EJP SOIL
European Joint Programme

Towards climate-smart sustainable management of agricultural soils

Deliverable 8.8

D8.8 2nd EU Policy Forum

Due date of deliverable: M39
Resubmission date: 29.09.2023

GENERAL DATA

Grant Agreement: 862695
Project acronym: EJP SOIL
Project title: Towards climate-smart sustainable management of agricultural soils
Project website: www.ejpsoil.eu

Start date of the project: February 1st, 2020
Project duration: 60 months
Name of lead contractor: INRAE

Funding source: H2020-SFS-2018-2020 / H2020-SFS-2019-1
Type of action: European Joint Project COFUND

DELIVERABLE NUMBER:	8.8
DELIVERABLE TITLE:	D8.8 2nd EU Policy Forum
DELIVERABLE TYPE:	Report
WORK PACKAGE N:	WP8
WORK PACKAGE TITLE:	Science to Policy
DELIVERABLE LEADER:	David Wall
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DISSEMINATION LEVEL:	PU
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DOI:	10.18174/652164

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List of acronyms and abbreviations

WP	Work Package
EU	European Union
SIREN	Stocktaking for agricultural soil quality and ecosystem services indicators and their reference values
SERENA	Soil Ecosystem services and soil threats modelling and mapping
MINOTAUR	Modelling and mapping soil biodiversity patterns and functions across Europe

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1. Overview of the Event

1.1. Event Details

The 2nd EJP SOIL EU Policy Forum was held on Wednesday 8th March 2023 online via Zoom from 09:00 CET – 12:30 CET. The event was titled "EJP SOIL Scientific Support for the EU Soil Health Law" and aimed to present scientific information in support of the policy needs for development of EU Soil Health Law based on research findings of the EJP SOIL. This forum promoted discussion on relevant issues and was intended to help support policy makers' understanding of these findings to better inform future decision making when deciding upon national positions and feedbacks regarding the EU Soil Health Law.

Name	Role in EJP SOIL	Presentation Title	Time
David Wall	WP8 Leader	Welcome Address	9:00 – 9:15
Antonio Bispo[1]	WP6 Soil data & reporting SIREN, SERENA & MINOTAUR Projects	Soil Health in a European Context	09:15 – 9:35
Maria Fantappiè	WP6 Soil data & reporting	Current knowledge on approaches to the evaluation of soil indicators	9:35 – 9:55
Fenny van Egmond	WP6 Soil data & mapping	MentiMeter Exercise	9:55 – 10:25
David Wall	WP8 Leader	Session 1 Summary	10:25 – 10:30
BREAK			
Costanza Calzolari	SERENA – Soil ecosystem services and soil threats modelling and mapping	Prioritizing, characterising and selecting soil health indicators at various scales based on prioritized soil threats and ecosystem services	11:00 – 11:20
Stefano Mocali	MINOTAUR- Modelling and mapping soil biodiversity patterns and functions across Europe	Prioritizing and selection of soil health relevant biological indicators	11:20 – 11:40
Fenny van Egmond	WP6 Soil data & mapping	MentiMeter Exercise	11:40 – 12:15
David Wall	WP8 Leader	Closing remarks & satisfaction poll	12: 15 – 12:30

Table 1 Agenda of the EJP SOIL 2nd EU Policy Forum

[1] Slides were prepared by both A. Bispo & J. Faber. J. Faber could not present due to illness.

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1.2. Invitations

An invitation email along with a registration link and a save the date flyer were drafted and circulated to each EJP SOIL National Communication Representative asking them to identify one policy stakeholder in their country and invite them to attend the 2nd EU Policy Forum. This was to ensure that in addition to the EU Policy Stakeholders invited, that national policy stakeholders were also considered and engaged with at this event. An email invitation along with the registration link and save the date were also sent to a list of EU policy stakeholders. The list of invited EU policy stakeholders is available in Annex 3.

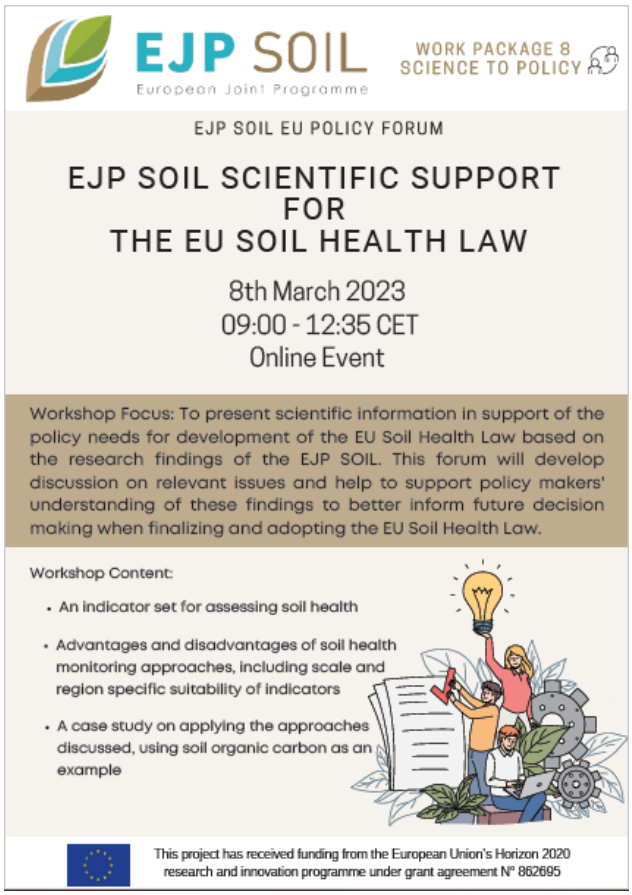

Figure 1 Save the date invitation to 2nd EU Policy Forum

1.3. Participants

The event was attended by ca. 100 persons from 64 institutes and 19 EU countries, 73% of these attendees classified themselves as interacting and engaging with policy at a national level in their respective countries while the other 23% classified themselves as engaging and interacting with policy at an European level (Figure 2).

Upon registration, all persons were asked to state the organisation to which they belong as well as if they engage with policy at a national or EU level. For those persons that attended the event the organizations and countries to which they belong are listed in the tables below based on if they engage with policy at an European (Table 2) or national (Table 3) level.

Country	Institute
Belgium	European Environmental Bureau
	Eurometaux
	European Landowner's Organisation
	European Commission
	European Economic and Social Committee
	IFOAM Organics Europe
	Fuels Europe
	REA
France	European Economic and Social Committee
	INRAE
Hungary	CEEweb for Biodiversity
Ireland	Department of Environment, Climate and Communications
Italy	University of Napoli
	CREA
Netherlands	Wageningen University & Research
	ISRIC
Poland	IUNG

Table 2 List of Institutes and countries of the attendees who identified as interacting with policy at a European level.

Country	Institute
Austria	Federal Ministry for Agriculture, Forestry, Regions and Water Management
	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology
	Environment Agency
	University of Natural Resources and Life Sciences (BOKU)
Belgium	Service public de Wallonie
	Department of Agriculture and Fisheries
	Government of Flanders
Switzerland	Agroscope
	Federal Office for Agriculture
Germany	Federal Ministry for the Environment
	Federal Environment Agency
	ahu GmbH Water Soil Geomatics
Estonia	Ministry of Rural Affairs
	Estonian Environment Agency
	Estonian University of Life Sciences
Spain	National Institute for Agricultural and Food Research and Technology
Finland	Ministry of Agriculture and Forestry
	Ministry of the Environment
	Geological Survey of Finland
	Finnish Environment Institute
France	INRAE
	Ministry of Agriculture
	Ministry of Ecological Transition
	Directorate General for Research and Innovation

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	Comité Champagne
	French Office for Biodiversity
Croatia	Ministry of Economy and Sustainable Transition
Ireland	Department of Agriculture, Food and the Marine
Italy	ISPRA
	National Research Council
	University of Palermo
	CREA
	Regional Agency for Services to Agriculture and Forestry
Lithuania	LAMMC
	Ministry of Environment of the Republic of Lithuania
	Ministry of Agriculture of the Republic of Lithuania
Luxembourg	Environment Agency
	Administration of Technical Agricultural Services
Netherlands	Ministry of Infrastructure and Water Management
Norway	NIBIO
Poland	Ministry of Agriculture and rural Development
Sweden	SLU
	Swedish Board of Agriculture
	Environmental Protection Agency
Slovenia	Ministry of Agriculture, Forestry and Food
	Ministry of Environment and Spatial Planning
	University of Ljubljana

Table 3 List of institutes and countries of the attendees who identified as interacting with policy at a national level.

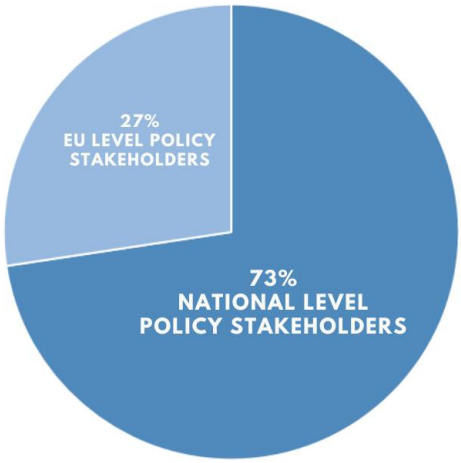

Figure 2 Percentages of the audience that engages with policy at a national or European level (n=84).

Of the 84[2] confirmed unique attendees, 73% identified as engaging with policy at a national level, while 27% identified as engaging with policy at an EU level (Figure 2).

[2] Due to technical issues with Zoom, identification of attendees was not functioning ideally and so while there were a greater number of attendees present throughout the event this is the number that can be correctly identified.

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2. General Summary of Presentations

The presentations of the event offered a logical flow of supporting scientific information beginning with an understanding of soil health within a European context and the proposal of several definitions of key concepts (Box 1 below, Section 4.1 Proposed definitions) so as to set the stage for further more in depth discussions in subsequent presentations.

Soil Health - the current capacity of a soil to function as a vital living system, within natural or managed ecosystem boundaries, to sustain plant and animal productivity and health, maintain or enhance water and air quality, and to further provide ecosystem services on the long-term without (increased) trade-offs between ecosystem services.

Soil Quality - the capability of the soil to potentially provide the desired ecosystem services (given soil type, land use and climate) when managed purposefully and sustainably.

(Definitions adapted, from SIREN final report; Faber et. al., 2022)

This was followed by a presentation on the various possible approaches to evaluate soil indicators and their pros and cons (Section 3.1.2 Current knowledge on approaches to the evaluation of soil indicators) which are further summarised below.

Approach	Description	Pros	Cons
Distribution	the actual distribution of measured values of the indicators is established and a statistical parameter is selected to set the threshold, e.g. the lower quartile of the distribution;	✓	✗ ✗
Fixed Targets	a threshold value is defined, based on literature, valid for either Europe or per pedoclimatic zone/ district;	✓	✗ ✗
Modelling – Natural Optimal values	the threshold is relative to the value of the indicator under a land use considered to be favourable, e.g. 80% of the value of the indicator under permanent grassland;	✓	✗ ✗
Relative changes	the increase / decrease of the current value of the indicator compared to that of time 0 value is considered, e.g. 0.4% increase in SOC content.	✓ ✓ ✓	✗ ✗

The other two presentations of the day focused on the link between soil threats, ecosystem services and relevant biological indicators and how to prioritise and select indicators. Soil threats and ecosystem services are inherently linked and can be considered two sides of the same coin. The SERENA project has developed key criteria that can be used to select indicators based on the prioritization of soil threats and ecosystem services (Table 5 Criteria for indicator selection based on findings of the SERENA project).

Standardized, scientifically proven and cost-effective biological indicators are available. The MINOTAUR project proposes a standardized **2 tiered system** of biological indicators for soil health assessment and monitoring (Figure 13 List of biological indicators assigned to tier 1). A holistic-based approach that uses multiple biological indicators within the context of available soil physical and chemical data in a specific scenario is recommended.

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3. Summaries of the Sessions

3.1. Session One

3.1.1. Soil Health in a European Context

Dr. Antonio Bispo, opened with the first presentation titled 'Soil Health in a European Context'. This set the stage for the day's presentation by introducing some definitions of key terms that had been developed by the SIREN and SERENA projects including that of soil health and soil quality.

> *Soil health is the current capacity of a soil to function as a vital living system, within natural or managed ecosystem boundaries, to sustain plant and animal productivity and health, maintain or enhance water and air quality, and to further provide ecosystem services on the long-term without (increased) trade-offs between ecosystem services. (Adapted, from SIREN final report; Faber et. al., 2022)*

This sparked a great deal of discussion on the idea of soil health versus soil quality, which occurred in both text exchanges in the Zoom chat and in discussion during the plenary session. The point was made by Dr. Bispo that soil health refers to the current state of the soil as it provides ecosystem services, while soil quality refers to the capability of the soil to deliver these ecosystem services in a sustainable way.

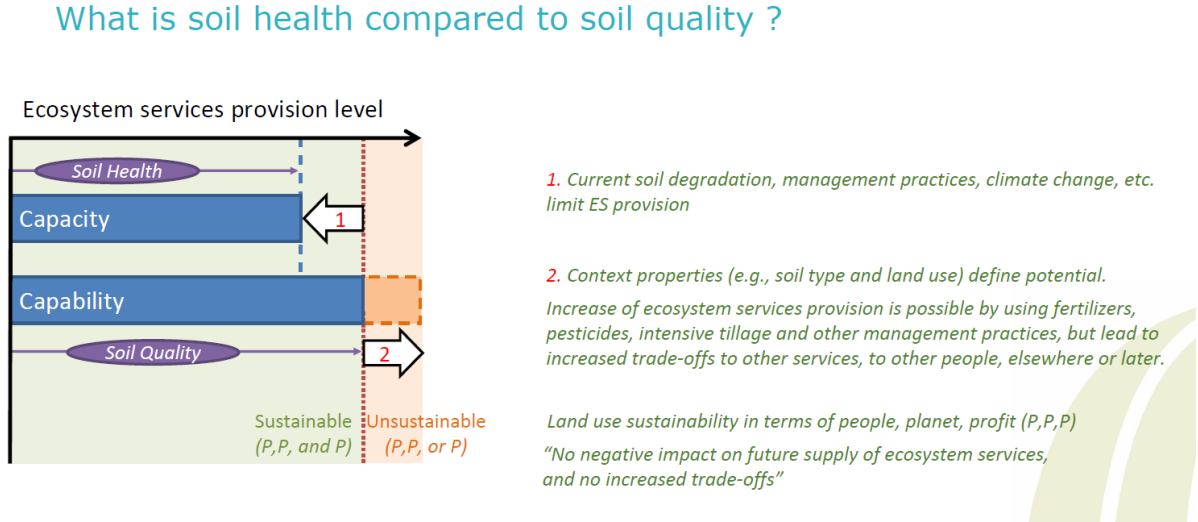

Figure 3 Slide form the presentation by Faber & Bispo comparing soil health and soil quality.

He also presented the definitions of other key terms that would be used throughout the presentations during the event.

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***Indicator**: a single or a set of variables to represent or infer a specific aspect of soil health.*

Indicators can be measured using analytical protocols, estimated through modelling or expert-based approaches and they can be quantitative, semi-quantitative or qualitative.

Evaluation criteria:

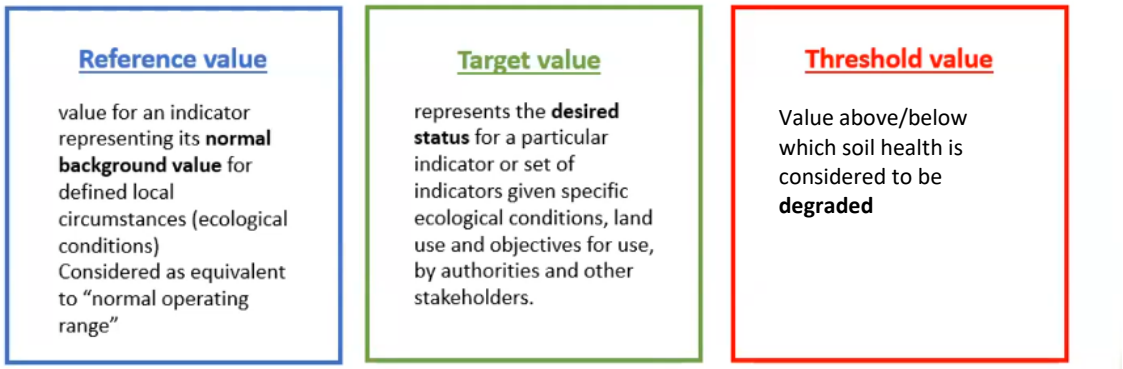

Figure 4 Definitions of other key terms developed by the SIREN project.

His presentation also highlighted the current understanding of what indicators are currently used in different MS to measure different aspects of soil health / quality and a proposed minimum indicator set based on the following criteria: relevance to EU policies, used in more than 50% of MS, used in more than 30% of scientific literature, application in current EU projects contributing to soil health assessment guidance. It was noted that while EU policies list also other contaminants, soil biodiversity and water regulation as key policy indicators, there is generally an omission in the implementation of such indicators by MS.

3.1.2. Current knowledge on approaches to the evaluation of soil indicators

Dr. Maria Fantappiè gave the next presentation in session one, in this she presented the different approaches to evaluating and stratifying soil indicators based on the proposed approaches of the EEA, EUSO and EJP SOIL. She also provided insight on the potential pros and cons of the various approaches.

These are:

- Fixed targets: a threshold value is defined, based on literature, valid for either Europe or per pedoclimatic zone/ district;
- Distribution: the actual distribution of measured values of the indicators is established and a statistical parameter is selected to set the threshold, e.g. the lower quartile of the distribution;
- Reference to optimal value: the threshold is relative to the value of the indicator under a land use considered to be favourable, e.g. 80% of the value of the indicator under permanent grassland;
- Relative changes: the increase / decrease of the current value of the indicator compared to that of time 0 value is considered, e.g. 0.4% increase in SOC content.

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	DISTRIBUTION	FIXED TARGETS	MODELING – NATURAL OPTIMAL VALUES	RELATIVE CHANGES
PRO'S	• Thresholds adapted to soil districts – pedoclimatic conditions.	• Simple also for no scientists	• If the modelling is properly elaborated could work fine to fix target values.	• Is a quick way to start evaluating the trends. • Allows for differentiation given by diverse pedoclimatic conditions. • Can be used by advisory services a field scale
CONS	• Lot of information needed, to have statistical distributions and must be stratified. • If the area is already degraded, then the information is biased.	• Needs stratifications: the thresholds must be adapted to specific pedoclimatic conditions. • Lot of information needed.	• There are few natural lands available in Europe to be taken as a reference: most forest and rangelands are managed. • Difficult to explain.	• May give problems to credit the farmers that have already done well. • The mapping for aggregation at smaller scales needs a temporal analysis.

Table 4 List of approaches to evaluating indicators and setting threshold values and the pros and cons

3.1.3. MentiMeter Session One Results

Ms. Fenny van Egmond then led a MentiMeter exercise, in which the audience was engaged to answer certain questions about targets and approaches to indicators. The results of these questions are presented in Figure 5 to Figure 12 below.

The results of the Mentimeter session showed that the audience little discarded any of the approaches to set thresholds but preferred relative changes and comparison to optimal values. There were contrasted responses between researchers and policy makers, showing in particular that the distribution approach did not seem feasible to policy makers. However, the reasons for this could not be explored within the time frame of the workshop. Results also showed that both categories of respondents prioritized pedoclimatic zones to set threshold values for indicators, and more generally prioritized biophysical zones (pedoclimatic zone, field, landscape) to administrative ones.

