Received: 30 October 2023 | Revised: 4 March 2024 | Accepted: 6 March 2024

DOI: 10.1111/ejss.13476

SURVEY ARTICLE

European Journal of Soil Science WILEY

Do we speak one language on the way to sustainable soil management in Europe? A terminology check via an EU-wide survey

Thomas Weninger[1] | David Ramler[1] | Giulia Bondi[2] | Sabina Asins[3] | Lilian O'Sullivan[2] | Francesca Assennato[4] | Alar Astover[5] | Antonio Bispo[6] | Luboš Borůvka[7] | Gabriele Buttafuoco[8] | Costanza Calzolari[9] | Nádia Castanheira[10] | Isabelle Cousin[6] | Erik van den Elsen[11] | Cecilie Foldal[12] | Rudi Hessel[11] | Žydrė Kadžiulienė[13] | Liia Kukk[5] | Maria J. Molina[3] | David Montagne[14] | Katrien Oorts[15] | Sylwia Pindral[16] | Fabrizio Ungaro[9] | Agnieszka Klimkowicz-Pawlas[16]

[1]Institute for Water and Land Management Research, Federal Agency for Water Management, Petzenkirchen, Austria

[2]Teagasc, Crops, Environment, Land Use Programme, Johnstown Castle, Co., Wexford, Ireland

[3]Centro de Investigaciones sobre Desertificación (CSIC, UV, GVA), Albal, Spain

[4]Institute for Environmental Protection and Research (ISPRA), Rome, Italy

[5]Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Tartu, Estonia

[6]INRAE, Info&Sols, Orléans Cedex 2, France

[7]Department of Soil Science and Soil Protection, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Prague-Suchdol, Czech Republic

[8]Institute for Agriculture and Forestry Systems in the Mediterranean, National Research Council of Italy (CNR-ISAFOM), Rende, Italy

[9]Institute of Bio Economy, National Research Council (IBE-CNR), Firenze, Italy

[10]National Institute of Agricultural & Veterinary Research, I.P. (INIAV), Oeiras, Portugal

[11]Team Soil, Water, and Land Use, Wageningen Environmental Research, Wageningen, The Netherlands

[12]Department Forest Ecology and Soil, Austria Research Centre for Forest, Vienna, Austria

[13]Lithuanian Research Centre for Agriculture and Forestry, Akademija, Lithuania

[14]Université Paris-Saclay, INRAE, AgroParisTech, UMR ECOSYS, Palaiseau, France

[15]Flemish Planning Bureau for the Environment and Spatial Development (VPO), Government of Flanders, Brussels, Belgium

[16]Institute of Soil Science and Plant Cultivation—State Research Institute (IUNG), Puławy, Poland

Correspondence
David Ramler, Institute for Water and Land Management Research, Federal Agency for Water Management,

Abstract

European soils are under increasing pressure, making it difficult to maintain the provision of soil ecosystem services (SESs). A better understanding of soil

Thomas Weninger and David Ramler contributed equally to this study.

Petzenkirchen, Austria.
Email: david.ramler@baw.at

Funding information
Horizon 2020 Framework Programme, Grant/Award Number: 862695

processes is needed to counteract soil threats (STs) and to promote sustainable soil management. The EJP SOIL programme of the EU provides a framework for the necessary research. However, different definitions of soil-related terms potentially lead to varied understandings of concepts. Furthermore, there are numerous indicators available to quantify STs or SESs. As unclear communication is a key barrier that hinders the implementation of research results into practice, this study aimed to answer the question about whether the terminology of large-scale initiatives is adequately understood within the soil-science community and non-research stakeholders. An online questionnaire was used to provide definitions for 33 soil-related terms in both scientific and plain language, as well as indicators for seven SESs and 11 STs. Participants were asked to rate their agreement with the definitions and indicators on a seven-grade Likert scale. The level of agreement was calculated as the percentage of ratings above 4, the neutral position. The survey was available from June to September 2023 and was distributed by a snowball approach. More than 260 stakeholders assessed the survey; 70% of respondents were researchers, and 15% were practitioners. Mean agreement levels for the definitions and indicators were generally high, at 85% and 78% respectively. However, it was apparent that the lowest agreement was found for terms that are relatively new, such as *Ecosystem Services* and *Bundle*, or unfamiliar for certain subgroups, such as ecological terms for stakeholders working at the farm scale. Due to their distinct majority, the results of this study primarily reflect the opinions of scientists. Thus, broad conclusions can only be drawn by comparing scientists with non-scientists. In this regard, the agreement was surprisingly high across all types of questions. The combined outcomes indicate that there is still a need to facilitate communication between stakeholders and to improve knowledge distribution strategies. Nevertheless, this study can support and be used by future projects and programmes, especially regarding the harmonization of terminology and methods.

KEYWORDS
EJP SOIL, soil indicators, soil policy stakeholders, soil science terminology, soil threats, soil-based ecosystem services, sustainable soil management

1 | INTRODUCTION

The increasing pressure on European soils is the result of unsustainable land management practices, including the application of high input—high yield agriculture. According to estimations by the European Council (EC), up to 70% of all soils in the European Union (EU) must be considered as unhealthy (EU, 2023; Veerman et al., 2020). The soil threats resulting from the current management include—among others—erosion, loss of soil carbon, soil compaction, sealing, contamination and a decline of biodiversity (Vanino et al., 2023), making it more and more difficult for soils to maintain the delivery of ecosystem services (Schwilch et al., 2016).

To counteract the emerging soil threats and to promote sustainable soil management, it is necessary to generate more knowledge on soil functioning at various scales (Thorsøe et al., 2023). Equally important is the distribution of the knowledge gained and, above all, its implementation into practice (Carmen et al., 2018; Fossey et al., 2020; Schwilch et al., 2016). Soil provides and generates ecosystem services, essential for the achievement of the sustainable development goals (SDGs) of the United Nations (UN, 2015). These include healthy food production, necessary to achieve zero hunger (SDG2/3); the implementation of techniques for collecting, storing and distributing irrigation water, as well as the application of fertilizers, pesticides, etc. that must guarantee water quality (SDG6); the preservation of biodiversity associated with crop fields (SDG15); or carbon sequestration in climate change mitigation (SDG13)—all this requires good soil management practices and the active participation of the entire food chain, including scientific research (Bouma et al., 2019; Lal et al., 2021).

In the EU, the transition to sustainable agriculture shall be achieved through initiatives and several large-scale projects and programmes such as the European Soil Strategy for 2030 (EC, 2021), the European Green Deal (EC, 2019), the Farm to Fork Strategy (EC, 2020a), the EU Biodiversity Strategy for 2030 (EC, 2020b), the New Common Agricultural Policy (EC, 2022) and A Soil Deal for Europe (EC, 2023). Moreover, one important step towards this goal is the European Joint Programme on Agricultural Soil Management (EJP SOIL; Cornu et al., 2023), that aims to establish an integrated, sustainable European research system and to develop and deploy a reference framework on climate-smart, sustainable agricultural soil management. A major part of the activities of EJP SOIL are directly related to the European Green Deal, additionally emphasizing the role of soil for a sustainable future (Keesstra et al., 2024).

