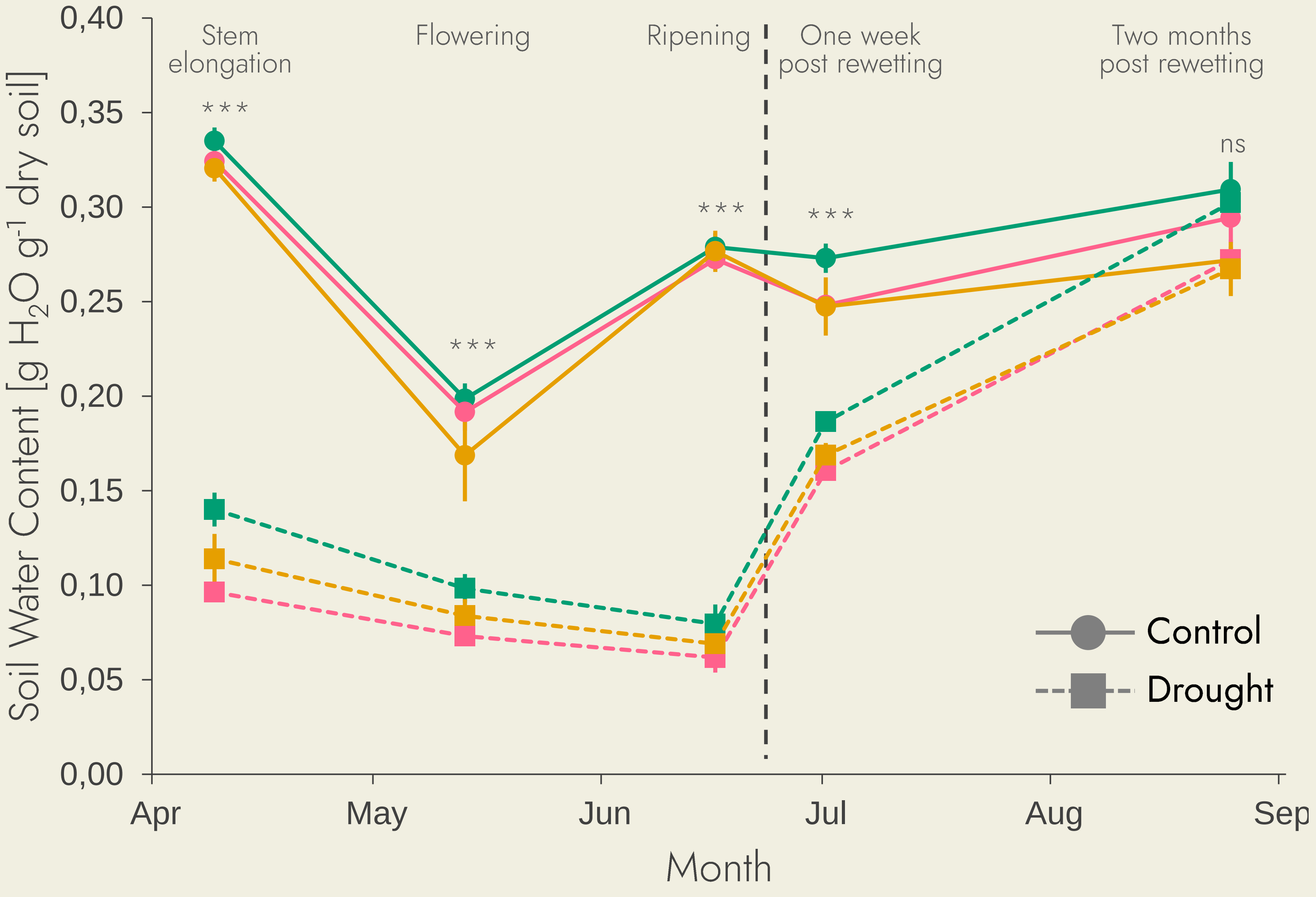
This research was funded through the 2019-2020 BiodivERsA joint call for research proposals, under the BiodivClim ERA-Net COFUND programme, and with the funding organisations Swiss National Science Foundation SNSF (31BD30_193666), Agencia Estatal de Investigacion AEI (SPCI202000X120679IV0), Agence nationale de la recherche ANR (ANR-20-EBI5-0006), Federal Ministry of Education and Research BMBF (16LC2023A), and General Secretariat for Research and Innovation GSRI (T12EPA5-00075)

MICROSERVICES

Soil organic matter and soil moisture retention



Krause et al. 2022 (Agronomy for Sustainable Development)



Kost et al. 2024 (European Journal of Soil Biology

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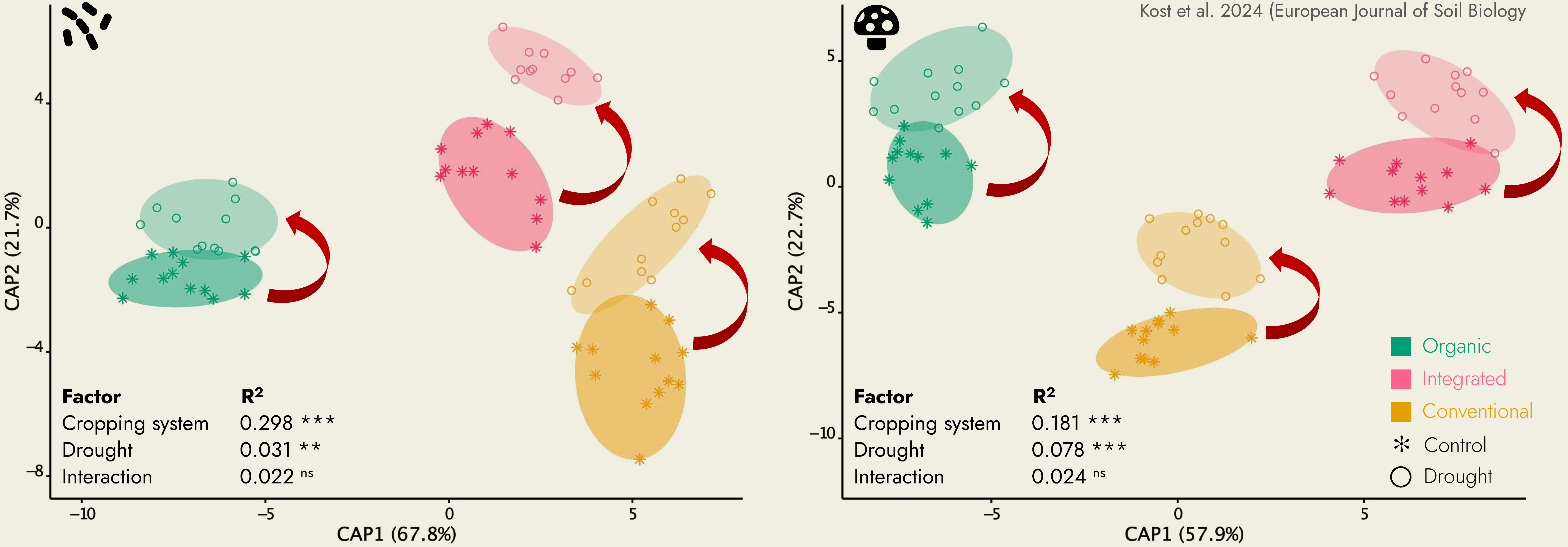
MICROSERVICES

Soil biodiversity shifts under drought



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MICROSERVICES

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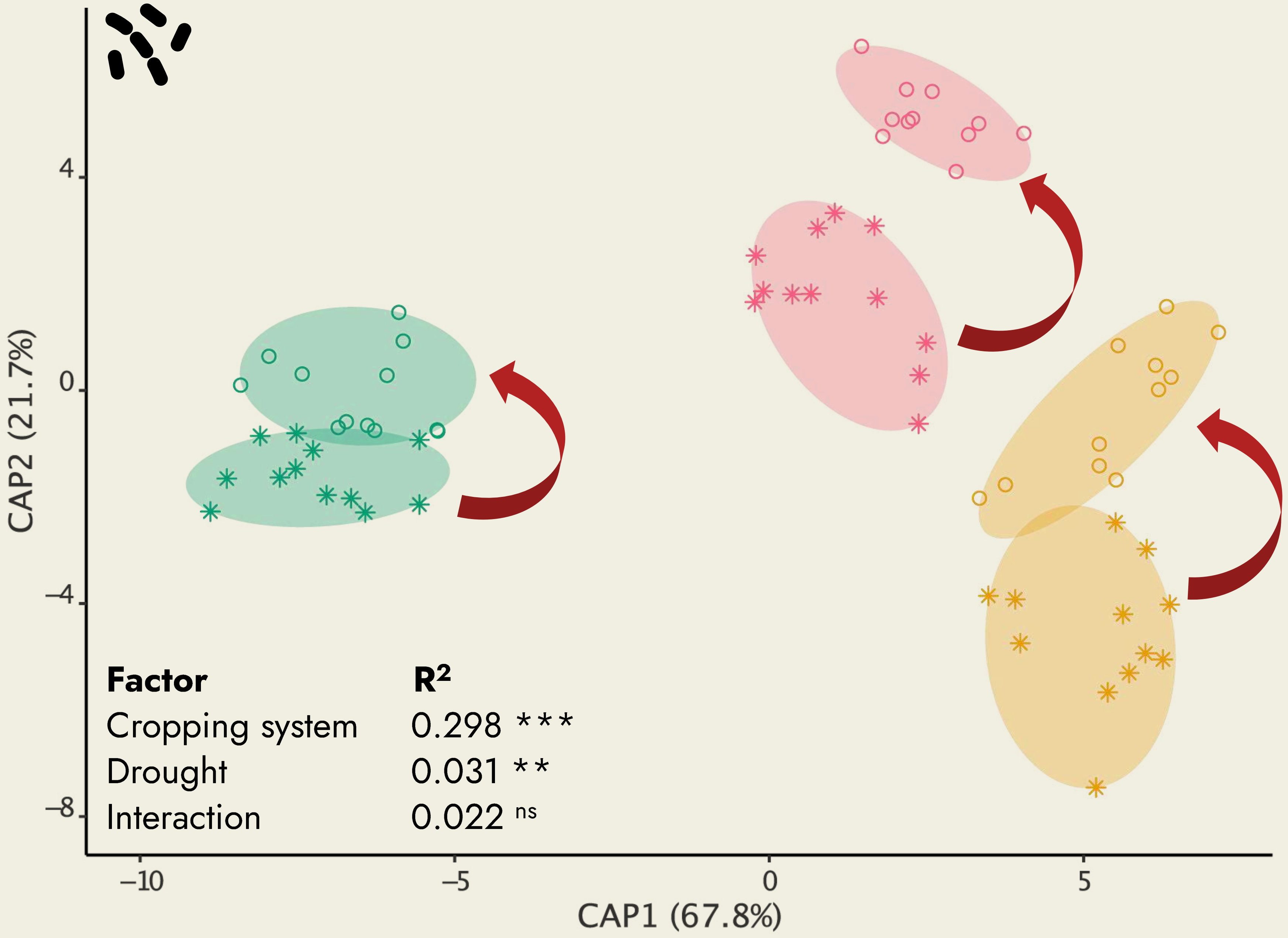


TAKE HOME

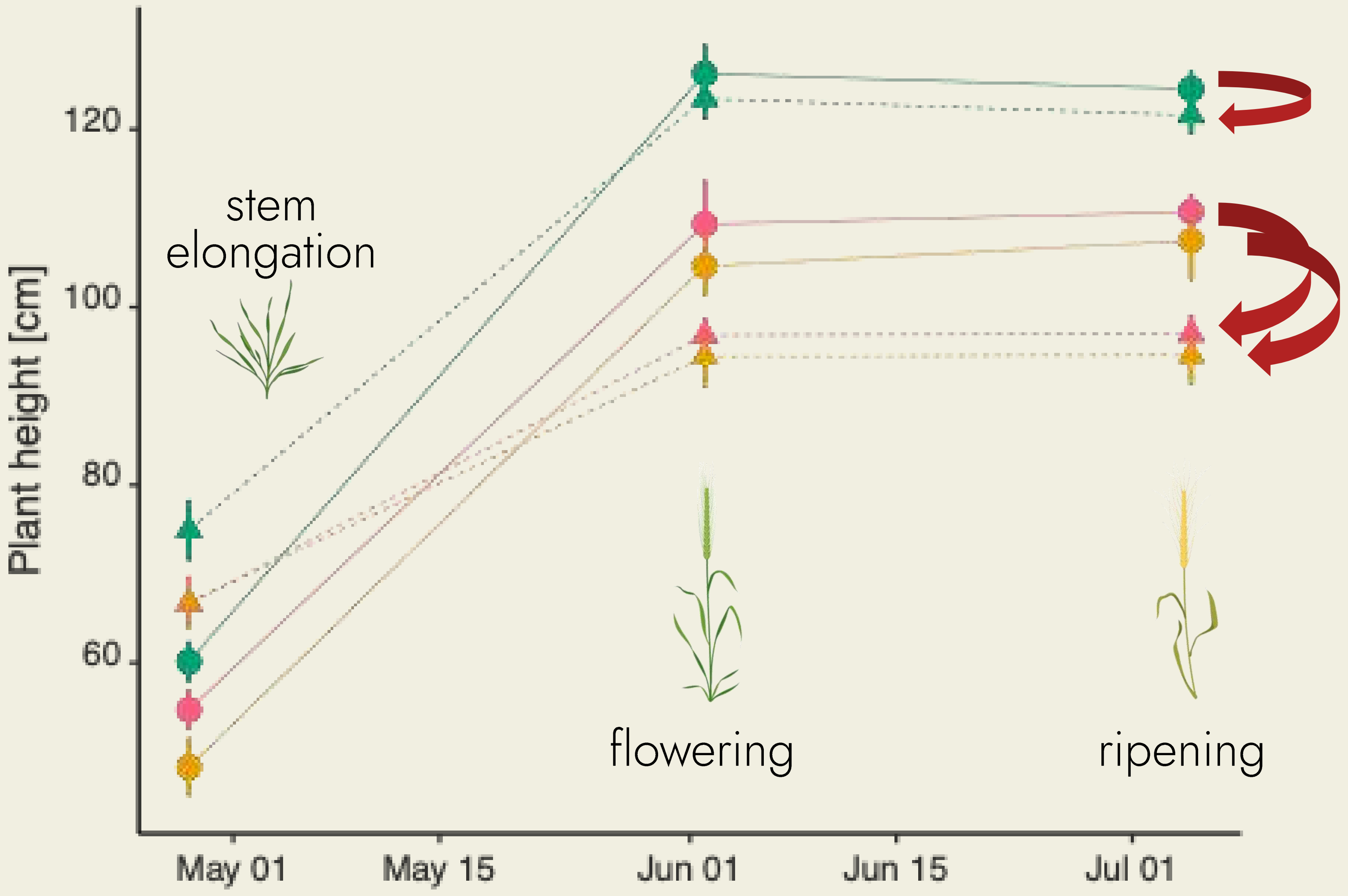
- There was **no indication that increased soil organic carbon (SOC)** in organic cropping systems **could enhance the resistance of soil biodiversity to drought**.
- **Drought effects increased in closer association with the crop** (bulk soil < rhizosphere < endosphere) and **impacted fungi more strongly** than prokaryotes.
- **Differences in soil biodiversity between cropping systems remained stable also under drought stress**, underscoring the importance of legacy effects of agricultural management on soil biodiversity.

Kost et al. 2024 (European Journal of Soil Biology

This research was funded through the 2019-2020 BiodivERsA joint call for research proposals, under the BiodivClim ERA-Net COFUND programme, and with the funding organisations Swiss National Science Foundation SNSF (31BD30_193666), Agencia Estatal de Investigacion AEI (SPCI202000X120679IV0), Agence nationale de la recherche ANR (ANR-20-EBI5-0006), Federal Ministry of Education and Research BMBF (16LC2023A), and General Secretariat for Research and Innovation GSRI (T12EPA5-00075)

MICROSERVICES

Plant growth



TAKE HOME

- **Drought reduced plant height by ~10%**. This reduction was **dependent on the management, showing stronger reduction in the conventional versus the organic system** (pointing to a potential role of plant growth regulators in negatively modulating the stress response).
- **These management-dependent drought effects were not observed for dry plant biomass**, raising questions about the impact on crop yield (which could not be assessed).

Kost et al. 2024 (European Journal of Soil Biology

biodiversa

This research was funded through the 2019-2020 BiodivERsA joint call for research proposals, under the BiodivClim ERA-Net COFUND programme, and with the funding organisations Swiss National Science Foundation SNSF (31BD30_193666), Agencia Estatal de Investigacion AEI (SPCI202000X120679IV0), Agence nationale de la recherche ANR (ANR-20-EBI5-0006), Federal Ministry of Education and Research BMBF (16LC2023A), and General Secretariat for Research and Innovation GSRI (T12EPA5-00075)

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SOILGUARD MICROSERVICES

Conclusions

1) **Location emerged as the primary driver of soil biodiversity and multifunctionality**, underscoring the need to consider the local context in decision-making processes. We recommend avoiding overgeneralizations and call for more local studies to better understand the factors driving these complex interactions.
2) **Management practices significantly influenced soil biodiversity and multifunctionality**, highlighting the capacity of agricultural interventions to steer soil biodiversity and its functions. Management effects were modulated by location, emphasizing the importance of contextualizing management decisions.
3) **Short-term drought had a small and context-dependent impact on soil biodiversity and multifunctionality**, indicating the substantial buffering capacity of soils. However, effects intensified in proximity to plants and were more pronounced for eukaryotes, raising concerns about crop performance and specific soil functions.
4) **Cropping systems harbor a unique soil biodiversity which is largely maintained under drought stress**, emphasizing the importance of legacy effects under future climate. Further research is needed to identify tipping points where specific outcomes of agricultural management decisions help buffer against climate stress.

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

SOILGUARD

The Valuation of Soil-mediated Contributions to People

Dr. Alexandra Dehnhardt, Tobias Möllney
Institute for Ecological Economy Research (IÖW)

Brussels, 31/03/2025

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Presentation Outline

PART 1	Introduction
PART 2	Conceptual approach and objectives
PART 3	Results: Socio-cultural values
PART 4	Results: Economic values
PART 5	Conclusion

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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Introduction

- Importance of intact and well-functioning ecosystems for human well-being is increasingly emphasized
  ⇒ Growing need to include the societal benefits in decision-making processes in order to achieve sustainable development
- Attention given to the importance of soils is still limited
  ⇒ Societal relevance and value attached to soils is still unknown
- Making socio-cultural and economic values more transparent is highly relevant for (better) policy-making
  ⇒ Analyzing trade-offs, communication of values, raising awareness, justifying policies

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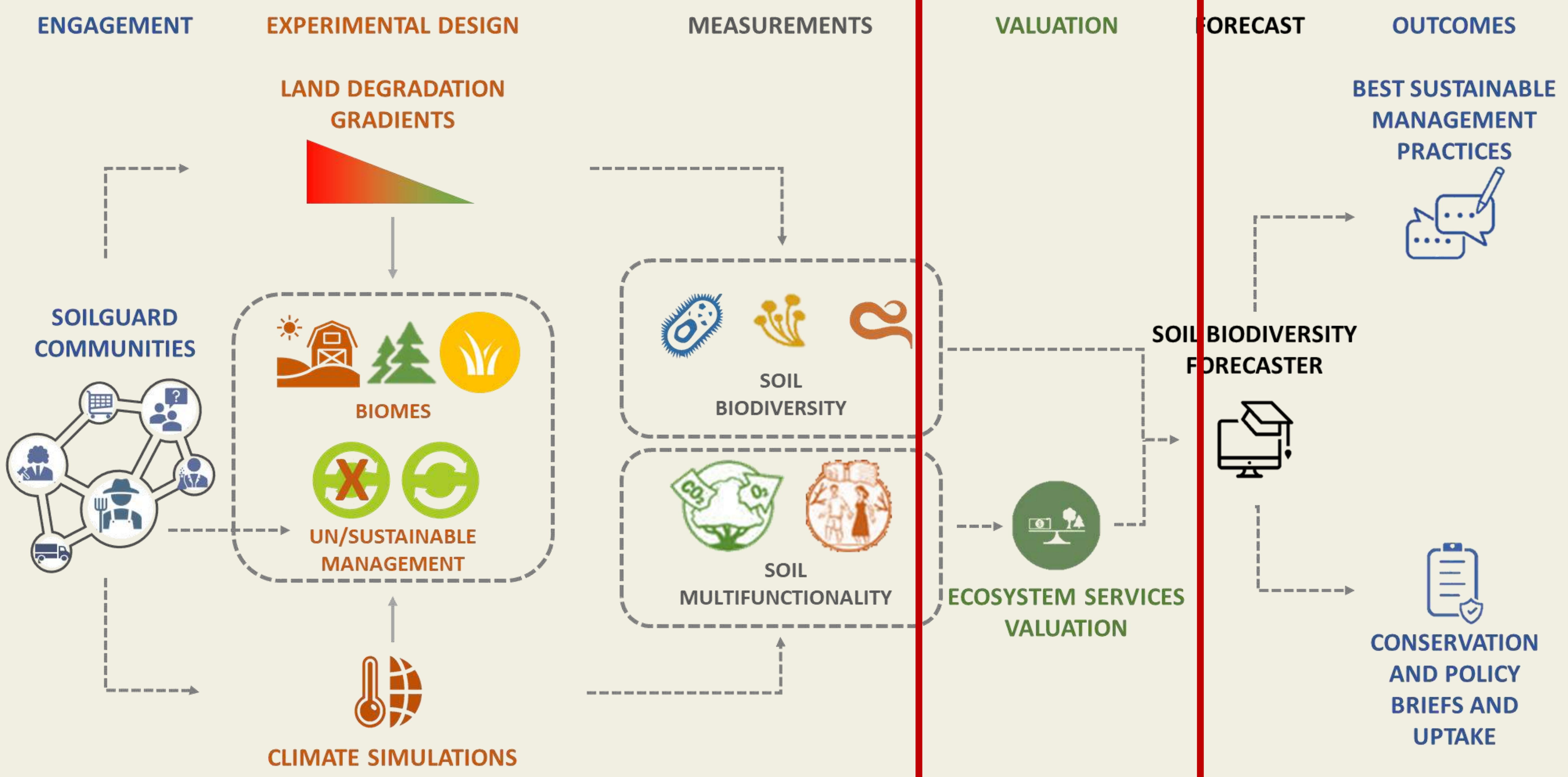
Concept



Source: SOILGUARD

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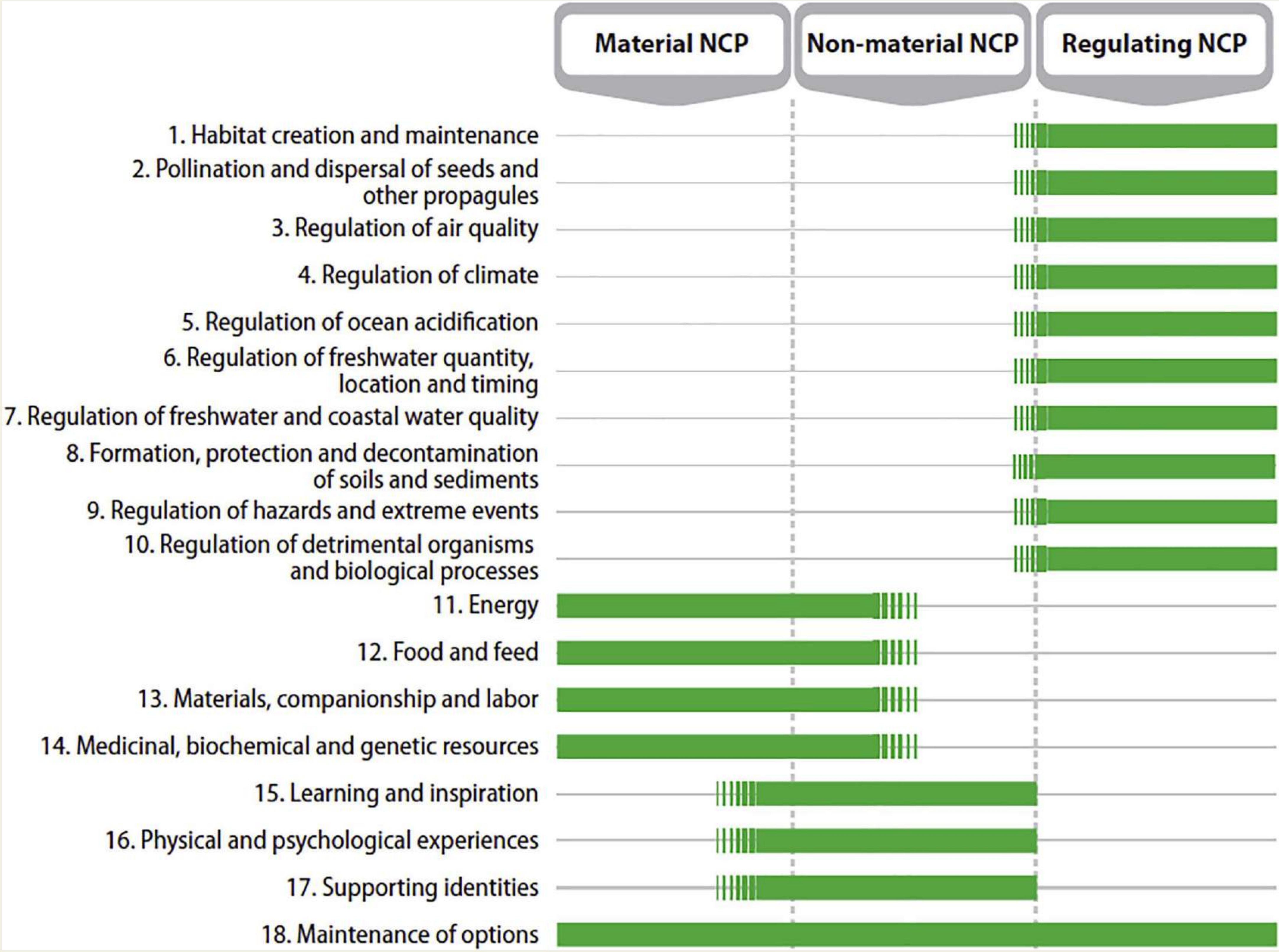
IPBES conceptual framework: "Nature's Contributions to People" (NCPs)