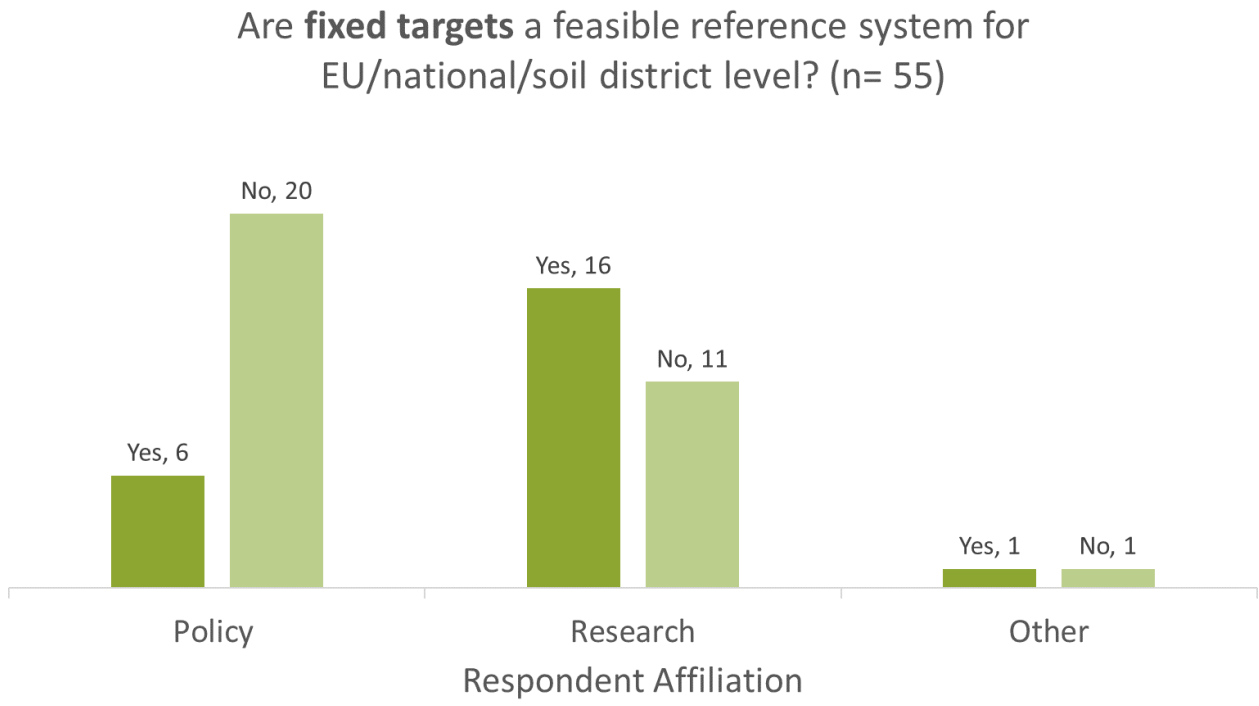

Figure 5 Audience responses on the feasibility of fixed targets categorized by respondent affiliation

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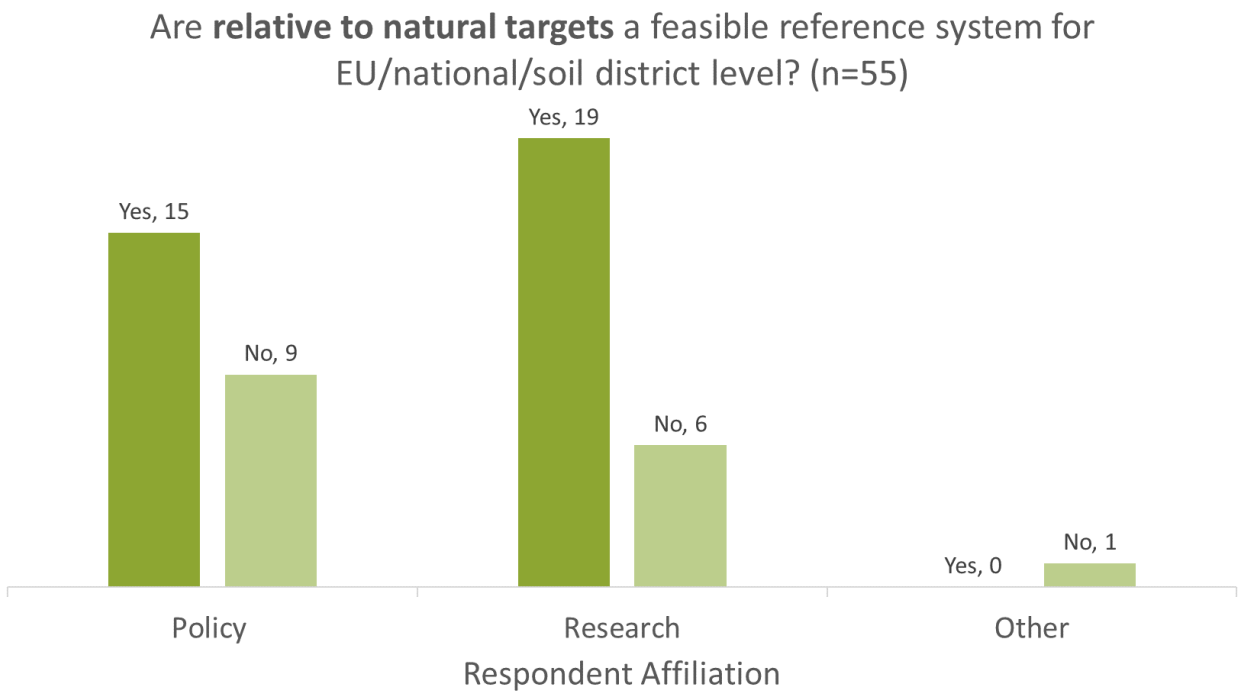

Figure 6 Audience responses on the feasibility of relative to natural targets categorized by respondent affiliation

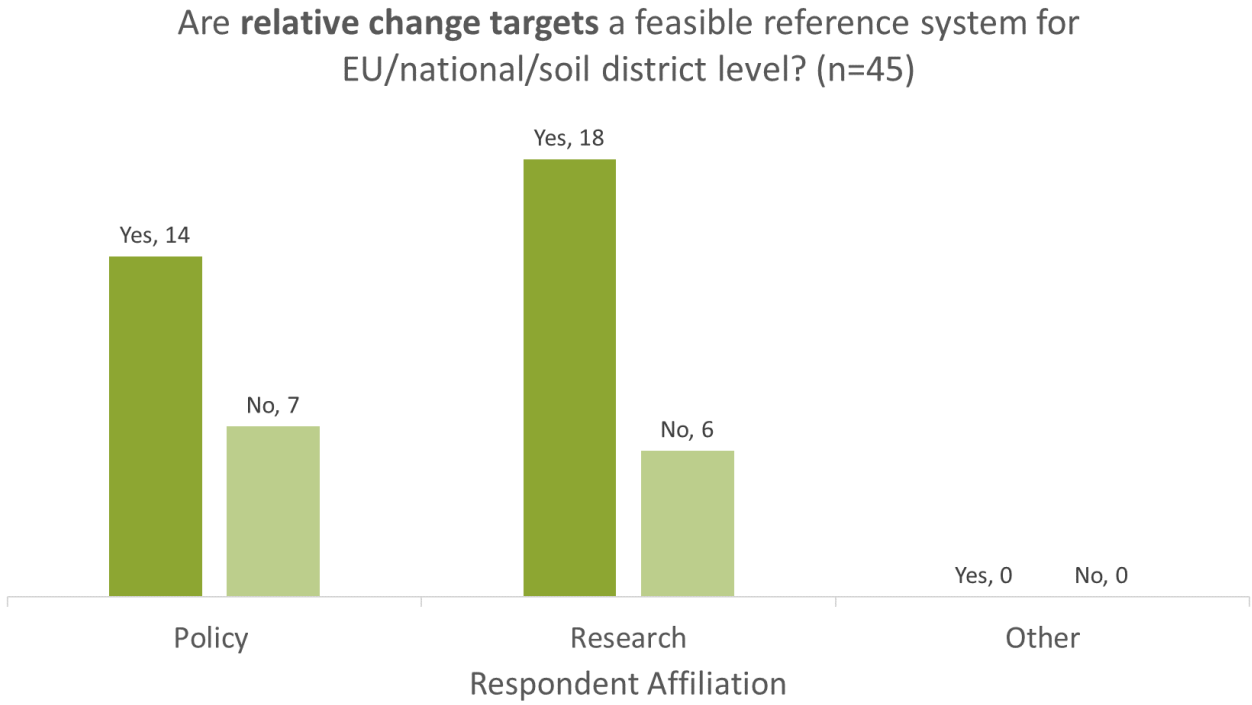

Figure 7 Audience responses on the feasibility of relative change targets categorized by respondent affiliation

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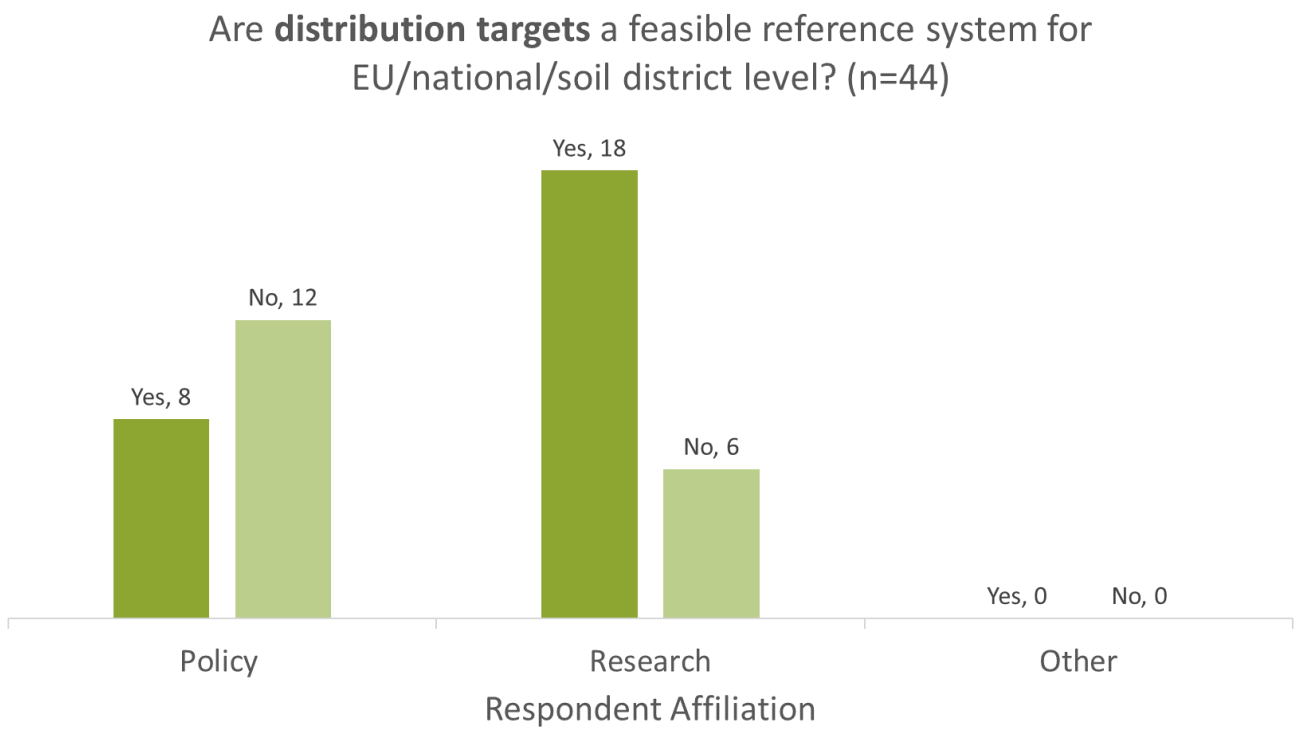

Figure 8 Audience responses on the feasibility of distribution targets categorized by respondent affiliation

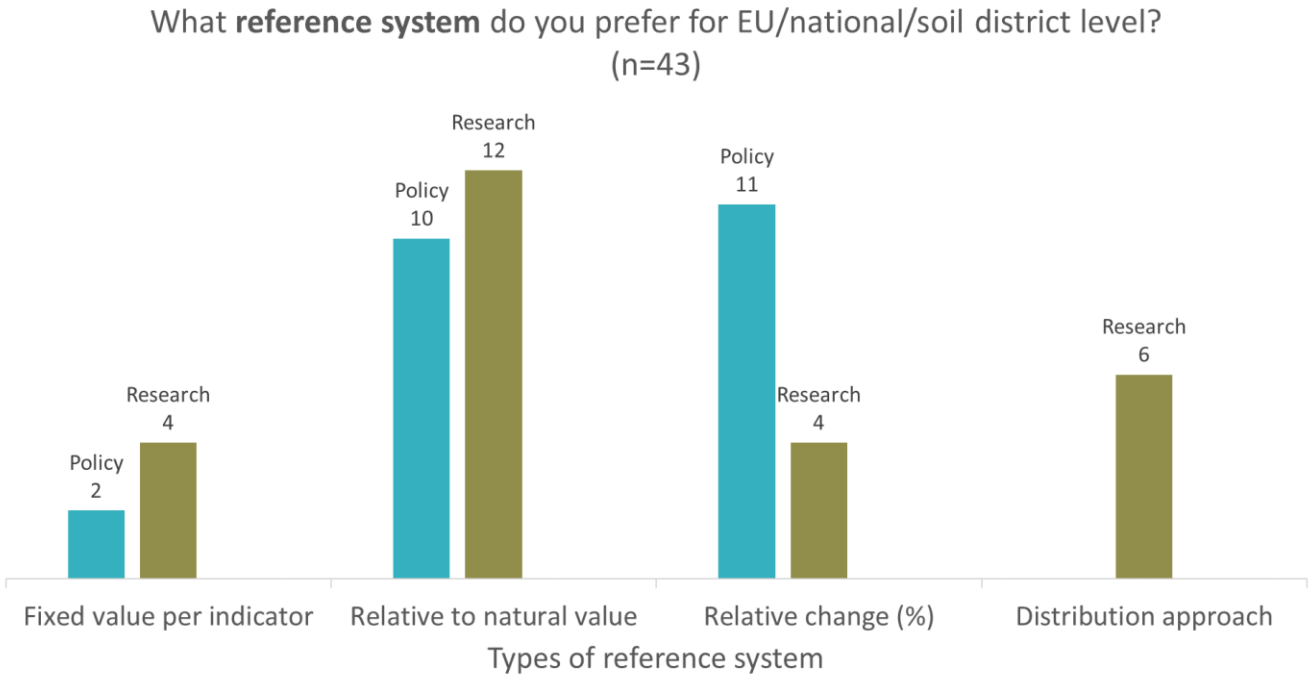

Figure 9 Preferred reference system of audience members based on their affiliation to research or policy.

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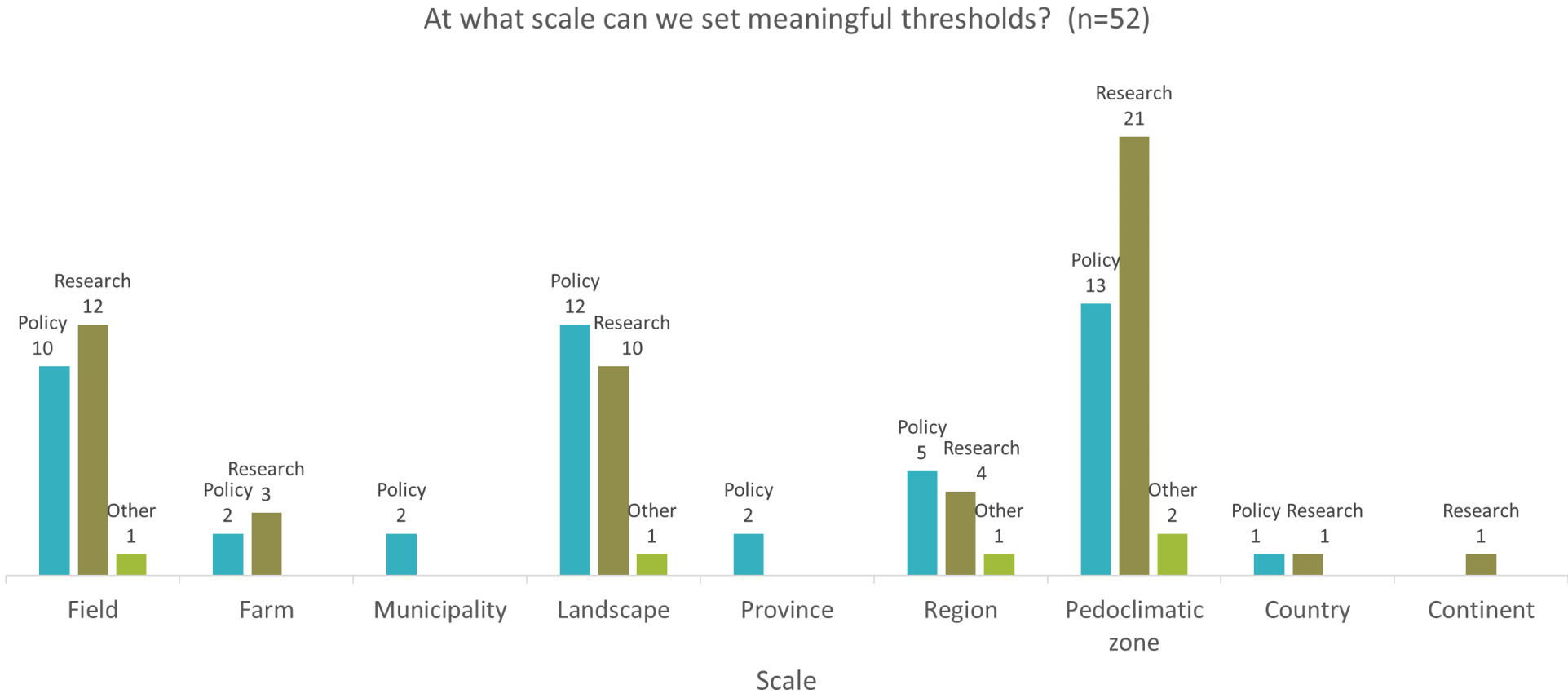

Figure 10 Audience responses on the scale at which meaningful thresholds can be set.

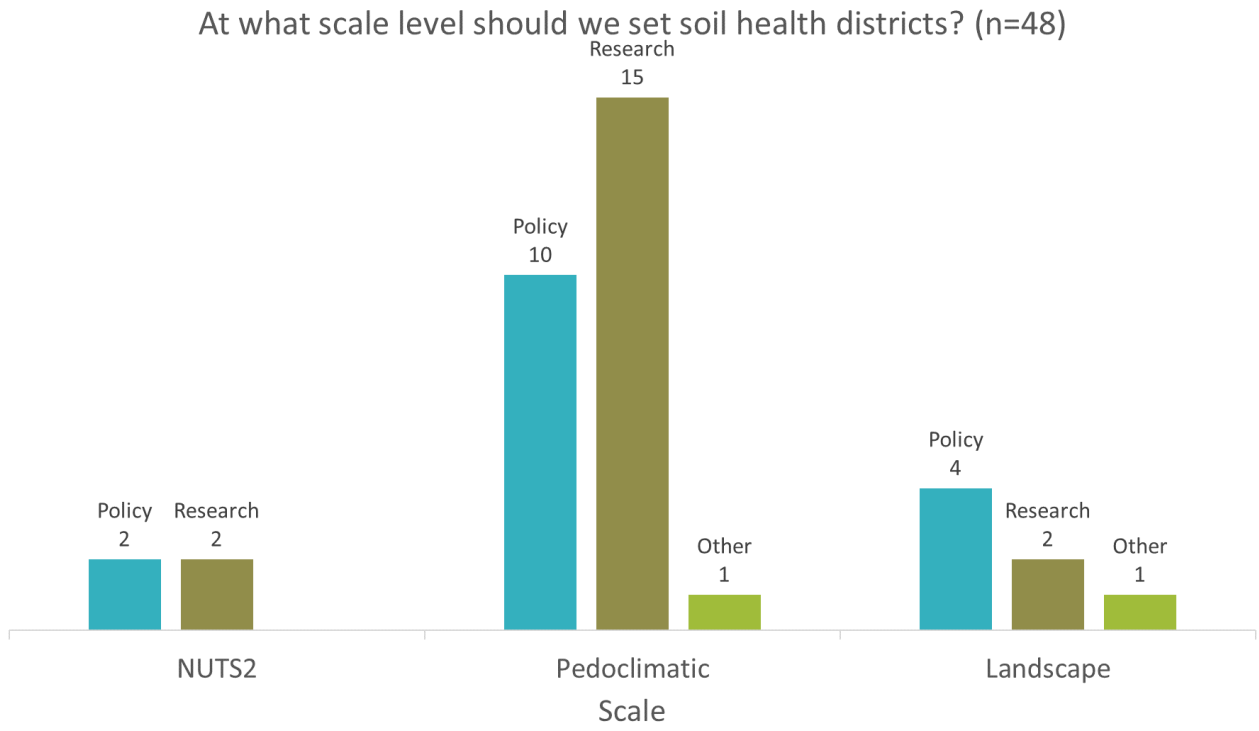

Figure 11 Audience responses on the scale at which soil districts should be set.

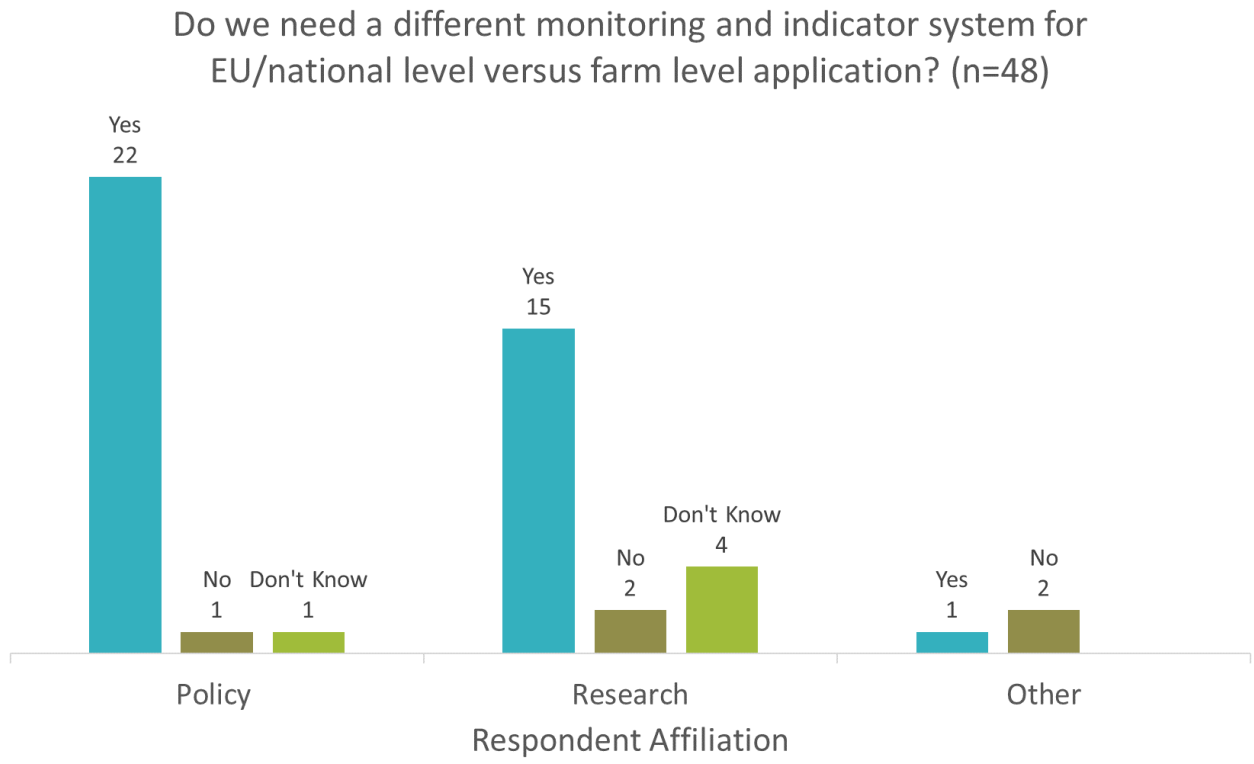

Figure 12 Audience responses on the need for different monitoring and indicator systems at EU level versus farm level.