This requires a joint effort and coordination of scientists across various fields. However, owing to the broad range of the topic, different application scales and the involvement of many individual member states and regions, there is a large variability of methodologies for assessing soil threats and indicators that are used to infer information about soil quality (Bünemann et al., 2018; van Beek et al., 2010; Vanino et al., 2023). One level higher, there are also different definitions and, consequently, different understandings of framework concepts such as Soil Quality, Soil Health, (Soil) Ecosystem Services or Soil Functions (Bonfante et al., 2020; Schwilch et al., 2016). Without a shared understanding of relevant concepts and terms, misunderstandings between different stakeholders and wrong interpretation of data are inevitable, eventually leading to a lower programme success and impact.

Ineffective or unclear communication is also one of the key barriers that hinder the implementation of research results into practice (Carmen et al., 2018; Vanino et al., 2023). An effective conversion of scientific knowledge into practical application requires co-operation and co-learning processes with all relevant stakeholders (Bouma, 2014). However, policy-near research often uses a certain type of language which is not necessarily intuitive and understandable for a broad audience (e.g. Jax et al., 2018; Keeney, 1989; Paul et al., 2021). Furthermore, different groups of stakeholders may have different perspectives on soil-related terms and parameters, which are expressed in different perceptions and definitions (Hoffman et al., 2014; Wade et al., 2021). To reach the aims of programmes such as the EJP SOIL, it is nevertheless fundamental to ensure that all involved stakeholders—from researchers to end-users, practitioners and decision makers—understand the terminology used and can sufficiently disentangle a common meaning based upon the source of the terminology. Consequently, there is a need for a more effective communication, requiring a harmonization of different approaches, a common language with clear definitions (Carmen et al., 2018) and a better understanding of knowledge gaps in sustainable soil management (Thorsøe et al., 2023).

Within EJP SOIL, the project SERENA aimed to assess, analyse and map soil ecosystem services bundles across European agricultural landscapes, highlighting how soil threats affect the supply of services through adoption of a set of site-specific reference thresholds. Among its many activities, one is dedicated to build up the pathways towards more effective communication by developing a harmonized body of knowledge about current states, conceptual differences and challenges or opportunities in soil research. This study was developed within the SERENA project, using a comprehensive survey, conducted within the soil-science community of Europe and other important soil-related stakeholders. It is based on a large body of science-derived definitions of terminology related to soil functions, soil ecosystem services (SESs) and soil threats (STs). Survey participants rated their agreement with each definition and the suitability of proposed indicators for SESs and STs. The study's purpose was to answer the pressing question about whether the language of large-scale science- or policy-driven initiatives is adequately understood within the

Highlights

- High overall agreement with presented definitions and indicators was shown with few exceptions.
- Good overall agreement with proposed indicators; scores can be used for indicator selection in future studies.
- About 70% of the participants were scientists from across the European Union, thus the predominantly positive results reflect a scientific rather than a societal consensus.
- Newer terms were less understood, especially by non-scientists.
- Low differences among stakeholder subgroups, with some notable exceptions.

interested community and effective enough to justify the amounts of money invested.

2 | METHODS

2.1 | Survey design

The questionnaire consisted of two parts; the first part asked for basic information about the field of activity and knowledge of the participants, and the second part aimed to assess the agreement with soil management terminology. This terminology and the definitions included in the survey were elaborated within a multinational project team of scientists from 16 countries in the EU. As a foundation, 15 terms were selected which build the key framework terms in the field of sustainable soil management (Table 1). The corresponding definitions were developed based on literature surveys and as a result of intensive internal discussions. Eleven STs and seven SESs were included in the framework. For the selected STs and SESs, a plain language definition was formulated by the project team alongside the scientific definition to minimize potential linguistic barriers to their understanding and to look for differences in the agreement between scientific and plain language. Furthermore, up to eight indicators were chosen based on a synthesis of the most relevant related documents (EEA, 2022; Faber et al., 2022; Huber et al., 2008), and an internal survey collecting information about actual implementation progress in the home states of the multinational project team. This selection was aimed at defining the most appropriate indicators for implementation in sustainable soil policy. The full texts of all definitions are included in Supplementary material A, the process of selecting terminology, definitions and indicators is presented in detail in van den Elsen et al. (2022), Michel et al. (2023), Foldal and Oorts (2023) and Montagne et al. (2023).

TABLE 1 Overview of soil management terminology as included in the survey.

Key framework terms	Soil threats	Soil ecosystem services
Soil quality	Soil erosion	Biomass/ Primary production
Soil health	Soil organic carbon loss	Habitat for biodiversity
Soil fertility	Nutrient imbalance	Soil erosion control
Ecosystem services	Soil acidification	Hydrological control
Soil conditions	Soil contamination	Environmental pollution control
Soil function	Waterlogging	Climate regulation
Soil ecosystem services	Soil compaction	Pest and disease control
Soil threat	Soil sealing	
Soil degradation	Soil salinization	
Bundle	Loss of diversity	
Service providing area	Soil drought	
Indicator		
Threshold		
Reference value		
Target value		

In the survey, the level of agreement with definitions and indicators was requested by way of Likert-scale questions which asked for a rating in seven classes (Joshi et al., 2015). The basic question for all definitions was: 'How strongly do you agree with the following definition for TERM?', while for indicator selection it was as follows: 'The following indicators were chosen to be the most appropriate ones to characterize the soil threat/soil ecosystem service TERM. How far do you agree with the selection?'. The aim of the survey was to assess how well the terminology is understood, which may also be described as revealing the degree of consensus. A high degree of consensus or agreement was reached when the majority of answers were positive, namely above a rating of four (cf. Diamond et al., 2014). The type of visualization was chosen to facilitate this assessment by a stacked barplot centred at the neutral score of four.

The survey was implemented in an online-tool for scientific surveys (www.soscisurvey.de; Leiner, 2019) which offers high functionality and usability for administrators and participants. It was possible to answer the questionnaire in 11 languages: Czech, Dutch, English, Estonian, French, German, Italian, Lithuanian, Polish, Portuguese and Spanish. To minimize stakeholder fatigue, a randomization module was implemented which selected five terms to be rated for STs and SESs, respectively (Table 1). For the framework definitions, the terms 'soil quality', 'soil health' and 'indicator' were included in every participation due to universal relevance with two further terms from the remaining list added randomly. The whole questionnaire in English language is attached in Supplementary material B.

The survey was online from June 13th to September 15th 2023 and was accessible via a link sent to all potential applicants who could fill in the questionnaire freely without having to register or provide personal information. As a distribution strategy, the snowball principle was chosen (Goodman, 1961). To optimize the distribution of the survey, a stakeholder database was addressed in a first phase. It consisted of approximately

160 individuals, evenly distributed among the following groups: farmers, national policy, European policy, scientists and a diverse group of 'others'. Three weeks after the start of the survey, the project team initiated a second phase by sending motivating invitation mails to various mailing lists. The messages contained the survey link and an encouragement to share the link with any potentially interested person. This snowball method was intended to organically expand the database and capture a diverse array of experts.