- Concept of **ecosystem services** focus on the *instrumental* values (means to a desired end)
- **NCPs** highlight a wider range of values: *intrinsic* values (independent of people as valuers) and *relational* values (meaningfulness of human-nature interrelations) in addition to *instrumental* values
- Development of an integrated valuation approach to account for the diversity of values and provide a more comprehensive understanding (economic and socio-cultural valuation)
- **"Soil-mediated Contributions to People" (SmCPs)** = contributions to society associated with soils



Source: Díaz et al. (2018). Assessing nature's contributions to people. Science, 359(6373), 270–272. https://doi.org/10.1126/science.aap8826

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Valuation of Soil-mediated Contributions to People (SmCPs)

OBJECTIVE 1

Develop a specific **integrated valuation approach** for soil-mediated contributions to people

OBJECTIVE 2

Quantify the region-specific **socio-cultural** and **economic** value of SmCPs perceived as essential by stakeholders

Understand the region-specific factors that **influence the value** (e.g., knowledge, perception)

OBJECTIVE 3

Quantify the region-specific **effects of soil management, land degradation and climate change** on economic and socio-cultural value of soil-mediated contributions to people

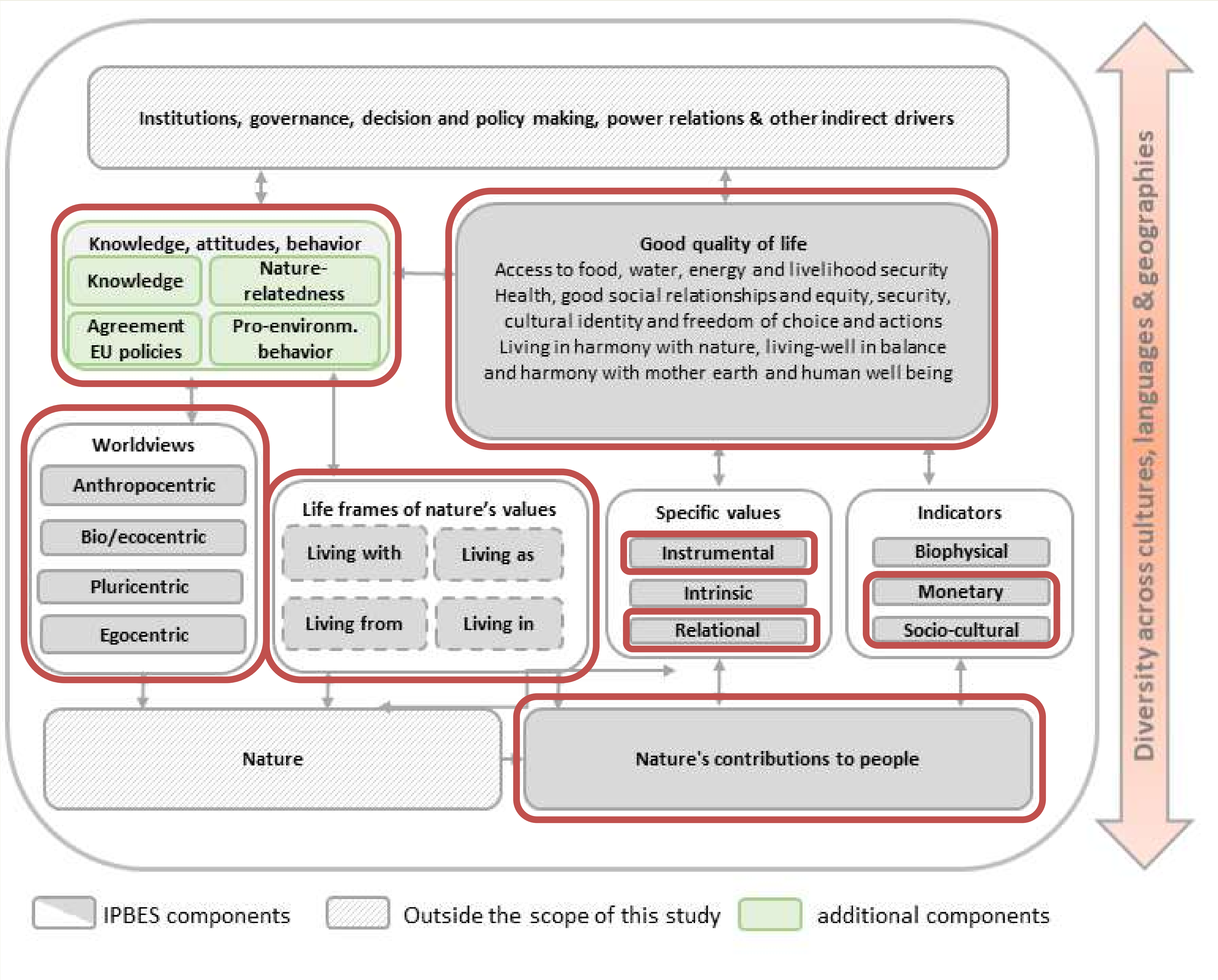
The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Icons: Flaticon.com; ltr: Freepik, Umeicon, Freepik

SOILGUARD

Adapted IPBES conceptual framework

- Exploring **social constructs** in three European countries across a climatic gradient: Denmark, Ireland, Spain
- Assessing **socio-cultural** (by ranking & rating) and **monetary values** (by WTP) for SmCPs across regions
- Modelling the determinants of socio-economic values by examining the influence of social constructs across the regions



Source: SOILGUARD, adapted and extended from: Pascual et al. (2023). Diverse values of nature for sustainability. Nature, 620(7975), ,813–823. https://doi.org/10.1038/s41586-023-06406-9

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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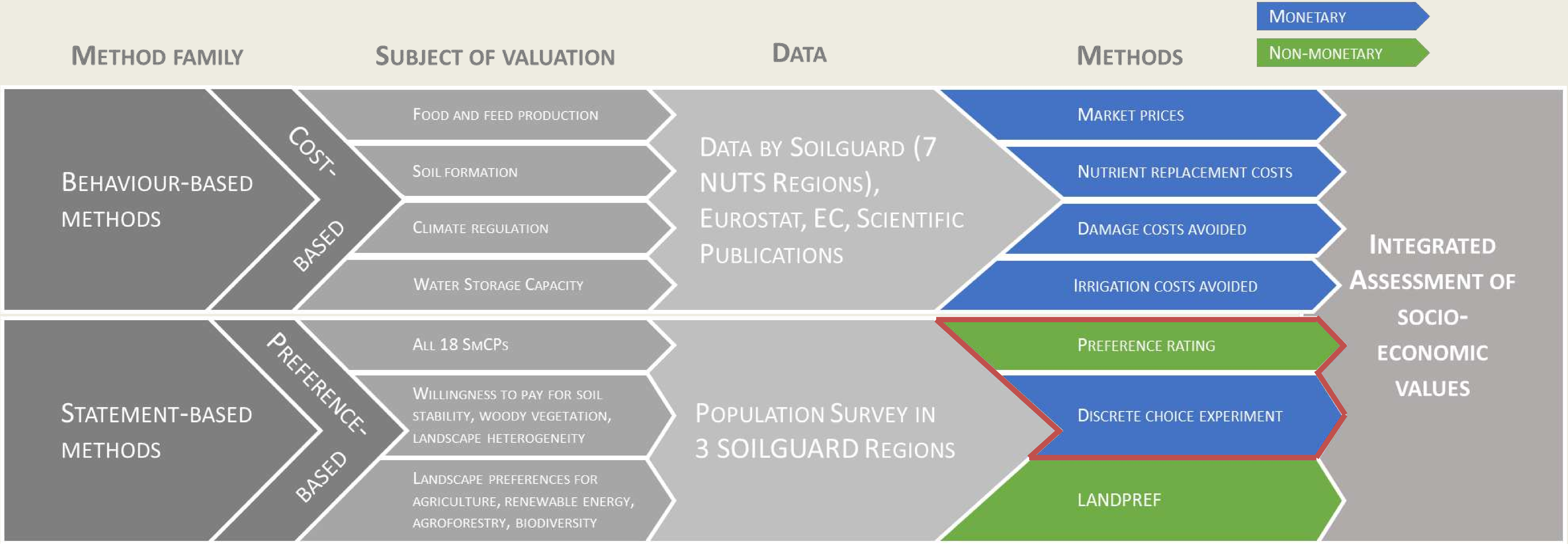
Value pluralism: Using different methods to estimate the effects on monetary and non-monetary value dimensions.
Overarching question: How do **changes** in **soil management practices** at different levels of land degradation in different regions affect socio-economic values in terms of benefits or forgone benefits?

Valuation Methods

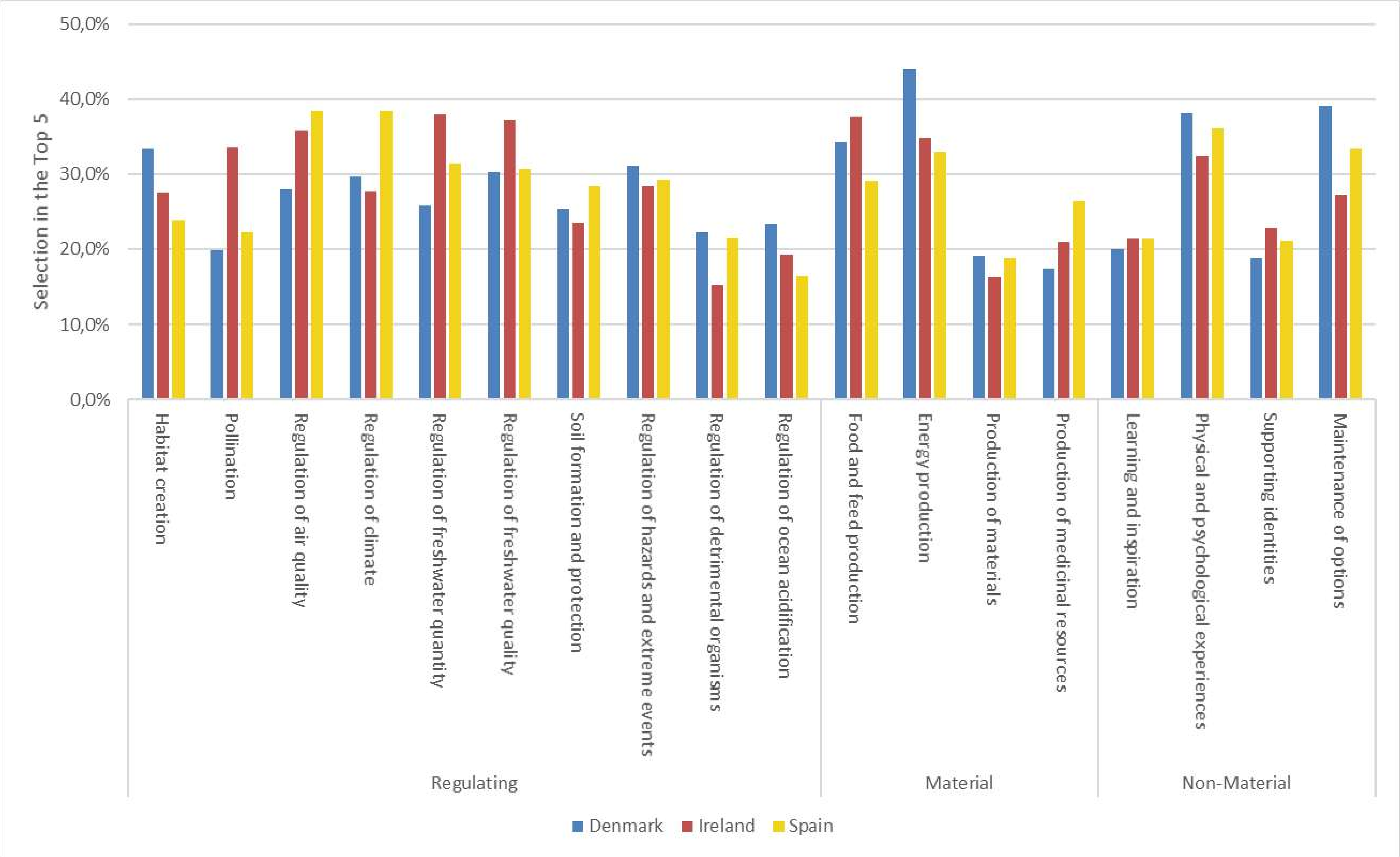


Source: SOILGUARD

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Socio-cultural values: Preference rating

- Soils are very **complex** ecosystems
- SmCPs with **no directly perceptible** connection to land use seem to be less important
- SmCPs, which are **more directly perceptible** and play a role in the reality of people's life appear to be higher ranked in all countries
- **Regulating SmCPs** (regulation of climate, freshwater quantity and quality) are comparatively easy to understand and appear to be quite **important**



The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Source: SOILGUARD

SOILGUARD

Economic valuation: Discrete Choice Experiment

- Estimate Willingness to Pay (WTP) for 3 selected attributes, influencing SmCPs
- Example choice set from the Discrete Choice Experiment
- Status quo relative to average in respective country as a whole

	Option 1	Option 2	Status Quo
Soil stability	2 Olympic stadiums of soil loss	1 Olympic stadiums of soil loss	10 Olympic stadiums of soil loss
Woody vegetation	70% increase	40% increase	28 m^2 for every 100 m^2 of land
Landscape heterogeneity	Multiple crops	Single crop	Single crop
Additional household expenditure	50 €	20 €	0 €
Which would you choose?	◌	◌	◌

Source: SOILGUARD

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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Valuation results

- Conditional logit WTP estimates
- WTP in € per person and year for changes indicated in parentheses

- Mostly highly significant results: Significant WTP to increase soil stability, woody vegetation & landscape heterogeneity
- Relative importance varies considerably between countries

Willingness to Pay [€/person-year]			
	Denmark	**Ireland**	**Spain**
n	414	411	440
Soil stability (per % increase)	0.77** (0.035)	1.70*** (0.035)	2.40*** (0.036)
Woody vegetation (per % increase)	2.15*** (0.044)	1.06*** (0.036)	0.13 (0.025)
Landscape heterogeneity (multiple crops on land vs. monoculture)	107.53*** (2.101)	116.49*** (2.321)	77.03*** (1.489)

Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1. Standard errors in parentheses.

Source: SOILGUARD

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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Conclusion

HIGHLIGHT 1

Poorly managed soils and soil degradation lead to a loss of the broad range of benefits healthy soils provide

HIGHLIGHT 2

Soils have essential value to people, but people perceive importance of SmCPs differently across countries

HIGHLIGHT 3

Benefits and foregone benefits affect different beneficiaries: farmers, local residents and society as a whole. Consideration and integration of their perspectives and values in management and policymaking is essential.

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Icons: Flaticon.com; ttb: nangicon, Umeicon, surang

SOILGUARD

Thank you for your attention.

Contact

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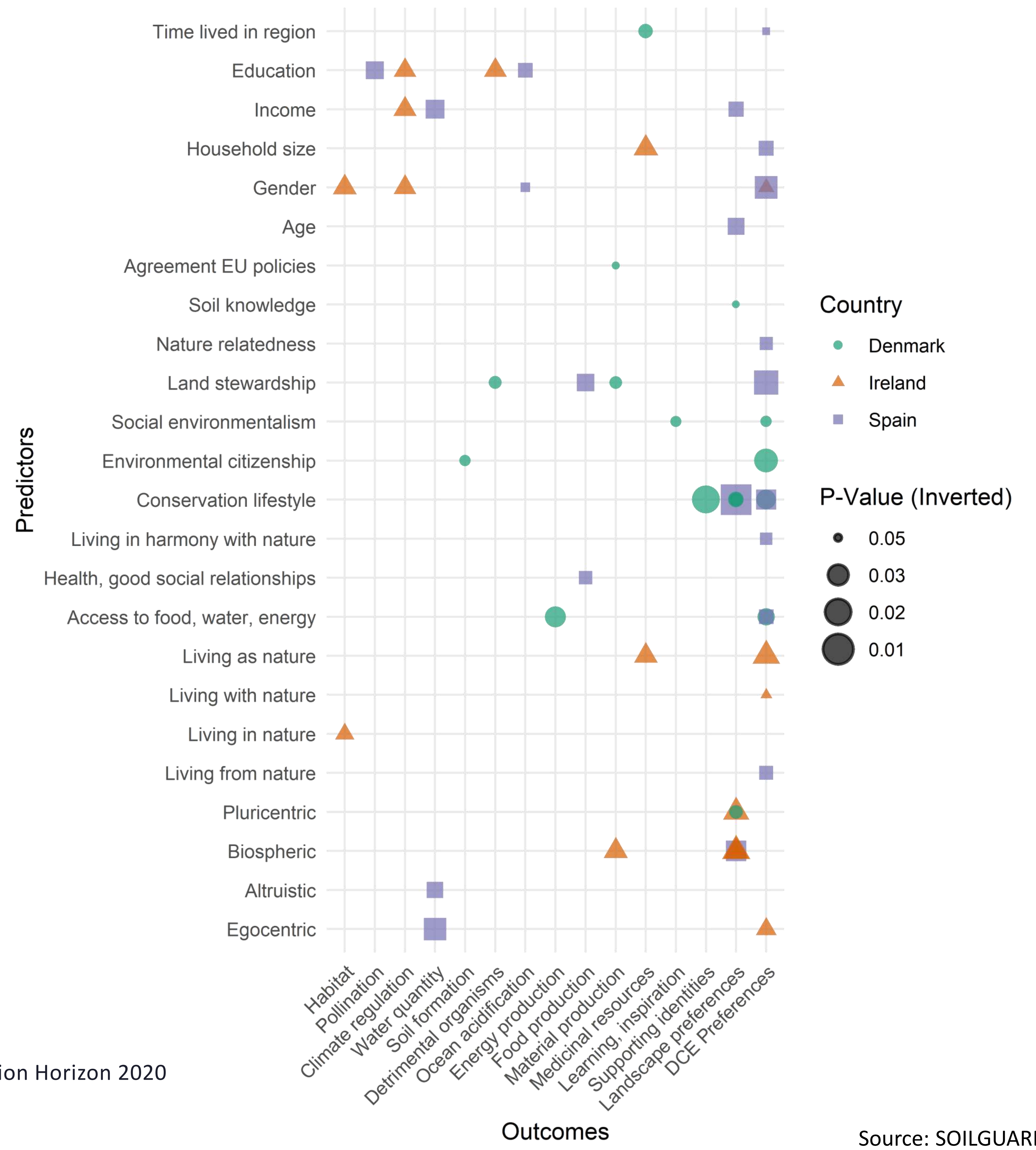
The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Determinants of value

- Determinants based on odd ratios after bi-/multinomial logistic regressions (p≤0.05) for the SmCP and landscape preferences outcomes.
- Determinants were included as interactions with the alternative specific constant in the Discrete Choice model (DCE) to determine the significance (p≤0.05) of influence of determinants on preference for overall changes in soil stability, woody vegetation and landscape heterogeneity.



Source: SOILGUARD

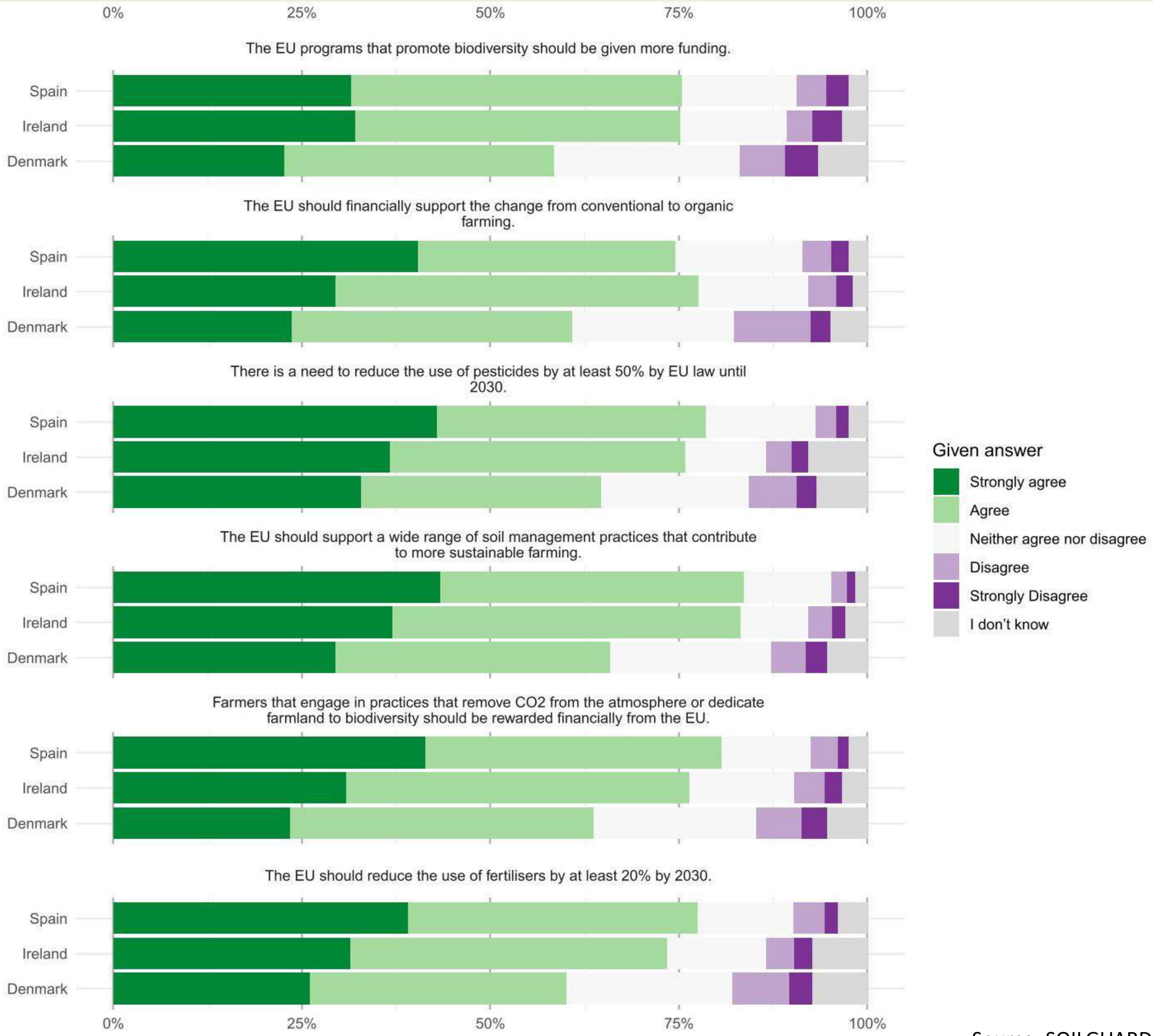
The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Agreement to EU policies

Support for measures regarding

- climate change mitigation and adaption (CAP, specific objective 4),
- water quality, soil, degradation, soil management practices (CAP, specific objective 5) and
- biodiversity and pesticides (CAP, specific objective 6).

Question: "Please indicate your agreement to policies and programs of the European Union (EU) with the following statements."