3.2. Session Two

3.2.1.1. Prioritizing, characterising and selecting soil health indicators at various scales based on prioritised soil threats and ecosystem services

Costanza Calzolari then gave her presentation which explored how soil health indicators could be prioritised based on the prioritization of soil threats and ecosystem services. She presented the work of the SERENA project which explores soil threats and soil ecosystem services as two sides of the same coin which can be bundled together within the framework of soil health. One of the key exercises of the project was the prioritization of these soil threats and ecosystem services based on stakeholders feedback. As a result, key criteria for selecting different indicators were determined and these criteria are outlined in Table 5 below.

Family of criteria	Characteristics	Definition
Scientific soundness	Fitness-to-purpose	Rates the nature of the object targeted by the indicator considering that SERENA aims at quantifying soil threats and soil-based ecosystem services
	Interpretability	Rates how the variable is expressed according to the possibility and the ease of spatial and temporal comparison and interpretation
	Sensitivity	Rates the sensitivity of the indicators to changes in climate, soil, use and or management conditions
Data availability	Measurability	Rates the availability of the indicator into formats widely used and made available for easy access. When not available, it rates the possibility and the ease in measuring the indicator.
	Scalability	Rates the current applications of the indicator from local to European levels and, when applied at the European level, the type of spatial and temporal coverage
Ability to convey information	Intuitivity	Rates the understandability of the indicator by policy makers and non-technical audiences
	Policy implementation	Rates the relevance of the indicator in addressing the key environmental issues faced by governments and other stakeholders

Table 5 Criteria for indicator selection based on findings of the SERENA project

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3.2.2. Prioritizing and selection of soil health relevant biological indicators

The final presentation of the day was made by Dr. Stefano Mocali, who presented the current work being done by the MINOTAUR project on biological indicators for monitoring soil biodiversity and ecosystem services. Soil organisms play a crucial role in providing soil-based ecosystem services which are essential to soil function and thus soil health. Despite their importance, there have not been many biological indicators included in policies at a European level despite a range of biological indicators that have been used by various EU research projects. Dr. Mocali highlighted the fact that there are standardized, scientifically proven and cost-effective biological indicators available and presented a 2-tiered approach for application of biological indicators in soil health monitoring. He stressed the need to contextualize biological indicators within the context provided by soil chemical and physical data and not to rely on any single biological indicator, but to use a minimum set of biological indicators to present a more robust picture overall. The minimum set of biological indicators with the highest priority is presented in Figure 13 below which lists those indicators assigned to Tier 1 based on information available in the literature and the outcomes from previous projects.

Priority level	Recommended indicators		Brief description	Methodology	Cost efficiency	Sensitivity to degradation processes
Tier I	Functional indicators	Microbial biomass C	Amount of microbial biomass per gram soil	ISO 14240-1:1997 ISO 14240-2:1997	Easy and cheap	1. Declining of SOC 2. Desertification 3. Erosion 4. Soil sealing and urbanization 5. Pollution and salinization 6. Compaction
		Microbial respiration	Production of CO2 per amount of soil	ISO 16072:2002	Easy and cheap	
		Enzyme activity	Measurement of several hydrolase activities in soil	ISO 20130:2018 ISO/TS 22939:2019	Easy and cheap	
	Structural indicators	Macrofauna (Earthworms)	Structural and functional diversity	ISO 23611-1:2018	Easy and cheap	
		Mesofauna	Structural and functional diversity	ISO 23611-2:2006 QBS-ar (Parisi et al., 2005)	Easy and cheap	
		Nematodes	Structural and functional diversity	ISO 23611-4:2006	Easy and cheap	
		Microbiota (bacteria and fungi)	Structural diversity of soil microbiota	DNA metabarcoding (ISO 11063:2020) and Plassart et al., 2012	Costs are reducing, tends to become easy and cheap	

HIGH PRIORITY

EJP SOIL MINOTAUR

Figure 13 List of biological indicators assigned to tier 1

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3.2.3. MentiMeter Session Two Results

Fenny van Egmond then led a second MentiMeter exercise, in which the audience was engaged to answer certain questions about indicators. The results of these questions are presented in Figure 14Figure 5 to Figure 21 Figure 19below.

This second Mentimeter session showed that participants were favourable to using soil indicators without threshold values being used. This would enable to implement monitoring systems where several indicators are being measured, before being able to propose and agree upon threshold values, which would facilitate implementation.
Audience responses regarding dissemination formats was very useful, showing that policy briefs and events (either workshops or webinars) are preferred channels for dissemination. This will be integrated in EJP SOIL dissemination strategy, with, as next steps related to Soil Health Law elaboration, the organisation of a follow up webinar on soil health indicators.

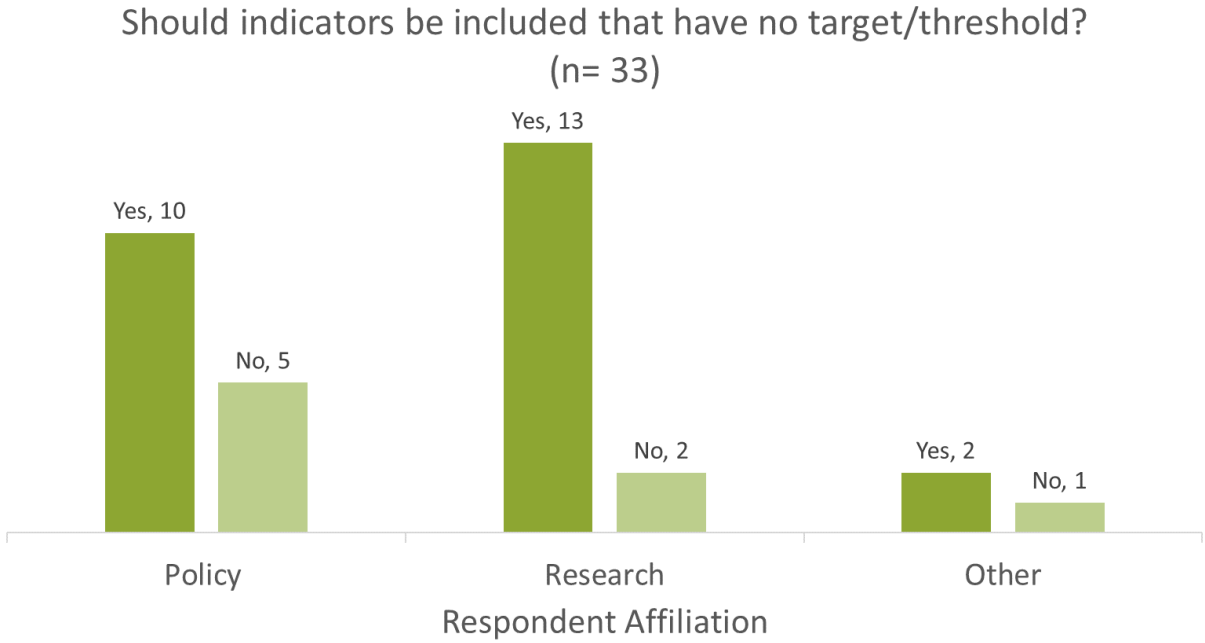

Figure 14 Audience responses on the inclusion of soil indicators that have no target / threshold

Figure 15 EU level indicators that were missing / not discussed according to those audience members affiliated with policy

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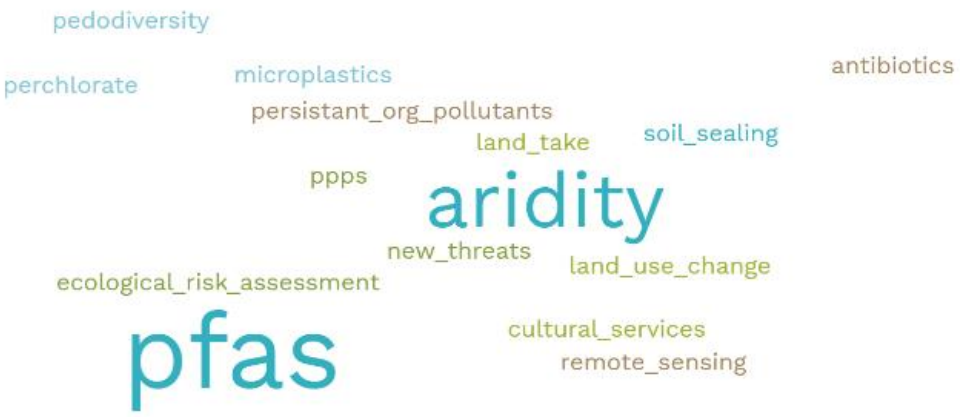

Figure 16 EU level indicators that were missing / not discussed according to those audience members affiliated with research

Figure 17 Other aspects to be considered when choosing indicators according to audience members affiliated with policy

Figure 18 Other aspects to be considered when choosing indicators according to audience members affiliated with research

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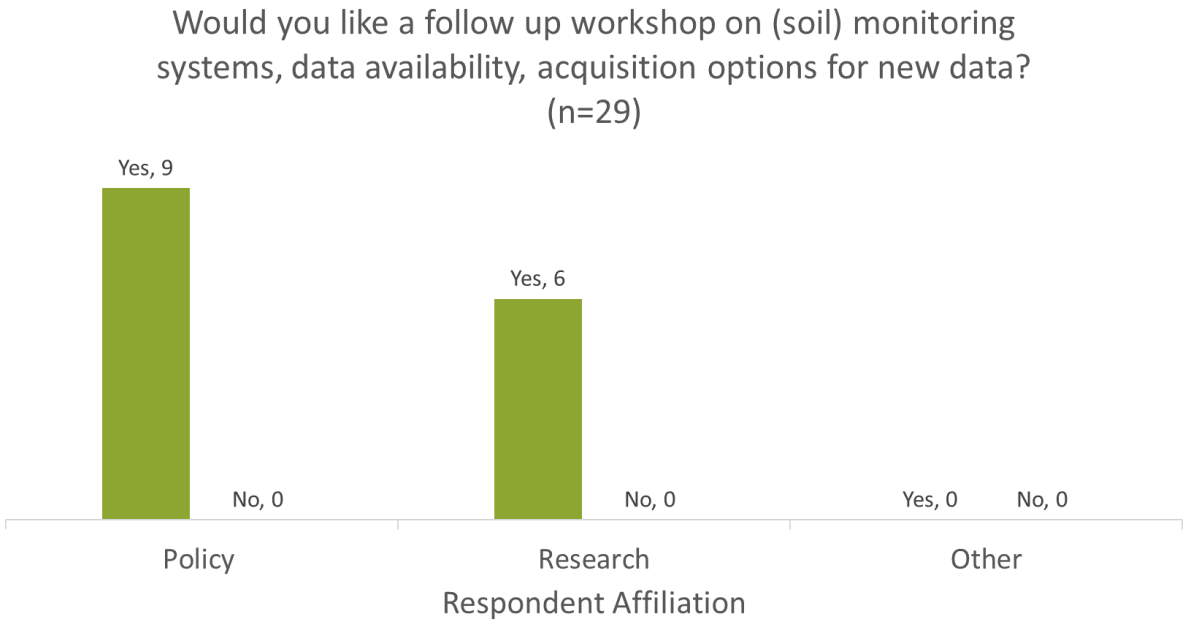

Figure 19 Audience responses on the preference for a follow up workshop

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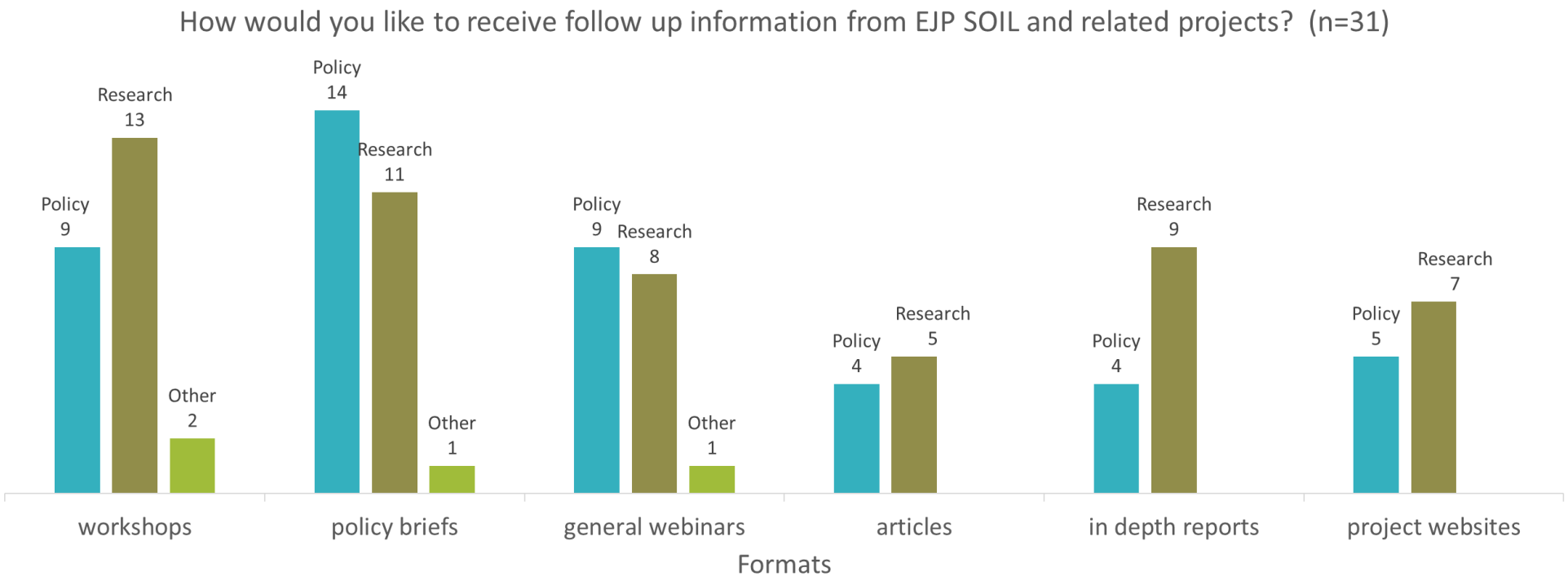

Figure 20 Audience responses on the preferred format for receiving follow up information

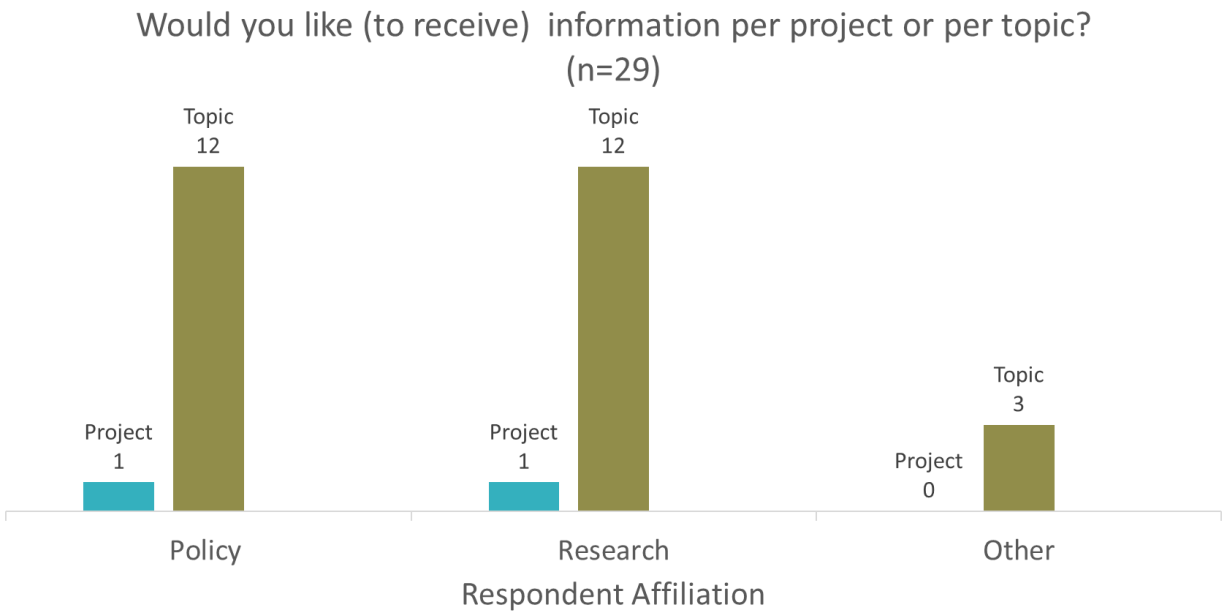

Figure 21 Audience responses on the preference to receive information by project or topic.

4. Key Takeaways

4.1. Proposed definitions

Soil Health - the current capacity of a soil to function as a vital living system, within natural or managed ecosystem boundaries, to sustain plant and animal productivity and health, maintain or enhance water and air quality, and to further provide ecosystem services on the long-term without (increased) trade-offs between ecosystem services.

Soil Quality - the capability of the soil to potentially provide the desired ecosystem services (given soil type, land use and climate) when managed purposefully and sustainably.

Indicator – a single or a set of variables to represent or infer a specific aspect of soil health

Reference Value – A value for an indicator representing its **normal background value** for defined local circumstances.

Target Value – represents the **desired status** for a particular indicator or set of indicators given specific ecological conditions, land use and objectives for use, by authorities and other stakeholders

Threshold - Value above/below which soil health is considered to be **degraded**

Definitions adapted, from SIREN final report; Faber et. al., 2022

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4.2. Pros & Cons of different approaches to evaluate indicators

Approach	Distribution	Fixed Targets	Modelling-Natural Optimal Values	Relative Changes
Description	The actual distribution of measured values of the indicators is established and a statistical parameter is selected to set the threshold, e.g. the lower quartile of the distribution	A threshold value is defined, based on literature, valid for either Europe or per pedoclimatic zone/ district	The threshold is relative to the value of the indicator under a land use considered to be favourable, e.g. 80% of the value of the indicator under permanent grassland	The increase / decrease of the current value of the indicator compared to that of time 0 value is considered, e.g. 0.4% increase in SOC content.
Pros	• Thresholds adapted to soil districts – pedoclimatic conditions	• Simple for non-scientists as well	• If the modelling is properly elaborated it could work well to fix target values.	• A quick way to start evaluating trends. • Allows for differentiation due to diverse pedoclimatic conditions. • Can be used by advisory services at field scale.

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Cons	• A lot of information is needed to have statistical distributions and must be stratified. • If the area is already degraded then the information is biased.	• Needs stratifications: the thresholds must be adapted to specific pedoclimatic conditions. • A lot of information needed.	• Few natural lands in Europe that can be used as a reference: most forests and rangelands are managed. • Difficult to explain.	• May result in problems to credit farmers that have already done well. • The mapping for aggregation at smaller scales needs a temporal analysis.

4.3. Prioritizing & Categorizing Indicators

- Soil threats and ecosystem services are inherently linked and can be considered two sides of the same coin.
- The SERENA project has developed key criteria that can be used to select indicators based on the prioritization of soil threats and ecosystem services (Table 5 Criteria for indicator selection based on findings of the SERENA project).

4.4. Available Biological Indicators

- Standardized, scientifically proven and cost-effective biological indicators are available.
- There is a proposed standardized **2 tiered system** of biological indicators for soil health assessment and monitoring (Figure 13 List of biological indicators assigned to tier 1).
- A holistic-based approach that uses multiple biological indicators within the context of available soil physical and chemical data in a specific scenario is recommended.

