Assess your soil's biodiversity status

Soil indicators: A comprehensive approach to future monitoring of soil biodiversity

Background:

A clear understanding of soil biodiversity is essential to explain the variations observed in soil functions. Consequently, SOILGUARD conducted one of the most extensive and comprehensive studies on soil biodiversity to date, establishing a network of 233 sites across 8 biogeographical regions and 3 biomes (cropland, grassland, and forest).

To determine the best indicators that represent a significant share of soil organisms' total diversity and their connection to various soil functions effectively, the project evaluated twenty biodiversity metrics, including the abundance, biomass, and diversity of micro- and macro-organisms.

Key takeaways:

Based on SOILGUARD data, the following biodiversity indicators are suggested:

1. Prokaryotes richness: measured by sequencing the V3V4 hypervariable region of 16S rRNA gene after DNA extraction, estimates the number of different operational taxonomic units (OTUs - ASVs) for bacteria and archaea.
2. Soil fungal biomass: measured by phospholipid fatty acids quantification (PLFAs), estimates the absolute abundance of living fungi.
3. Mites abundance: measured by microscope counting after Tullgren funnel extraction, estimate the total abundance of living microarthropods at a determinate moment.
4. Total microbial storage biomass: measured by neutral lipid fatty acids quantification (NLFAs), estimates the absolute abundance of dormant microbes.

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Key Findings

Four indicators can represent over 70% of soil biodiversity in European croplands (Figure 1).

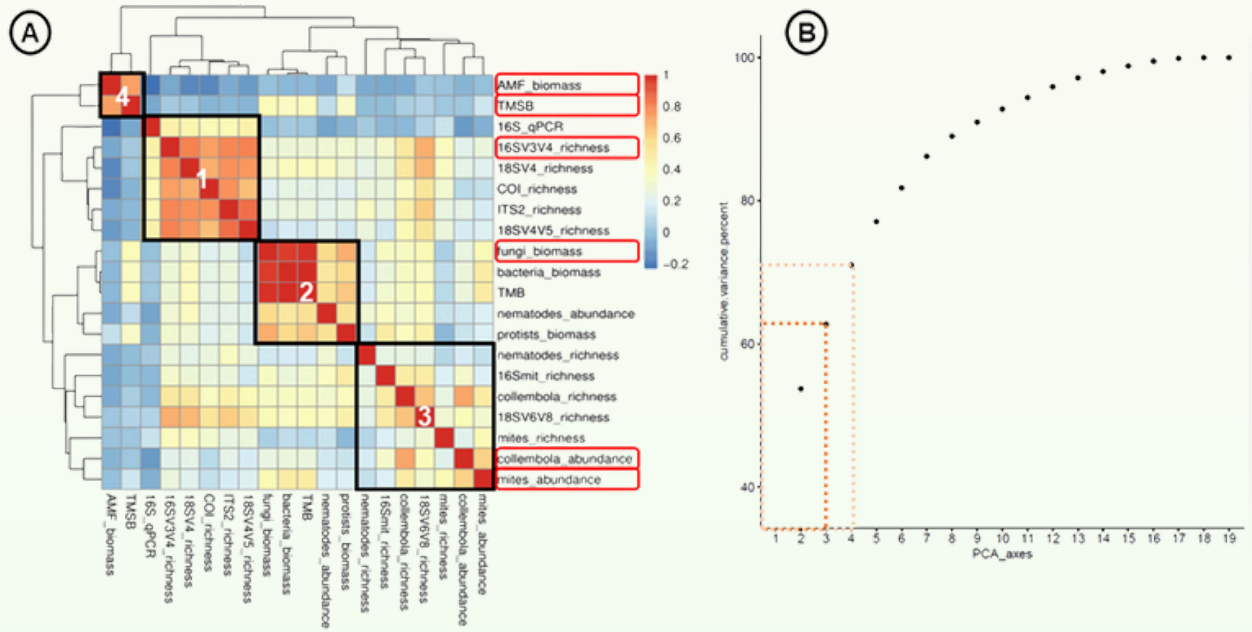
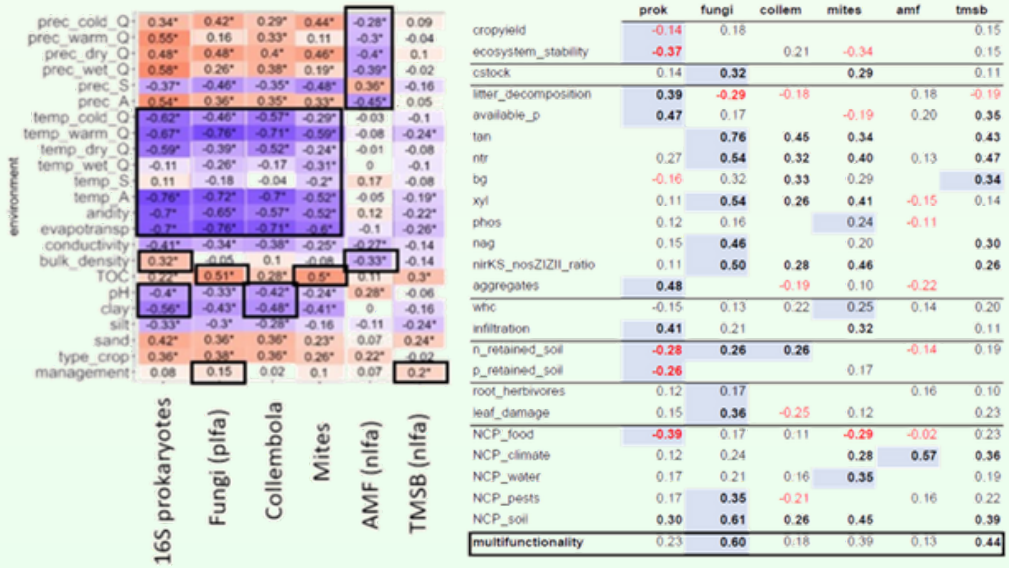


Figure 1. Four soil biodiversity indicators. *Correlation (Pearson´s) coefficients and hubs (black boxes) across the 20 soil biodiversity indicators evaluated (A), and their dimensionality (B), as represented with a Principal Component Analysis. Match between the hubs (A) and axes (B) is provided with the white number in A.*

The 4 indicators respond to environmental changes and are linked to multiple soil functions that crucial for the well-being of our societies (Figure 2 & Table 1).