2.2 | Analyses

Not every participant completed the questionnaire. Only participants who completed at least one section were included in the analysis (i.e. framework definitions, SESs, STs). For the assessment of the level of agreement with definitions and indicators, we displayed the data as stacked bar charts, following Heiberger and Robbins (2014). Participants specified their agreement with the provided definitions by selecting a score from 1 (strongly disagree) to 7 (strongly agree), with 4 as a neutral position. The level of agreement was primarily quantified as the percentage of participants who chose a score higher than 4 (and vice versa the level of disagreement as the percentage of scores lower than 4). Furthermore, we calculated standard descriptive statistics (mean, standard deviation, range). Although the arithmetic mean can be problematic when applied to Likert scale-like data (Sullivan & Artino, 2013), a visual inspection of the data confirmed a sufficiently symmetrically distribution with no evidence of bimodality. Consequently, the mean was considered as an additional proxy for the level of agreement. The subgroup differences were determined by the difference between the mean score of each subgroup for a definition and the overall mean score calculated using all data (global mean score for a definition). Subgroups were analysed in more detail using the scale of main interest and expertise (*Scale*), environmental region of main activity and expertise (*Region*) and stakeholder identity (*Stakeholder*). In the analysis, only those subgroups that had a sufficiently large sampling size were included. Sample sizes were, however, still low for some stakeholder subgroups and terms. Thus, for the display of results and discussion, cases with a sample size of less than five were excluded. Furthermore, we grouped all science-related stakeholders (termed 'Scientists'; stakeholder subgroups 'Research', 'Academic' and 'Student') and compared them with the remaining other stakeholder subgroups ('Non-Scientists').

Python 3.9.12 embedded in the Spyder 5.2.2 environment was used for figure generation (*matplotlib*), statistics and data handling (*pandas*, *numpy*).

3 | RESULTS

3.1 | Composition and characterization of participants

A total of 398 participants started the questionnaire, of which 184 (46.2%) fully completed the task. We considered 264 (66.3%) participants with valid contributions (i.e. having finished at least one section). Due to the different amount of questions per section, the random allocation procedure and partially unanswered questions, the available sample sizes for the definitions range from 63 to 263.

The vast majority of participants had an academic background; more than 97% had at least a Bachelor's degree, 59.5% had a doctorate. This was mirrored by the stakeholder identity, with 69.6% academics or researchers. Farmers and advisors comprised 5.3% and 9.5%, respectively, policy makers and representatives from the industry contributed under 3% each (Figure 1). The main interest or expertise of the participants was more evenly distributed among the European, National and Regional scales, with 22.5%, 33.2% and 26.0%, respectively, and the Farm scale with 10.7%. The questionnaire was sent out to 27 EU countries. We received responses from 19 countries, however, almost two thirds of all answers came from four countries, namely France (23.6%), Spain (15.2%), Austria (14.8%) and Germany (12.2%). This is was also reflected in the predominant environmental region of activity, where almost 90% of all participants indicated their main activity and experience to be within the Continental (36.6%), Mediterranean (23.7%), Atlantic (22.1%) or Alpine (6.9%) region. The gender distribution was 54.0% males and 41.4% females; the rest did not respond to that question. Around 70% of all participants were between 36 and 65 years old, and 41.1% had already participated in other EJP-Soil activities. The conviction that it is important to have formal definitions in soil management was high with a mean score of 6.5; two thirds of all participants selected the highest rating (7).

3.2 | Framework definitions, soil ecosystem services and soil threats

The overall agreement with the provided definitions was high (Figures 2–4). Only two definitions had an

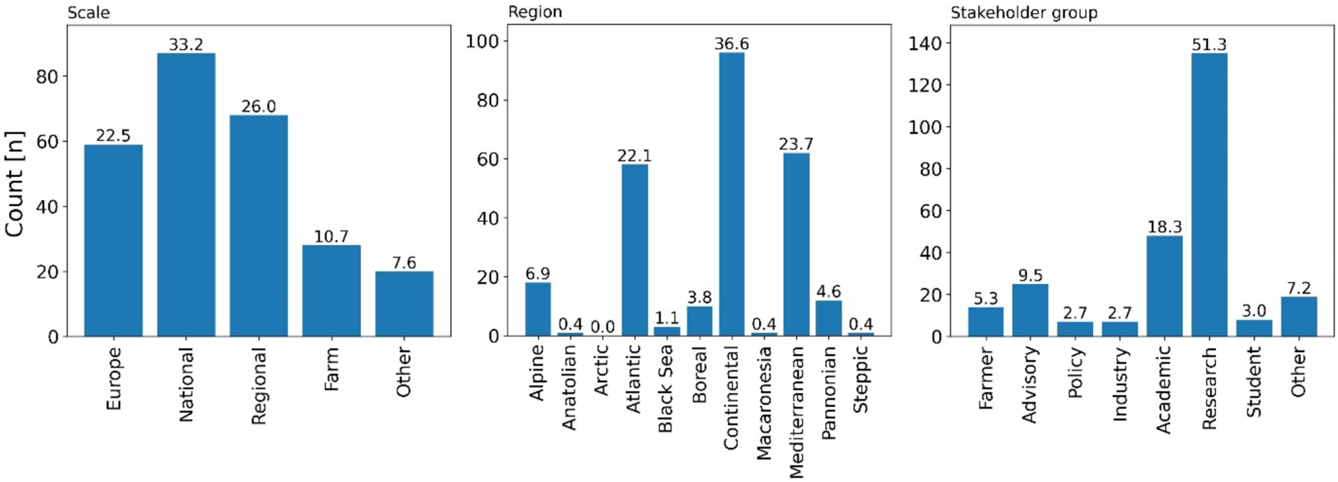

FIGURE 1 Composition of participants regarding the scale of main interest and expertise (*Scale*), environmental region of main activity and expertise (*Region*) and stakeholder identity (*Stakeholder*). Numbers above the bars show the percentage distribution.

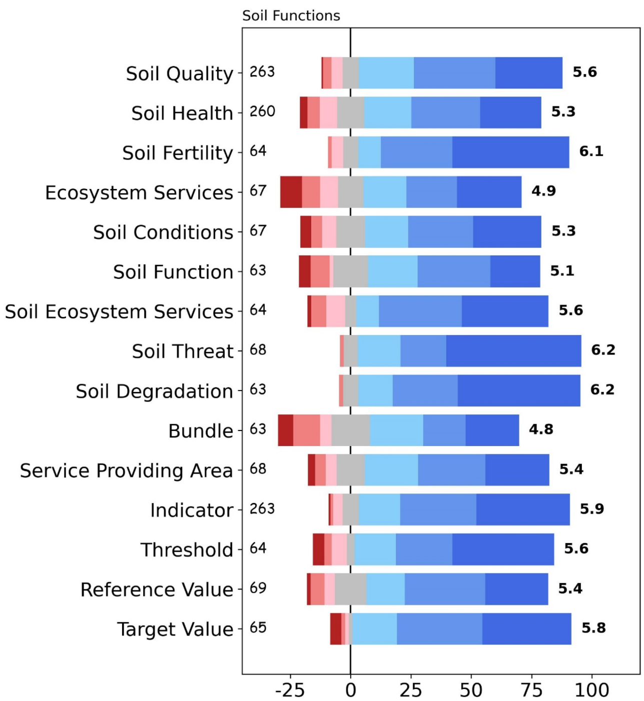

FIGURE 2 Percentual agreement with the framework definitions. Dark red—strongly disagree (1), grey—neutral (4), dark blue—strongly agree (7). Numbers in italics on the left indicate sample size (i.e. number of valid responses for the respective definition); numbers in bold right of the bars indicate the mean score.