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5. Annex 1 - Satisfaction Survey Results

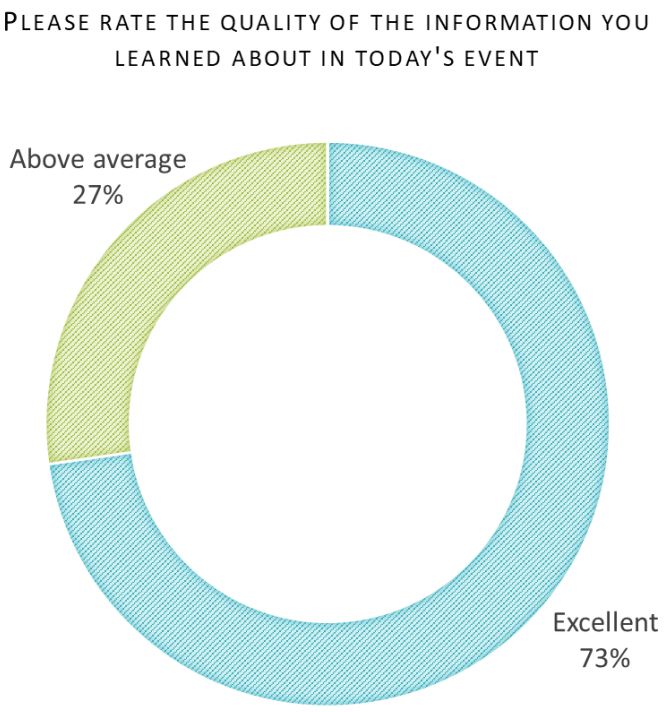

Figure 22 Ratings for the quality of information presented in the event

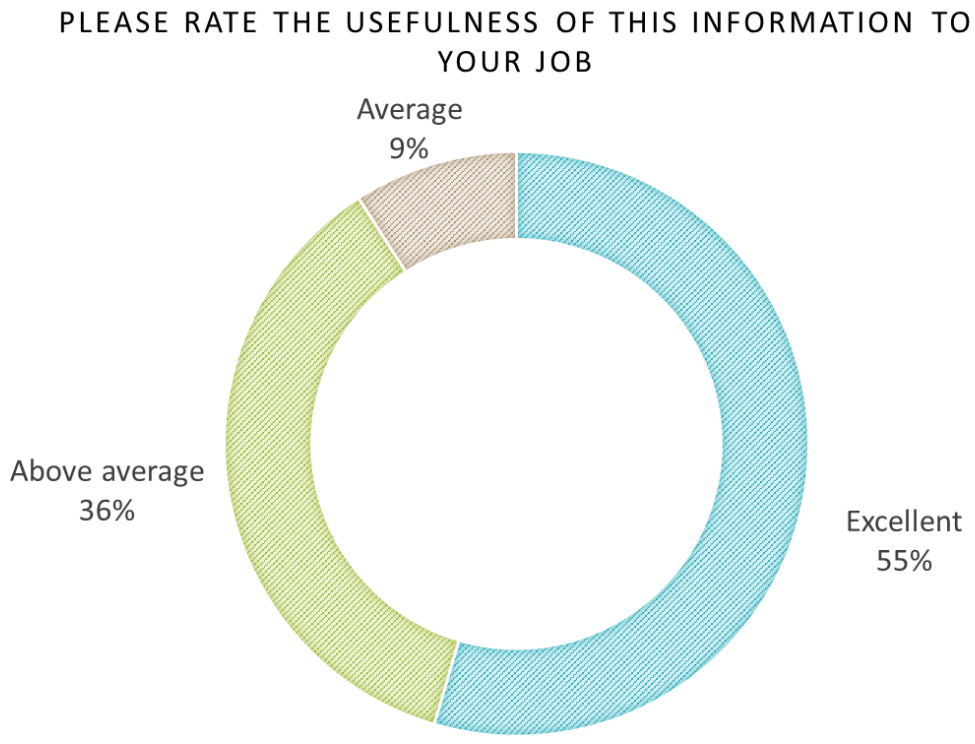

Figure 23 Ratings for the usefulness of information presented in the event

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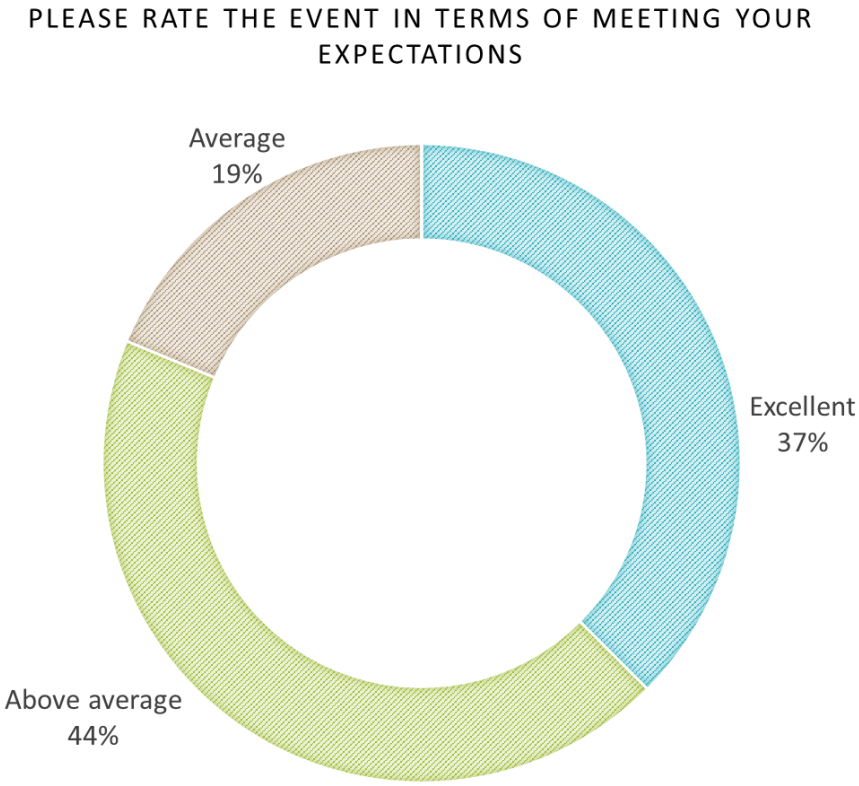

Figure 24 Ratings for meeting expectations of the event

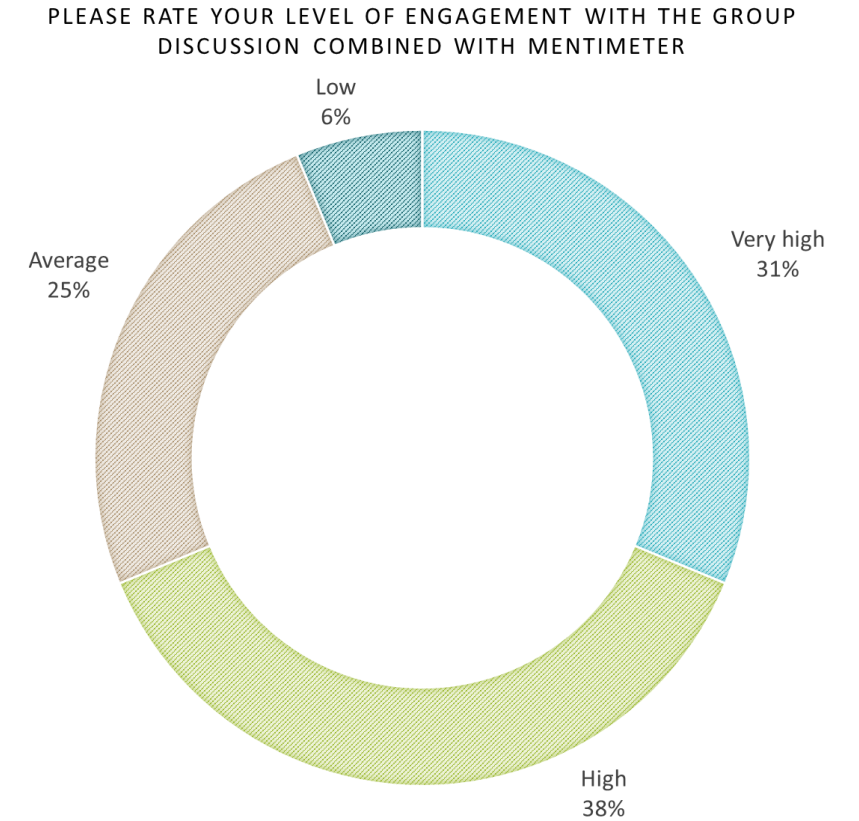

Figure 25 Ratings for persons level of engagement at the event

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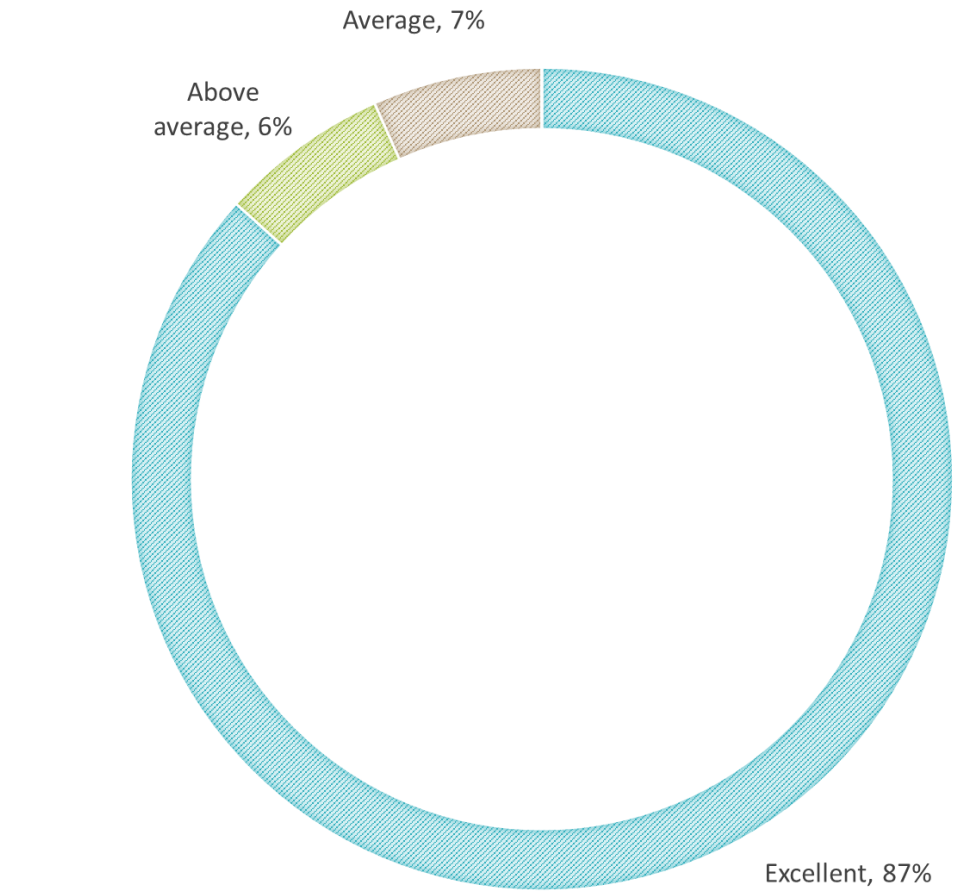

Figure 26 Ratings for overall organisation of the event

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6. Annex 2 – Questions from the Chat

How comparable are the analytical methods and evaluation values of the SQ indicators proposed by SIREN used in the MS?

Rather than « soil quality » could we use « soil potential » ?

How do the definitions relate to the definitions in the Soil Strategy?

As a general question, is there an integrated approach to monitor soil health, considering several (if not all) the components of soil system? And integrating also social and economic factors, not only physical or natural factors… as this is the main challenge for soils in the future, to be able to be sustainably managed! (ISPRA)

What is the timeline for the SERENA project? Will it be in line with the SHL proposal?

SHL proposal is scheduled to come out before this summer.

The methodology to measure biological indicators seems to be clear, but are there also site-specific reference/target/threshold values for these indicators available?

It is crucial that interpretation of indicators allows recommendations to land users, otherwise it's just monitoring for monitoring

Are these conclusions for indicators for agriculture land or also for forest land? **Sigbert Huber, Austria**: Biological indicators are certainly important, but what are the costs for monitoring of Tiers I indicators compared to Tier II indicators per plot/site?

What kind of recommendations for land managers can be associated to Tier I and II indicators? Is it foreseen to have such recommendations in the project final report?

it is important to know which part of the indicator is under the control of the land manager and which part is out of control (eg: climate change), such that the risk to miss the target is proportionate. Two issues are important: monitoring (even if some indicators have not yet some thresholds) and action (for the indicators having clear thresholds)

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7. Annex 3 - Power Point Presentations

7.1. Soil Health in a European Context

SIREN - Stocktaking for Agricultural Soil Quality and Ecosystem Services Indicators and their Reference Values

- **Stocktake** of soil data use in ES assessment by EJP SOIL Member States; stocktake of **indicators** and reference values
- **Framework** linking Soil Quality to ES, with consistent **definitions** of key concepts
- Proposal for **harmonised and tiered** pan-European SQ monitoring regarding Green Deal policy objectives: "**minimum dataset**"
- Stakeholder participation in the development of national monitoring schemes; **top-down indicator selection**
- Knowledge gaps and needs towards policy implementation in MS

EJP SOIL
European Joint Programme

SIREN

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Some definitions from SIREN and SERENA projects (1/2)

Soil Health *is the current capacity of a soil to function as a vital living system, within natural or managed ecosystem boundaries and land-use boundaries, to sustain plant and animal productivity and health, maintain or enhance water and air quality, and to further provide ecosystem services on the long-term without (increased) trade-offs between ecosystem services.*

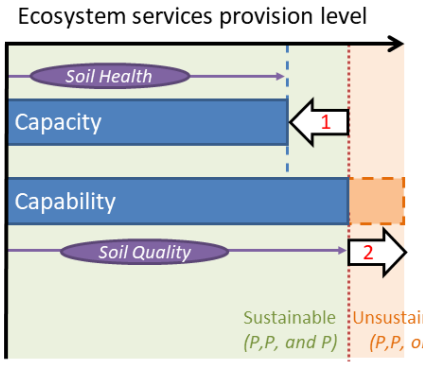
Adapted, from SIREN final report (Faber et. al., 2022)

Soil fertility *is the ability of a soil to sustain plant growth by providing essential plant nutrients, water and favorable chemical, physical, and biological properties as a habitat for plant growth.*

Adapted after FAO definition of Soil Fertility (online source: https://www.fao.org/global-soil-partnership/ar-eas-of-work/soil-fertility/en/).

1	Soil quality	9	Ecosystem service / soil threat bundle
2	Soil health	10	Service providing unit
3	Soil fertility	11	Service providing area
4	Soil function	12	Soil degradation
5	Soil threat	13	Thresholds
6	Ecosystem services	14	Reference values
7	Soil Ecosystem Services	15	Target value
8	Indicator		

What is soil health compared to soil quality ?



1. Current soil degradation, management practices, climate change, etc. limit ES provision

2. Context properties (e.g., soil type and land use) define potential.

Increase of ecosystem services provision is possible by using fertilizers, pesticides, intensive tillage and other management practices, but lead to increased trade-offs to other services, to other people, elsewhere or later.

Land use sustainability in terms of people, planet, profit (P,P,P)

"No negative impact on future supply of ecosystem services, and no increased trade-offs"

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Some definitions from SIREN and SERENA projects (2/2)

***Indicator**: a single or a set of variables to represent or infer a specific aspect of soil health.*

Indicators can be measured using analytical protocols, estimated through modelling or expert-based approaches and they can be quantitative, semi-quantitative or qualitative.

Evaluation criteria:

Reference value

value for an indicator representing its **normal background value** for defined local circumstances (ecological conditions)
Considered as equivalent to "normal operating range"

Target value

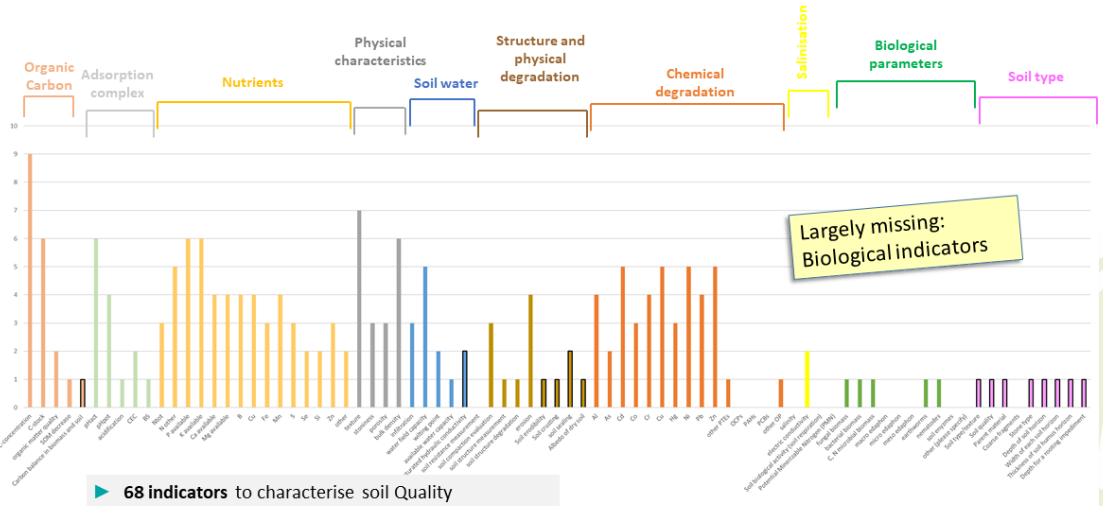
represents the **desired status** for a particular indicator or set of indicators given specific ecological conditions, land use and objectives for use, by authorities and other stakeholders.

Threshold value

value above/below which soil quality is considered to be **degraded**

SQI used in Member States

- Soil indicators from EJP SOIL T2.4.2
- New categories (with black contours)
- Answers from CZ, DK, ES, FI, FR, IE, IT, LV; LT, PT, SK



- **68 indicators** to characterise soil Quality
- **Top 3** : [C], texture, [N] [P] [Bd]
- **Biological indicators** still rarely used
- **Organic Pollutants** not used

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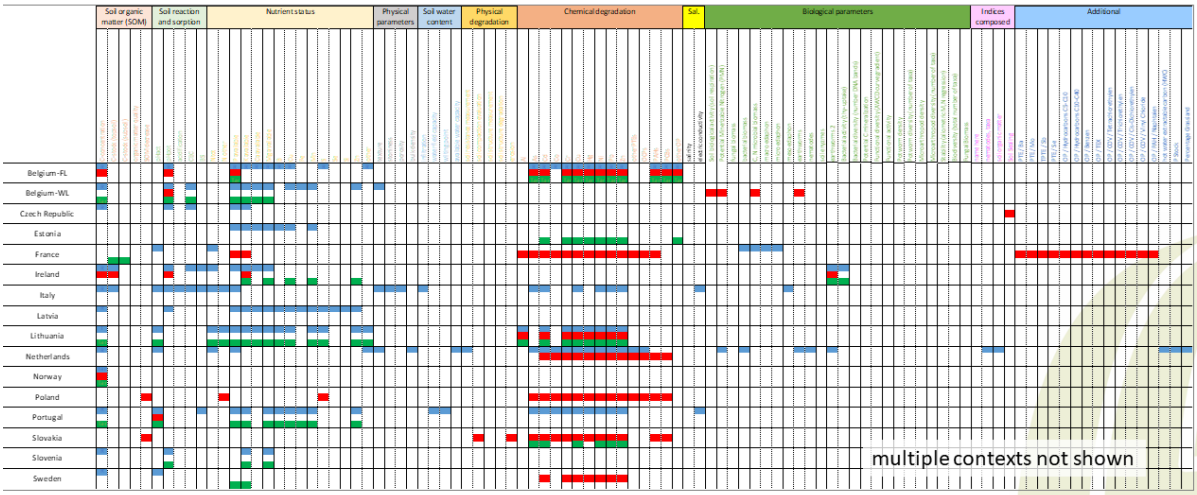
SQI criteria in Member States

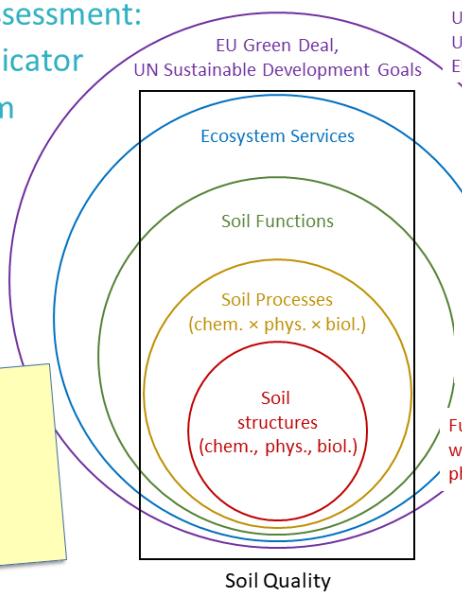
REFERENCE values
THRESHOLD values
TARGET values



EJP SOIL European Joint Programme

SIREN

Soil Health assessment: top-down indicator selection from land use objectives



UN CCD, CCC : Desertification, Climate change
UN SDG2, 13, 15 : Food security, Climate change
EU Green Deal : Climate Law, F2F

Decomposition and fixing processes
(Class 2.2.4.2 in CICES V5.1)

Natural soil fertility, a balance of SOM mineralisation versus humification, and immobilisation vs. mobilisation of nutrients

Biochemical: respiration, litter decomposition;
Biophysical: soil aggregation, bioturbation;
Physicochemical: carbon concentration, bulk density

Functional biodiversity, with chemical and physical resources

Guidance is missing

cf. NEN5737:2010
ISO 19204:2017

site-specific ERA
contaminated soils

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Indicators used in some EU and international policies

ST/SESs	indicator	N of documents	Examples of documents
SOC loss	SOC stock	9	SDG13, SDG 15, FAO-ITPS: SSM, EU Mission, Biodiv. Strat., Soil Strat., Forest Strat.
	SOC concentration	7	SDG13, SDG 15, FAO-ITPS: SSM, EU Mission, Biodiv. Strat., Soil Strat., Forest Strat.
Soil erosion	soil loss by wind/water erosion	6	UNCCD, SDG 15, FAO-ITPS: SSM, EU Mission, Biodiv. Strat., Forest Strat.
Loss of diversity	Earthworm occurrence	6	SDG2, SDG15, FAO-ITPS: SSM, EU Mission, Biodiv. Strat., Soil Strat., Forest Strat.
	biodiversity indices	6	SDG2, SDG15, FAO-ITPS: SSM, Forest Strat.
	microbial biomass values	6	SDG2, SDG15, FAO-ITPS: SSM, EU Mission, Forest Strat.
Environmental pollution control	concentration of pollutants	8	SDG15, FAO-ITPS: SSM, EU Mission, Farm2Fork, Biodiv. Strat., Soil Strat.,
GHG and climate regulation/C sequestration	GHG emissions	10	SDG13, SDG15, FAO-ITPS: SSM, EU Mission, Farm2Fork, EU Climate Law, Soil Strat., Forest Strat.
	potential C sequestration	7	SDG15, FAO-ITPS: SSM, EU Mission, Farm2Fork, Biodiv. Strat., EU Climate Law, Forest Strat.
Habitat for biodiversity	diversity/richness	6	SDG15, FAO-ITPS: SSM, EU Mission, Soil Strat., Forest Strat.
Erosion control	soil erosion rates	6	SDG13, SDG15, FAO-ITPS: SSM, EU Mission, Biodiv. Strat., Forest Strat.