Source: SOILGUARD

The research leading to these results has received funding from the Europ
Research & Innovation programme under the Grant Agreement no. 10100

Overview of the SOILGUARDIANS app

Laurence Jones, Els Dhiedt, Georgios Manassakis

31/03/2025

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

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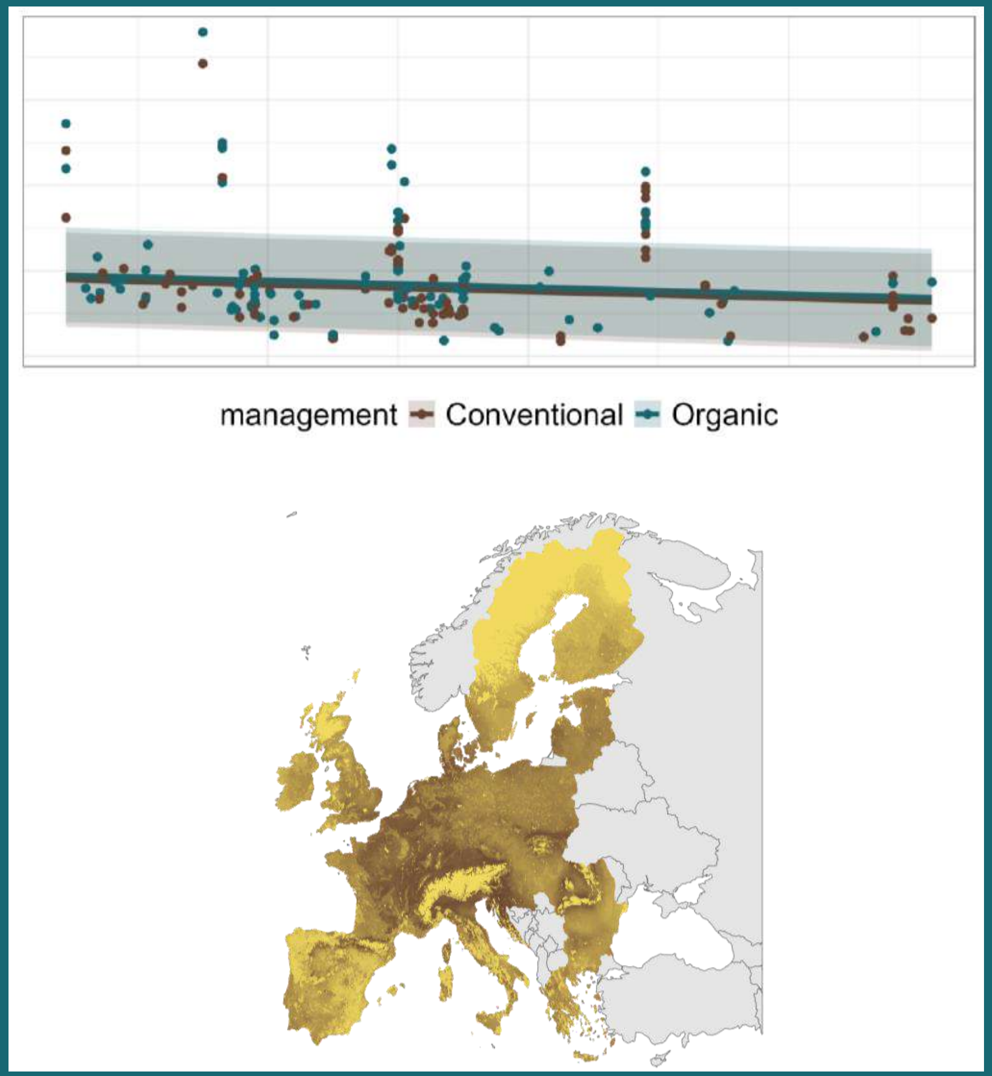
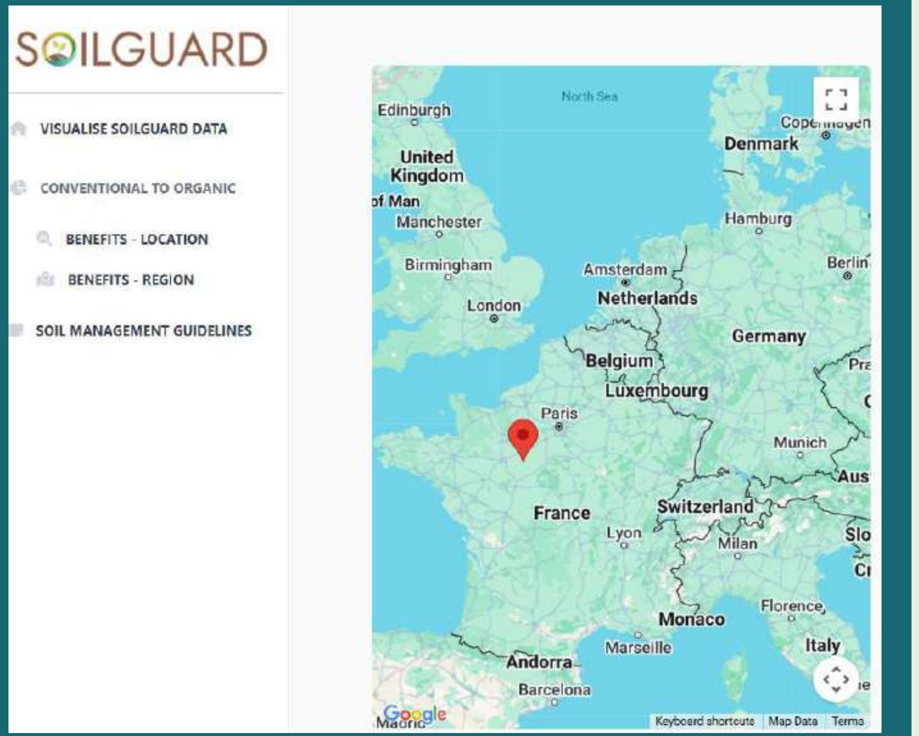
Environmental variables

Soil management:
- Conventional
- Organic

Modelled benefits



SOILGUARDIANS app



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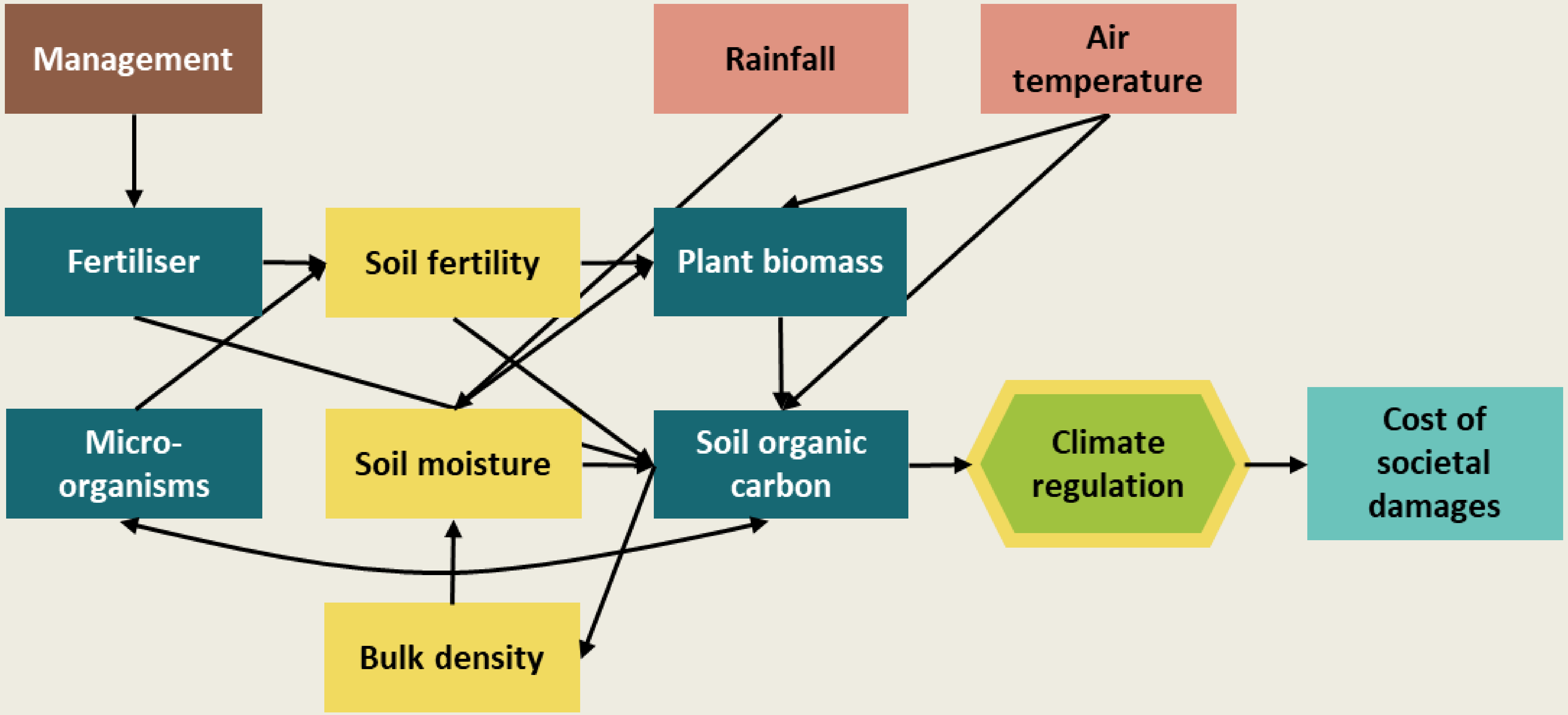
Evidence chain



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SOILGUARD

Soil organic carbon

Nitrous oxide emission

Crop yield

Hydraulic conductivity

Saturated water content

Soil diversity

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Tamás Kovács – pixabay
Gabriel Jimenez, Vidar Nordli-Mathisen, Ivan Ivanovič – Unsplash

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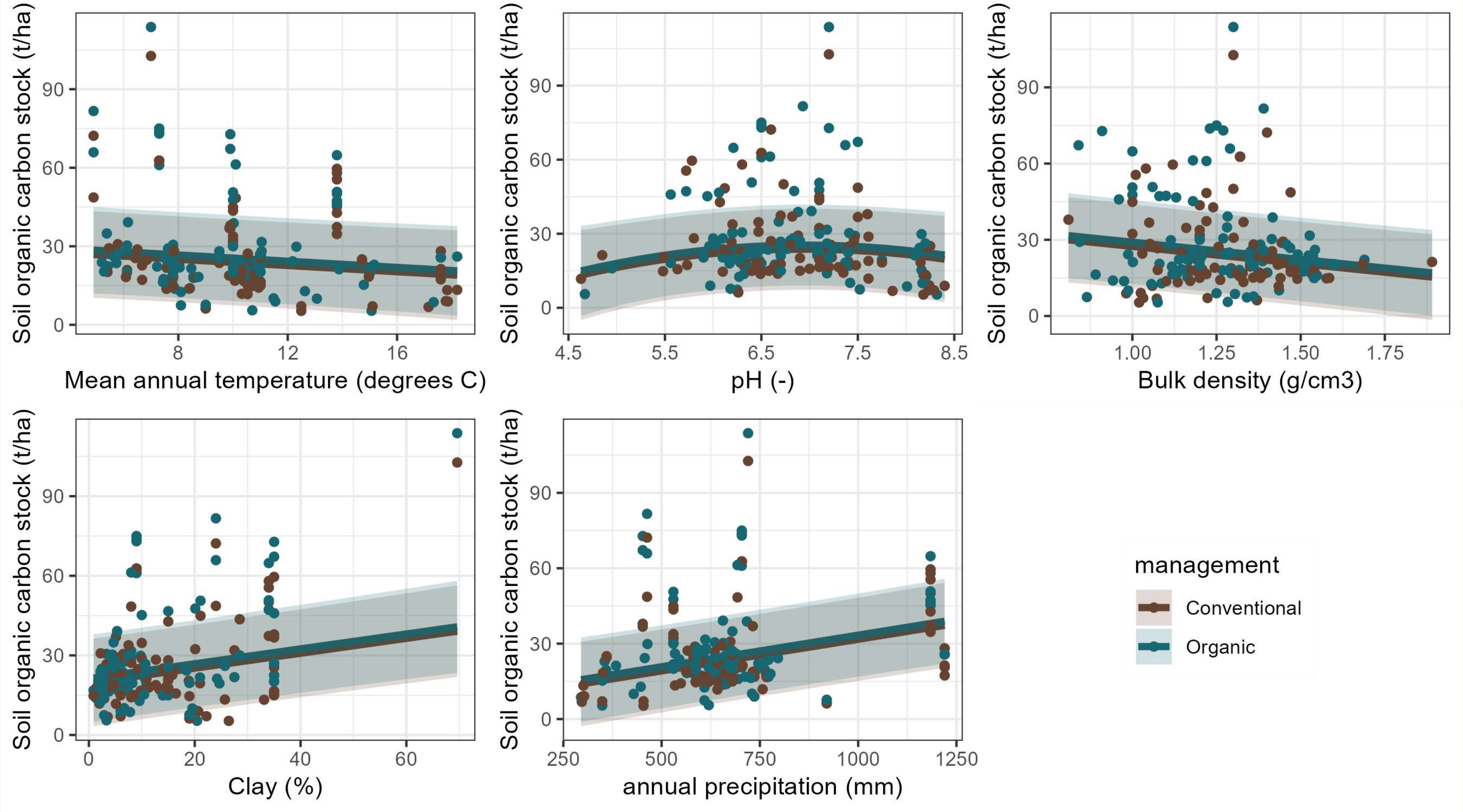
Soil organic carbon



Statistical model

Data to fit model: SOILGUARD & literature

Avoided cost of societal damages

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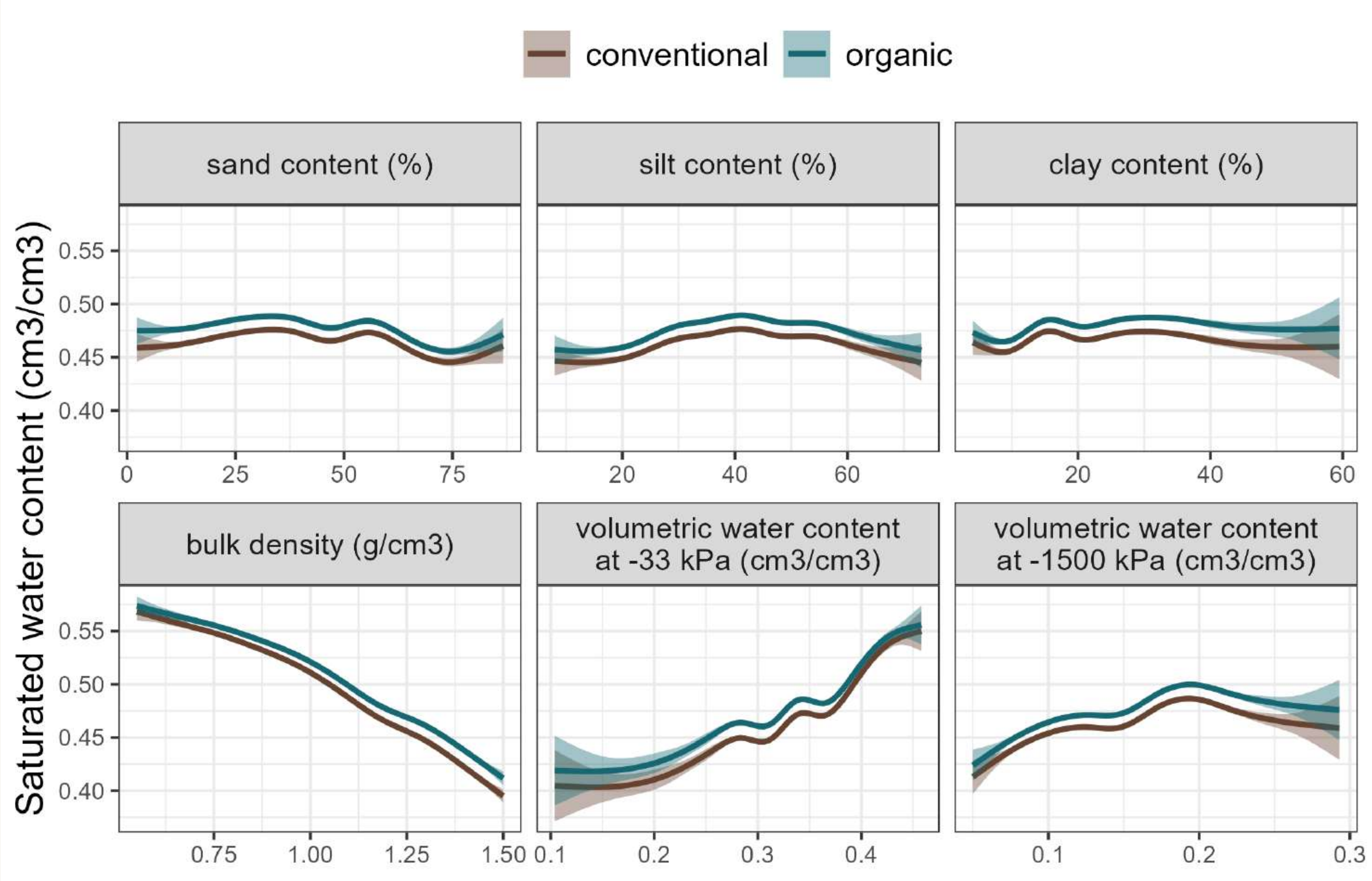
Saturated water content



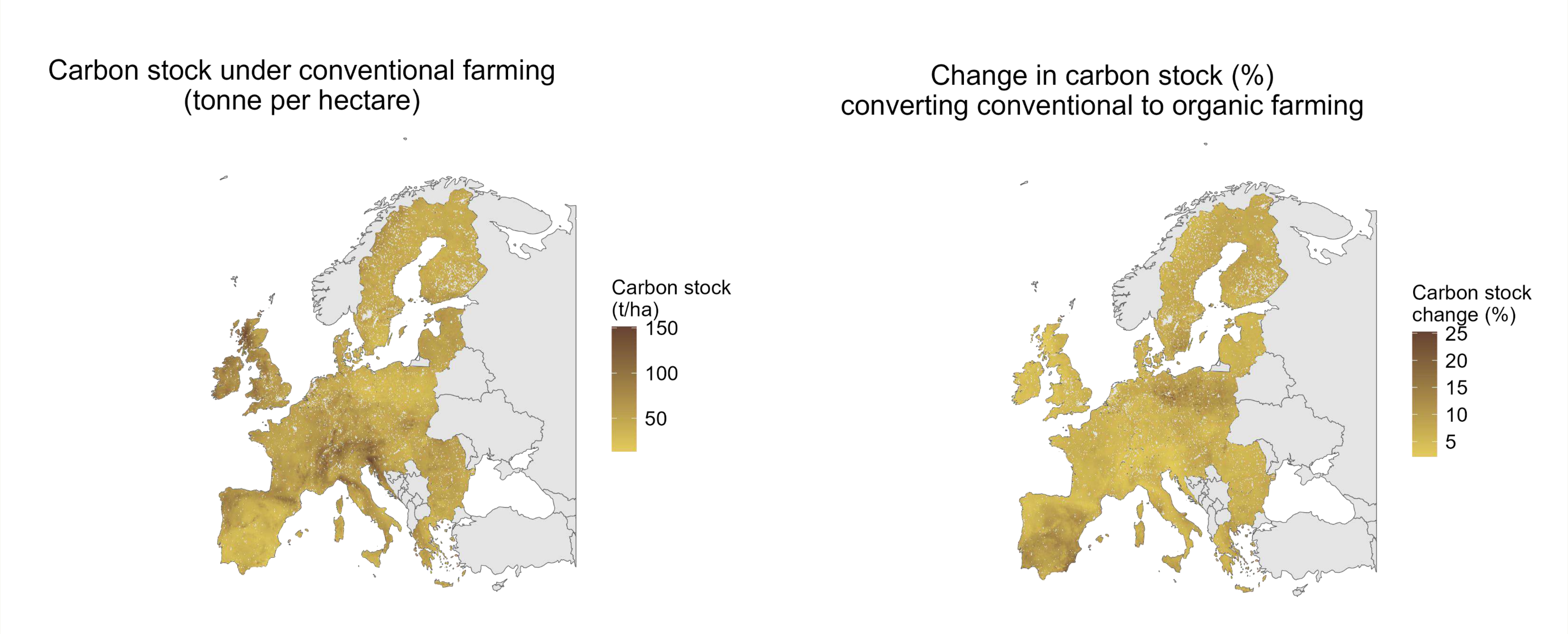
Rosetta model to predict hydraulic properties

Irrigation cost avoided

The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

SOILGUARD

Soil organic carbon



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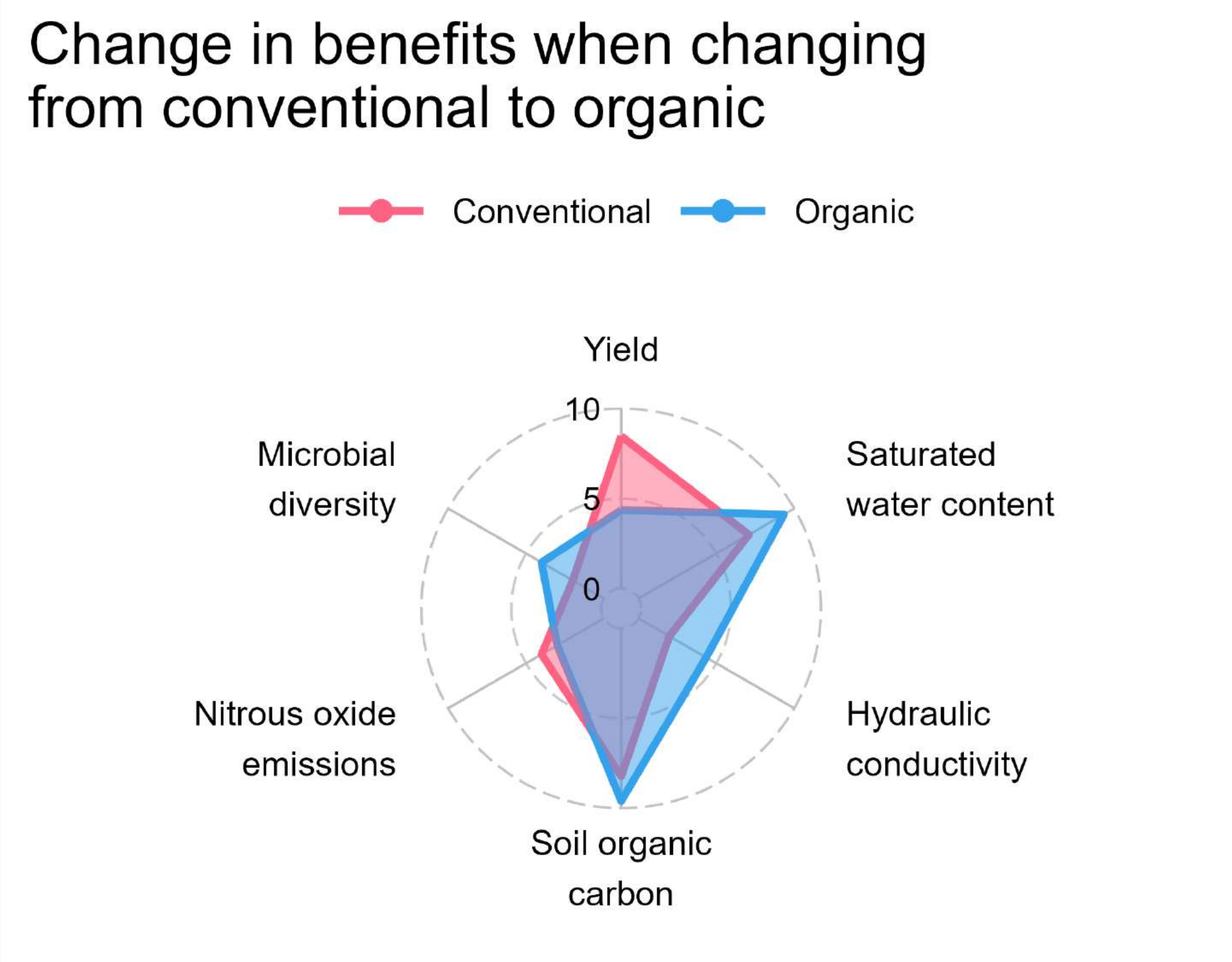
SOILGUARD

Point predictions



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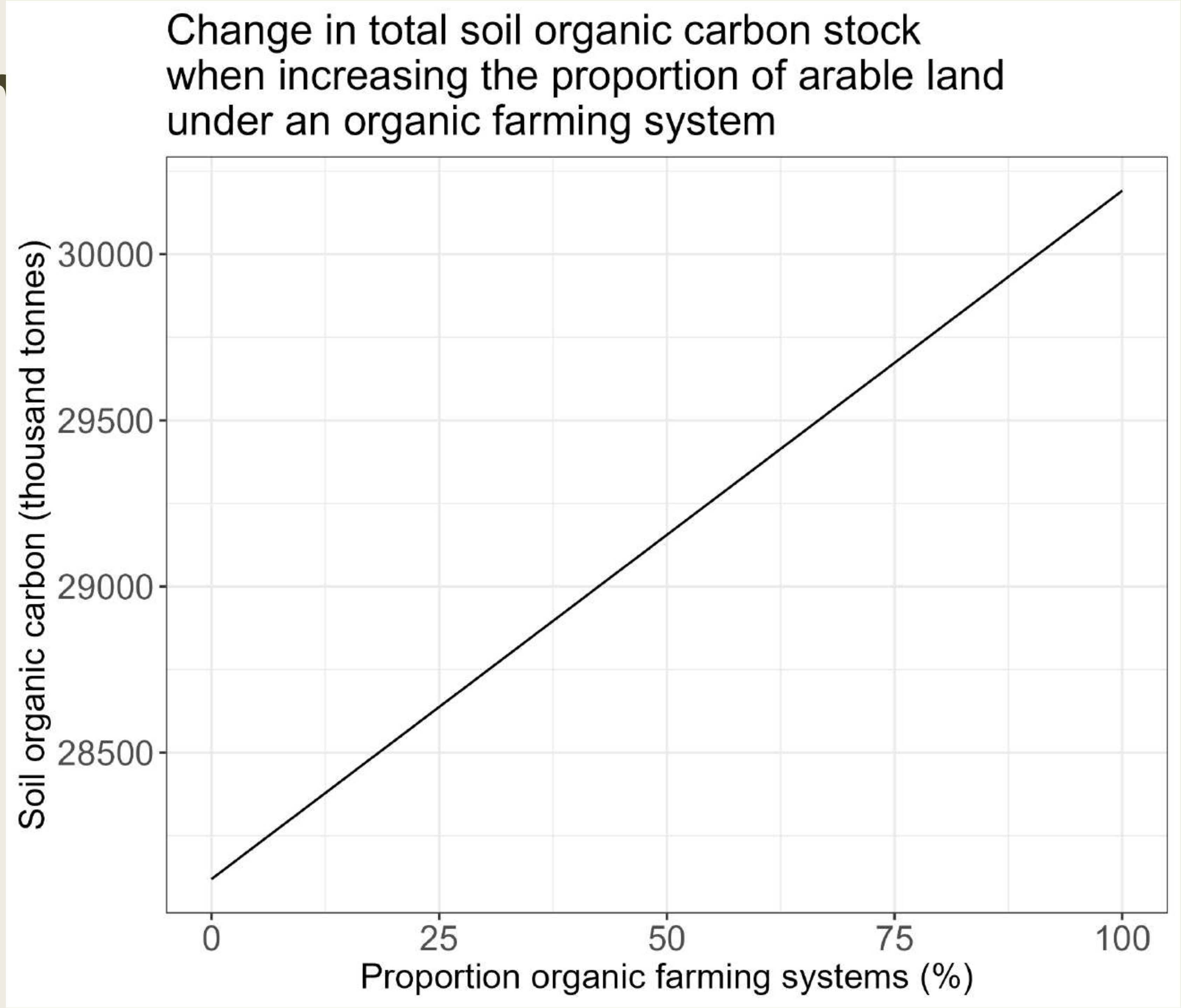
NUTS2-level prediction



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Live demo SOILGUARDIANS app

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SOILGUARD

Thank you for your attention.