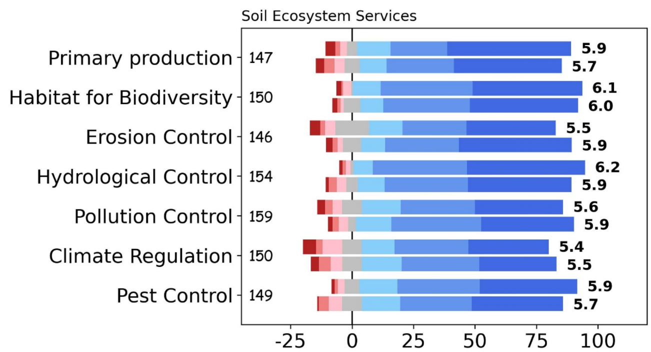

FIGURE 3 Percentual agreement with the definitions for soil ecosystem services. Dark red—strongly disagree (1), grey—neutral (4), dark blue—strongly agree (7). Numbers in italics on the left indicate sample size (i.e. number of valid responses for the respective definition); numbers in bold right of the bars indicate the mean score. The upper bars at each term refer to the scientific definition, the lower bars to the definition in plain language.

agreement under 70%, namely *Ecosystem Services* (65.7%) and *Bundle* (61.9%), which were also the only definitions with a mean score below 5. Scientific definitions were commonly better rated than those in plain language. Among the 18 definitions in SES and ST, the scientific definition had higher agreements and mean scores in 14 cases (Figures 3 and 4). The agreement with the scientific definitions for STs was especially high, eight out of 11 definitions had an agreement over 90%, and nine a mean score above 6 (Figure 4).

3.3 | Appropriateness of the selected indicators

Generally, the indicators provided for SESs were considered less appropriate than those for STs (Figure 5). This was characterized by a lower level of agreement and lower mean score. Among the SES indicators, the lowest levels of agreement were found for 'yields' (*Primary*

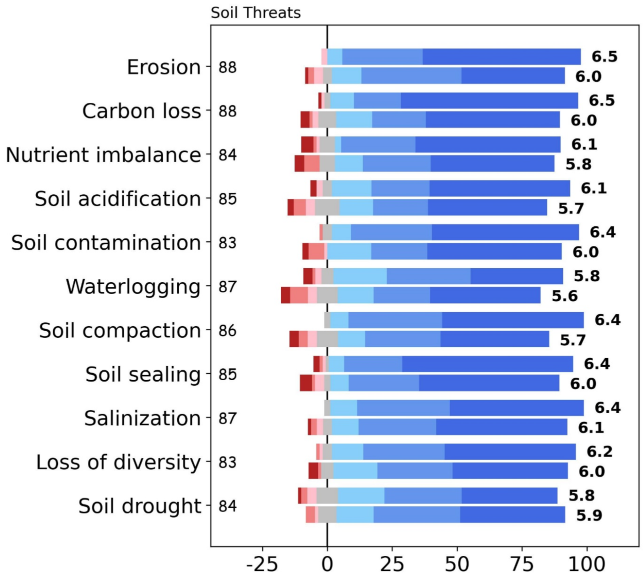

FIGURE 4 Percentual agreement with the definitions for soil threats. Dark red—strongly disagree (1), grey—neutral (4), dark blue—strongly agree (7). Numbers in italics on the left indicate sample size (i.e. number of valid responses for the respective definition); numbers in bold right of the bars indicate the mean score. The upper bars at each term refer to the scientific definition, the lower bars to the definition in plain language.

Production), 'net water supply' (*Hydrological Control*), 'organic carbon stock in plants' (*Climate Regulation*), as well as for 'ratio of fungi/bacteria' and 'mortality' (*Pest Control*), with less than 60%; the indicators 'yields', 'net water supply' and 'organic carbon stock in plants' also had disagreement levels above 30%. Among the ST indicators, 'risk of soil organic carbon deficiency' (*Carbon Loss*) had an agreement level of 47.7%. This was the only ST indicator with an agreement lower than 60%. Furthermore, 'risk of soil organic carbon deficiency' had the lowest agreement among all indicators and, together with 'net water supply', had also the lowest mean scores (both <4.5).

3.4 | Group differences

Subgroup differences were commonly low, with an average deviation from the global mean score of <0.3. There were, however, some notable exceptions (Figure 6). Among the 'Scale' subgroups, the mean scores for *Service Providing Area* at the European (6.1) and Regional scale (6.1) differed more than 1 point from the National (4.8) and 1.7 points from the Farm scale (4.3). Among the 'Region' subgroups, high intra-group differences were found for the definitions of *Soil Fertility*, *Soil Conditions* and *Bundle* (>1.5 points), as well as for the SES *Erosion Control* (>2 points). Generally, the Atlantic region subgroup had lower mean scores for all but two definitions (*Threshold* and *Primary Production*); 10 of them being more than 0.5 points below the global mean. The lowest mean score of all subgroups was found for the definition of *Bundle* at the Alpine region with 3.4, which is a deviation of 1.4 points below the global mean. Among the 'Stakeholder' subgroups, the Advisory subgroup had 1.5 and 1.4 points higher mean scores than the Academic subgroup for the framework definition of *Ecosystem Services* and the ST *Soil Acidification* respectively. The Farmer subgroup had lower mean scores than all other groups for *Pollution Control* (>0.9 points). Generally, the Advisory subgroup had higher mean scores for all but four definitions; nine of them being more than 0.5 points above the global mean.

The scientific definitions commonly received higher mean scores than the plain language definitions, for example, 78% across all stakeholder subgroups. The highest differences in mean scores between non-scientists and scientists were found for the scientific definitions of the SES *Primary Production* (0.5 higher for non-scientists) and the ST *Soil Acidification* (0.7) respectively; and for the plain language definitions of the SES *Climate Regulation* (−0.5) and the ST *Salinization* (0.5).

4 | DISCUSSION

4.1 | Reflections on methodology and interpretations

The structure of the participants, and in particular, their professional background, showed a strong majority of scientists. This needs to be considered in interpreting the results, which, consequently, primarily reflect the opinions of the (soil) research community. Furthermore, sample sizes are too small for most subgroups to draw reliable conclusions; nevertheless, more general statements can be made by grouping all other stakeholders ('non-scientists') and the comparison with scientists. This limits our ability to answer our research question of whether there is a common understanding and agreement on the proposed definitions and indicators which includes a diverse range of stakeholders. Nevertheless, the insights gained from the responses of an international population of researchers are valuable and important, as they can be used for a much-needed harmonization of the terminology and methods used in future studies and national and international projects and programmes.