Shortlist "minimum dataset" for harmonised SQ monitoring across Europe

Criteria:

- EU Policy-relevant
- >50% MS
- >30% sci. literature
- Appl. in EU projects

Biodiversity data
- Structural
- Functional

Policy Indicator	Soil Quality Indicator
Soil physical condition	Texture, Porosity, Bulk density
Soil fertility	C concentration Total N P K pH
Erosion evaluation	Based on calculation
Salinity	Electric conductivity
Contamination	Heavy metal trace elements
Other contaminants	*Recommended to be included in a first tier **
Soil biodiversity	
Water regulation	

** Based on our selection strategy, we observed significant omissions regarding indicators for soil biodiversity, organic contamination and water regulation/filtration. As soil condition data in these areas are called for by policies and stakeholders and (standardised as well as novel) methods are scientifically available, we recommend to also include relevant indicators in this 1st tier minimum dataset. Based on our stocktake and reviews it is yet impossible to select any without making subjective choices, which we wanted to avoid.*

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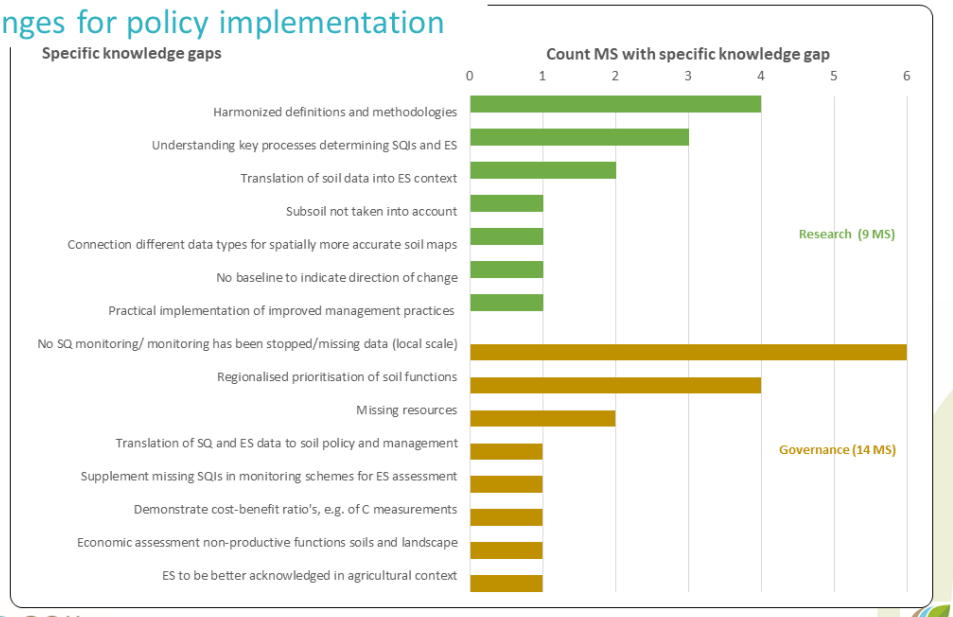
Challenges for policy implementation



To conclude

- SIREN can be seen as starting point
- Other projects and activities of EJP SOIL may build on results
- Main outcomes in a policy brief


Policy brief
9 January 2023
Soil health and ecosystem services: monitoring and evaluation
Summary
Key messages and recommendations
Context

https://ejpsoil.eu/soil-research/siren

- Policy brief
- Report
- Video presentation

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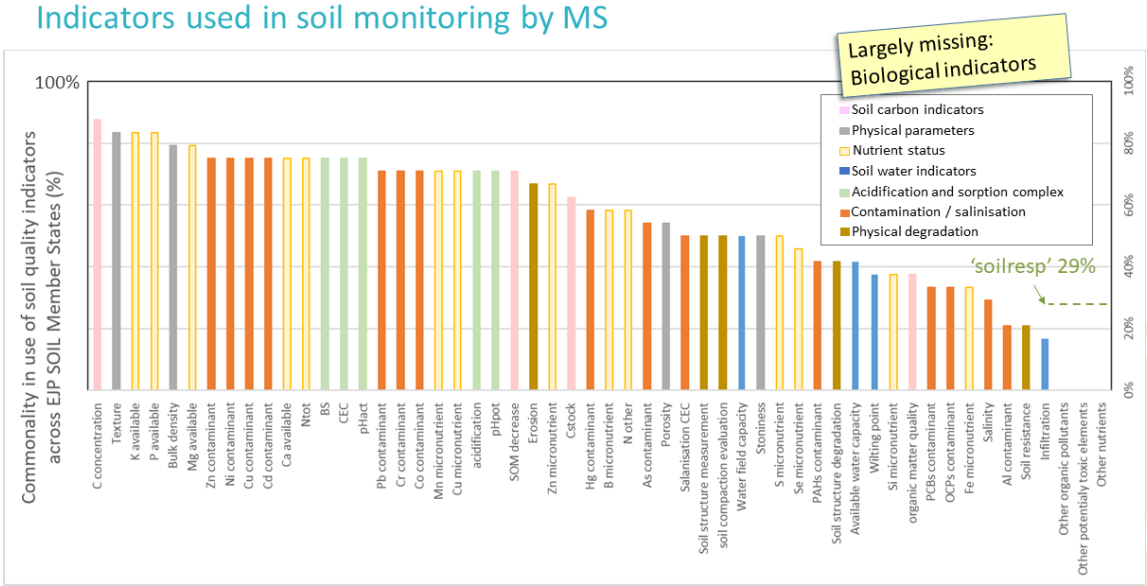
Soil health relevancy to EU policy

EU Green Deal strategies:

- Sustainable development
- Farm2Fork
- Chemicals
- Waste
- Climate
- Biodiversity
- Soil (renewed Nov. 2021)

Indicators used in soil monitoring by MS



Source: T2.4.2 stocktake

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What is soil health???

- Functional approach, evolving from limited focus on 'soil fertility' and 'absence of contamination'
- Conceptual evolution, progressing development in European understanding
- cf. 'Public health'

WHO Constitution:

"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

➢ Public health care is shifting towards 'coping'

Soil health relevancy to EU policy

EU Green Deal strategies:

- Sustainable development
- Farm2Fork
- Chemicals
- Waste
- Climate
- Biodiversity
- Soil (renewed Nov. 2021)

EU Soil Health Law 2023:

- Soil chemical, physical and biological characteristics in good structural and functional condition.
- Continued provision of (max.) number of (essential) ES
- No increase in existing trade-offs

Service provision is now elementary → *Indicators soil health linkable to ES*

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Complementary approaches to soil health

1. Promote resistance to soil stresses
- Evaluate soil functions (cf. SMS)
- Reference values, for evaluation
- Threshold values, for protection
- Target values, for remediation

➢ Focussed on soil functions related to land use

2. Exploit capacity to sustainably deliver ES
- Evaluate goods and services (cf. MAES)
- Reference values, for evaluation
- Threshold values, for trade-off stabilisation
- Target values, for sustainable development

➢ Broad array of ES, beyond land use objectives

Soil health is assessed locally ⟺ Sustainable land use is assessed globally

SMS: Soil health objectives, targets and indicators

1. Soil pollutants, excess nutrients and salts
2. Soil organic matter
3. Soil structure (incl. bulk density and absence of soil sealing and erosion)
4. Soil biodiversity
5. Soil nutrients and pH
6. Vegetation cover
7. Landscape heterogeneity
8. Area of forest and other wooded lands
9. Global footprint

Specific Targets and Indicators			
Objectives	**Land Management Targets**	**Soil Health Targets**	**Six Soil Health Indicators**
Land degradation and desertification	*50% degraded land restored*	*Strong reduction in degradation and desertification*	*All 6 soil health indicators*
Soil organic carbon	*Conservation of high carbon soils and a reverse of carbon loss in croplands.*	*A switch from a 0.5 % loss per year to a 0.1-0.4% increase in SOC concen-tration in cropland soils* *30-50% reduced area of peatland losing carbon*	*Soil organic carbon stock* *Vegetation cover*
Soil sealing and net land take	*Urban recycling of land from 13 to 50%* *No net land take by 2050*	*Switch from 2.4% to no net soil sealing*	*Soil structure including soil bulk density and absence of soil sealing and erosion* *Vegetation cover*
Soil pollution	*25% of land under organic farming* *Doubling of rate of remediated sites prioritising brown field sites*	*5-25% additional land (i.e. over and above the 25% in full organic) with reduced risk from a range of pollutants*	*Presence of soil pollutants, excess nutrients and salts*
Erosion	*50% degraded land restored*	*Prevention on 30-50% of land with unsustainable erosion risk*	*Soil structure including soil bulk density and absence of soil sealing and erosion.* *Vegetation cover*
Soil structure	*50% degraded land restored*	*Reduction by 30-50% of soil with compaction*	*Soil bulk density and other measures of soil structure*
While not being a soil indicator in the strict sense, mission activities will be assessed against their impact on the health of soils outside Europe			
Global footprint	*Strenathened international cooperation; trade regulations, including carbon tax*	*20-40% reduction of current global footprint*	*Food, feed and fibre imports leading to land degradation and deforestation*

Table 1 Objectives of the mission board and the targets and indicators used to assess progress and achievement. (Source MB 2020)

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Soils essential for provision *many* ecosystem services

- Common International Classification of Ecosystem Services (CICES):
  83 classes
  29 (in)directly soil-regulated
- Shortlist 25 ES
  responsive to agricultural management
  (Paul et al. 2021)
- Assessment by bundles of services

For discussion

"No increase in trade-offs"
requires assessment of *all* (83) ES,
including not-soil related services.

Enter your answer "Yes" or "No" in the chat, please.

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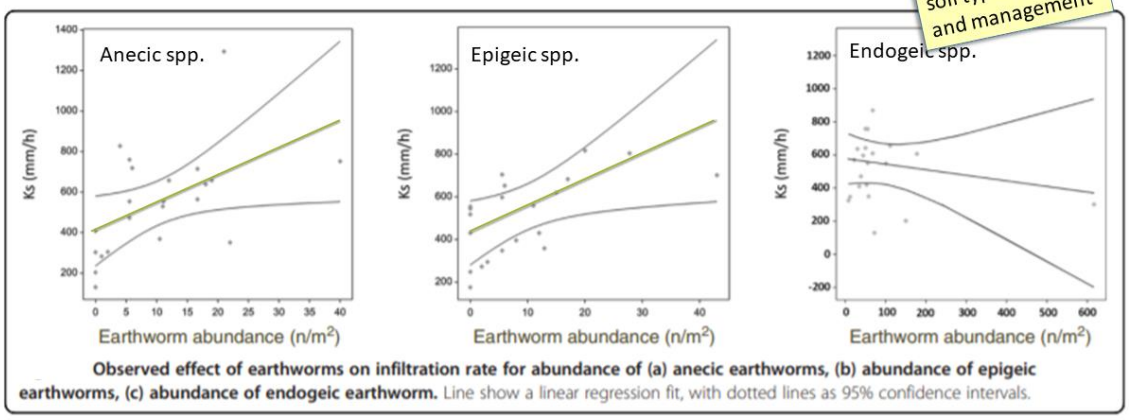
Example EPF: regulation of water infiltration by earthworm groups

contextualisation: benchmarking for soil type, land use and management



Observed effect of earthworms on infiltration rate for abundance of (a) anecic earthworms, (b) abundance of epigeic earthworms, (c) abundance of endogeic earthworm. Line show a linear regression fit, with dotted lines as 95% confidence intervals.

Spurgeon et al. 2013

Mirco Barbero, DG ENV:

- Need information on transfer functions: how to combine data, what is possible, what not, provide timeline

  SIREN: examples ecological production functions
  SERENA: identified bundles ES

- For indicators: provide an overview of what is scientifically proven, under debate and wrong and provide timelines for that

- Threshold systems: pro's and con's

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Rainer Baritz, EEA:

- Help define the research questions: make a list/agenda

  SIREN: research priorities

- Try to be ready for the questions that stakeholders in country will ask when the Law is accepted, their information needs and be ready

  SIREN: research and governance needs by Member States

- More work needed on thresholds/target values

  SERENA, MINOTAUR

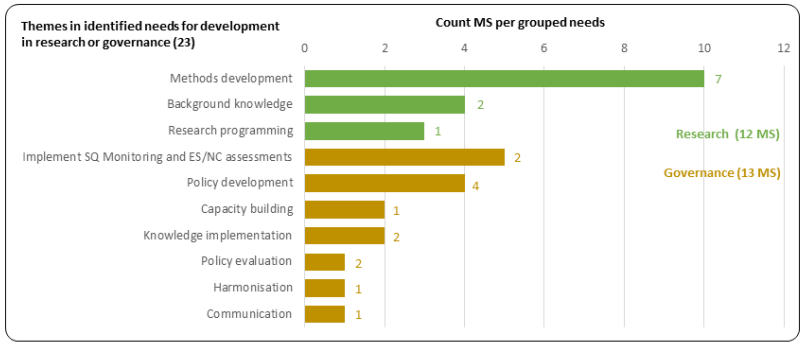

Fig. D7.B. Number of MS that have identified a particular theme for development need in research (green bars) or governance (brown bars), based on aggregation of 23 specifically expressed needs, the actual number of which per theme is indicated at the top of the bars.

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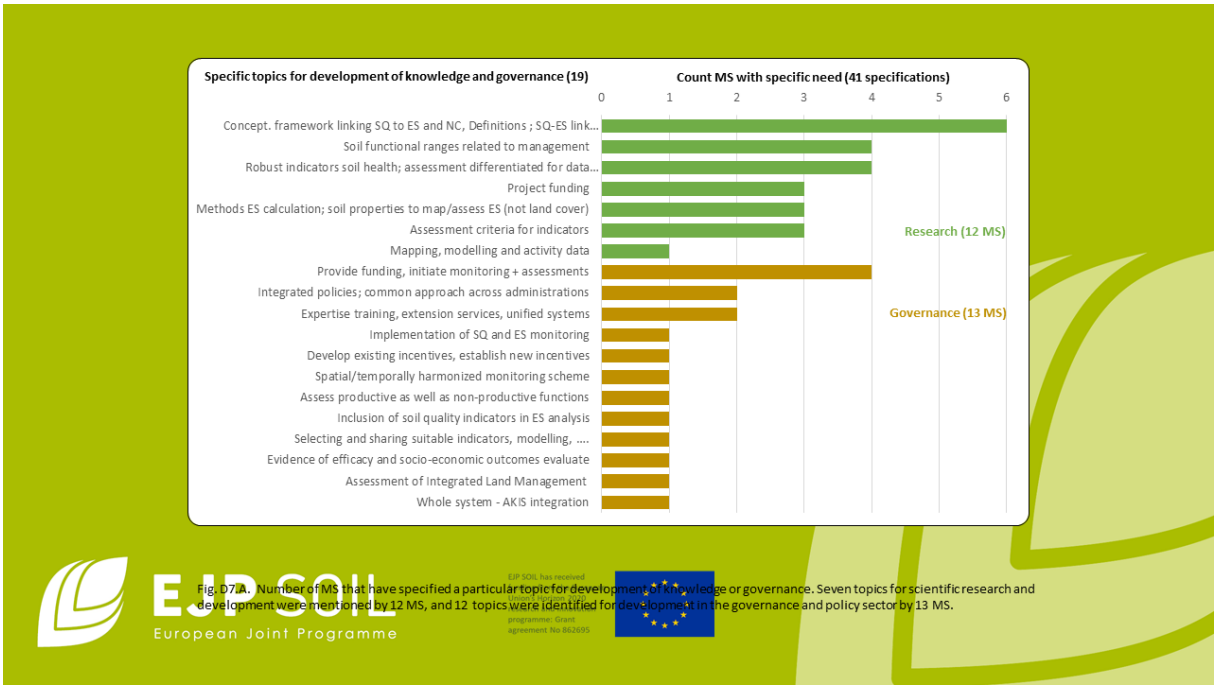

Fig. D7.A. Number of MS that have specified a particular topic for development of knowledge or governance. Seven topics for scientific research and development were mentioned by 12 MS, and 12 topics were identified for development in the governance and policy sector by 13 MS.

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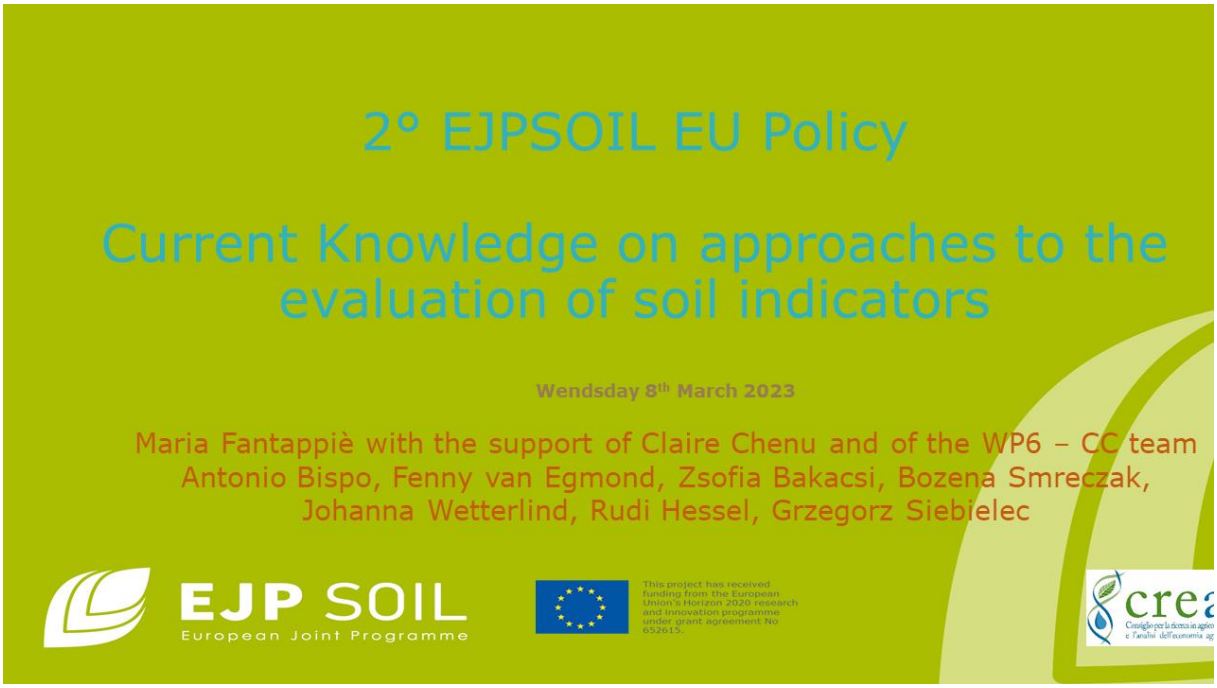
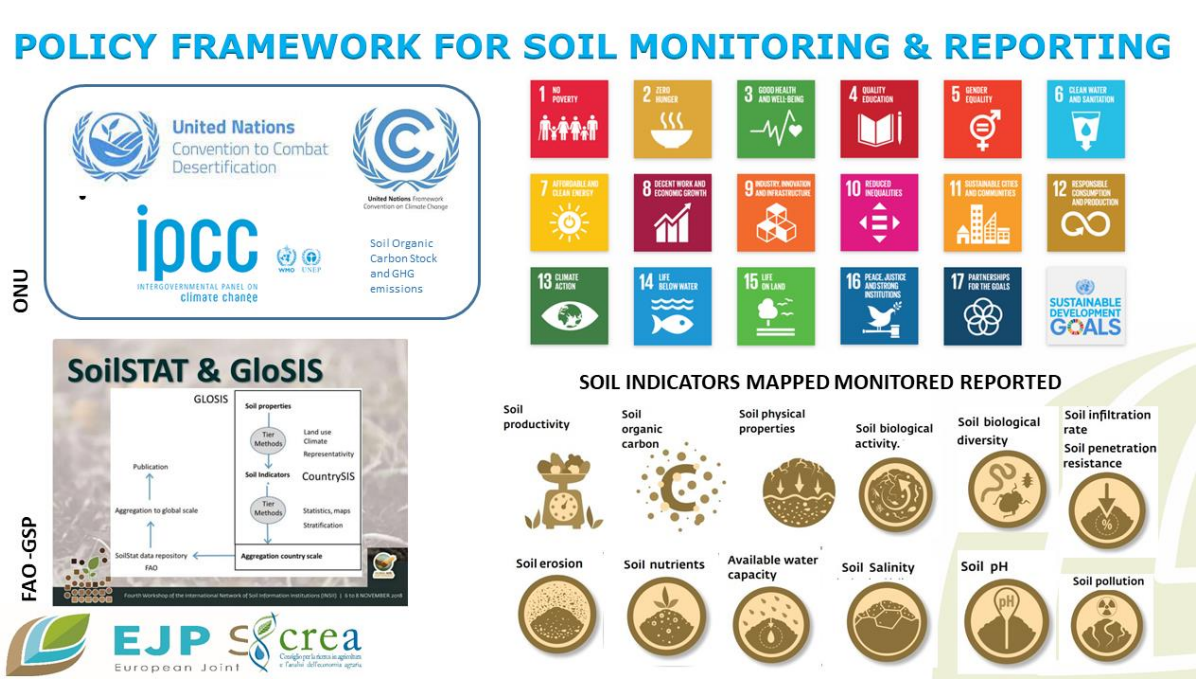
7.2. Current knowledge on the approaches to the evaluation of soil indicators