Contact:

lj@ceh.ac.uk

gmanassakis@wings-ict-solutions.eu

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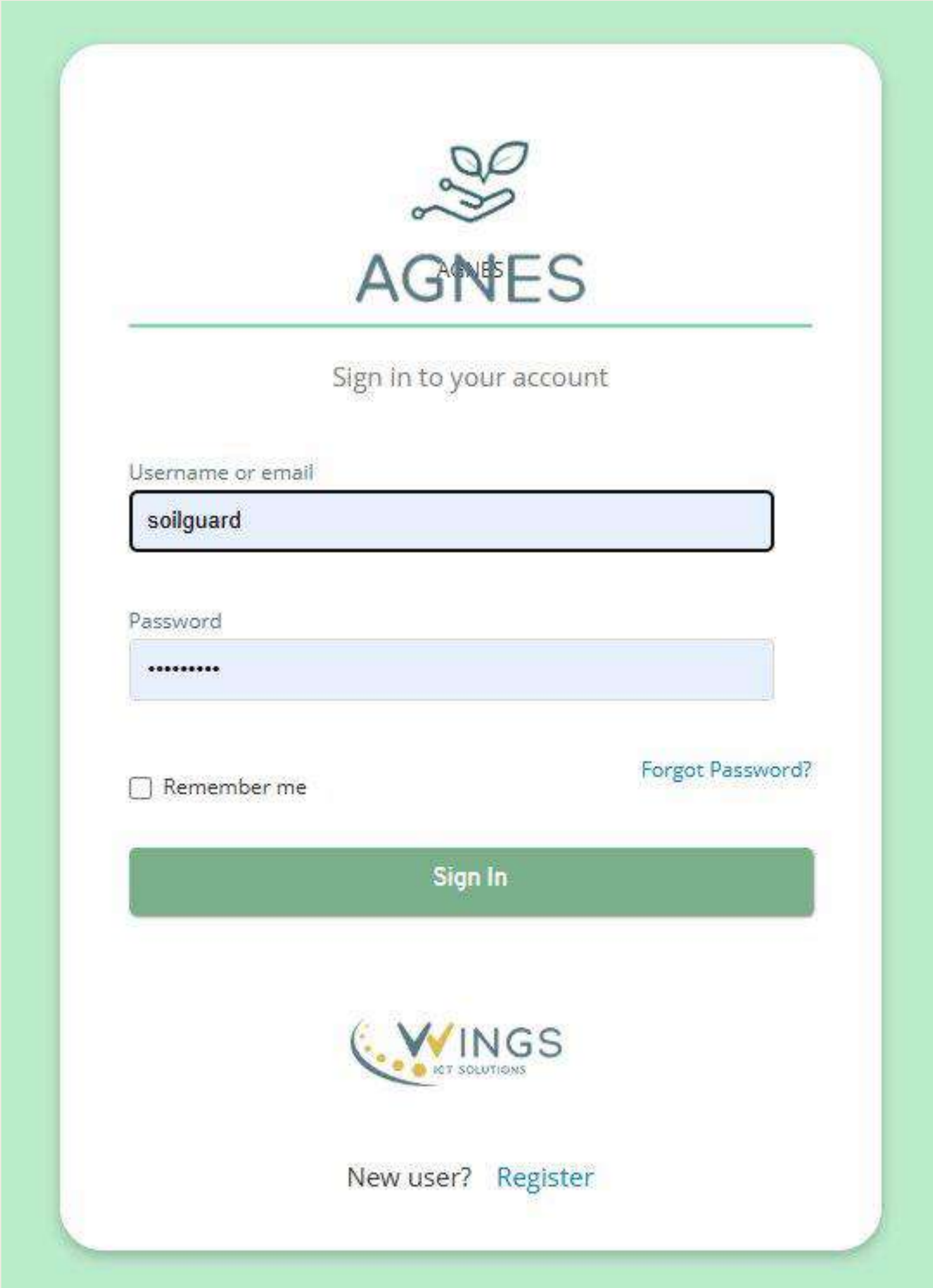

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SOILGUARD

VISUALISE SOILGUARD DATA

CONVENTIONAL TO ORGANIC

SOIL MANAGEMENT GUIDELINES

Welcome to SOILGUARDIANS!

You need to Sign In to access the SOILGUARD data.

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SOILGUARD

VISUALISE SOILGUARD DATA

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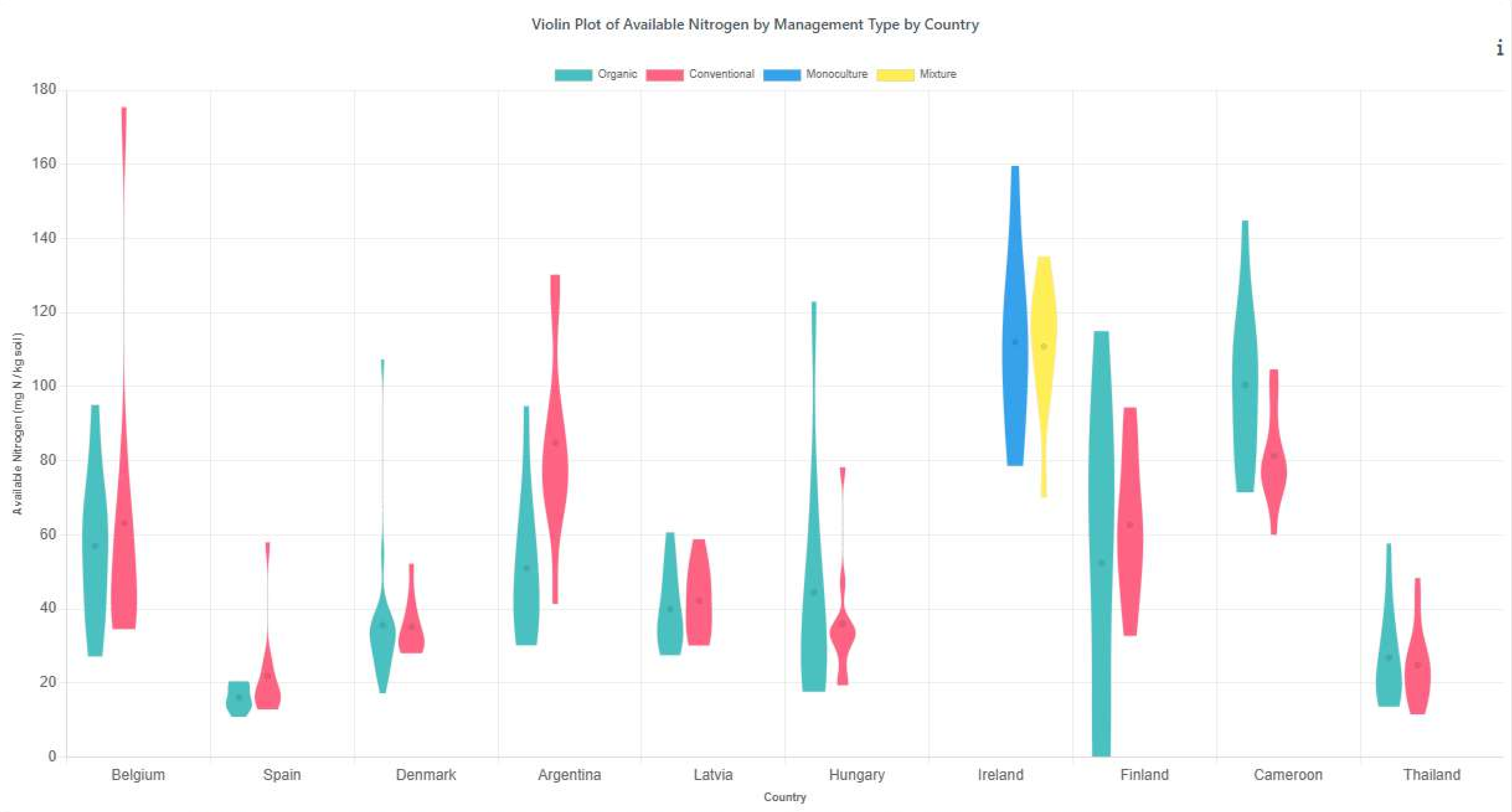
The Metadata Portal allows users to visualize and analyze data generated within the SOILGUARD project, offering insights into soil properties, management practices, and indicators. By selecting a parameter from the drop-down menu, users can compare datasets across different countries, enabling cross-regional assessments.

To visualize data, please select a parameter from the dropdown list. You can hover over the graph to see detailed information regarding the values. Additionally, you can filter out specific categories by clicking on their names in the legend, allowing for a more customized data exploration experience.

Available Nitrogen



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Soil Data Inspection

Use the map to select a location by clicking on it. The coordinates will update the Selected Soil Data fields avaiable.

Fields for **Phosphorus (P)**, **Potassium (K)**, **Crop Type**, **Farming System**, **Area of farm** and **Yield** are also required to be filled in by the user.

Once complete, you can save the location to *My Soil Data* for future use, by checking the box "Add to My Soil Data".

Selecting this option saves the edited values currently shown in the table. Once saved, the locations can be retrieved from the left side of the page.

Then, you can choose an action for the Soil Data in use between: **Predictions**, **Economic Values** and **Benchmarking.**

Alternatively, select a dataset from saved data to perform these actions.

Details on the fields are provided below.

Climate

Mean Temperature
Base index representing the average air temperature over 3 days.

Total Precipitation
Sum of rainfall and the assumed water equivalent of snowfall for a 3-day period.

Soil Nutrients

Nitrogen (N)
Total Nitrogen (N)

Phosphorus
Total Phosphorus (P)

Potassium
Total Potassium (K)

Field Properties

Soil Texture
Refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil.

Clay
Proportion of clay particles (< 0.002 mm) in the fine earth fraction.

Sand
Proportion of sand particles (> 0.05 mm) in the fine earth fraction.

Silt
Proportion of silt particles (≥ 0.002 mm and ≤ 0.05 mm) in the fine earth fraction.

Soil Organic Carbon
Soil organic carbon content in the fine earth fraction.

Organic Carbon Density
Organic carbon density of the fine earth fraction.

Bulk Density
Bulk density of the fine earth fraction.

PH
Soil PH.

☰

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BENEFITS - LOCATION

BENEFITS - REGION

SOIL MANAGEMENT GUIDELINES

42.95422226957125 | 11.58300781249999 | Seggiano, Province of Grosseto, Italy

Saved Locations

Location: Farkadona, Greece
Coordinates: 39.58837622832235, 22.147460669279088

Location: Livorno, Province of Livorno, Italy
Coordinates: 43.50658973715422, 10.38039933971671

Location: 16, 97711 Thundorf in Unterfranken, Germany
Coordinates: 50.216878061559484, 10.334959864616383

Selected Soil Data

CLIMATE (3-DAY FORECAST)

Average Temperature (°C)	Total Precipitation (mm)
7.9	5.6

NUTRIENTS

Nitrogen (g/kg)	Phosphorus (g/kg)	Potassium (g/kg)
2.6	N/A	N/A

FARM PROPERTIES

Farming System	Crop Type *
Conventional	Potato

Area of farm (ha)	Yield (t/ha)
5	5

FIELD PROPERTIES

Soil Texture	Clay % (g/100g)
Clay loam	31.7

Sand % (g/100g)	Silt % (g/100g)
28.3	40

Soil Organic Carbon (g/kg)	Organic Carbon Density (hg/m³)
4.5	33.3

Bulk Density (kg/dm³)	pH
1.2	7.40

Select action for this Soil Data

☐ Add to My Soil Data

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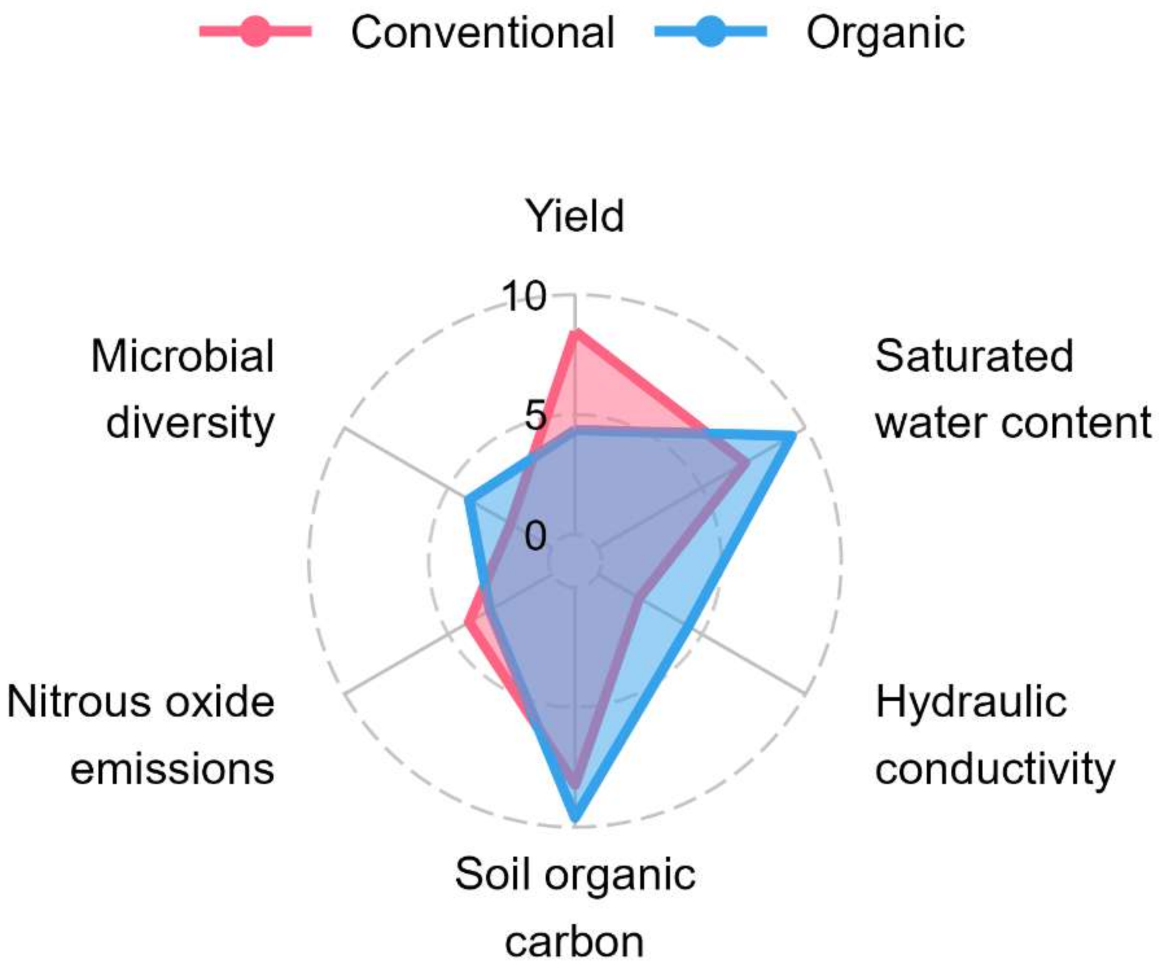
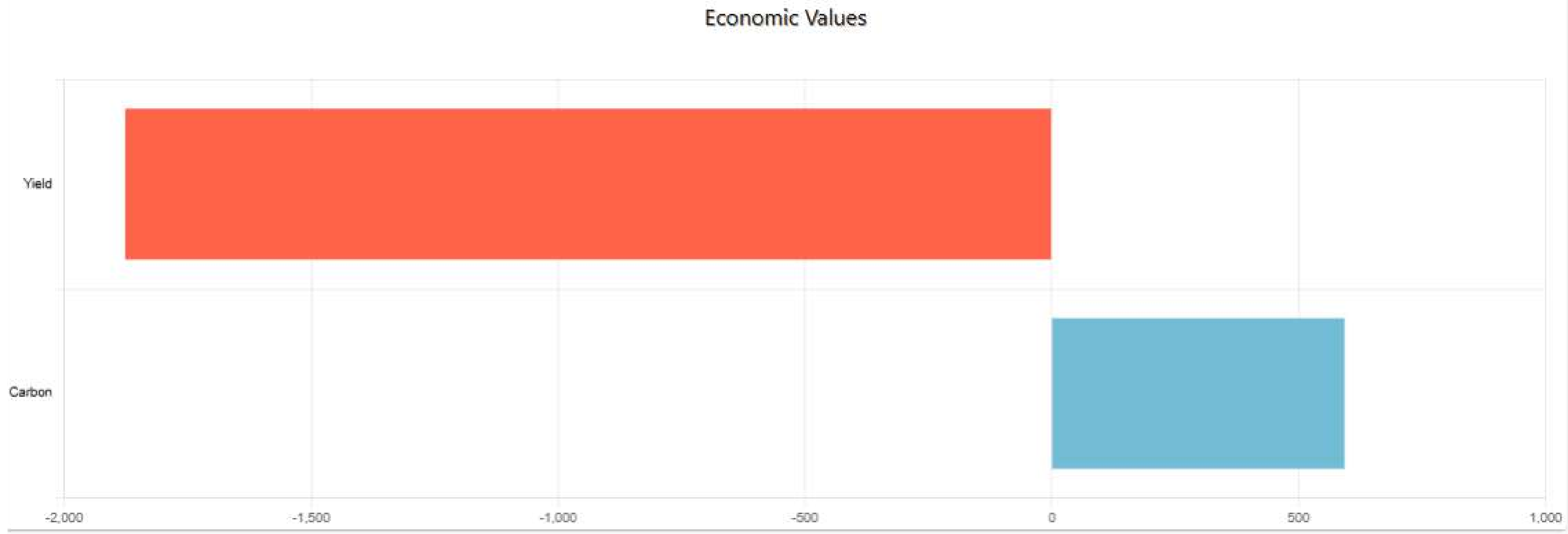
Change in benefits when changing from conventional to organic

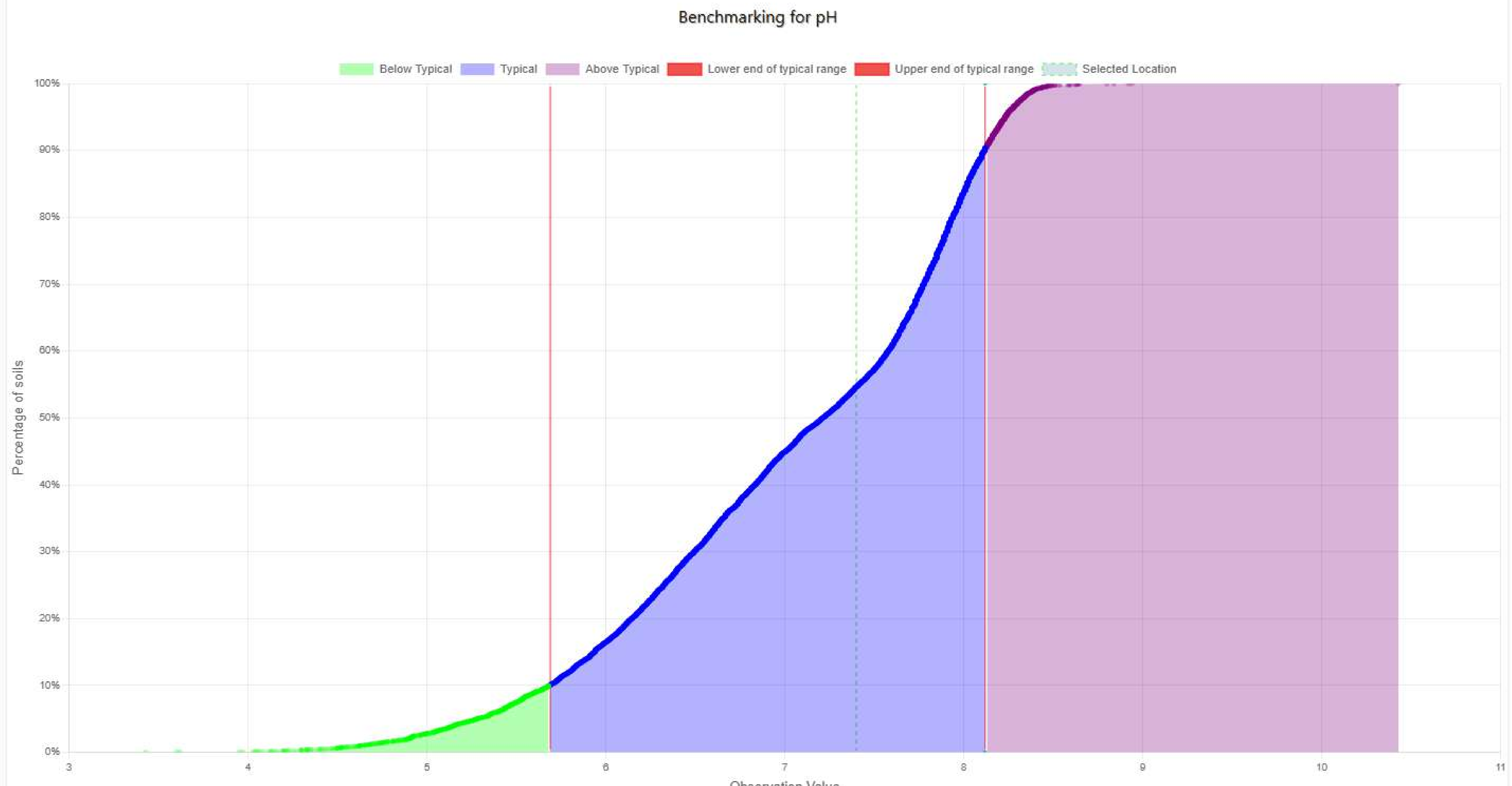




NCP	Conventional farming	Organic farming	Economic value
Carbon stock	8.10 tonnes	8.93 tonnes	593.31 €
Yield	25.00 tonnes	16.55 tonnes	-1876.32 €

Measure name	Measure	Unit
Conventional yield	25.00	tonnes
Organic yield	16.55	tonnes
Economic value	593.31	€
Relative yield conventional	0.00	N/A
Relative yield organic	0.00	N/A

Bulk Density Soil Organic Carbon pH



Regional Outputs

In this page, the map displays the European Union's NUTS 2 subdivisions, similar to this. You can see each subdivision's NUTS code and name by hovering over it with the cursor.

In order to calculate the regional outputs, simply select a NUTS2 region by clicking it on the map. Then you need to enter the **current** and **target proportions of arable land under organic farming**, using 2 using 2 slider bars (%) and finally click on **Calculate NCPs**.

Details on the outputs are provided below.

Spider (Radar) Chart

Displays standardised average biophysical values. Currently supported NCPs:

Soil Organic Carbon

Soil organic carbon is the amount of carbon in the soil for a defined depth and area. Carbon stored in the soil is not emitted as CO_2 to the atmosphere and promotes climate change mitigation. **Robustness**: High

Hydraulic Conductivity

The hydraulic conductivity determines how fast the water moves through the soil. When this is fast, the risk of flooding and runoff is lower. **Robustness**: Medium

Yield

The yield is the dry weight at crop's harvest. **Robustness**: Low

Line Chart

Shows NCPs as a function of proportion arable land converted from conventional to organic.

Density Plot

Shows NCP output distribution for a particular proportion of arable land.

Table

All NCP outputs in a common table.

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BENEFITS - LOCATION

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Proportion of arable land under organic farming (%)