A major target in the design of the survey was to motivate a high number of participants by ensuring a convenient, motivating participation experience and the

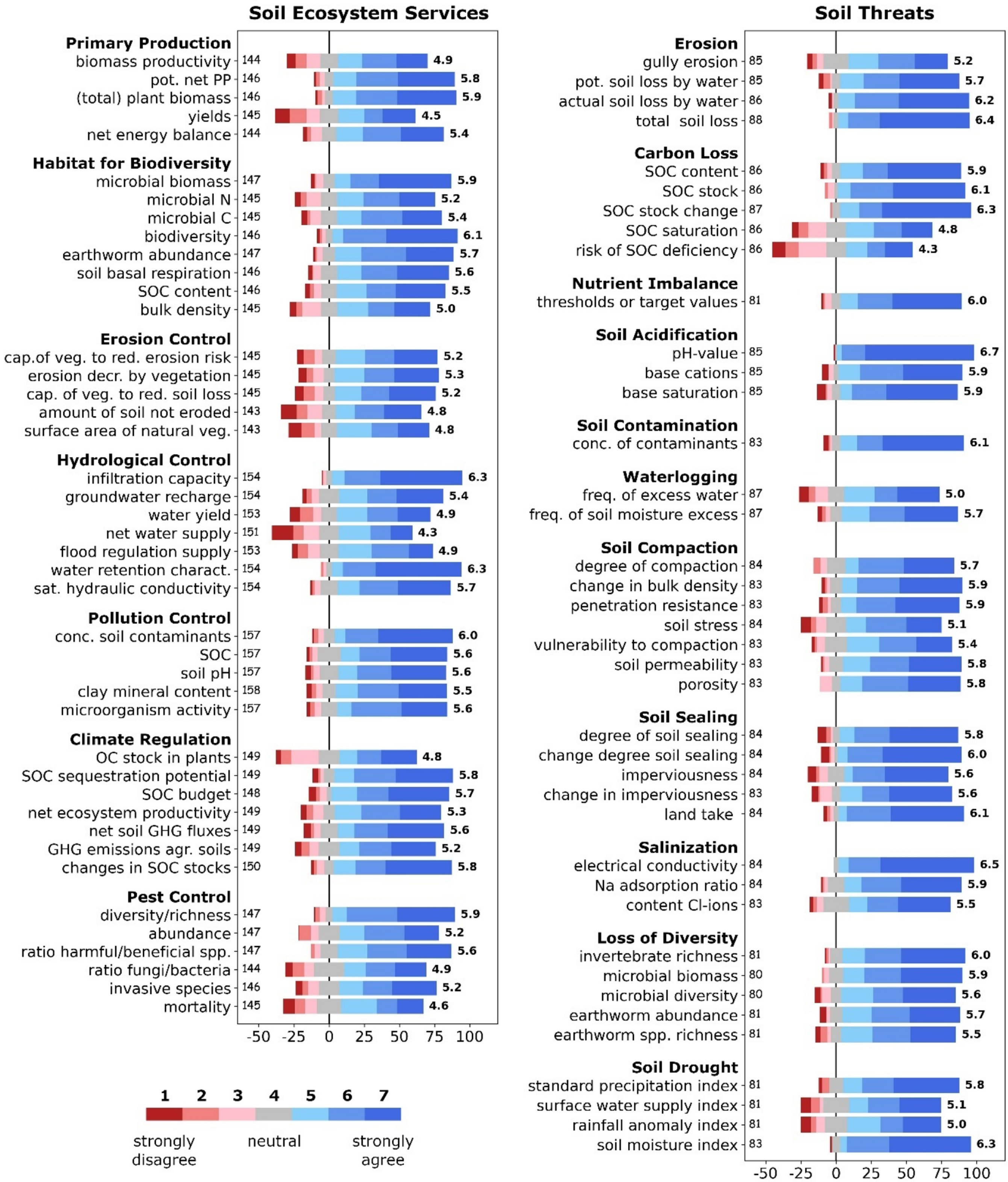

FIGURE 5 Percentual agreement with the indicators for soil ecosystem services (left) and soil threats (right). Numbers in italics on the left indicate sample size (i.e. number of valid responses for the respective indicator); numbers in bold right of the bars indicate the mean score.

potential for preferably rapid completion. Due to a vast frequency of surveys and demands for stakeholder involvement in the European soil policy activities, such preconditions may be seen as crucial for ensuring adequate participation. However, despite our efforts to make the questionnaire easily understandable and workable,