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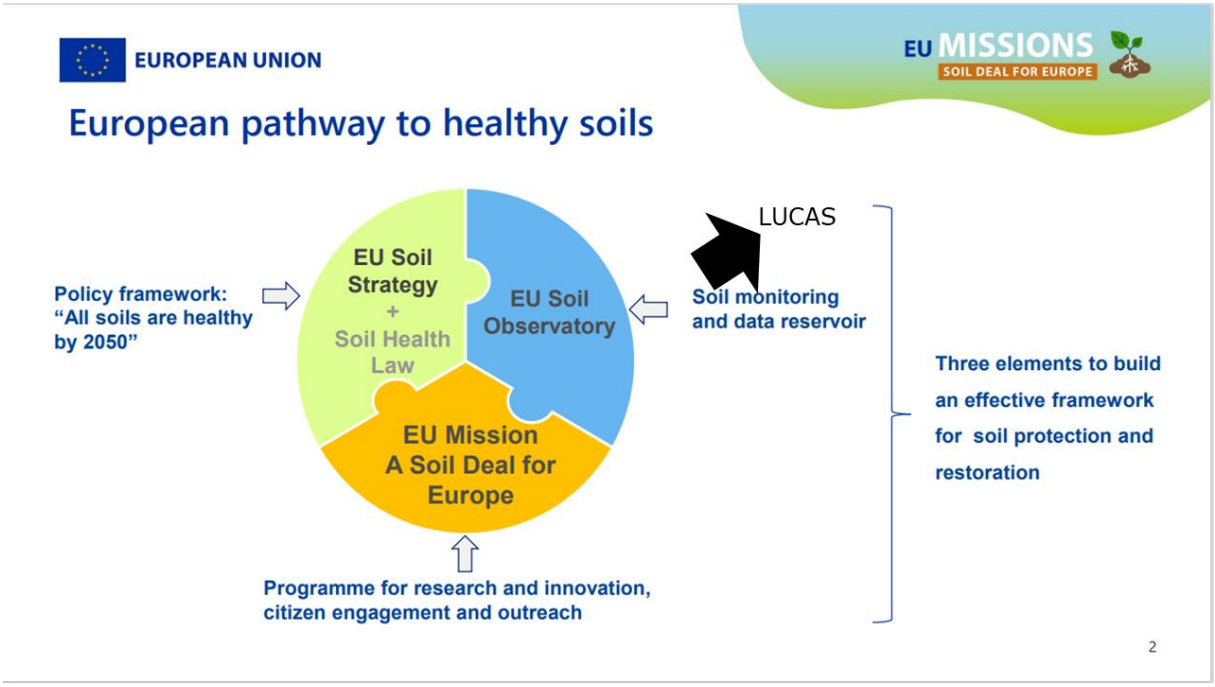

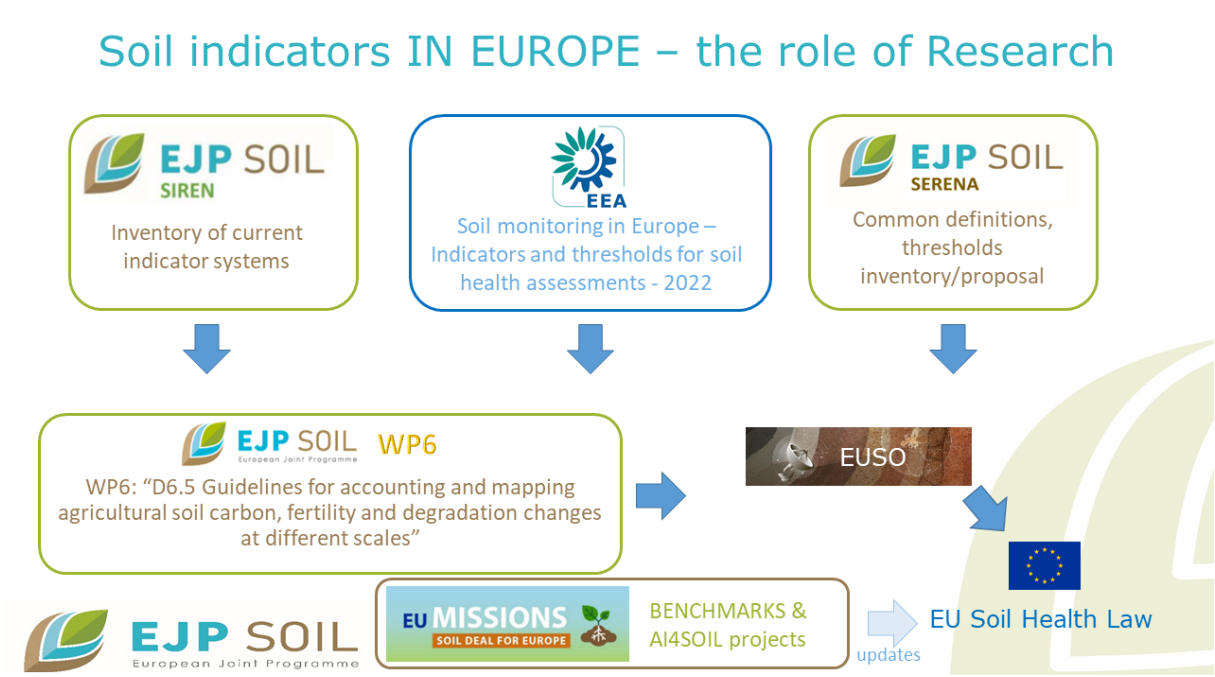

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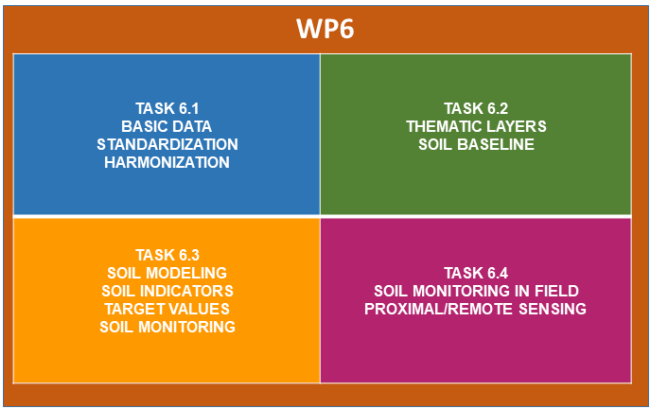
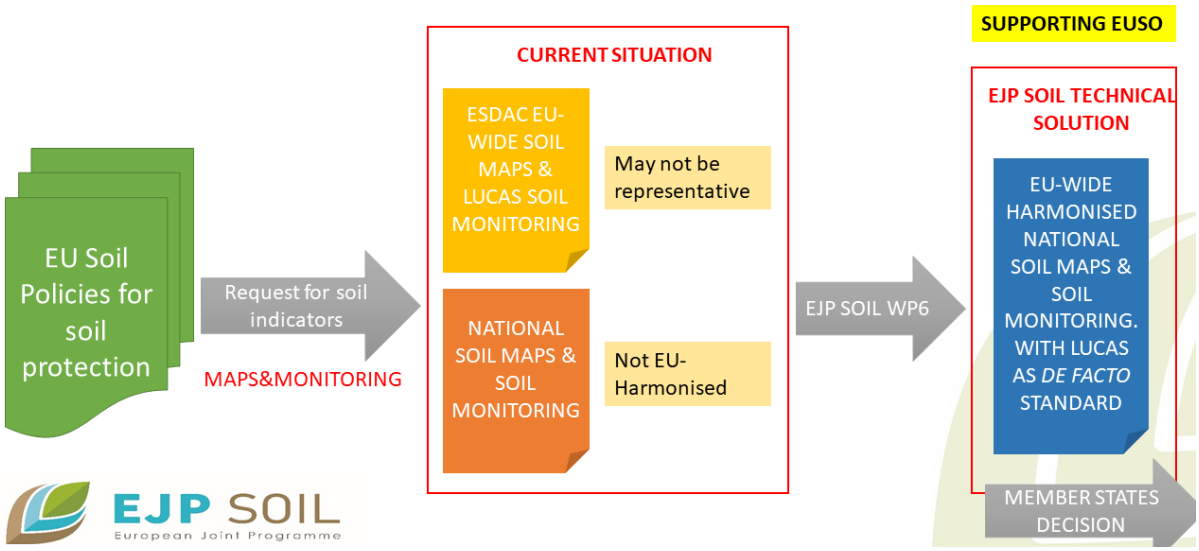
EJPSOIL - WP6 "Supporting harmonised soil information and reporting"



EJPSOIL - WP6 "Supporting harmonised soil information and reporting"

THE WP6 VISION IS CONVERGING TO EUSO VISION



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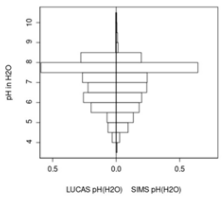
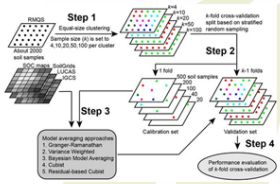
THE PROPOSED SOLUTIONS TO COMBINE LUCAS AND NATIONAL SOIL MONITORING NETWORKS

ONGOING

- **Statistical comparison** of national and LUCAS sampling strategies/schemes (develop the same approach)
- **Statistical comparison** of national data with LUCAS data, country/country (develop the same approach)
- Develop transfer functions (from sampling to analytical methods), taking the opportunity of **LUCAS 2022 DOUBLE SAMPLING**
- Identify / test methods to merge national and LUCAS datasets or existing maps
- Develop interpretation values/scoring approaches



D = 0.286, p-value = 0.617



https://ejpsoil.eu/fileadmin/projects/ejpsoil/WP6/EJP_SOIL_Deliverable_6.3_Dec_2021_final.pdf

Concepts for mapping (1-5.)

AUXILIARY VARIABLES	POINT DATASETS	DSM METHOD
Common Stack EU-wide auxiliary variables (AVs) 1_EU-wide auxiliary variable 2_EU-wide auxiliary variable 3_EU-wide auxiliary variable	(WOSIS+)LUCAS (1.) (WOSIS+) LUCAS+national point data (2.)	*DSM method*: a good EU inference model **EU-wide mapping**
n_EU-wide auxiliary variable n+1_EU-wide auxiliary variable	(The most predictive AVs at national level SELECTED from Stack) (3.) (WOSIS+)LUCAS+national point data	*DSM method*: a good national inference model
Common Stack EU-wide AVs, parly substituted by national auxiliary varaiables 1_EU-wide AVs partilally SUBSTITUTED by national AVs 2_EU-wide auxiliary variable 1_EU-wide AVs partilally SUBSTITUTED by national AVs n_EU-wide auxiliary variable n+1_EU-wide auxiliary variable	(WOSIS+)LUCAS+national point data (4.)	**Country-driven mapping for volunteers** **2-steps mixed procedure for mapping (suggested by Thunen)** (5.) a) each country selects the best inference model + b) the best EU inference model to handle transboundary effects

Research opportunities for volunteers

Research opportunities for volunteers

Utilization of **auxiliary datasets** at differenet levels	3 approaches for **co-utilization** of the LUCAS and national datasets:	b) the best EU inference model to handle transboundary effects Selection of inference **method**
Level 1. the regionally relevant parts of the European AVS **Level 2.** the best available national spatial data **Level 3.** to change the respective predictors of the best available national spatial data to those, which are derived from the European AVs.	**Approach 1.** observation data merging **Approach 2.** map products merging **Approach 3.** observation data merging with discrimination	**Approach 1.** a common, well-known, tried and trusted method should be applied by each partners **Approach 2.** mapping would be carried out using a common set of tools, and the best performing results for each country

TESTING OF THE BEST DIGITAL SOIL MAPPING PROCEDURE WITH THE BEST ACCURACY AND THE LOWEST TRANSBOUNDARY ISSUES

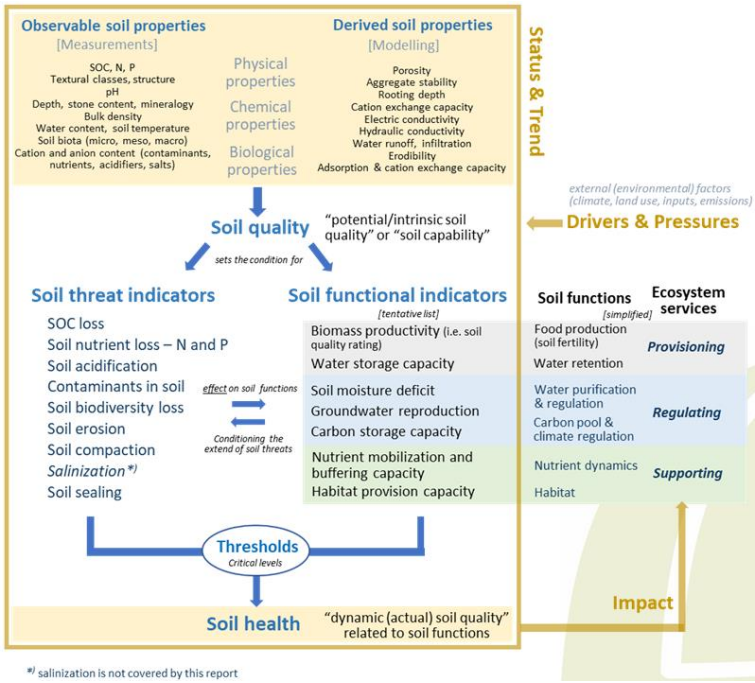
5 APPROACHES TESTED

APPROACH	POINT DATA	AUXILIARY VARIABLES	DSM METHOD
EU-WIDE	WOSIS+LUCAS	EU-WIDE	EU-WIDE-SELECTED
EU-WIDE	WOSIS+LUCAS+NATIONAL	EU-WIDE	EU-WIDE-SELECTED
COUNTRY-DRIVEN	WOSIS+LUCAS+NATIONAL	EU-WIDE	COUNTRY-BEST
COUNTRY-DRIVEN	WOSIS+LUCAS+NATIONAL	EU-WIDE+NATIONAL	COUNTRY-BEST
MIXED	2 STEP PROCEDURE, HARMONISING NATIONAL MAPS		

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Soil health indicator framework

SLIDE FROM
RAINER BARITZ
European Environment Agency



WORKING ON SOIL INDICATORS

THE DELIVERABLE D6.5 (deadline June 2023)

Guidelines for accounting and mapping agricultural soil carbon, fertility and degradation changes at different scales

SOIL FERTILITY INDICATORS	SOIL DEGRADATION INDICATORS
SOC	SOC DECLINE
SOIL NUTRIENTS AND NUTRIENTS BALANCE	SOIL NUTRIENTS DECLINE AND UNBALANCE
ECEC AND EXCHANGABLE BASES	SODIFICATION
pH	ACIDIFICATION
ELECTRICAL CONDUCTIVITY	SALINIZATION
SOIL WATER CONTENT	SOIL ARIDITY
SOIL ROOTING DEPTH	SOIL EROSION
SOIL BIODIVERSITY	SOIL BIODIVERISY LOSS
SOIL STRUCTURE	SOIL COMPACTION
	SOIL SEALING
	SOIL CONTAMINATION

EJP SOIL General Meeting, 07-06-2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Updates on **Deliverable D6.5**

Soil parameters/indicators:

- SOC (including SOC decline and effects on soil degradation, on climate...)
- Soil nutrients (including nutrient imbalance)
- ECEC and exchangeable bases (including sodification)
- pH (including acidification)
- Electrical conductivity (including salinization)
- Available water capacity (links with soil aridity)
- Soil structure (including compaction)
- Soil biodiversity (including soil biodiversity loss)
- Soil erosion
- Soil sealing
- Soil contamination

SELECTED SOIL PROPERTIES (INDICATORS)

measurable and possibly affected by management

DIFFERENT APPROACHES TO EVALUATE SOIL HEALTH INDICATORS

- **How to evaluate soil health? Using threshold/reference values ? How specific will the "Soil Health Law" be: how much will be fixed at EU-scale or local scale?**
  - Threshold values values (as done by EEA)
  - Target values based on modelling or data driven approaches … on semi-natural land uses, such as pastures (as proposed by EUSO)
  - Reference values based on the statistical population of soil districts – soil types
  - Relative changes (one of the EJPSOIL proposals) or
  - Just considering the application/not application of SSM practices.
- **Is monitoring the topsoil enough?** Soil properties are reported to vary significantly differently in topsoil and subsoil in relation to soil management practices.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Existing documents / EEA (presented during EIONET meeting Nov 2022)

Soil_Report TH-AL-22-018-EN-N.pdf

European Environment Agency

EEA Report | 2022

Soil monitoring in Europe

Indicators and thresholds for soil health assessments

Revised Version Sept. 2022

Soil threat	Land use	Indicator	Thresholds
Soil organic carbon loss	Agriculture	Deceedance of optimal SOC	Sand: 1,5 (1,0-2,0) [% SOC] Silt: 1,9 (1,4-2,4) Loam and clay: 1,6 (1,0-2,8)
Nutrient loss	Agriculture	Exceedance of critical levels of mineral nitrogen	NH_3 in air: 1 – 3 [mg NH_3 m^{-3}] NO_3 in ground water: 50 [mg NO_3 l^{-1}] N in surface water: 1.0 to 2.5 [mg N l^{-1}]
	Forest	N limitation based on exceedance of C/N ratio	C/N 20-25 leakage from forests: 1 [mg N l^{-1}]
	Agriculture	Deceedance of optimal phosphorus	P concentration 25-35 (optimal P fertility class)
	Forest	P limitation based on exceedance of N/P ratio	N/P ratio > 18 (coniferous forests) N/P ratio > 25 (deciduous forests)
Acidification	Agriculture	Critical pH levels	pH < 4.5 - 4.7
	Forest	Critical inorganic Al levels	base cation/aluminium ratio = 1 (0.5-2.0)
Soil pollution	Agriculture	Exceedance of screening values for critical risk from heavy metal pollution	Cd, Cu, Pb and Zn by country [mg/kg] (Arsenic still to be added; review of organic pollutants ongoing)
Soil erosion	Agriculture	Actual rate of soil loss by water erosion	2 [t ha^{-1} yr^{-1}] (soil loss tolerance)
Soil biodiversity loss		Loss of soil biodiversity (subindicators) *to be developed*	a) safe minimum standard of conservation b) Operating Ranges (OR) for specific soil animals and microorganisms
Soil compaction	Agriculture	Harmful subsoil compaction (subindicators) *priority (sub) indicators*	Saturated hydraulic conductivity (Ks) < 10 [cm/d] Air capacity (AC) < 5 [%]
Soil sealing		Sealed area per total area	National targets to achieve No Net Land Take

EJP SOIL European Joint Programme

SOC TARGET VALUES – EEA REPORT

EEA Report | 2022

Soil monitoring in Europe

Indicators and thresholds for so

Soil_Report TH-AL-22-018

SOIL TEXT CLASS		SOC target (% soil mass, dag kg-1) - Climatic water balance (mm) during summer – less than -100
SAND	MINERAL	0.73
SILT	MINERAL	1.89
LOAM AND CLAY	ORGANIC	0.91
LOAM AND CLAY	MINERAL	0.87

opland soils based on extensive

			nce (mm) during summer (*)	
			-100 to 0	More than 0
	Null (*)	0.70	1.2	1.7
Silt	Max. both	2.37	1.92	1.44
	Organic and mineral	2.19	1.72	1.24
	Organic	2.07	1.61	1.18
	Mineral	1.89	1.5	1.11
	Null	1.71	1.24	0.77
Loam and clay	Max. both	0.99	1.64	2.8
	Organic and mineral	0.95	1.2	2.67
	Organic	0.91	1.12	2.63
	Mineral	0.87	1.07	2.59
	Null	0.82	1.16	2.46

Notes: (*) Negative water balance: potential evapotranspiration more than precipitation during summer. Positive values indicate climate- induced surplus in the water budget from April to September.
(*) Maximal application of organic and mineral fertiliser.
(*) Null = no fertiliser applied

Source: Compiled from Wessolek et al. (2008). Data are valid for Germany and neighbouring countries for different soil textures, climatic conditions and fertilisation regimes.