Current

Target

Calculate Benefits

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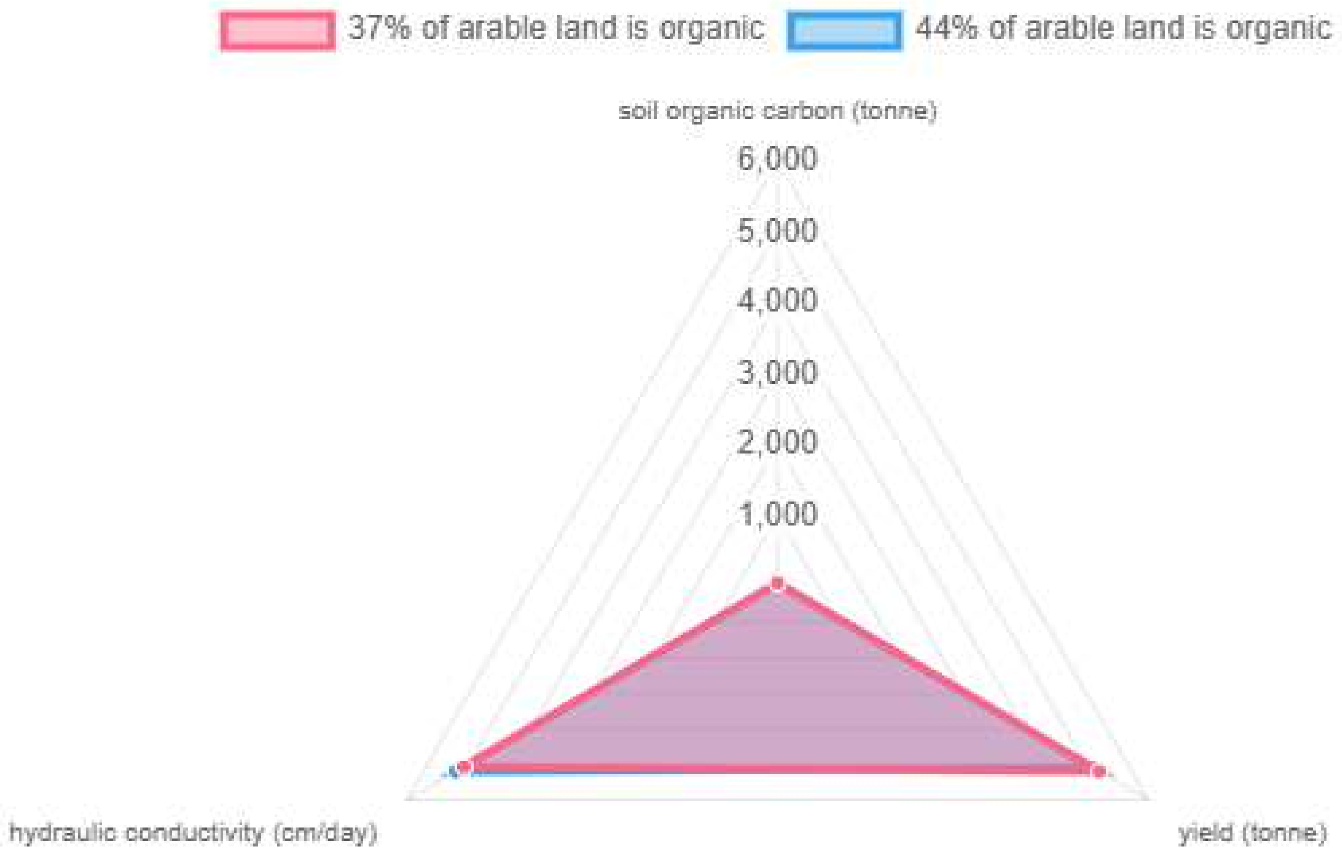
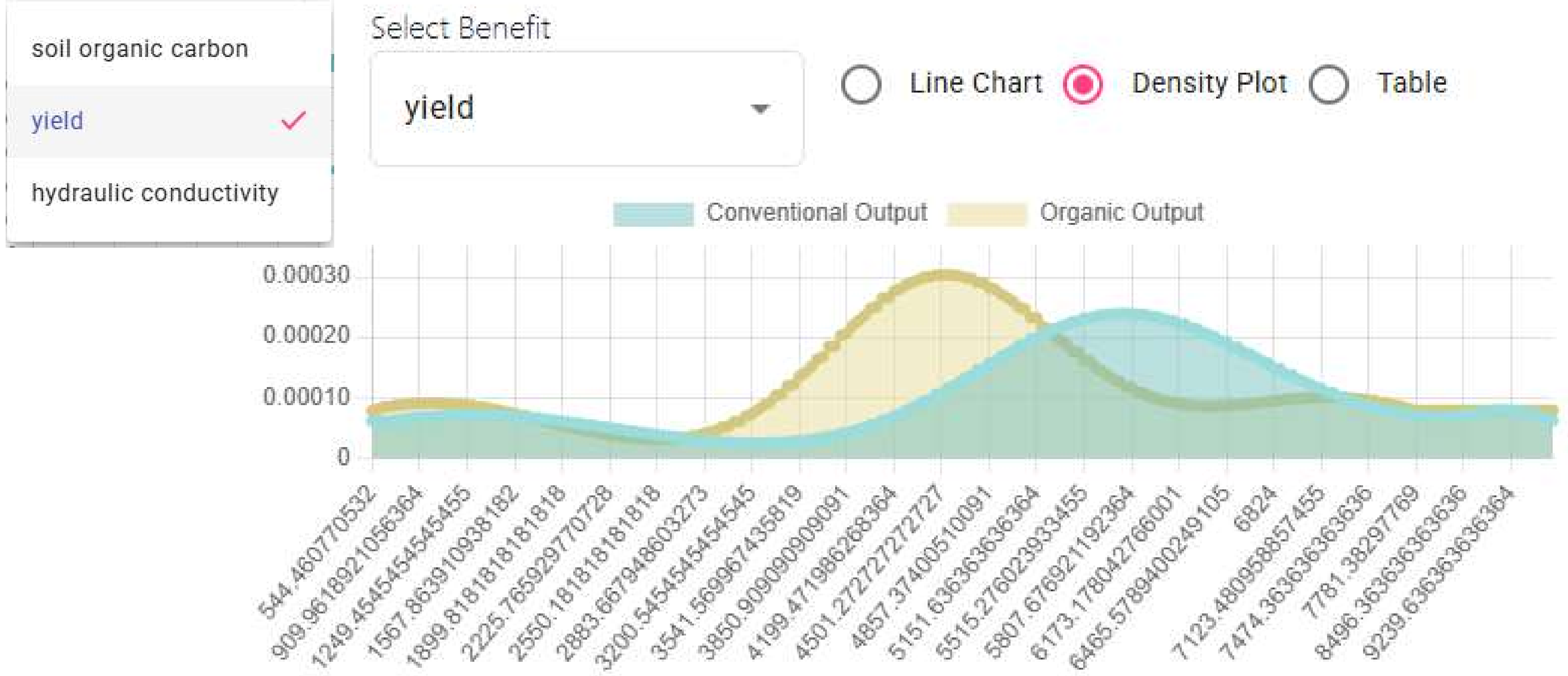
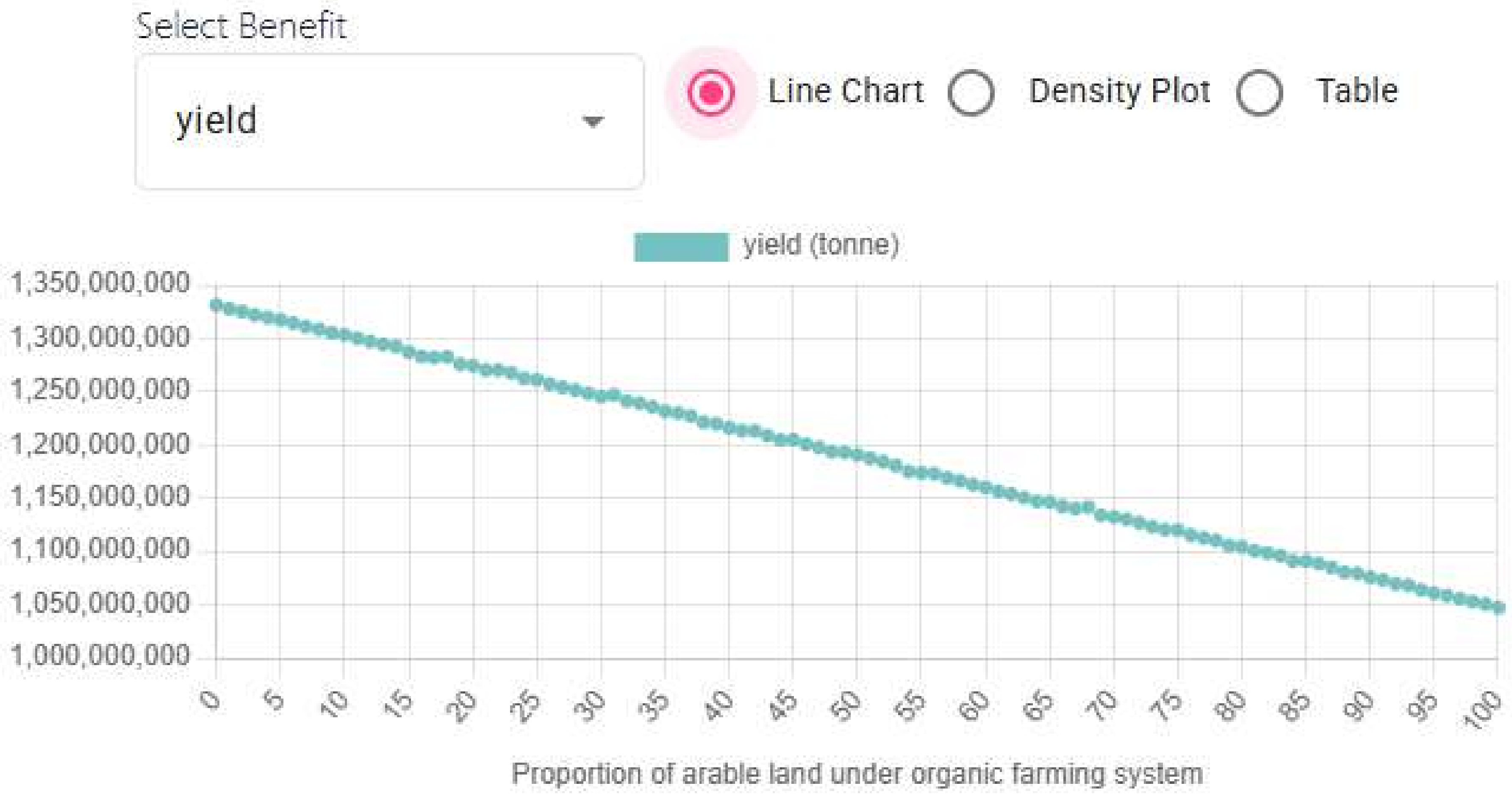
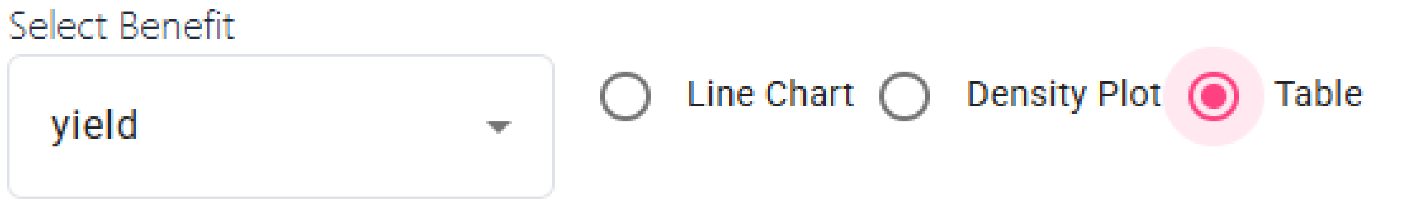
Change in NCPs when switching from conventional to organic









NCP	Unit	X% Organic	Y% Organic	Effect of Shift
soil organic carbon	tonne	55.80	55.79	-0.01
yield	tonne	5210.25	5114.72	-95.54
hydraulic conductivity	cm/day	5076.69	5212.23	135.54

☰

SOILGUARD

VISUALISE SOILGUARD DATA

CONVENTIONAL TO ORGANIC

BENEFITS - LOCATION

BENEFITS - REGION

SOIL MANAGEMENT GUIDELINES

General | Conservation | Policy

Know your soils

Rationale: All soils have different inherent properties that result in different capabilities and vulnerabilities. For example, clay soils have high nutrient retention but are prone to compaction, while sandy soils drain well but are more prone to erosion. Managing soils based on their specific characteristics can lead to better outcomes.

What to do: Identify soil characteristics like texture and drainage. Use tools such as satellite imagery to assess field potential. Monitor areas for issues like low yield and inspect problem areas.

Assess your soil physical health

Build and maintain soil organic matter

Balance fertility and pH

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SOILGUARD´s Soil biodiversity indicators

Giulia Bongiorno (WUR), Pablo Sánchez-Cueto (LEITAT)

LEITAT Technological Center

WAGENINGEN UNIVERSITY & RESEARCH

31/03/2025

The research leading to these results has received funding from the European Union Horizon 2020
Research & Innovation programme under the Grant Agreement no. 101000371.

Presentation Outline

PART 1	Biodiversity monitoring methodologies
PART 2	Molecular vs microscopic methods
PART 3	Soil biodiversity indicators

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Biodiversity monitoring

European Green Deal & EU Biodiversity strategy → EU Soil strategy for 2030 → EU Directive on soil monitoring and resilience

key soil threats in the EU, such as erosion, floods and landslides, loss of soil organic matter, salinisation, contamination, compaction, sealing, as well as loss of soil biodiversity.

Measuring soil biodiversity:

- Biomass/Abundance
- Richness
- Community composition

HOW?

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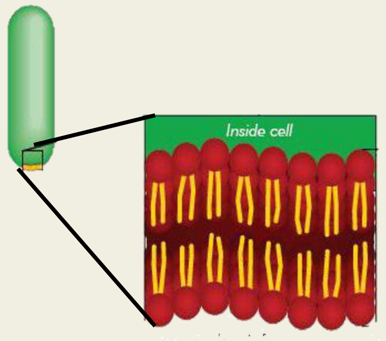
Biodiversity monitoring

METHOD

Morphological methods

Biochemical methods

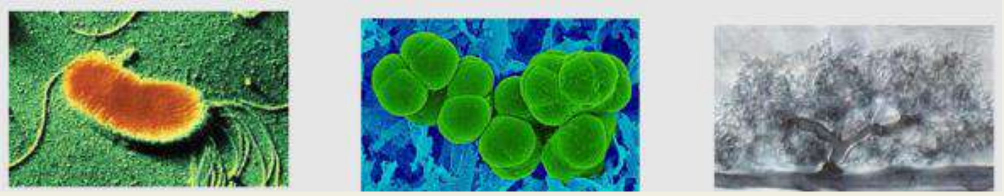


Molecular methods

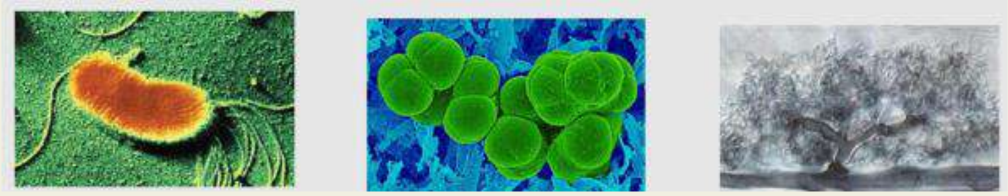
WHO

Soil fauna

Soil microorganisms



Soil microorganisms



More recently........soil fauna

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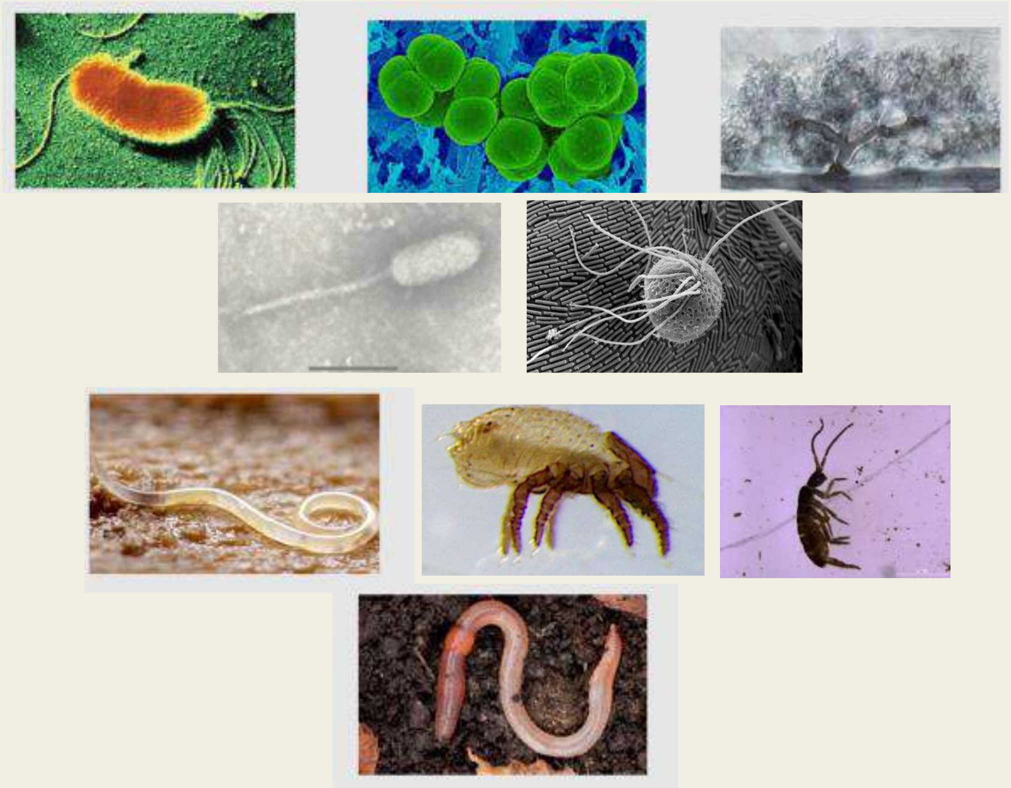
Biodiversity monitoring

Sequencing, qPCR

Abundance, richness, community composition

eDNA (environmental DNA)



Scale the sampling, harmonization across biota groups, facilitate the identification......if taxonomic annotation in databases is reliable!

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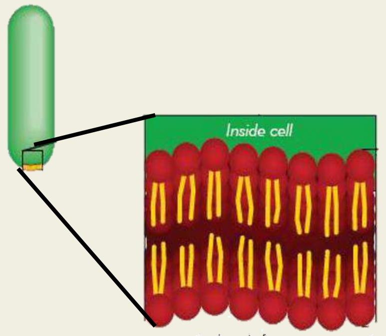
Biodiversity monitoring

METHOD



WHO

Nematodes

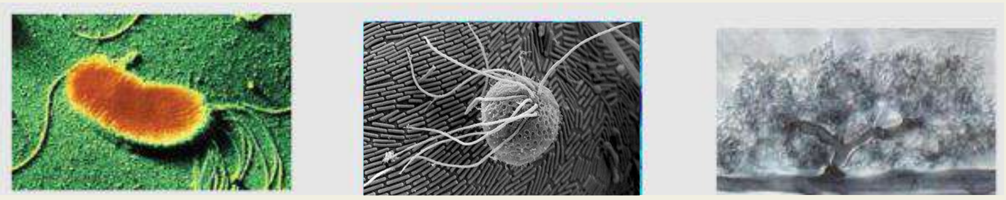
Acari

Collembola

Bacteria

Fungi

Protists



Bacteria

Fungi

Virus

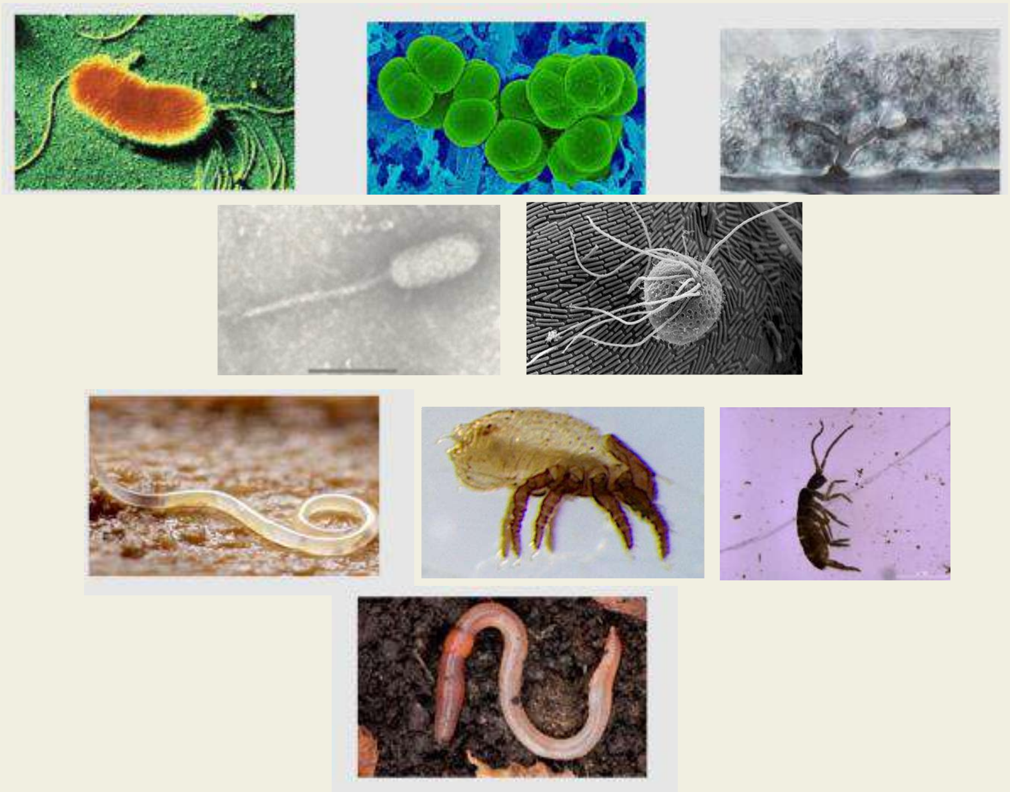
Protists

Nematodes

Acari

Collembola

Earthworms



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Methods’ comparison

- Different methods available for the same organism.
- New developments have some potential advantages.
- But are they reliable?
- How do they compare with traditional ‘Gold standard’ methods?

Nematodes

Acari

Collembola

With

&

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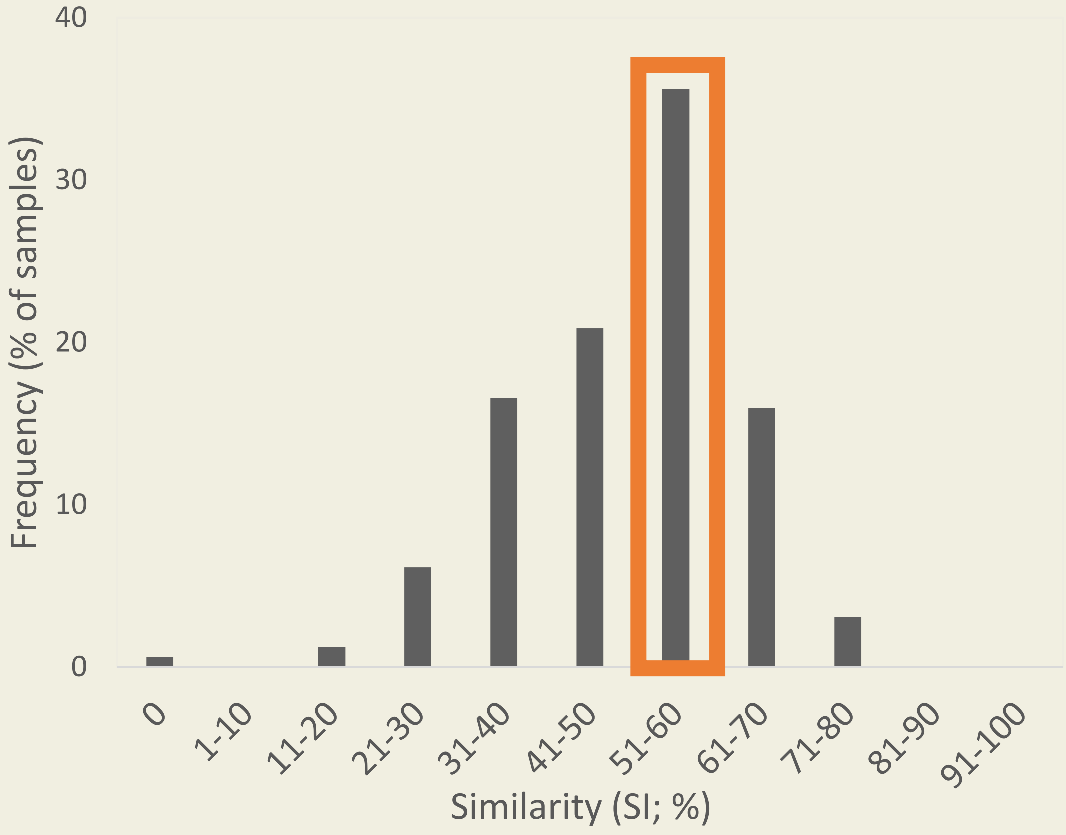
Molecular vs microscopic

Similarity Index (p/a of families)

SI = (2 * number of taxa in common) / (number of taxa in sample 1 + number of taxa in sample 2)*100%)

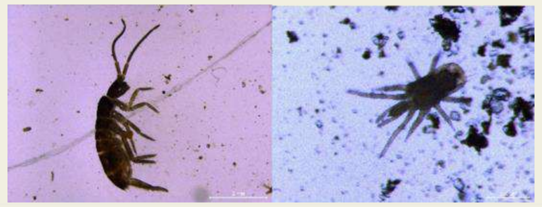
(Sørensen, 1948)

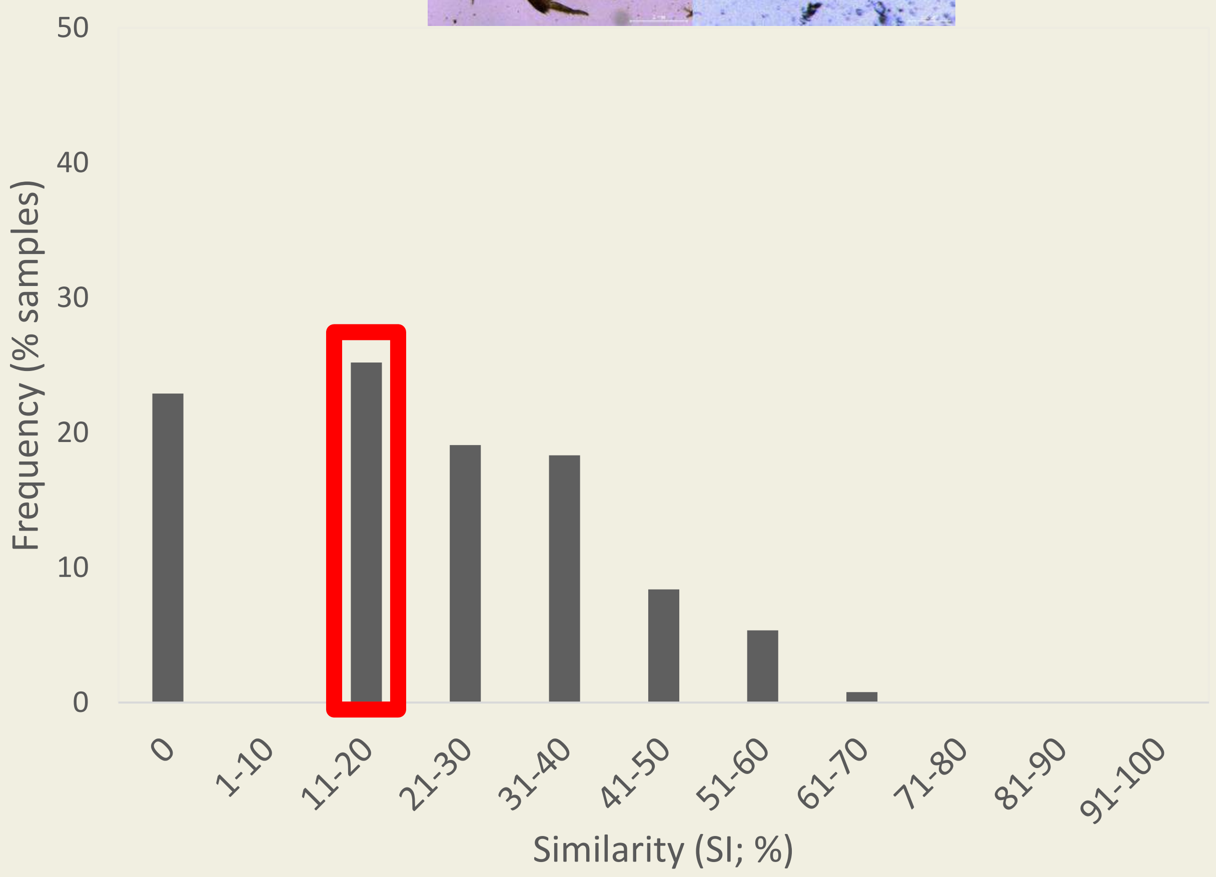
Nematodes



Number family: molecular 57 vs morphological 47

Acari & Collembola





Number family: molecular 34 vs morphological 74

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Bongiorno et al., in preparation