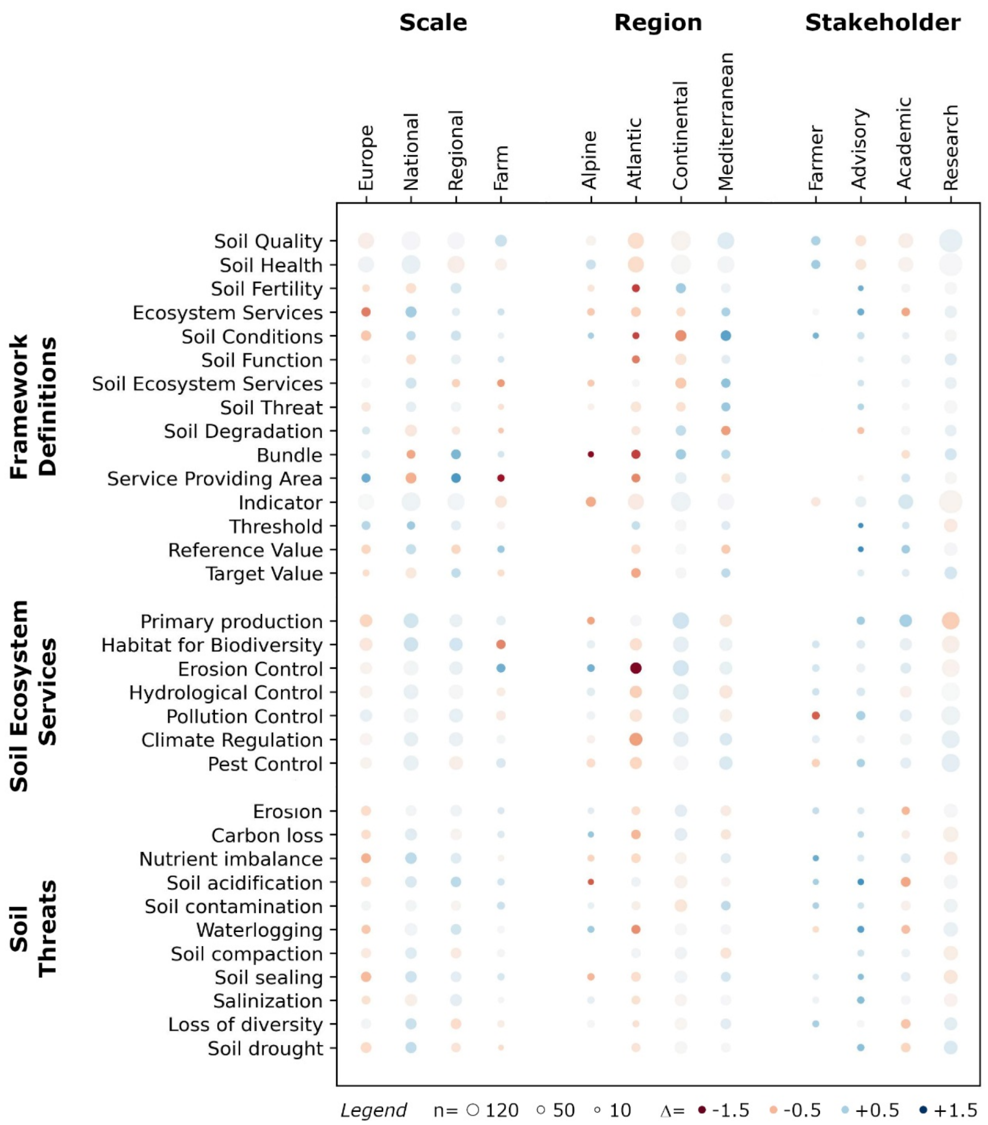

FIGURE 6 Difference matrix for mean scores of selected subgroups for framework definitions and scientific definitions of SES and ST. Blue colouring indicates a mean score of the subgroup higher than the global mean, red colouring a lower mean score. The intensity of the colours indicates the size of the difference (deviation from global mean). Circle size indicates sampling size (only definitions with $n > 5$).

the topic probably remained abstract. Thinking about 16 definitions may be perceived as exhausting, which is also reflected in the overall low completion rate below 50%. This applies especially to non-scientists which are less used to the underlying practice of abstract and conceptual thinking (Wade et al., 2021). Farmers had the lowest completion rate of all stakeholders, which highlights that this group is probably the hardest to reach and least familiar or comfortable with scientific questioning. Similar surveys with more practical questions achieved higher participation rates of farmers (Mason et al., 2023).

The distribution strategy, the snowball principle, was intended to reach a broad range of stakeholders (Goodman, 1961). However, even though the scientists of the project team, who were the initiators of the spread, tried to balance the groups of stakeholders addressed, their mails seemed to achieve higher priority among science colleagues on their mailing lists. A reason for the poor response rate from non-scientists, especially farmers, could also be that they do not expect their contribution to lead to concrete changes, either because they believe that decisions will be made elsewhere or because of the expectation (or experience) that their voice will not be heard anyway (Dernat et al., 2022; Fielke et al., 2018; Schulp et al., 2022). Schulp et al. (2022) stated that the intrinsic motivation of farmers is crucial for their engagement, which might lack in conceptual discussions about terminology. In this regard, it might be worth while to consider that numerous studies deal with the communication of policy and science concepts in order to influence farmer decisions (e.g. Creissen & Lamichhane, 2024; Dessart et al., 2019; Prost et al., 2023), whereas research about how to engage practitioners in policy development is underrepresented (Bouma, 2022; Busse et al., 2023; Höhler et al., 2024; Zindler et al., 2023).

Based on these insights, we may put forward recommendations for future studies. Advancing the dissemination strategy, for example, by including low-barrier channels like social media, might be a promising option for future surveys involving non-scientist soil experts (Leighton et al., 2021). Organizations or institutions such as regional agricultural authorities as cooperation partners could act as multiplicators. A highly promising approach, however, is the direct involvement of stakeholder groups in the projects or practical cooperation at an early stage and continuous interaction (Adamsone-Fiskovica & Grivins, 2022; Bouma, 2019; Mason et al., 2023; Salvia et al., 2018). Agricultural practitioners might also play a major role in research project teams, as is intended in the EU Mission 'A Soil Deal for Europe' with its approaches of lighthouse farms and living labs (Bouma & Veerman, 2022; Löbmann et al., 2022; Veerman et al., 2020).

According to Carmen et al. (2018), a common language with clear definitions is necessary to put abstract concepts such as Ecosystem Services into practice. However, they also acknowledge that some stakeholders identified the usefulness of some ambiguity in terminology to facilitate a dialogue and the development of a common understanding between different stakeholders in a specific situation. This raises the question of how far the concept-based language of soil policy, and in particular, the definitions, needs to be adapted to suit each stakeholder group.

4.2 | Framework definitions, soil ecosystem services and soil threats

Overall, there is a surprisingly good consensus regarding the definitions proposed for the framework of sustainable soil management. Only two out of 51 definitions received agreement levels below 70% or mean scores below five on the seven-grade Likert scale. As this study was, to the knowledge of the authors, the first one asking for feedback on science-based soil terminology definitions, a comparison to other studies is not possible. Nevertheless, it may be assumed that the broad approach, including a large number of soil experts for the derivation of the presented definitions and indicator allocation, led to strongly accepted results, at least within the scientific community. Furthermore, it was rather surprising that there was only a low number of distinct differences between scientists and non-scientists, but also between scientific and plain language definitions.

Although there was a strong overall agreement with the definitions, some showed distinctively lower than average results. While long-established terms like *Soil Fertility*, *Indicator*, *Soil Threat*, or similar terms received strong agreement, relatively newer terms like *Ecosystem Services* and *Bundle* were less highly rated. This correlates to former informal perceptions within the author team that it is harder to communicate new concepts or terminology to different groups of stakeholders than established terminologies. Therefore, the formulation of definitions for new terms needs to be carried out with more care and anticipation than for established ones, where it may be assumed that even a tolerance for ambiguity has developed in long years of practice. Besides the novelty of a term, also the familiarity with concepts from other disciplines may play a role. For instance, the 'Scale' subgroup Farm, which comprises not only actual farmers but also researchers and other stakeholders that primarily work with and at the scale of individual farms, agreed less with definitions such as *Soil Ecosystem Services*, *Service Providing Area*, or *Habitat for Biodiversity* (Figure 6). Although these terms are common in ecology—from where they also originate—their usage and relevance in fields related to agriculture is a more recent development, which could contribute to the lower agreement levels (Bünemann et al., 2018; Power, 2010). These findings are further corroborated by the general trend found that well established terms or long known concepts (e.g. *Primary Production*, *Soil Acidification*, *Erosion*, *Salinization*) constantly received higher mean scores from non-scientists (both for scientific and plain language definitions), while newer terms, or SESs and STs that gained importance more recently (e.g. *Pest Control*, *Climate Regulation*, *Soil Drought*, *Waterlogging*), received lower scores.

We also provided the survey participants with the opportunity to make comments after each definition, in case they had something to add, criticize or suggest. On a general level, the plain language definitions were often criticized as being more complicated than the scientific ones. This might indicate the difficulty for scientists to formulate understandable language. As the majority of participants had a scientific background, this could also be influenced by a higher familiarity with scientific language. Another issue frequently put into question throughout multiple definitions was the limitation to agricultural soils at the expense of forest soils, wetlands or urban soils. This restriction was, however, predetermined by the EJP SOIL framework targets. The framework definitions for *Ecosystem Service* and *Bundle* received the lowest values of agreement of all terms. For *Ecosystem Service*, of 21 given comments, 14 criticized the anthropocentric nature of the definition or suggested at least to replace 'well-being' as a target by something like 'benefits for society'. Out of the 19 comments for *Bundle*, 13 criticized the term as unnecessary, vague or non-understandable. Within the SES definitions, *Erosion Control* and *Climate Regulation* had the lowest agreements. Often cited drawbacks were conceptual issues, especially because of different understandings including the emphasis on vegetation cover instead of directly soil related processes and also indicators for *Erosion Control*, the lack of a bigger picture beyond the scope of soil science, as well as over complicated definitions for *Climate Regulation*. Within the ST definitions, *Waterlogging* received the lowest rating. The main criticism was again on the anthropocentric view, especially that waterlogging is only a threat from a productivity point of view. Moreover, the definition was said to need more clarification, especially in the integration of different processes or causes for waterlogging. The full list of comments is attached in Supplementary material C.