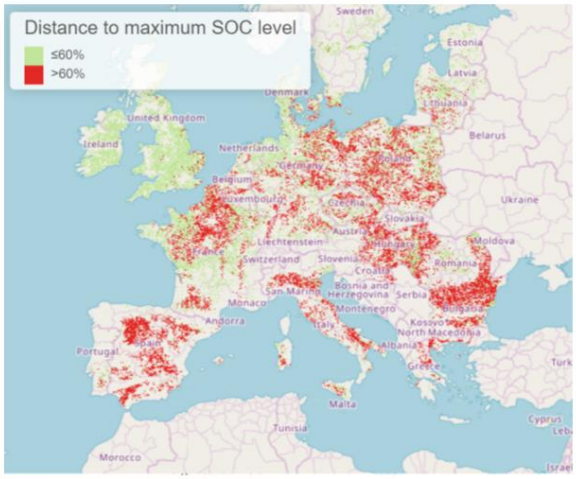
IT CONSIDERS DIFFERENT SOIL TYPES AND CLIMATES, BUT THE NOTE STATES THAT THE DATA ARE VALID FOR GERMANY AND NEIGHBOURIGN COUNTRIES.
=> TO BE TESTED

EJP SOIL European Joint Programme

European Environment Agency

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Soil degradation indicators – Distance to maximum SOC level - EUSO Dashboard prototype

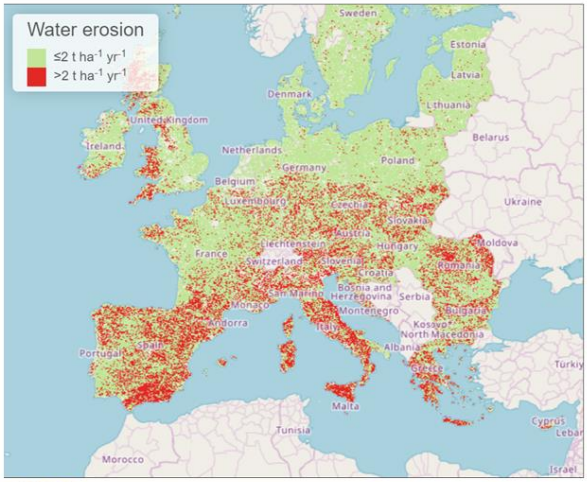


The layer covers cropland and grassland in the EU+UK. For each pixel, the **maximum SOC level is calculated as the increase in SOC content that would be achievable if the land was kept under continuous grassland for 40 years** (without ploughing). In this layer, soils are considered unhealthy if the distance that separates them from the maximum is more than 60% of current levels. Conversely, soils are healthy if current levels of SOC are close to the maximum (distance less than 60%). The 60% threshold has been chosen as providing a reasonable and pragmatic distance gap from the maximum SOC level achievable. (De Rosa D. et al., 2023, upcoming publication)

IT IS BASED ON SOC MODELING

https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/

Soil degradation indicators – Soil Water Erosion - EUSO Dashboard prototype



The layer displayed here is the result of a model combining these factors to estimate the long-term average annual rate of soil erosion on all erodible lands in the EU+UK. The layer covers all erodible types of land (agricultural, forests, grasslands, sparse vegetation areas). **Soils which were estimated to have an erosion rate higher than 2 tonnes ha-1 yr-1 are considered unhealthy**, because this is significantly higher than the average rate of soil formation in Europe estimated to be 1.4 tonnes ha-1 yr-1 (Panagos et al., 2015 - RUSLE 2015)

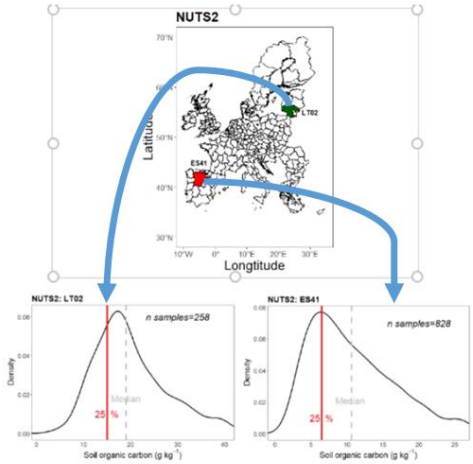
IT IS BASED ON A THRESHOLD
(THE SAME AS SET BY EEA REPORT)

https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

EUSO Dashboard (work in progress) (presented at EIONET meeting Nov 2022)

Soil Districts and Thresholds

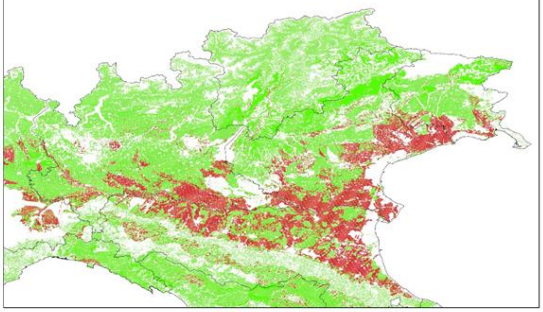


METHOD PROPOSED BUT STILL NOT APPLIED IN THE EUSO DASHBOARD

SOC DECLINE RISK AREAS

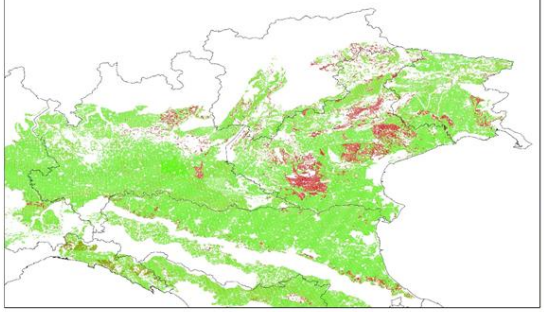
USING NATIONAL DATA

Applying EEA thresholds approach



SOIL TEXT CLASS		SOC target (% soil mass, dag kg-1) - Climatic water balance (mm) during summer <-100
SAND	MINERAL	0.73
SILT	MINERAL	1.89
LOAM AND CLAY	ORGANIC	0.91
LOAM AND CLAY	MINERAL	0.87

Applying reference values



Applying an approach of **reference values in the population of the Soil Types**. The target considered for arable lands was set as reaching the 60% of mean SOC content of meadows in the same Soil Type population.

THE ACTUAL HIGHER VALUES IN THE POPULATION ARE LOWER THAN THE OPTIMAL VALUES ESTIMATED BY MODELING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

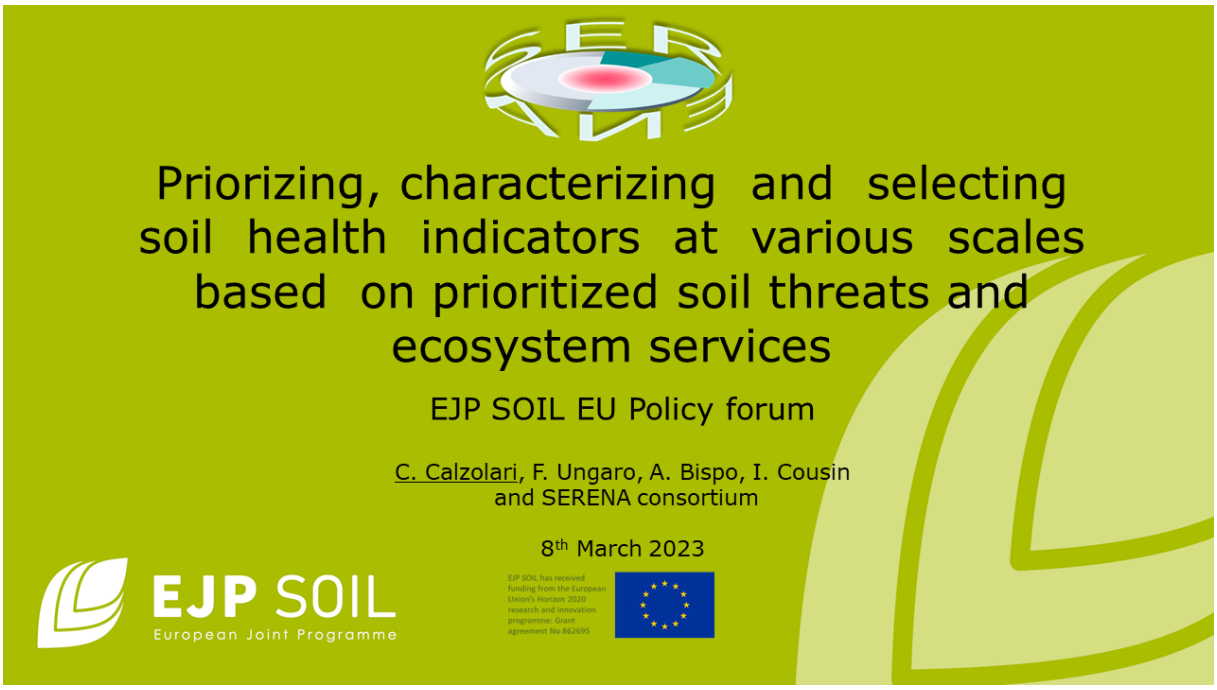
DIFFERENT APPROACHES TO EVALUATE SOIL HEALTH INDICATORS – PROS AND CONS – EJPSOIL SCIENTISTS

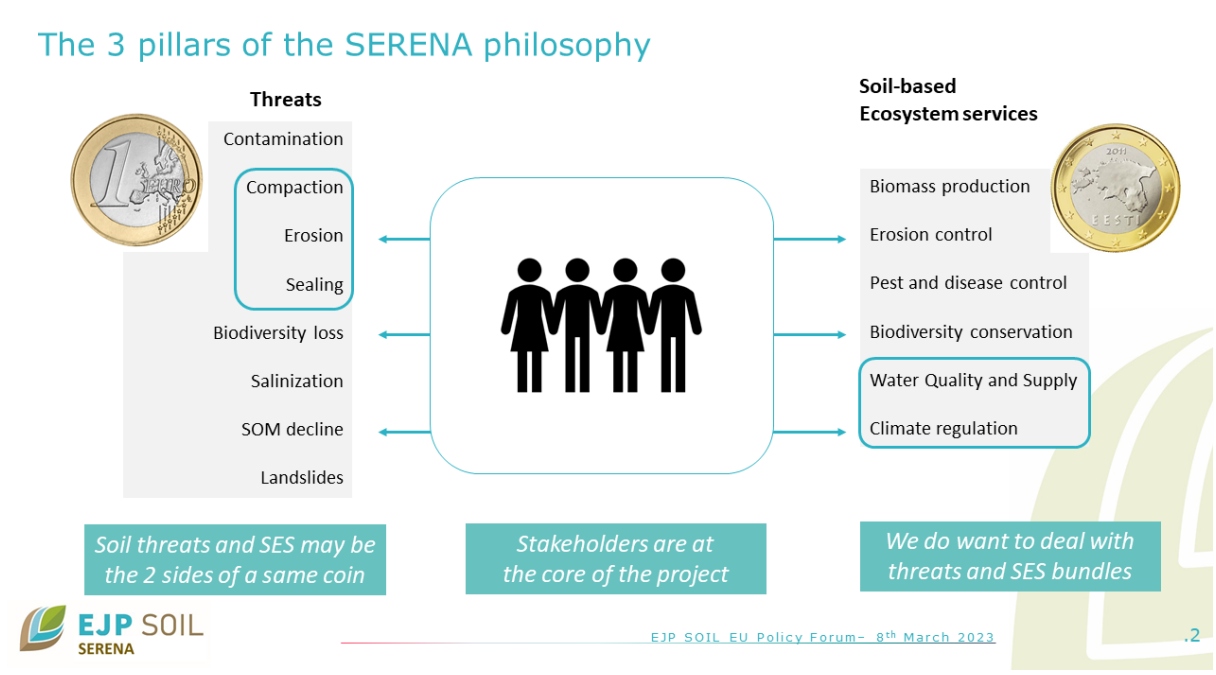
	DISTRIBUTION	THRESHOLDS	MODELING – NATURAL OPTIMAL VALUES	RELATIVE CHANGES
PROS	• Thresholds adapted to soil districts – pedoclimatic conditions.	• Simple also for no scientists	• If the modelling is properly elaborated could work fine to fix target values.	• Is a quick way to start evaluating the trends. • Allows for differentiation given by diverse pedoclimatic conditions.
CONS	• Lot of information needed, to have statistical distributions and must be stratified. • If the area is already degraded, then the information is biased.	• Needs stratifications: the thresholds must be adapted to specific pedoclimatic conditions. • Lot of information needed.	• There is few natural lands available in Europe to be taken as a reference: most forest and rangelands are managed. • Difficult to explain.	• May give problems to credit the farmers that have already done well.

SUMMARISED RESULTS OF A KLAXOON PERFORMED IN AN EJPSOIL INTERNAL MEETING OF SOIL INDICATORS EXPERTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

7.3. Prioritizing, characterising and selecting soil health indicators at various scales based on prioritized soil threats and ecosystem services

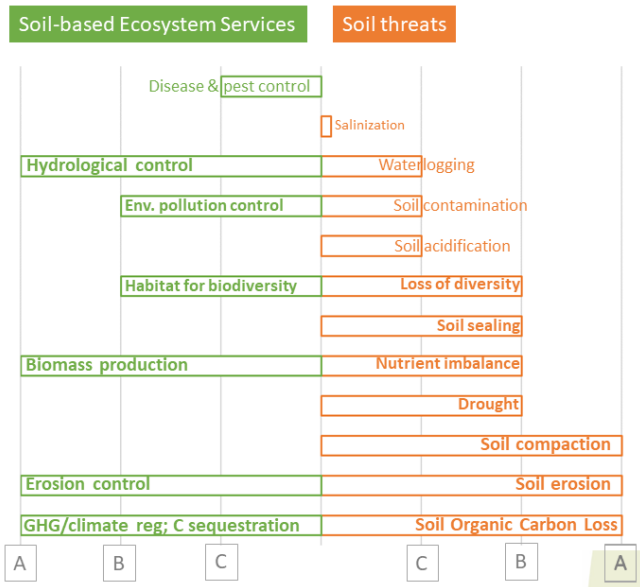




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Prioritization of **Soil Threats** and **Ecosystem Services** in the SERENA consortium

A : « very important »
B : « important »
C : « less important »



EJP SOIL SERENA

Main **Soil threats**

Proportion of literature studies dealing with **Soil Threats** at the EU scale

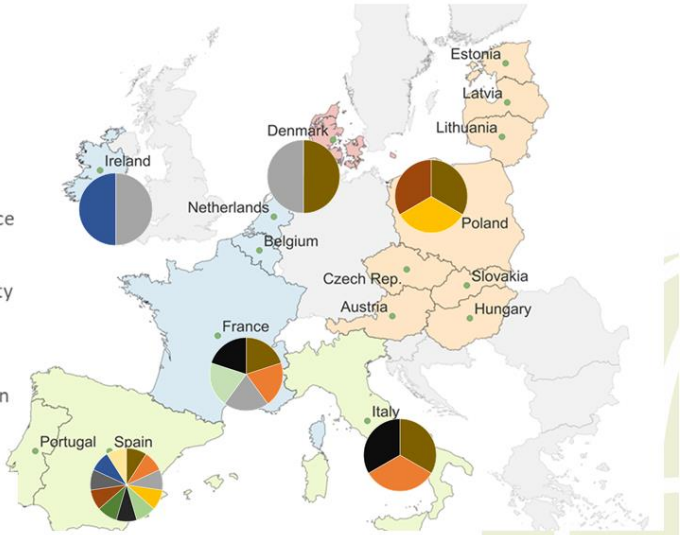
A
- SOC loss
- Soil erosion
- Soil compaction

B
- Drought
- Nutrient imbalance
- Soil sealing
- Loss of biodiversity

C
- Soil acidification
- Soil contamination
- Water logging

D
- Salinization

Soil Threats
priorization by Member states



EJP SOIL SERENA

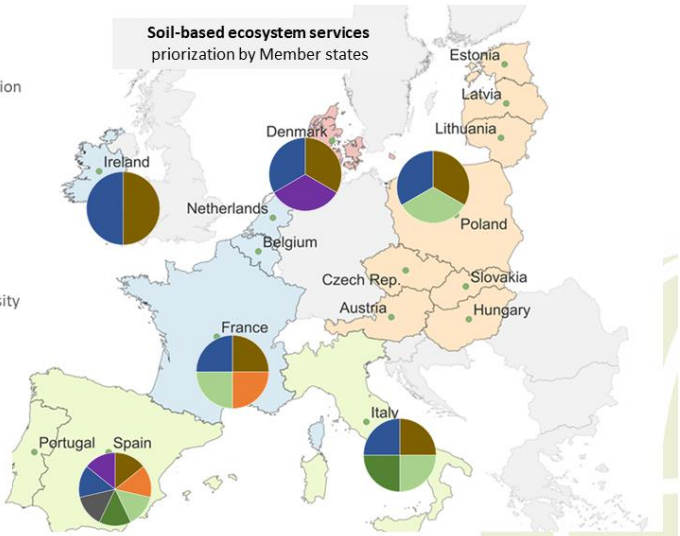
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Main **Soil-based Ecosystem services**

Proportion of literature studies dealing with **Soil-based Ecosystem Services** at the EU scale

- A
  - GHG climate regulation
  - Erosion control
  - Biomass production
  - hydrological control
- B
  - Habitat for biodiversity
  - Environmental pollution control
- C
  - Pest and disease control

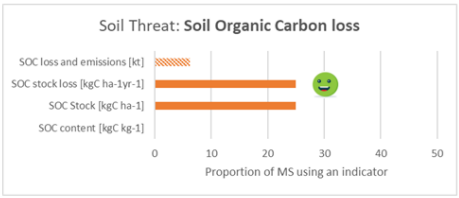
Soil-based ecosystem services priorization by Member states

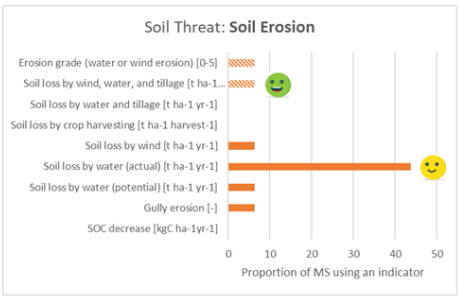


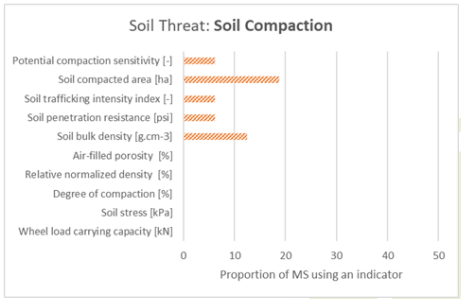
EJP SOIL SERENA

Soil threats indicators / potential for harmonization accross Europe

- Indicator selected from the literature
- Other indicator used by MS at regional or national level
- « Ideal » indicator for harmonisation
- « realistic » indicator for harmonisation



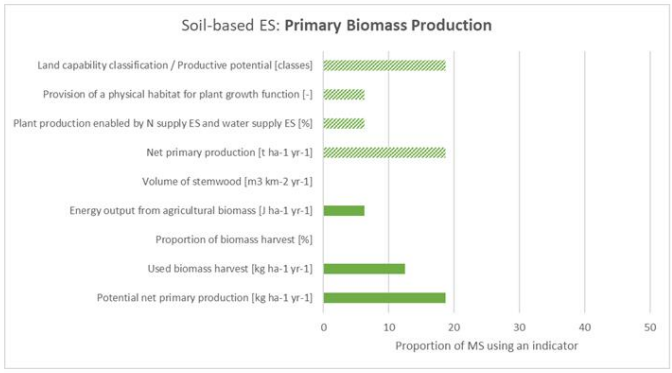


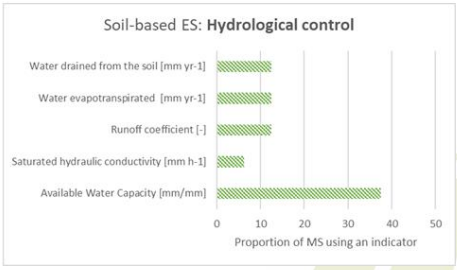


EJP SOIL SERENA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Soil-based ecosystem services indicators / potential for harmonization accross Europe





Indicator selected from the literature

Other indicator used by MS at regional or national level

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • Interpretability • Sensitivity
Data availability	• Measureability • Scability
Ability to convey information	• Intuitivity • Policy implementation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• **Fitnesss-to-purpose** • Interpretability • Sensitivity
Data availability	• Measureability • Scability
Ability to convey information	• Intuitivity • Policy implementation

Fitness: Rates the nature of the object targeted by the indicator considering that SERENA aims at quantifying soil threats and soil-based ES

12 ST: The indicator represents the actual risk for a threat (i.e., a process that can degrade the soil conditions, functions or the services that soils provide) under current conditions and type of use

12 ES: The indicator represents the amount of a service (i.e. the contribution of the natural system to human well-being before the addition of built, human or social capital) used or experienced by people under current conditions and type of use

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • **Interpretability** • Sensitivity
Data availability	• Measureability • Scability
Ability to convey information	• Intuitivity • Policy implementation

Interpretability: Rates how the variable is expressed according to the possibility and the ease of spatial and temporal comparison and interpretation

12 Quantitative variable for which references, thresholds or target values are politically or scientificaly defined

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • Interpretability • **Sensitivity**
Data availability	• Measureability • Scability
Ability to convey information	• Intuitivity • Policy implementation

Sensitivity: Rates the sensitivity of the indicator to changes in climate, soil, use and or management conditions

12 The assessment of the indicator depends on all the conditions mentioned

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • Interpretability • Sensitivity
Data availability	• **Measureability** • Scability
Ability to convey information	• Intuitivity • Policy implementation

Measurability: Rates the availability of the indicator into formats widely used and made available for easy access. When not available, it rates the possibility and the ease in measuring the indicator

12 Variable currently available in databases

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • Interpretability • Sensitivity
Data availability	• Measureability • **Scability**
Ability to convey information	• Intuitivity • Policy implementation

Scalability: Rates the current applications of the indicator from local to European levels and, when applied at the European level, the type of spatial and temporal coverage

12 The indicator has been applied at the European level, is spatial exhaustive (no spatial division) and refers to one of the last five years (at least)

EJP SOIL SERENA

EJP SOIL EU Policy Forum– 8th March 2023 .13

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • Interpretability • Sensitivity
Data availability	• Measureability • Scability
Ability to convey information	• **Intuitivity** • Policy implementation

Intuitivity: Rates the understandability of the indicator by policy makers and non technical audiences

12 The indicator is easily and clearly understood by policy makers or non-technical audiences

EJP SOIL SERENA

EJP SOIL EU Policy Forum– 8th March 2023 .14

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • Interpretability • Sensitivity
Data availability	• Measureability • Scability
Ability to convey information	• Intuitivity • **Policy implementation**

Policy implementation: Rates the relevance of the indicator in addressing the key environmental issues faced by governments and other stakeholders

12 The indicator is implemented in the European environmental policies or in all MS minus 5

EJP SOIL SERENA

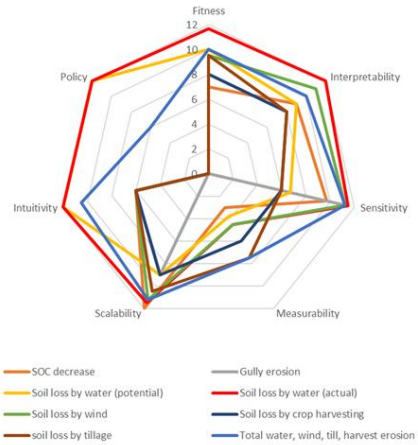
EJP SOIL EU Policy Forum– 8th March 2023 .15

Strategy to choose indicators

Elements to characterize the indicators

Family of criteria	Characteristics
Scientific soundness	• Fitnesss-to-purpose • Interpretability • Sensitivity
Data availability	• Measureability • Scability
Ability to convey information	• Intuitivity • Policy implementation

Ranking and **selecting** the indicators (example soil erosion)



EJP SOIL SERENA

EJP SOIL EU Policy Forum– 8th March 2023 .16

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

To conclude… next SERENA EJP SOIL activities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

7.4. Prioritising and selection of soil health relevant biological indicators

EJP Soil Policy Forum
WP8 - EJP SOIL Scientific Support for the Soil Health Law
8th March 2023

Prioritizing and selection of soil health relevant biological indicators

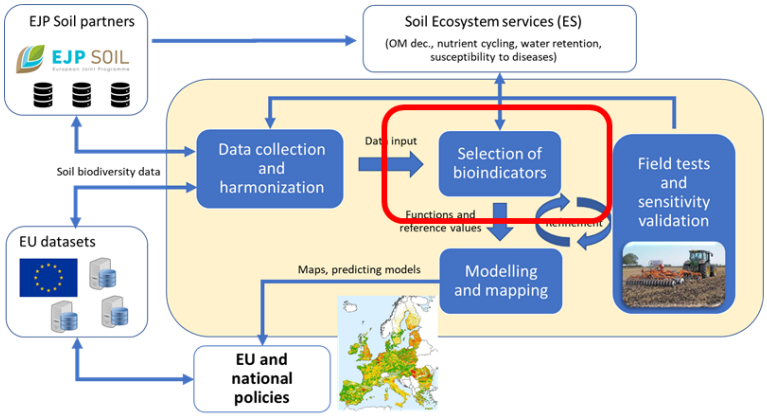
Coordinator: Stefano Mocali (CREA)
Co-Coordinator: Jack Faber (WR)

EJP SOIL has received funding from the European Union's Horizon 2020 research and innovation programme: Grant agreement No 862695

1

The MINOTAUR project
Modeling and mapping soil biodiversity patterns and functions across Europe

MINOTAUR aims to provide models, maps and policy-relevant **biological indicators** with validated reference values for monitoring soil biodiversity and associated functions.