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Molecular vs microscopic

Shared and unique families

Animal parasites

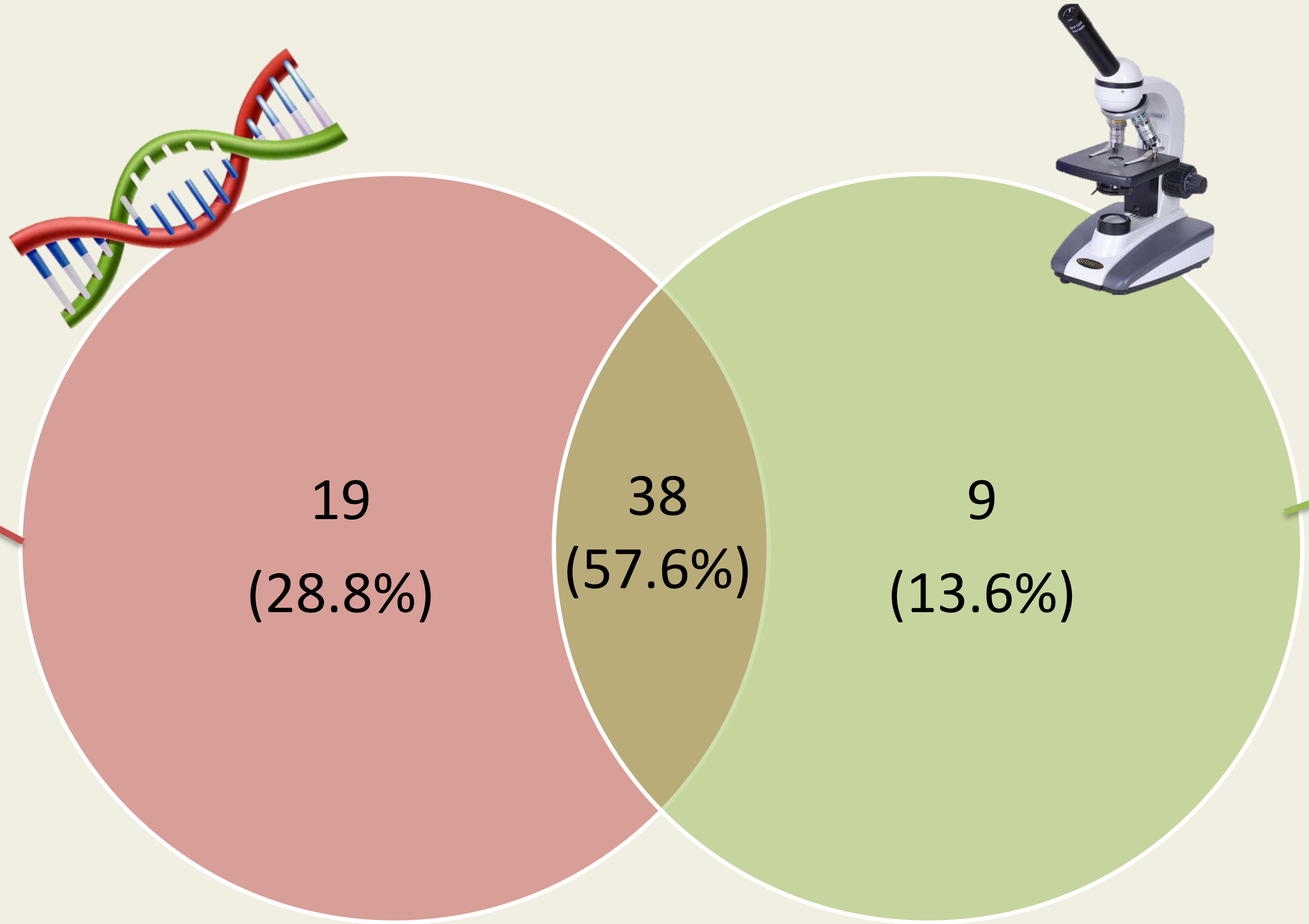
Difficult to recognize

Extraction issues

Never found in micros/rare

Taxonomic issues

Relic DNA



Not picked up by the molecular

Molecular database

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Bongiorno et al., in preparation

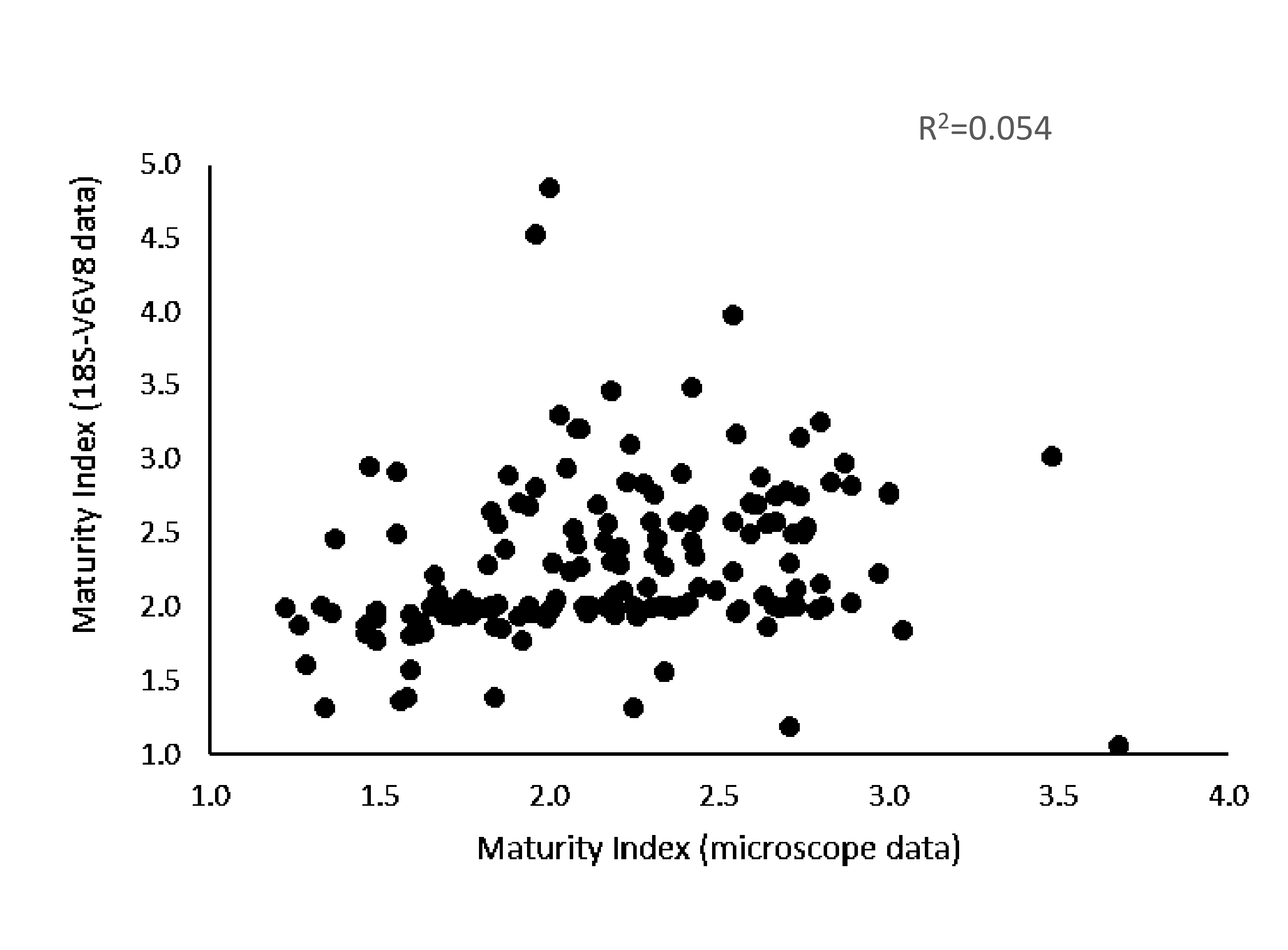
Molecular vs microscopic

Maturity Index

Ecological measure of environmental disturbance based on nematode species composition (Bongers, 1990)

MI = ($\sum$ (p_i x cp-value)) / ($\sum$ p_i)

Nematode-based soil health indicator



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Bongiorno et al., in preparation

Molecular vs microscopic

- Different methods available depending on organism.

- New methodologies available → Important to compare them with 'Gold standard' methods.

- Little agreement between morphological and molecular method for soil fauna, in particular acari and collembola.

- Each method has limitations
  - Morphological: skills needed, costs, laborious
  - Molecular: databases, relic DNA, no abundance determination (sequencing)

    → complementary?

    DNA extraction fom nematodes (no eDNA)?

- Careful interpretation of results from novel methods!

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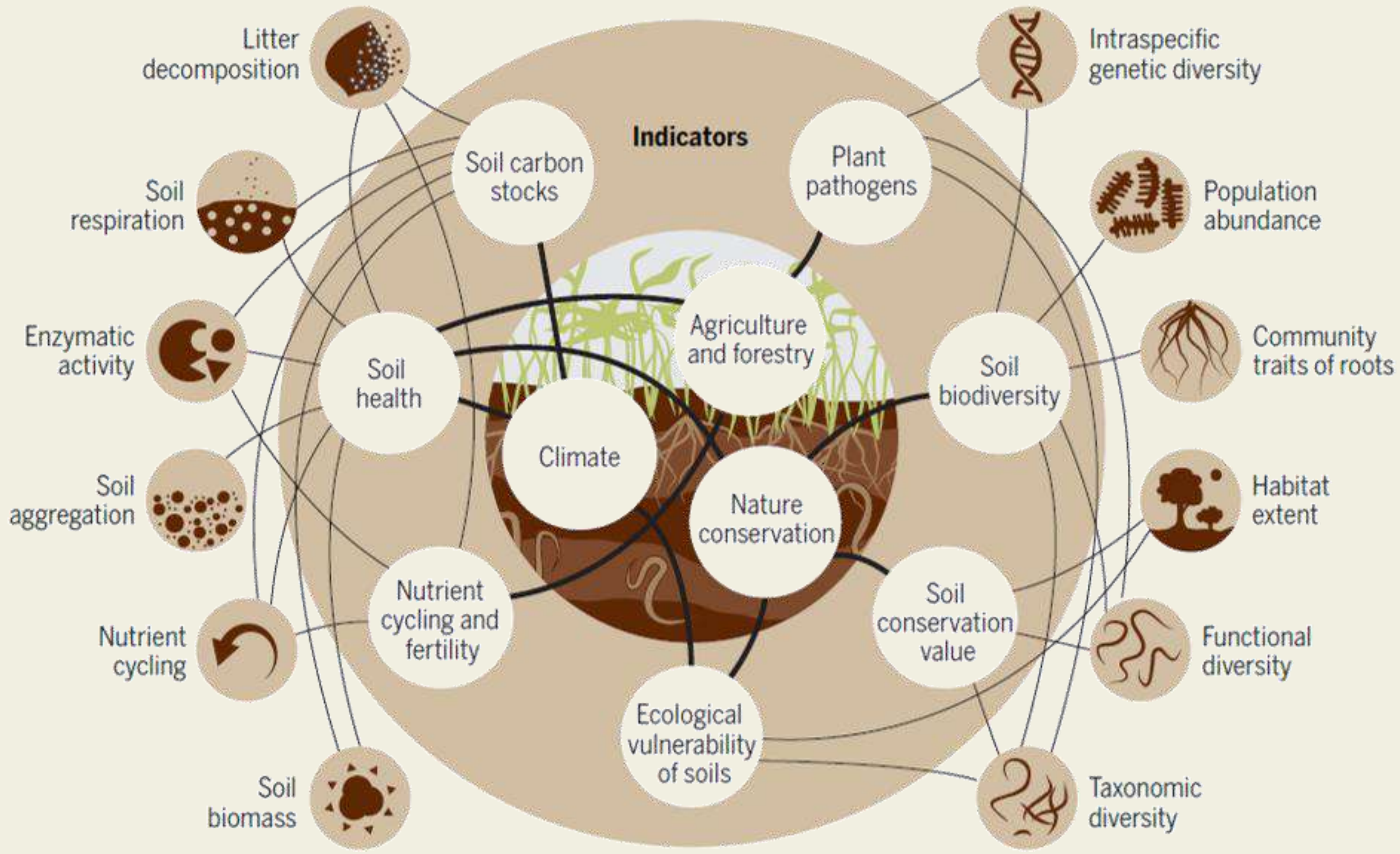
Soil biodiversity indicators

SOILGUARD



**Guerra et al. 2021. Science: 10.1126/science.abd7926

- The **soil ecosystem interactions are very complex**. Investigation of these key aspects on soils is necessary to understand soil health.

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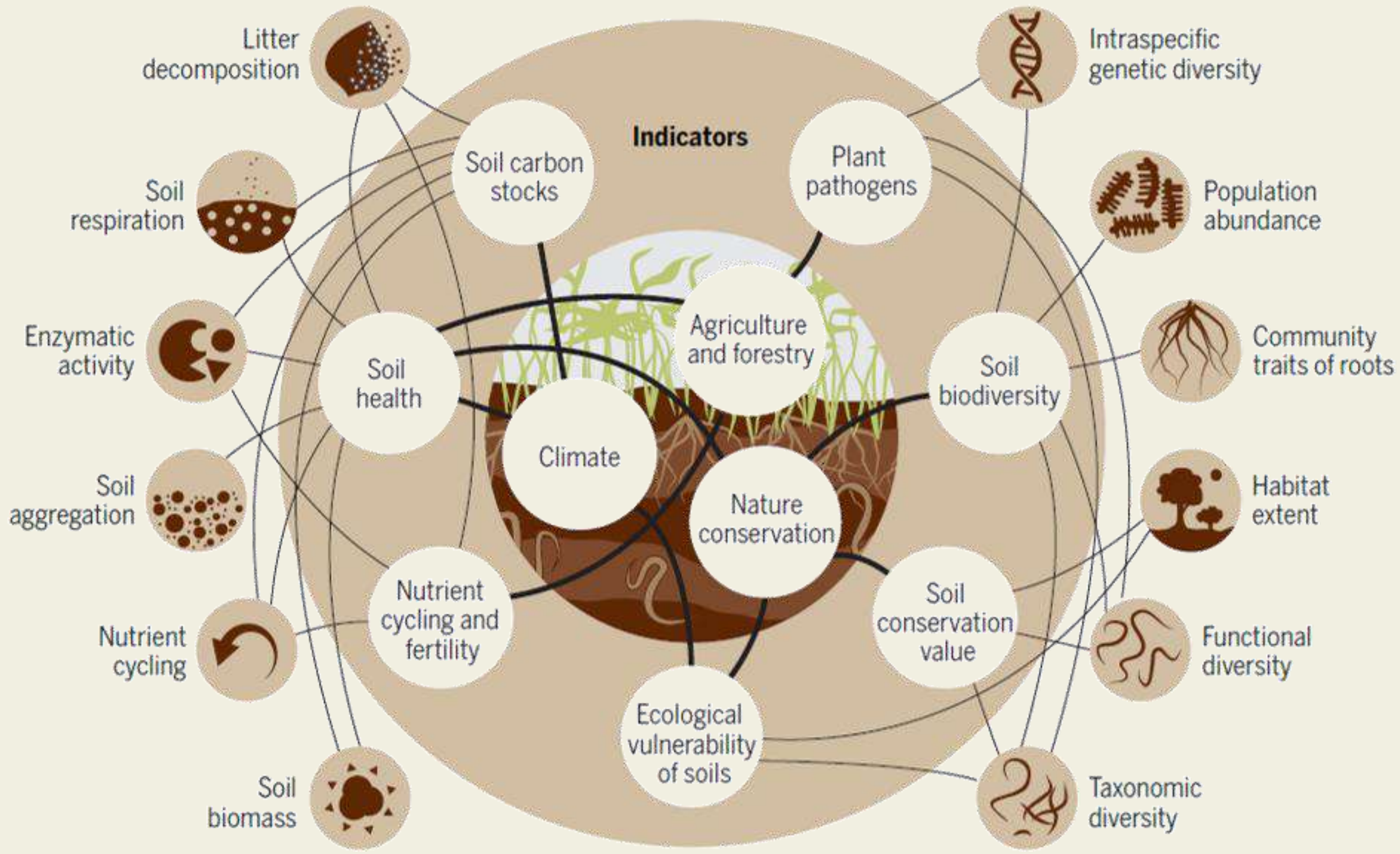
Soil biodiversity indicators



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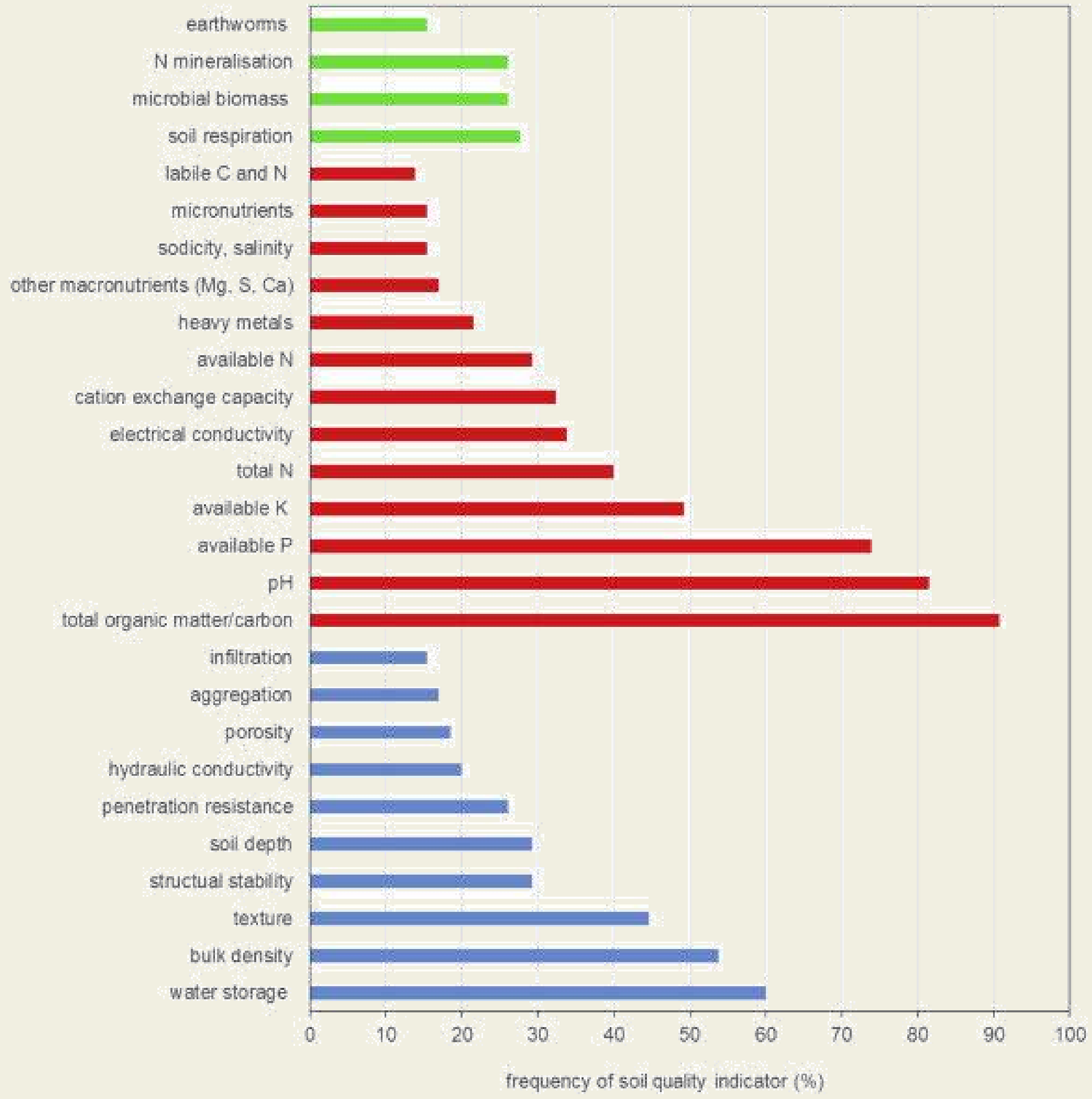

*Bünemann et al. 2018. SBB: https://doi.org/10.1016/j.soilbio.2018.01.030

- The **soil ecosystem interactions are very complex**. Investigation of these key aspects on soils is necessary to understand soil health.
- **Information about soil biodiversity indicators is present in numerous datasets, but sparse**. Other soil properties are better represented.

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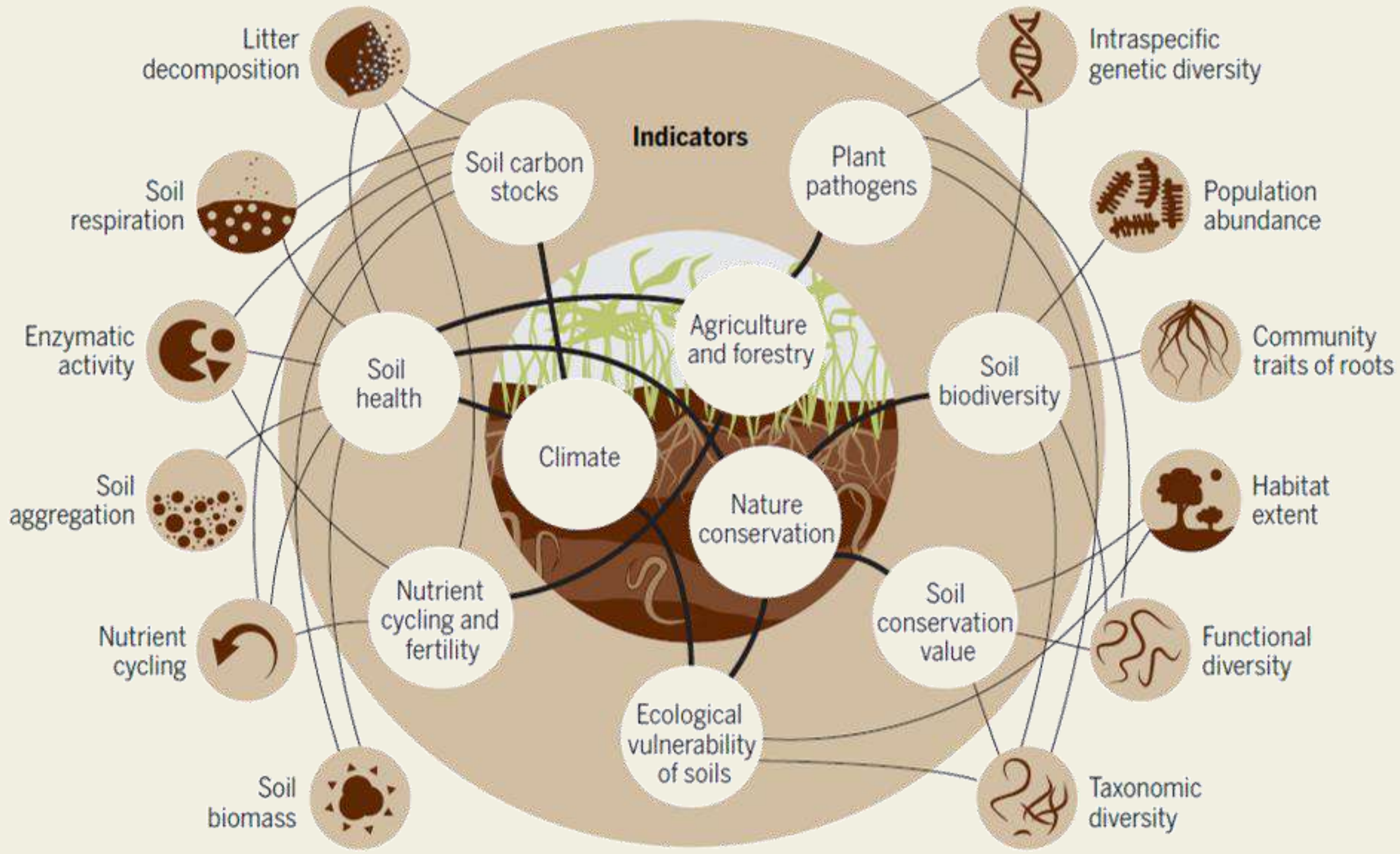
Soil biodiversity indicators

SOILGUARD



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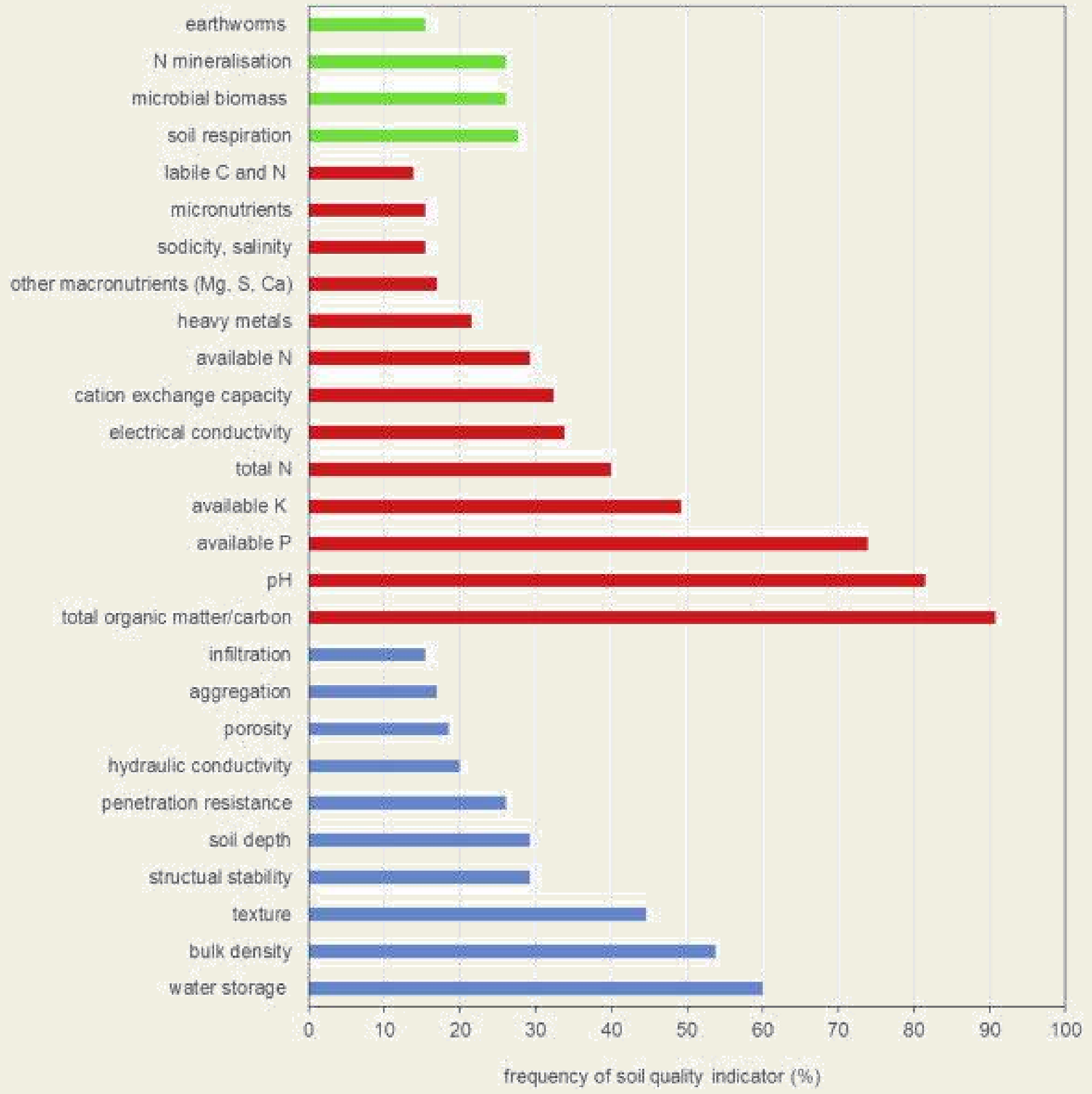

*Bünemann et al. 2018. SBB: https://doi.org/10.1016/j.soilbio.2018.01.030

- The **soil ecosystem interactions are very complex**. Investigation of these key aspects on soils is necessary to understand soil health.
- **Information about soil biodiversity indicators is present in numerous datasets, but sparse**. Other soil properties are better represented.
- **Robust, feasible, and easy to interpret biodiversity indicators are needed.** Reducing the number and standardizing these indicators is essential for the success of future global monitoring programs.