4.3 | Appropriateness of the selected indicators

The agreement with the SES and ST indicators was generally high, most had levels of agreement >70% and mean scores above five. Nevertheless, there were also certain indicators with relatively high disagreement rates, for instance, 'risk of soil organic carbon deficiency' for the ST *Carbon Loss*, or 'net water supply' for the SES *Hydrological Control*. Quite generally, the agreement with the indicators was markedly lower compared to the definitions with a higher range of agreement levels and scores. The different indicators were, however, selected to support very different representations of the considered threats and services. In the case of climate regulation indicators, for example, some consider only the soil system, the plant system or the ecosystem as a whole; some assess capacities, current stocks or fluxes; and some are directly linked with the removal of CO_2, while others are not. As is well known for capacity, flow and demand (Baró et al., 2016), there is no doubt that assessing the same service with these highly different indicators will produce very different service levels and patterns.

The need to assess soil threats and services appears now to be widely shared across Europe and largely favoured in technical considerations concerning the choice of an appropriate indicator, which is a necessary but insufficient step (Czúcz et al., 2020; Heink et al., 2016). The indicators were selected based on a thorough literature review and expert discussions (Montagne et al., 2023) and were then rated by the soil-science community and participants from related fields. Consequently, the indicator assessment is of high relevance and may be directly used to select appropriate indicators by future studies. Whether the underlying reasons for low agreement scores of some indicators are based on scientific (e.g. indicator is considered not appropriate), practical (e.g. indicator is hard to measure or cost-intensive) or other aspects (e.g. unfamiliarity with indicator), are, however, not known and beyond the scope of this paper. Nevertheless, the differences between scientists and non-scientists regarding the mean scores of the indicators were generally low; they were less than 0.5 for more than 80% of all indicators and less than 0.3 on average. Interestingly, for the vast majority of indicators with large differences (e.g. > 0.5), scientists gave higher scores than non-scientists. Among those indicators were, for instance, 'surface water supply index', 'net soil greenhouse gas fluxes', 'invasive species' or 'rainfall anomaly index', that is, indices that are probably not well known outside of science. It appears, that familiarity plays a major role regarding the agreement with an indicator.

4.4 | Group differences

Interestingly, some subgroups showed almost consistently higher or lower mean scores compared to the other groups and the global mean. The Atlantic region had on average a 0.4 points lower score across all definitions (Figure 6). The majority of responses from this region came from France (52%) and the Netherlands (19%), the latter with notably lower scores than the former. The reason behind this remains unclear. Because of the clear pattern, it seems, however, to be a systematic issue, possibly affected by a different survey participant composition, which may have been further influenced by cultural differences. For instance, France had a higher proportion of older people that participated in the survey. Low sample sizes impede a more detailed breakdown for stakeholder groups. Some broad generalizations can, however, be made when stakeholders are grouped into non-scientists and scientists, for instance, that familiarity with a term seems to play a role. This would imply that concepts that are new, or not well known outside of academia, need to be emphasized and better communicated to other stakeholders, especially if they are of high importance (e.g. related to climate change). How this is best achieved needs to be discussed, as does whether science itself or other institutions with stronger ties to agriculture (or other stakeholders) should be primarily responsible (Ingram, 2014; Osmond et al., 2010).

5 | CONCLUSION

Overall, there is a high level of agreement on the terminology related to sustainable soil management, at least within the European scientific community. This solid and harmonized understanding of the concepts involved is not obvious, but forms the basis for progress in formulating efficient strategies for implementation into agricultural practice. However, inclusion of different stakeholders in discussions on sustainable soil management remains challenging, as shown by the low response rates from non-scientist subgroups. The combination of ratings and text comments, including suggestions for improvement, provides valuable insights into the lively discussions and perceptions across a wide range of EU member states. The results can significantly support future work to harmonize terminology and, in particular, the methodologies subsequently used in national or EU-wide soil mapping tasks or soil health state assessments. For instance, this study could support the discussion and, eventually, the implementation of a proposed directive on soil monitoring and resilience, taking into account the current debate on the definition of ecosystem services, the 'critical' or 'unhealthy loss' of services, and their notable relevance for the instruments of compensation and territorial governance.

AUTHOR CONTRIBUTIONS

David Ramler: Formal analysis; writing – original draft; writing – review and editing; investigation; data curation; visualization. **Thomas Weninger:** Conceptualization; investigation; writing – original draft; writing – review and editing; methodology; data curation. **Giulia Bondi:** Methodology; writing – review and editing. **Sabina Asins:** Writing – review and editing; methodology. **Lilian O'Sullivan:** Methodology; writing – review and editing. **Francesca Assennato:** Writing – review and editing; methodology. **Alar Astover:** Methodology; writing – review and editing. **Antonio Bispo:** Writing – review and editing; project administration. **Luboš Borůvka:** Methodology; writing – review and editing. **Gabriele Buttafuoco:** Methodology; writing – review and editing. **Costanza Calzolari:** Writing – review and editing; project administration. **Nádia Castanheira:** Methodology; writing – review and editing. **Isabelle Cousin:** Writing – review and editing; project administration. **Erik van den Elsen:** Writing – review and editing; methodology. **Cecilie Foldal:** Methodology; writing – review and editing. **Rudi Hessel:** Methodology; writing – review and editing. **Žydrė Kadžiulienė:** Methodology; writing – review and editing. **Liia Kukk:** Methodology; writing – review and editing. **Maria J. Molina:** Methodology; writing – review and editing. **David Montagne:** Methodology; writing – review and editing. **Katrien Oorts:** Methodology; writing – review and editing. **Sylwia Pindral:** Methodology; writing – review and editing. **Fabrizio Ungaro:** Project administration; writing – review and editing. **Agnieszka Klimkowicz-Pawlas:** Methodology; writing – review and editing.