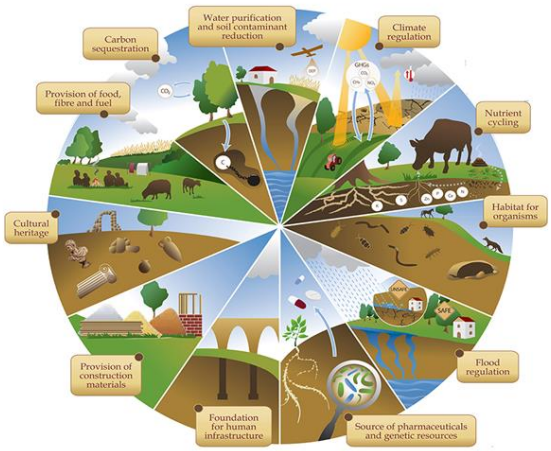
The project will collaborate with relevant international soil biodiversity networks and programs to harmonize and integrate soil biodiversity data and contribute to support long-term harmonized EU soil information.

WP8 - EJP SOIL Scientific Support for the Soil Health Law, 8th March 2023 2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Ecosystem services provided by soil and its biota

Service type	Goods or services provided
Provisional	Clean water through infiltration; Production of food, fuel, fibre and raw materials
Regulative	Mitigation of floods and droughts through water retention; Regulation of biogeochemical cycling, global climate patterns, animal and plant populations, and potential pests and pathogens; Erosion control; Bioremediation; Translocation of nutrients, particles, gasses (incl. trace gasses)
Supporting (processes)	Nutrient cycling incl. decomposition, retention and delivery of nutrients; Soil biological activity; Soil formation; Water cycling



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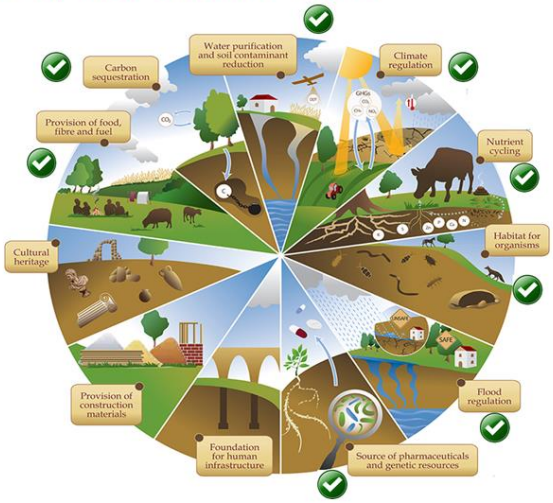

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Soil health objectives, targets and indicators across Europe

1. Land degradation and desertification
2. Soil organic carbon
3. Soil sealing and net land take
4. Soil pollution
5. Erosion
6. Soil structure (compaction)
7. Global footprint

NO biological indicators!

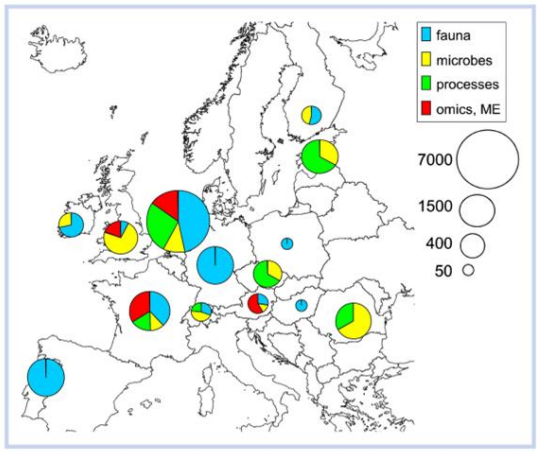
Specific Targets and Indicators			
Objectives	**Land Management Targets**	**Soil Health Targets**	**Six Soil Health Indicators**
Land degradation and desertification	*50% degraded land restored*	*Strong reduction in degradation and desertification*	*All 6 soil health indicators*
Soil organic carbon	*Conservation of high carbon soils and a reverse of carbon loss in croplands.*	*A switch from a 0.5 % loss per year to a 0.1-0.4% increase in SOC concen-tration in cropland soils* *30-50% reduced area of peatland losing carbon*	*Soil organic carbon stock* *Vegetation cover*
Soil sealing and net land take	*Urban recycling of land from 13 to 50%* *No net land take by 2050*	*Switch from 2.4% to no net soil sealing*	*Soil structure including soil bulk density and absence of soil sealing and erosion* *Vegetation cover*
Soil pollution	*25% of land under organic farming* *Doubling of rate of remediated sites prioritising brown field sites*	*5-25% additional land (i.e. over and above the 25% in full organic) with reduced risk from a range of pollutants*	*Presence of soil pollutants, excess nutrients and salts*
Erosion	*50% degraded land restored*	*Prevention on 30-50% of land with unsustainable erosion risk*	*Soil structure including soil bulk density and absence of soil sealing and erosion.* *Vegetation cover*
Soil structure	*50% degraded land restored*	*Reduction by 30-50% of soil with compaction*	*Soil bulk density and other measures of soil structure*
While not being a soil indicator in the strict sense, mission activities will be assessed against their impact on the health of soils outside Europe			
Global footprint	*Strenathened international cooperation; trade regulations, including carbon tax*	*20-40% reduction of current global footprint*	*Food, feed and fibre imports leading to land degradation and deforestation*

Table 1 Objectives of the mission board and the targets and indicators used to assess progress and achievement. (Source MB 2020)

Use of soil biodiversity indicators across Europe (from EcoFINDERS)

Although all soil biodiversity indicators have been used extensively over the last 2 decades, their use across Europe is rather heterogeneous.

Whereas the literature review allowed the identification of approximately 100 potential indicators, the inventory of existing monitoring networks showed that few indicators were actually used.



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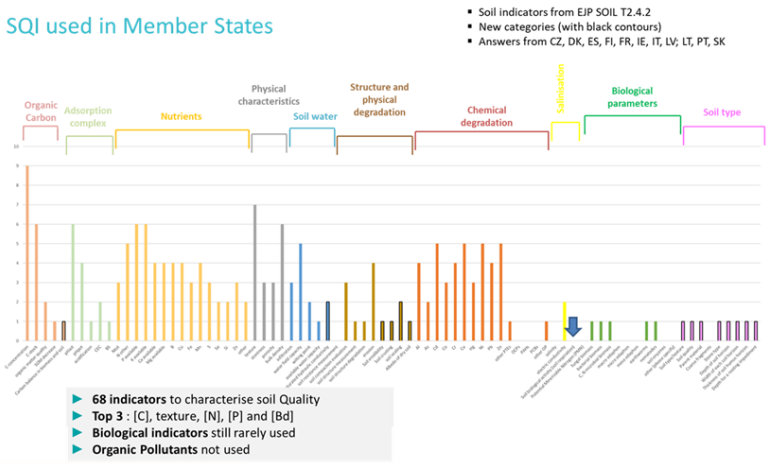
From SIREN

SQI used in Member States



- Biological activity (soil respiration)
- Potential Minerizable Nitrogen (PMN)
- fungal biomass
- bacterial biomass
- C, N microbial biomass
- macro edaphon
- micro edaphon
- meso edaphon
- earthworms
- nematodes
- soil enyzmes
- Bacterial activity (thy-uptake)
- Bacterial diversity (number DNA bands)
- Potential C mineralization
- Functional diversity (AWCD curve gradient)
- Functional activity
- Potworm density
- Potworm diversity (number of taxa)
- Microarthropod density
- Microarthropod diversity (number of taxa)
- Stability (allometric M,N regression)
- Biodiversity (total number of taxa)

Implementation of biological indicators as part of national campaigns on soil health monitoring, as reviewed under 24 EJP SOIL Member States (source: EJP Soil D2.2).

Indicator	Measurement	Degree of implementation (n. of countries)	Number of countries with evaluation criteria established		
			Reference value	Threshold value	Target value
Biological activity	Soil respiration	7		1	
	Soil enzymes	5			
	Potential Minealizable Nitrogen	4	1	1	
Microorganisms	C, N microbial biomass	6	1	1	
	Bacterial biomass (various methods)	5	2		
	Bacterial activity (Thy-incorporation)	1	1		1
	Fungal biomass (various methods)	5			
Macro-edaphon	Invertebrate species counts	3	1		
	Earthworms, species composition and biomass, ecological groups	6	3	2	1
Meso-edaphon	Collembola/ Acari species counts, trophic groups	4	1		
	Nematodes species composition, trophic groups, coloniser-persister groups	5	1		
Micro-edaphon	Protozoa counts	3	1		

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Relevancy of some biological indicators with respect to Green Deal Strategies (source: EJP Soil, EcoFINDERS, literature)

Indicator	Measurement	Relevancy for EU policy objectives			Translation into ecosystem services
		Soil Strategy	Biodiversity Strategy	Climate Strategy	
Biological activity	Soil respiration	-	-	+/-	-
	Soil enzymes	+	-	-	-
	Potential Mineralizable Nitrogen	+	-	-	+/-
Microorganisms	C, N microbial biomass	+	-	+/-	-
	Bacterial biomass (various methods)	+	-	+/-	+/-
	Bacterial diversity (DNA metabarcoding)	+/-	+	-	-
	Bacterial activity (Thy-incorporation)	+	-	+/-	-
	Fungal biomass (various methods)	+	-	+/-	+
	Fungal diversity (DNA metabarcoding)	+/-	+	+/-	-
Macro-edaphon	Invertebrate species counts	+/-	+	-	-
	Earthworms, species composition and biomass, ecological groups	+	+/-	+	+
Meso-edaphon	Collembola/ Acari species counts, trophic groups	+	+	-	-
	Nematodes species composition, trophic groups, coloniser-persister groups	+	+	-	-
Micro-edaphon	Protozoa counts	+	-	-	-
Soil fauna	Diversity (16S+18S DNA metabarcoding)	+/-	+	-	-

Bünemann et al. 2018, Faber et al., 2021

Soil functional groups

Soil hosts more than 25% of all biodiversity on the planet. Soil organisms can be classified into three main groups which describe the principal function they perform in the soil:

1) Chemical engineers (**CE**): are the smallest organisms in soil. They decompose and mineralize organic matter, transform residues into nutrients and play a key role in bioremediation.

2) Biological regulators (**BR**): are a diverse bunch which control the activities of the chemical engineers, and form a crucial link in the food web by regulating biological dynamics through grazing, predation or parasitism, control of soil-borne pests and diseases

3) Ecosystem engineers (**EE**): spend their lives restructuring the soil matrix, mixing and moving soil as they graze, and creating habitable spaces and conditions for other soil organisms. Their indirect contribution to nutrient cycling plays a key role in improving soil fertility and plant production

Microorganisms

Microfauna

Mesofauna

Macrofauna

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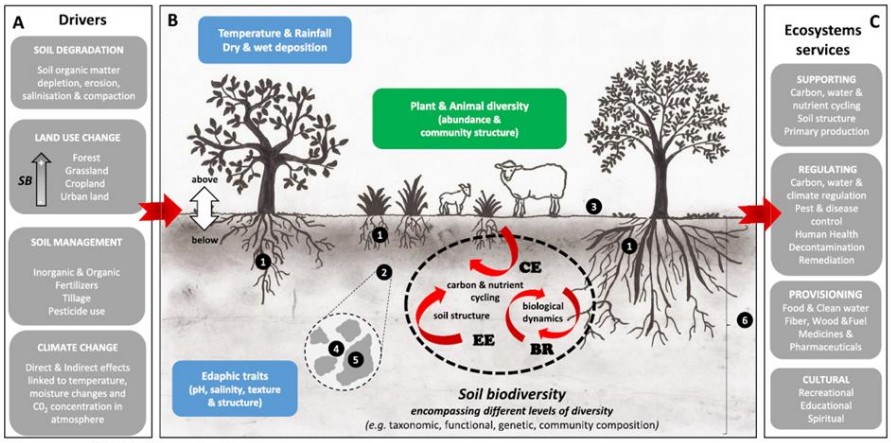
Soil biodiversity overview



Source: El Mujtar et al., 2019

Soil ecosystems services (C) depend on diversity and specific functional activity of CE (e.g. nutrient cycling, mineralization of organic matter, bioremediation), BR (e.g. regulation of biological dynamics through grazing, predation or parasitism, control of soil-borne pests and diseases), and EE (e.g. creation and modification of soil structure)

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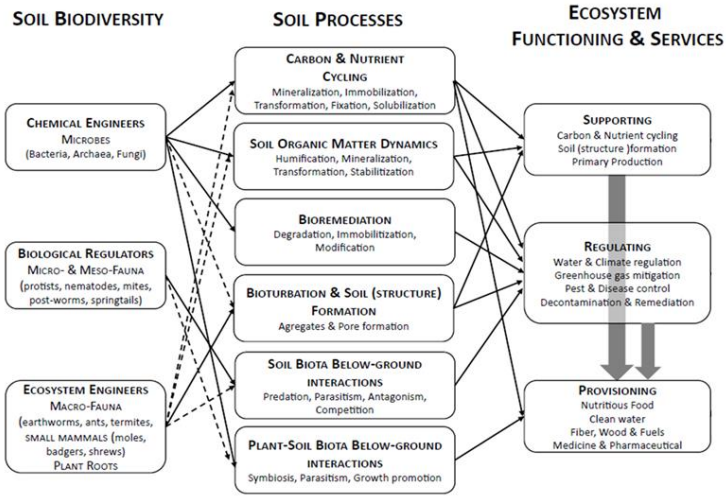
Relationships between soil biodiversity, soil processes and ecosystem functioning and services

Soil biodiversity contribute to soil processes and, consequently, to ecosystem functioning and services including food security and human health.



Source: El Mujtar et al., 2019

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Proposal of a 2-tiered system of biological indicators

Priority level	Recommended indicators		Brief description	Methodology	Cost efficiency	Sensitivity to degradation processes
Tier I	Functional indicators	Microbial biomass C	Amount of microbial biomass per gram soil	ISO 14240-1:1997 ISO 14240-2:1997	Easy and cheap	1. Declining of SOC 2. Desertification 3. Erosion 4. Soil sealing and urbanization 5. Pollution and salinization 6. Compaction
		Microbial respiration	Production of CO2 per amount of soil	ISO 16072:2002	Easy and cheap	
		Enzyme activity	Measurement of several hydrolase activities in soil	ISO 20130:2018 ISO/TS 22939:2019	Easy and cheap	
	Structural indicators	Macrofauna (Earthworms)	Structural and functional diversity	ISO 23611-1:2018	Easy and cheap	
		Mesofauna	Structural and functional diversity	ISO 23611-2:2006 QBS-ar (Parisi et al., 2005)	Easy and cheap	
		Nematodes	Structural and functional diversity	ISO 23611-4:2006	Easy and cheap	
		Microbiota (bacteria and fungi)	Structural diversity of soil microbiota	DNA metabarcoding (ISO 11063:2020) and Plassart et al., 2012	Costs are reducing, tends to become easy and cheap	

HIGH PRIORITY

Proposal of a 2-tiered system of biological indicators

Priority level	Recommended indicators	Brief description	Methodology	Cost efficiency	Sensitivity to degradation processes
Tier II	N Mineralization	Rate of microbial degradation of an organic substance containing nitrogen	ISO 14238:2012 May require proper sampling dates	Easy and cheap	1. Declining of SOC 2. Desertification 3. Erosion 4. Soil sealing and urbanization 5. Pollution and salinization 6. Compaction
	Microfauna (Protista)	Abundance and diversity	Based on DNA metabarcoding (Santos et al., 2015)	Easy and cheap	
	Specific functional genes	Abundances of particular known genes (e.g. amoA, nifK) in soil.	ISO 17601:2016 qPCR	Easy and cheap	
	Soil fauna activity	Functional diversity	Litter bags (Brad ford et al., 2002), Bait lamina (ISO 18311:2016) May require proper sampling dates	Easy and cheap	
	Microbial community ecophysiological profile	Microbial metabolic potential	AWCD (BIOLOG)	Easy and cheap	

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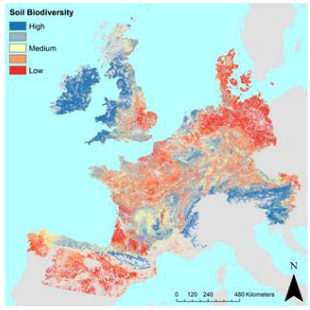
National scale soil biological surveys

A number of national surveys have been established in the last 20 years which include monitoring of soil biodiversity or ecosystem function, (i.e. The Netherlands (BISQ, NSMN) (Rutgers et al., 2009, 2019), France (RMQS), (Cluzeau et al., 2009), UK (Countryside Survey) (Black et al., 2003), Italy (QBS-ar in Emilia Romagna Region) (Menta et al., 2017) and Germany (BDF) (Römbke et al., 2013), etc.



Spatial scale of application of selected indicators

National/Regional survey	Reference	Microbial biomass	Soil respiration	BIOLOG	Enzyme activity	Macrofauna (Earthworms)	Mesofauna (QBS-ar)	Microfauna (nematodes)	Microbiota (Bacteria & Fungi)
Netherland	DSQN-BISQ (Rutgers et al., 2009)	X	X	X		X			
	BLN (Agricultural Soil Quality in NL)	X	-			X			
Belgium	Krüger et al., 2017	X	X	X		X			
France	RMQS-Biodiv programme (Cluzeau et al., 2012, Imbert et al., 2022)	X	X	X		X			
UK	Countryside Survey-SQID	X	-	-		-			
EU	LUCAS	X	X	-	-	X	X*	X	X

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A minimum set of indicators is needed

TOC → Biodiversity → Soil health

However:

- Single indicators are not always reliable (i.e. soil respiration)
- Soil with low TOC values are not always «unhealthy»
- Etc.

Soil health relevant biological indicators

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Soil health relevant biological indicators

- Soil respiration

Soil health relevant biological indicators

- Soil respiration
- Microbial biomass

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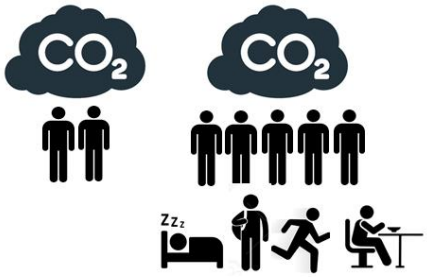
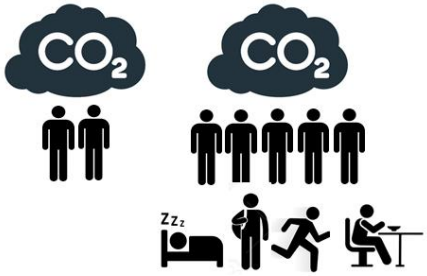
Soil health relevant biological indicators



- Soil respiration
- Microbial biomass
- Enzyme activity

Soil health relevant biological indicators



- Soil respiration
- Microbial biomass
- Enzyme activity

Functional indicators

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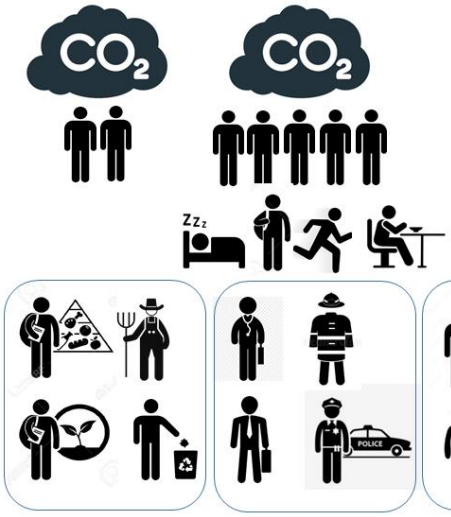
Soil health relevant biological indicators



- Soil respiration
- Microbial biomass
- Enzyme activity

- Chemical Engineers
- Biological Regulators
- Ecosystem Engineers

Conclusions

1. Standardized, scientifically proven and cost-effective biological indicators are available
2. Proposal for standardized 2-**tiered system** of biological indicators for soil health assessment and monitoring (minimum dataset)
3. Biological indicators should be contextualized with soil chemical-physical data in a specific scenario (soil type, climate, land use and management)
4. A holistic-based integration of multiple soil health indicators is recommended
5. Work on validation/refinement of bioindicators under field conditions (in progress)
6. Work on establishment of thresholds/target values (in progress)

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