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Soil biodiversity indicators

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Objetive:

Establish a minimum set of indicators to comprehensively assess soil biodiversity, which are sensitive to environmental and management changes and are also linked to soil function.

Steps and criteria followed to identify a set of soil biodiversity indicators:

1. How many indicators are needed to reflect a high percentage of soil biodiversity variation, and what is their complementariness?
2. Are these candidates for indicators sensitive to environmental factors or managements?
3. Do they show relationship with important soil ecological functions?

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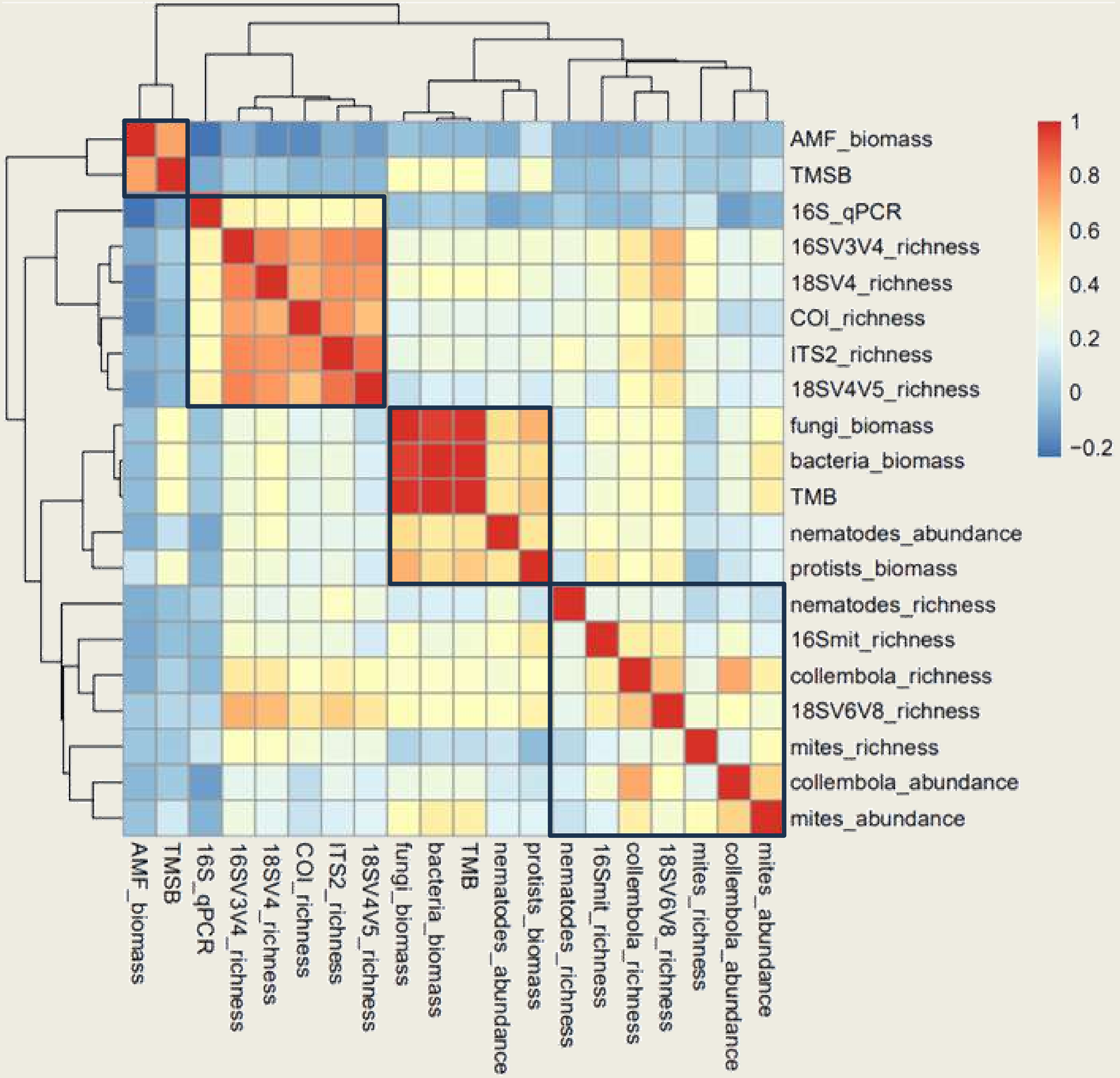
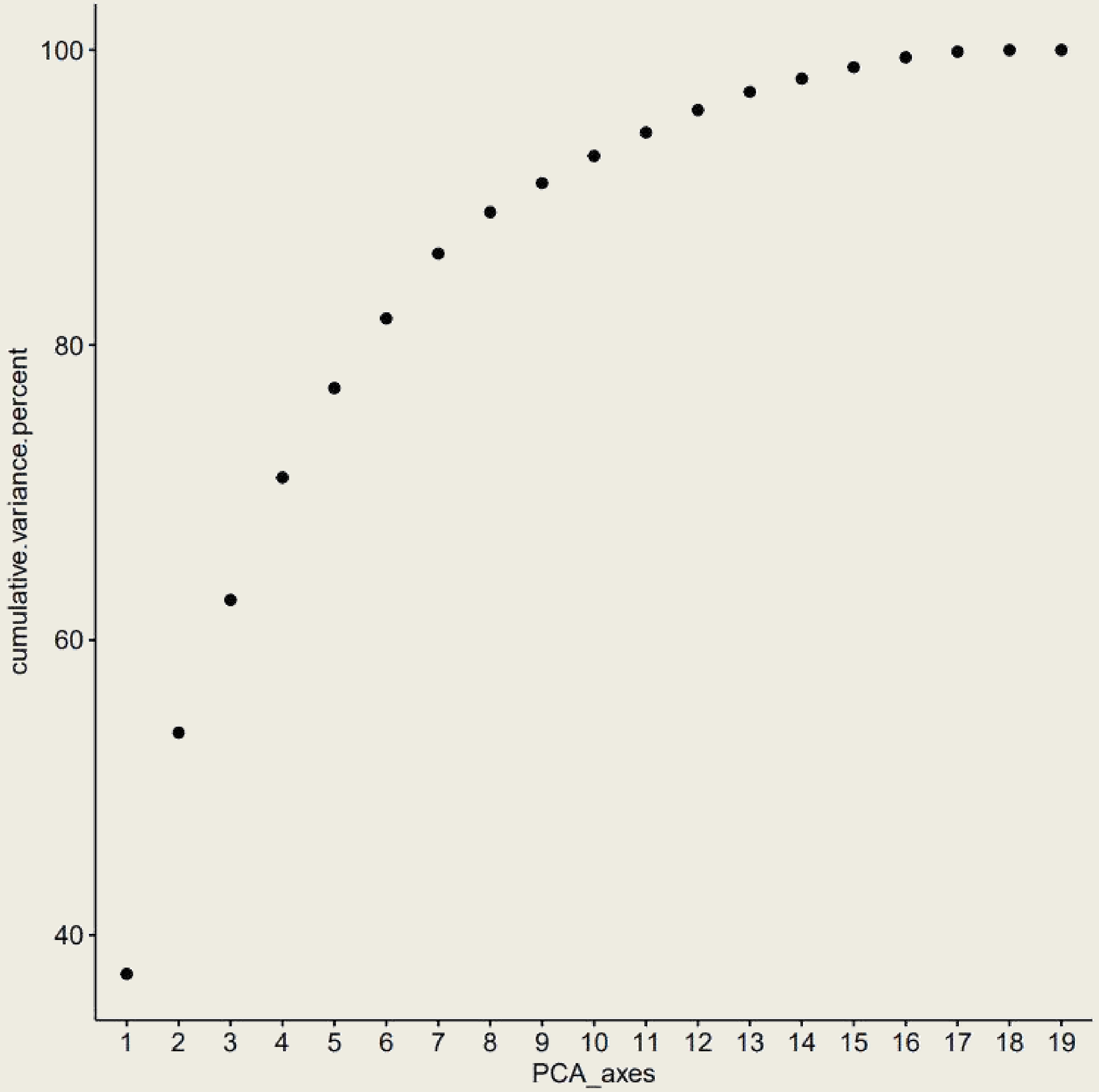
Soil biodiversity indicators

1. How many indicators





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Soil biodiversity indicators

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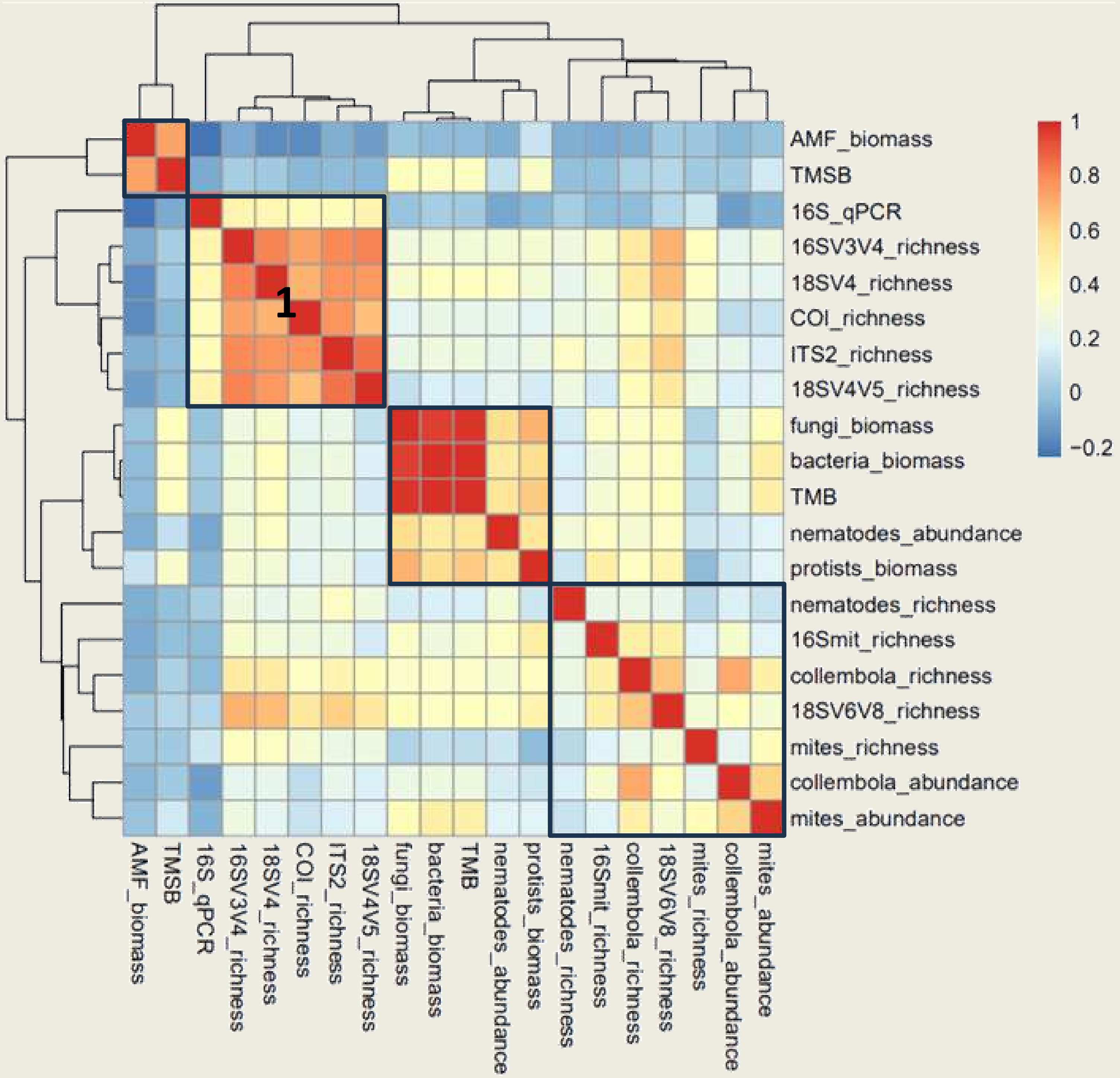
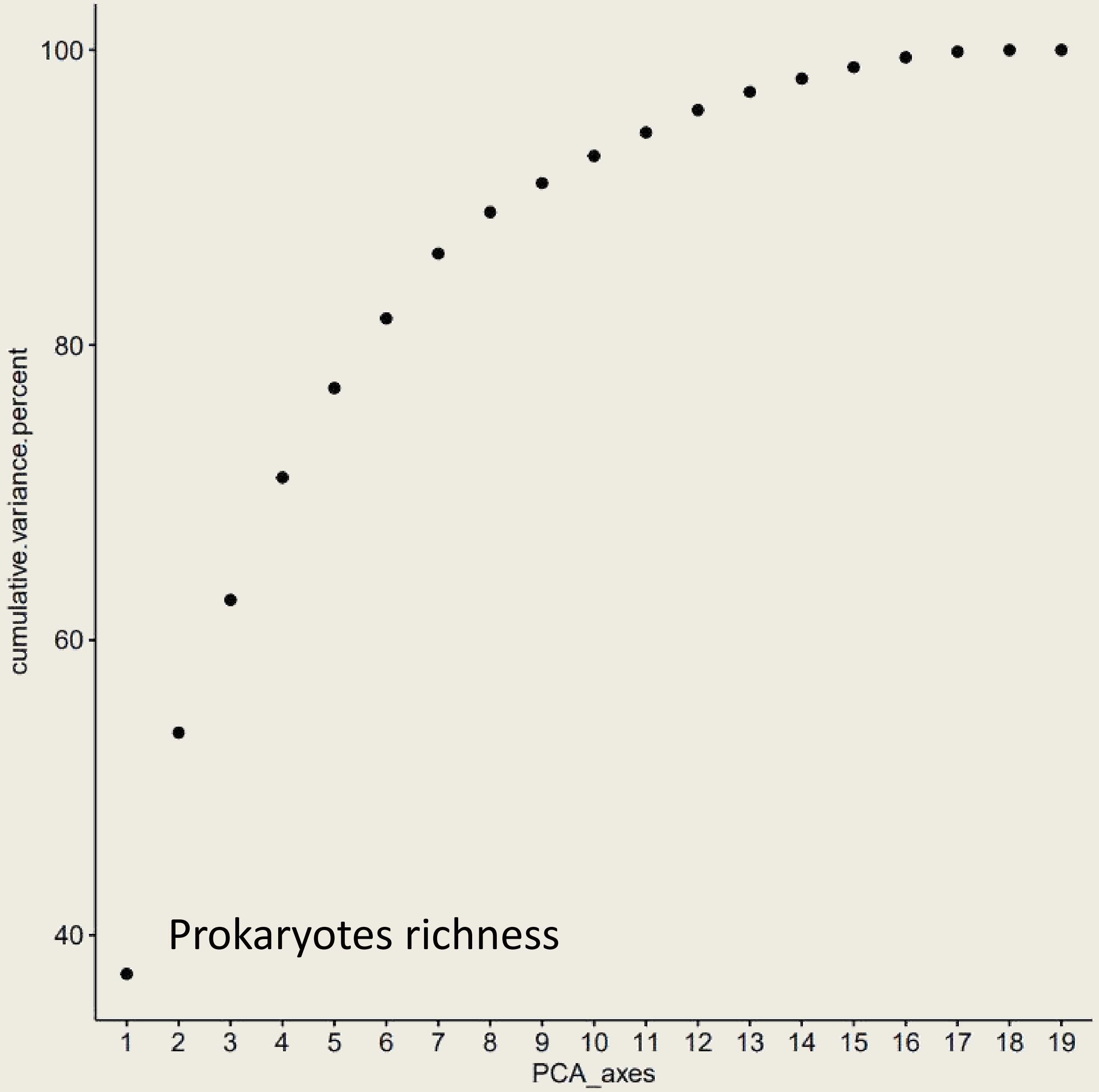
1. How many indicators

1. Prokaryotes richness (16S)*





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Soil biodiversity indicators

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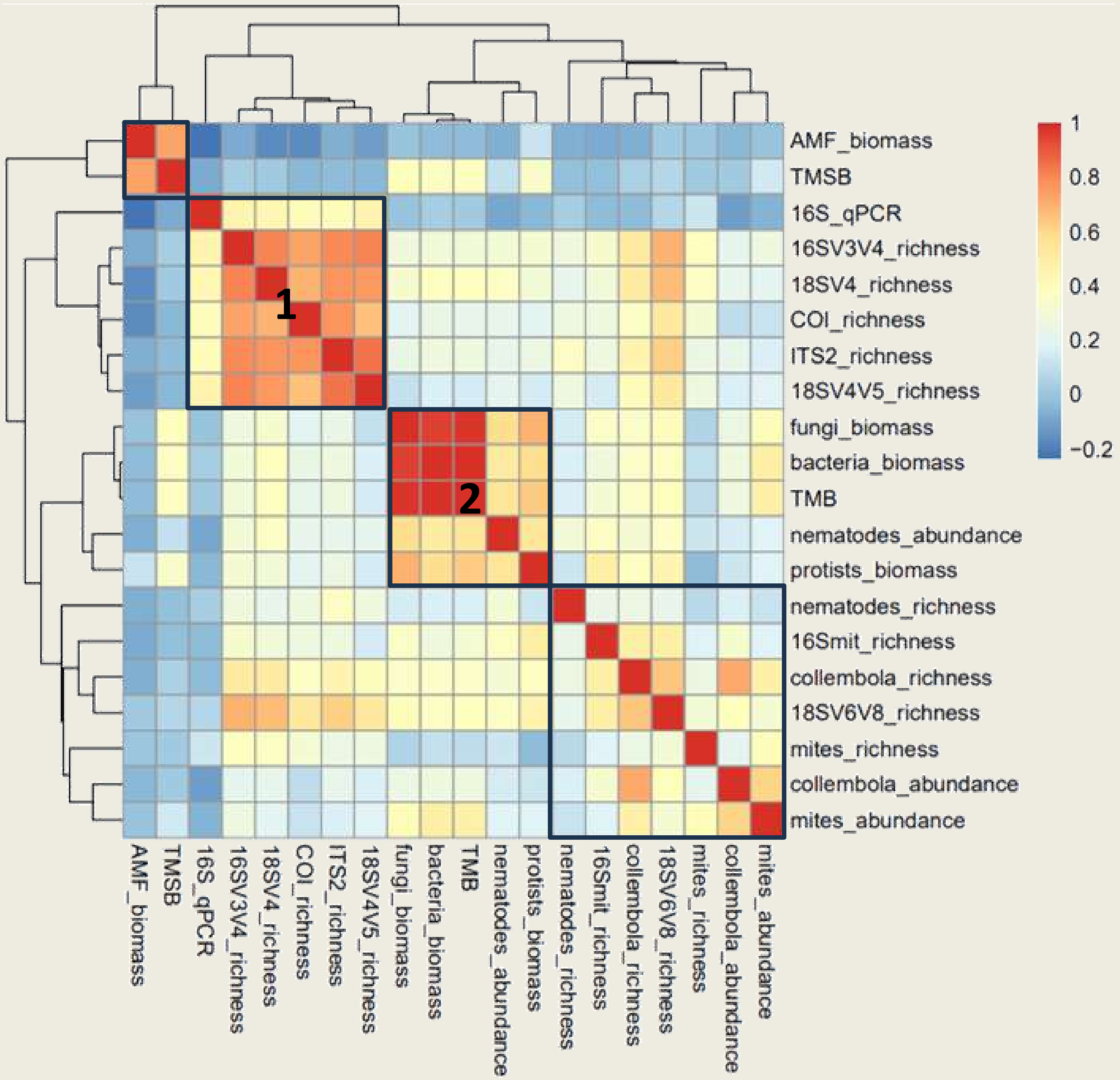
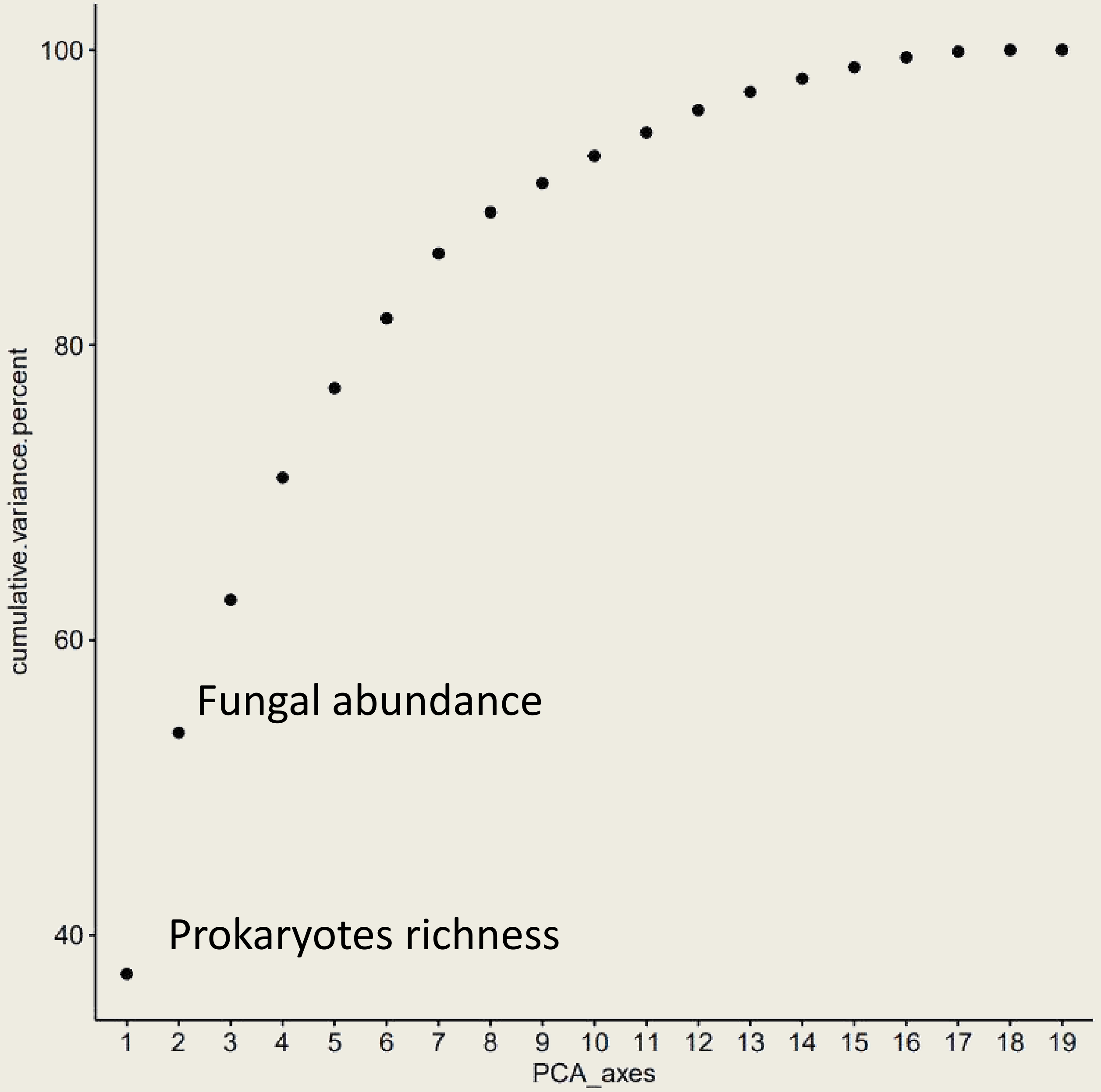
1. How many indicators