	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
NCP_food	-0.39	0.17	0.11	-0.29	-0.02	0.23
NCP_climate	0.12	0.24		**0.28**	**0.57**	**0.36**
NCP_water	0.17	0.21	0.16	**0.35**		0.19
NCP_pests	0.17	**0.35**	-0.21		0.16	0.22
NCP_soil	**0.30**	**0.61**	**0.26**	**0.45**		**0.39**
multifunctionality	0.23	**0.60**	0.18	0.39	0.13	**0.44**

Figure 2. Environmental responses (left) and functional consequences (right). *Correlations (Spearman´s) between the best candidates for soil biodiversity indicators and climate, soil attributes (texture: silt and sand content, pH, bulk density, electric conductivity) and management (type of crop, organic vs conventional).*

Further reading:

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Table 2. *The link between soil biodiversity indicators, environmental responses and functional consequences. This table has been on the results presented in Fig. 2.*

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	Soil C stocks, nutrient cycling

Cross-validation on international croplands and other biomes (grasslands, forests) demonstrated the high representativeness of these indicators also in other types of soil biomes (Figure 3).

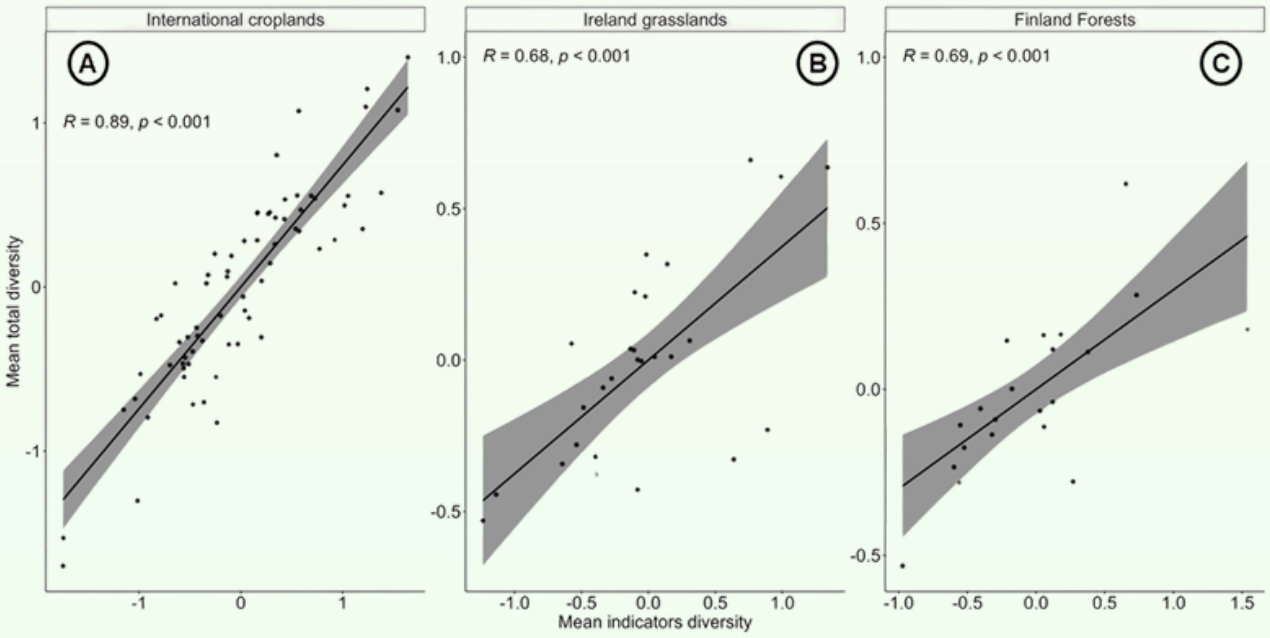

Figure 3. Out-of-sample test. *Correlations (Person´s) between the multiversity using the four indicators suggested (richness prokaryotes, abundance of fungi, mites and total microbial storage biomass vs the multidiversity index calculated with all our 20 soil biodiversity indicators in croplands (A), grasslands (B) and forests (C).*

Recommendation

The selected indicators, based on the SOILGUARD study, provide a broader range of biodiversity information at no additional cost. These are suggested as standardized metrics to follow on soil monitoring protocols, while allowing to the different stakeholders some flexibility in their choice of another soil biodiversity descriptors. The application of these four indicators in soil biodiversity studies should be carefully assessed, always considering the context of the questions being asked, with particular focus on repeated sampling over time and across seasons to gain better insights into long-term effects. The data collected should be used to generate a global understanding of soil biodiversity status, link it with soil health, and assess the trade-offs of future climate change impacts or shifts in soil management practices.

Further reading:

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Sustainable soil management to unleash soil biodiversity potential and increase environmental, economic, and social well-being