1. Prokaryotes richness (16S)*
2. Fungal abundance (PLFAs)*





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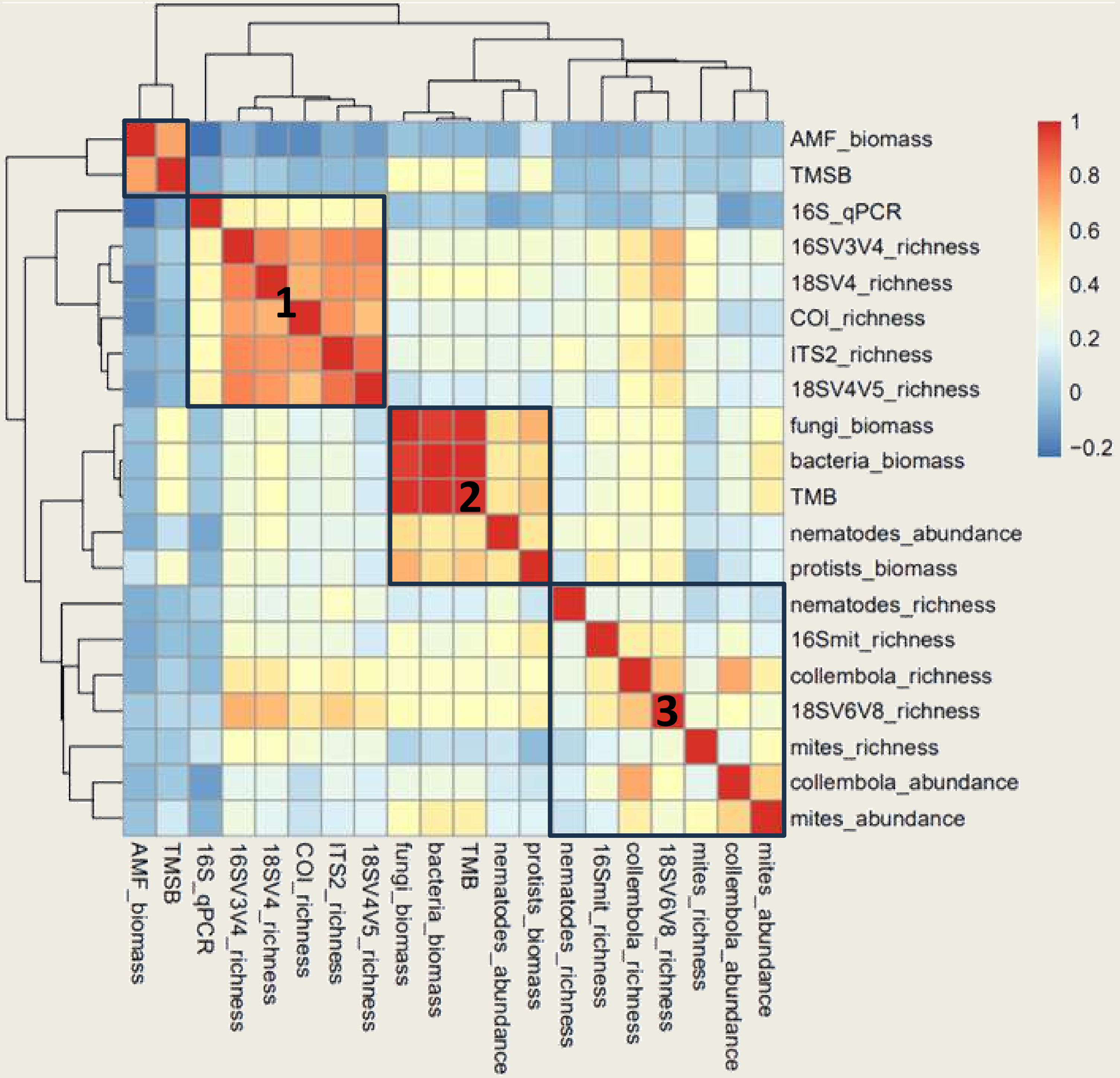
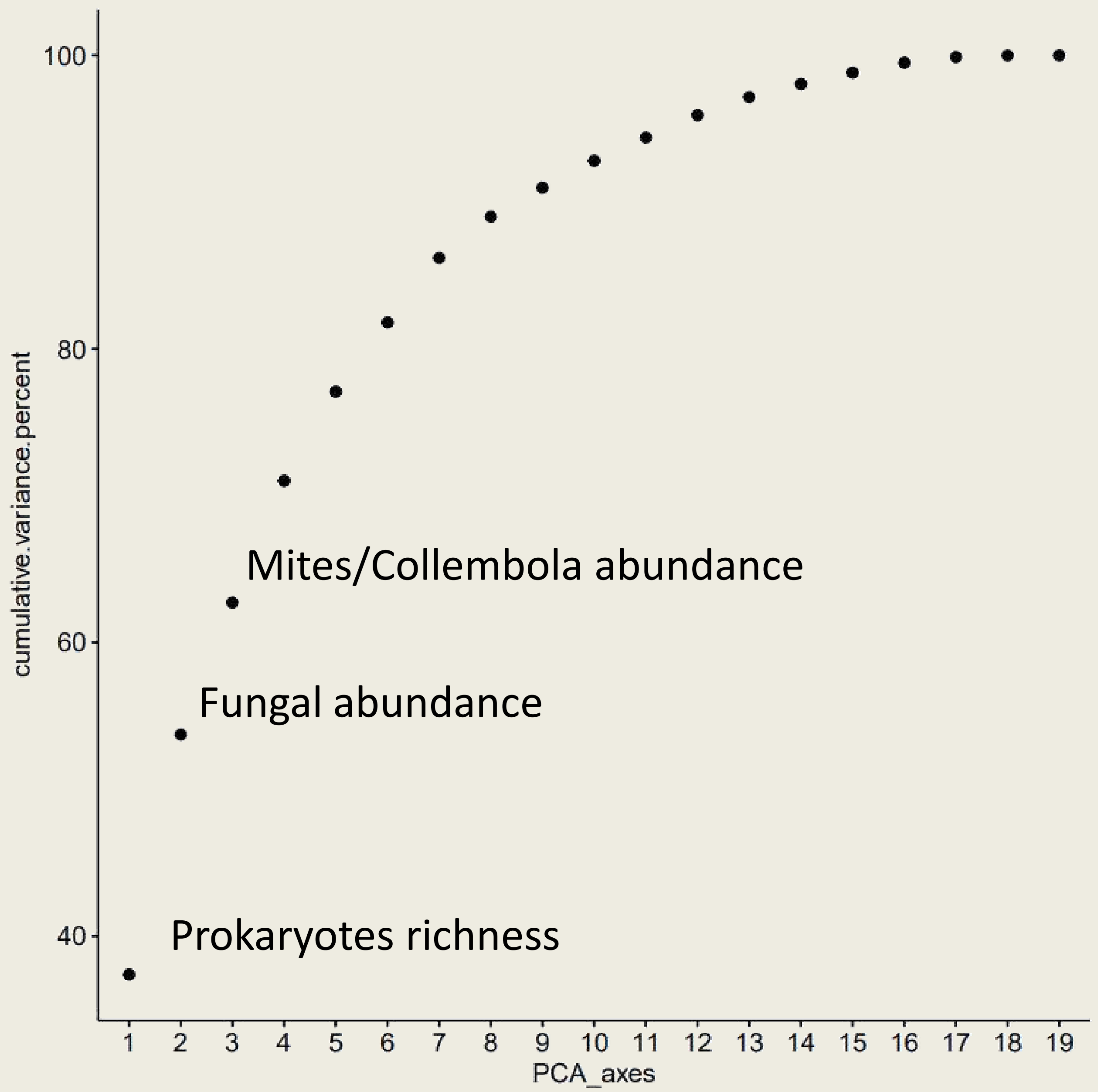
Soil biodiversity indicators

1. How many indicators

1. Prokaryotes richness (16S)*
2. Fungal abundance (PLFAs)*
3. Mites or Collembola abundance (microscope)*





The research leading to these results has received funding from the European Union Horizon 2020 Research & Innovation programme under the Grant Agreement no. 101000371.

Soil biodiversity indicators

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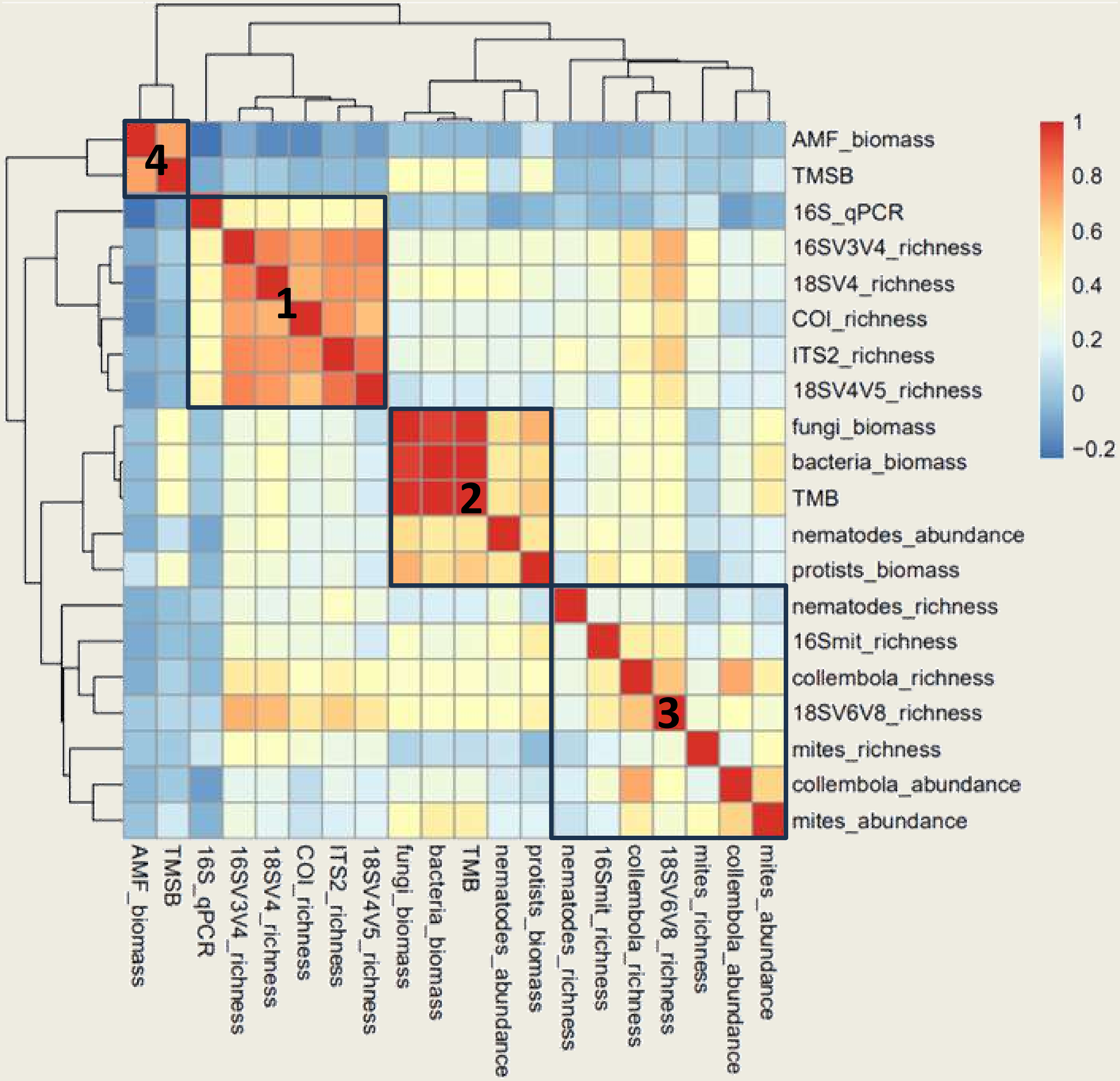
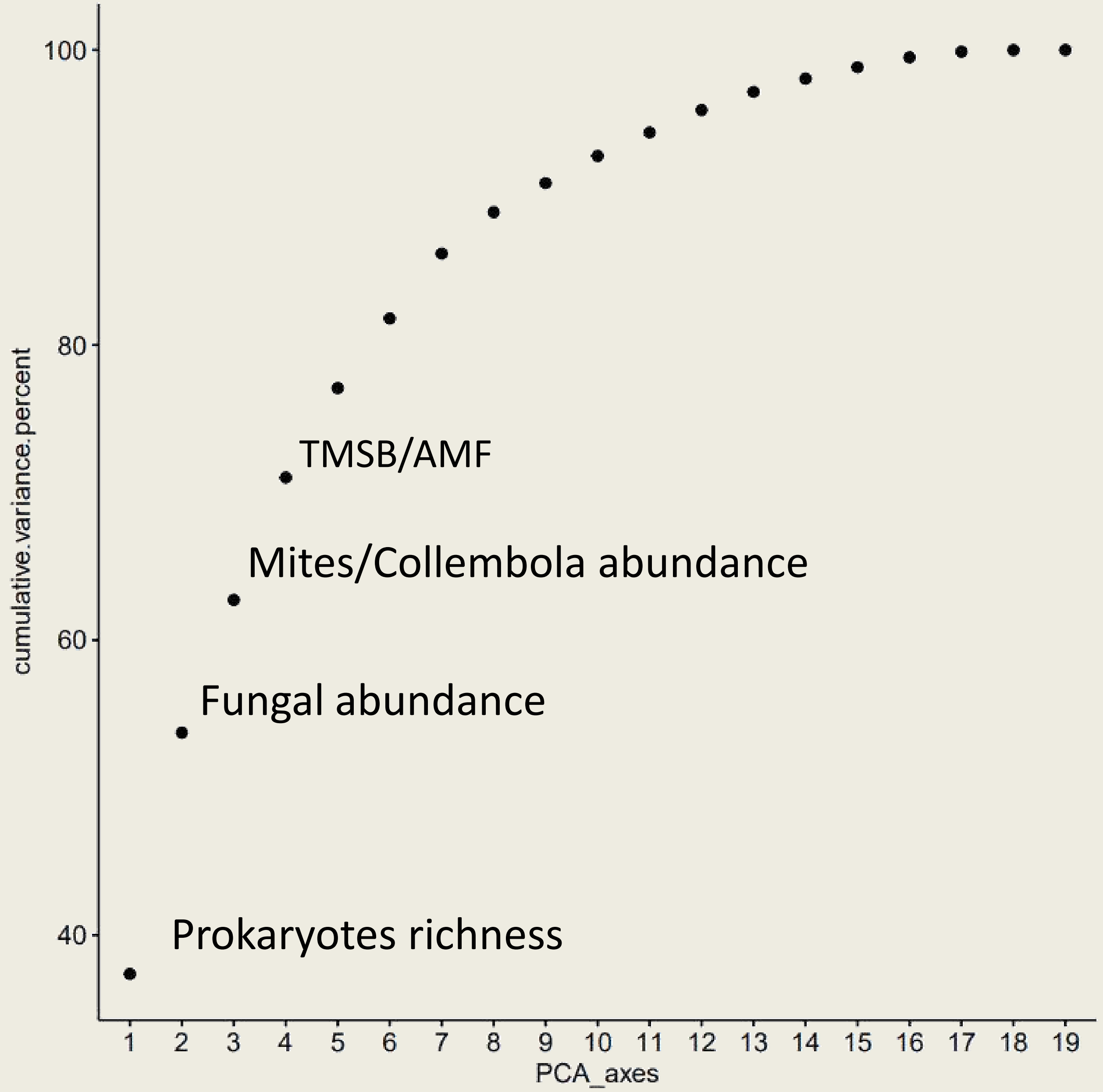
1. How many indicators

1. Prokaryotes richness (16S)*
2. Fungal abundance (PLFAs)*
3. Mites or Collembola abundance (microscope)*
4. TMSB or AMFs (NLFAs)

Four measures: >70% variation





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Soil biodiversity indicators

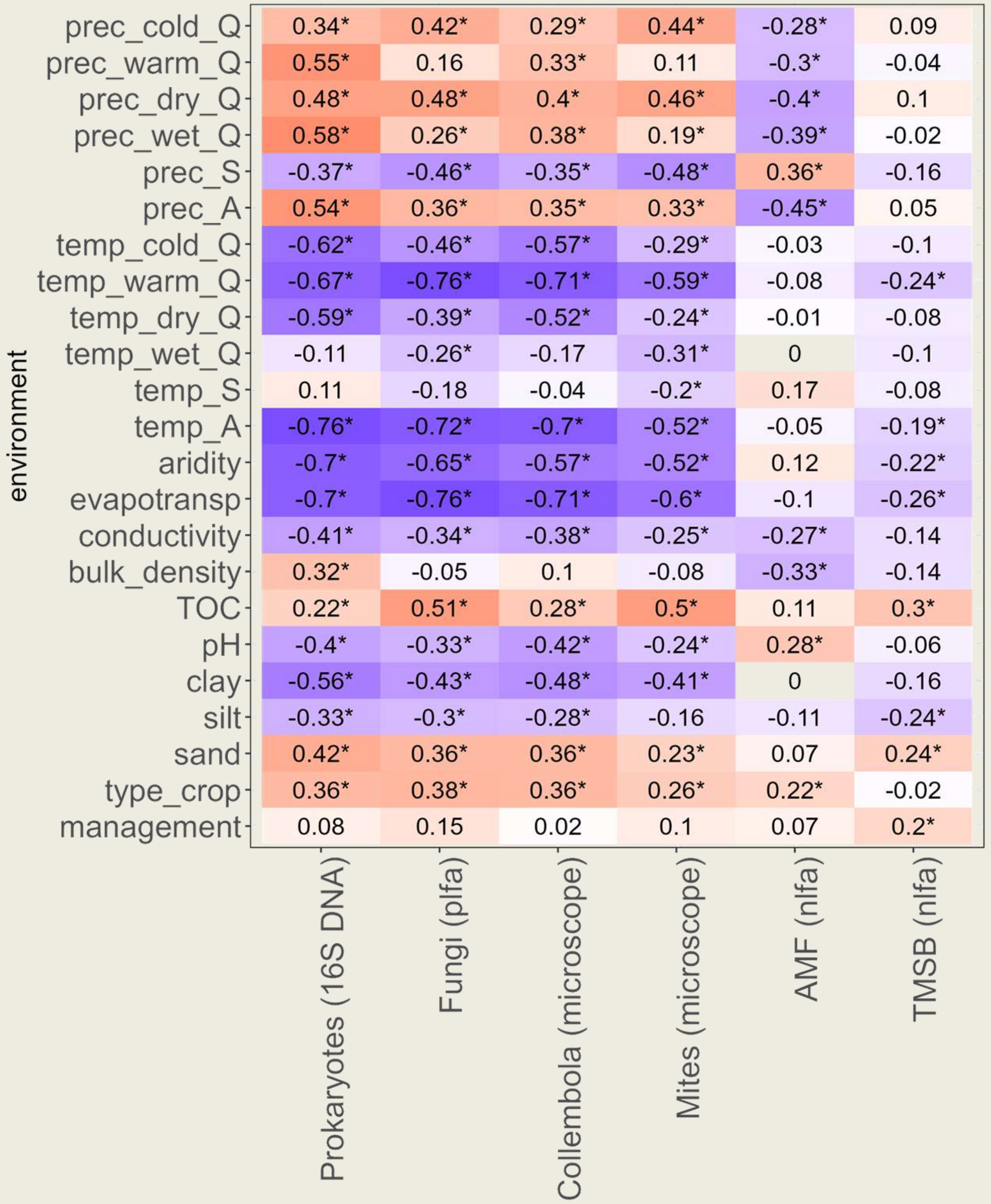
2. Sensitive to environmental factors or managements

1. Prokaryotes richness*

2. Fungal abundance*

3. Mites or Collembola*

4. TMSB or AMFs



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Soil biodiversity indicators

SOILGUARD

2. Sensitive to environmental factors or managements

1. Prokaryotes richness
pH, textura, climate
2. Fungal abundance
Soil C, management, climate
3. Mites or Collembola
Texture, soil C, climate
4. TMSB or AMFs
Weak climate response,
Management, compaction

environment	Prokaryotes (16S DNA)	Fungi (plfa)	Collembola (microscope)	Mites (microscope)	AMF (nlfa)	TMSB (nlfa)
prec_cold_Q	0.34*	0.42*	0.29*	0.44*	-0.28*	0.09
prec_warm_Q	0.55*	0.16	0.33*	0.11	-0.3*	-0.04
prec_dry_Q	0.48*	0.48*	0.4*	0.46*	-0.4*	0.1
prec_wet_Q	0.58*	0.26*	0.38*	0.19*	-0.39*	-0.02
prec_S	-0.37*	-0.46*	-0.35*	-0.48*	0.36*	-0.16
prec_A	0.54*	0.36*	0.35*	0.33*	-0.45*	0.05
temp_cold_Q	-0.62*	-0.46*	-0.57*	-0.29*	-0.03	-0.1
temp_warm_Q	-0.67*	-0.76*	-0.71*	-0.59*	-0.08	-0.24*
temp_dry_Q	-0.59*	-0.39*	-0.52*	-0.24*	-0.01	-0.08
temp_wet_Q	-0.11	-0.26*	-0.17	-0.31*	0	-0.1
temp_S	0.11	-0.18	-0.04	-0.2*	0.17	-0.08
temp_A	-0.76*	-0.72*	-0.7*	-0.52*	-0.05	-0.19*
aridity	-0.7*	-0.65*	-0.57*	-0.52*	0.12	-0.22*
evapotransp	-0.7*	-0.76*	-0.71*	-0.6*	-0.1	-0.26*
conductivity	-0.41*	-0.34*	-0.38*	-0.25*	-0.27*	-0.14
bulk_density	0.32*	-0.05	0.1	-0.08	-0.33*	-0.14
TOC	0.22*	0.51*	0.28*	0.5*	0.11	0.3*
pH	-0.4*	-0.33*	-0.42*	-0.24*	0.28*	-0.06
clay	-0.56*	-0.43*	-0.48*	-0.41*	0	-0.16
silt	-0.33*	-0.3*	-0.28*	-0.16	-0.11	-0.24*
sand	0.42*	0.36*	0.36*	0.23*	0.07	0.24*
type_crop	0.36*	0.38*	0.36*	0.26*	0.22*	-0.02
management	0.08	0.15	0.02	0.1	0.07	0.2*

Response diversity

Indicators for climate (1-3), soil C (1,3), management (2,4), pH and texture (1,3) or compaction (1,4)

Important to note: these indicators significantly respond to various environmental factors but not necessarily to management shifts in the present study. TMSB and fungal biomass showed the strongest association with management. Collembola the lowest.

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Soil biodiversity indicators

3. High relationship with important soil ecological functions

Effect diversity

1. Prokaryotes richness

2. Fungal abundance

3. Mites or Collembola abundance

4. TMSB or AMFs

	prok	fungi	collem	mites	amf	tmsb
cropyield	-0.14	0.18				0.15
ecosystem_stability	**-0.37**		0.21	-0.34		0.15
cstock	0.14	**0.32**		**0.29**		0.11
litter_decomposition	**0.39**	**-0.29**	-0.18		0.18	-0.19
available_p	**0.47**	0.17		-0.19	0.20	**0.35**
tan		**0.76**	**0.45**	**0.34**		**0.43**
ntr	0.27	**0.54**	**0.32**	**0.40**	0.13	**0.47**
bg	-0.16	0.32	**0.33**	0.29		**0.34**
xyl	0.11	**0.54**	**0.26**	**0.41**	-0.15	0.14
phos	0.12	0.16		0.24	-0.11	
nag	0.15	**0.46**		0.20		**0.30**
nirKS_nosZIZII_ratio	0.11	**0.50**	**0.28**	**0.46**		**0.26**
aggregates	**0.48**		-0.19	0.10	-0.22	
whc	-0.15	0.13	0.22	0.25	0.14	0.20
infiltration	**0.41**	0.21		**0.32**		0.11
n_retained_soil	**-0.28**	**0.26**	**0.26**		-0.14	0.19
p_retained_soil	**-0.26**			0.17		
root_herbivores	0.12	0.17			0.16	0.10
leaf_damage	0.15	**0.36**	-0.25	0.12		0.23
multifunctionality	0.23	**0.60**	0.18	0.39	0.13	**0.44**

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SOILGUARD

Soil biodiversity indicators

3. High relationship with important soil ecological functions

Effect diversity

1. Prokaryotes richness
Infiltration, P, aggregates, food (-)
2. Fungal abundance
Stronger functional effects (MF), C stocks
3. Mites or Collembola abundance
Water availability, C stocks, food (-)
4. TMSB or AMFs
Nutrient cycling

	prok	fungi	collem	mites	amf	tmsb
cropyield	-0.14	0.18				0.15
ecosystem_stability	**-0.37**		0.21	-0.34		0.15
cstock	0.14	**0.32**		**0.29**		0.11
litter_decomposition	**0.39**	**-0.29**	-0.18		0.18	-0.19
available_p	**0.47**	0.17		-0.19	0.20	**0.35**
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ntr	0.27	**0.54**	**0.32**	**0.40**	0.13	**0.47**
bg	-0.16	0.32	**0.33**	0.29		**0.34**
xyl	0.11	**0.54**	**0.26**	**0.41**	-0.15	0.14
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n_retained_soil	**-0.28**	**0.26**	**0.26**		-0.14	0.19
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SOILGUARD

Take home messages

4 soil biodiversity descriptors technically and conceptually complementary

Soil biodiversity indicators	Response of soil organisms	Changes in ecosystem functioning
Prokaryotes richness	Climate, soil C, pH and texture, compaction	Water infiltration capacity, phosphorous availability, soil aggregate stability, food production
Fungal biomass	Climate, management	Overall multifunctionality, soil organic carbon
Mites abundance	Climate, soil C, pH and texture	Water availability, nutrient cycling
Total microbial storage biomass	Management, compaction	Nutrient cycling

The SOILGUARD indicators provide a **standardized** approach to soil biodiversity monitoring. The data from this set of indicators will help assess **soil biodiversity**, **health**, and the **impact of climate change and soil management** in a **cost-effective** way.

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SOILGUARD

Thank you!

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SOILGUARD

Expert Panel Discussion: Measuring Soil Biodiversity, future strategies for harmonization and challenges

Ana Rocha (Moderator)

Director of EU's Agri & Forestry-Related Policies, ELO

ELO European Landowners' Organization

Tamas Krisztin

Integrated Biosphere Futures Research Group of the IIASA Biodiversity and Natural Resources Program and scientific coordinator of the LAMASUS Project.

LAMASUS Land Management for Sustainability

Nataliya Zinych

Corporate Public Affairs Manager at John Deere.

JOHN DEERE

Geert Magona van der Meer

Geert is a regenerative agriculture project manager at reNature.

reNature.

Diedrich de Ghellinck

Diedrich is a Land Manager at AgriLand.

AGRILAND

SOILGUARD

Expert Panel Discussion 2: Linking Soil Monitoring and Resilience to Policy

Elodie Champseix (Moderator)

Natural Resources Senior Officer at IUCN

IUCN

Max Meister

Natural resource management expert actively involved in European soil policy at NABU and Member of the EC Expert Group on CRCF

NABU

Ana Rocha

Director of EU's Agri & Forestry-Related Policies, ELO

ELO European Landowners' Organization

Micro Barbero

Mirco leads the policy team on soil protection and sustainable land use within the Unit Land Use and Management in DG-ENV at the EC.

European Commission