ACKNOWLEDGEMENTS

This research has been carried out within the framework of the SERENA project. SERENA (Soil Ecosystem seRvices and soil threats modElling aNd mApping) is an EJP SOIL internal project. EJP SOIL has received funding from the European Union's Horizon 2020 research and innovation programme: Grant agreement No 862695. Very special thanks go to the team of soscisurvey.de for freely providing the online-platform for survey design and execution for scientific use and DeepL.com for support in the translations.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Thomas Weninger https://orcid.org/0000-0001-9004-4426
David Ramler https://orcid.org/0000-0003-4833-0351
Giulia Bondi https://orcid.org/0000-0002-8896-0262
Sabina Asins https://orcid.org/0000-0001-5496-3943
Lilian O'Sullivan https://orcid.org/0000-0002-5333-5758
Francesca Assennato https://orcid.org/0000-0003-0267-7499
Alar Astover https://orcid.org/0000-0002-8924-6925
Antonio Bispo https://orcid.org/0000-0002-6985-8385
Luboš Borůvka https://orcid.org/0000-0001-5317-0933
Gabriele Buttafuoco https://orcid.org/0000-0002-0280-8658
Costanza Calzolari https://orcid.org/0000-0002-2126-9290
Nádia Castanheira https://orcid.org/0000-0002-9276-1805
Isabelle Cousin https://orcid.org/0000-0002-8114-7113
Erik van den Elsen https://orcid.org/0000-0001-5409-9761
Cecilie Foldal https://orcid.org/0000-0002-3853-314X
Rudi Hessel https://orcid.org/0000-0002-1859-309X
Žydrė Kadžiulienė https://orcid.org/0000-0001-6181-5885
Liia Kukk https://orcid.org/0000-0002-0825-799X
David Montagne https://orcid.org/0000-0003-4735-4618
Katrien Oorts https://orcid.org/0000-0003-1997-4473
Sylwia Pindral https://orcid.org/0000-0002-1065-8004
Fabrizio Ungaro https://orcid.org/0000-0003-0116-6611
Agnieszka Klimkowicz-Pawlas https://orcid.org/0000-0002-4529-5274

REFERENCES

Adamsone-Fiskovica, A., & Grivins, M. (2022). Knowledge production and communication in on-farm demonstrations: Putting farmer participatory research and extension into practice. *The Journal of Agricultural Education and Extension*, *28*, 479–502. https://doi.org/10.1080/1389224X.2021.1953551

Baró, F., Palomo, I., Zulian, G., Vizcaino, P., Haase, D., & Gómez-Baggethun, E. (2016). Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region. *Land Use Policy*, *57*, 405–417. https://www.sciencedirect.com/science/article/pii/S0264837716305555

Bonfante, A., Basile, A., & Bouma, J. (2020). Targeting the soil quality and soil health concepts when aiming for the United Nations sustainable development goals and the EU green Deal. *Soil*, *6*, 453–466. https://soil.copernicus.org/articles/6/453/2020/

Bouma, J. (2014). Soil science contributions towards sustainable development goals and their implementation: Linking soil functions with ecosystem services. *Journal of Plant Nutrition and Soil Science*, *177*, 111–120. https://doi.org/10.1002/jpln.201300646

Bouma, J. (2019). How to communicate soil expertise more effectively in the information age when aiming at the UN sustainable development goals. *Soil Use and Management*, *35*, 32–38. https://doi.org/10.1111/sum.12415

Bouma, J. (2022). How about the role of farmers and of pragmatic approaches when aiming for sustainable development by 2030? *European Journal of Soil Science*, *73*, e13166. https://doi.org/10.1111/ejss.13166

Bouma, J., Montanarella, L., & Evanylo, G. (2019). The challenge for the soil science community to contribute to the implementation of the UN sustainable development goals. *Soil Use and Management*, *35*, 538–546. https://doi.org/10.1111/sum.12518

Bouma, J., & Veerman, C. P. (2022). Developing management practices in: "Living labs" that result in healthy soils for the future, contributing to sustainable development. *Land*, *11*, 2178. https://doi.org/10.3390/land11122178

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., Fleskens, L., Geissen, V., Kuyper, T. W., Mäder, P., Pulleman, M., Sukkel, W., van Groenigen, J. W., & Brussaard, L. (2018). Soil quality—A critical review. *Soil Biology and Biochemistry*, *120*, 105–125. https://www.sciencedirect.com/science/article/pii/S0038071718300294

Busse, M., Zscheischler, J., Zoll, F., Rogga, S., & Siebert, R. (2023). Co-design approaches in land use related sustainability science—A systematic review. *Land Use Policy*, *129*, 106623. https://www.sciencedirect.com/science/article/pii/S0264837723000893

Carmen, E., Watt, A., Carvalho, L., Dick, J., Fazey, I., Garcia-Blanco, G., Grizzetti, B., Hauck, J., Izakovicova, Z., Kopperoinen, L., Liquete, C., Odee, D., Steingröver, E., & Young, J. (2018). Knowledge needs for the operationalisation of the concept of ecosystem services. *Ecosystem Services*, *29*, 441–451. https://www.sciencedirect.com/science/article/pii/S2212041616305083

Cornu, S., Keesstra, S., Bispo, A., Fantappie, M., van Egmond, F., Smreczak, B., Wawer, R., Pavlů, L., Sobocká, J., Bakacsi, Z., Farkas-Iványi, K., Molnár, S., Møller, A. B., Madenoglu, S., Feiziene, D., Oorts, K., Schneider, F., da Conceição Gonçalves, M., Mano, R., … Chenu, C. (2023). National soil data in EU countries, where do we stand? *European Journal of Soil Science*, *74*, e13398. https://doi.org/10.1111/ejss.13398

Creissen, H. E., & Lamichhane, J. R. (2024). The value of socio-behavioural, farmer's surveys and participatory research for crop protection. *Crop Protection*, *177*, 106568. https://ui.adsabs.harvard.edu/abs/2024CrPro.17706568C

Czúcz, B., Haines-Young, R., Kiss, M., Bereczki, K., Kertész, M., Vári, Á., Potschin-Young, M., & Arany, I. (2020). Ecosystem service indicators along the cascade: How do assessment and mapping studies position their indicators? *Ecological Indicators*, *118*, 106729. https://www.sciencedirect.com/science/article/pii/S1470160X2030666X

Dernat, S., Rigolot, C., Vollet, D., Cayre, P., & Dumont, B. (2022). Knowledge sharing in practice: A game-based methodology to increase farmers' engagement in a common vision for a cheese PDO union. *The Journal of Agricultural Education and Extension*, *28*, 141–162. https://doi.org/10.1080/1389224X.2021.1873155

Dessart, F., Barreiro Hurle, J., & Van Bavel, R. (2019). Behavioural factors affecting the adoption of sustainable farming practices: A policy-oriented review. *European Review of Agricultural Economics*, *46*, 417–471. https://academic.oup.com/erae/article/46/3/417/5499186

Diamond, I. R., Grant, R. C., Feldman, B. M., Pencharz, P. B., Ling, S. C., Moore, A. M., & Wales, P. W. (2014). Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. *Journal of Clinical Epidemiology*, *67*, 401–409. https://doi.org/10.1016/j.jclinepi.2013.12.002

EC. (2020a). Communication from the commission to the European Parliament, the council, the European economic and social committee and the Committee of the Regions. A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. *COM(2020)*, 381.

EC. (2020b). Communication from the commission to the European Parliament, the council, the European economic and social committee and the Committee of the Regions. EU Biodiversity Strategy for 2030 Bringing nature back into our lives. *COM(2020)*, 380.

EC. (2021). Communication from the commission to the European Parliament, the council, the European economic and social committee and the Committee of the Regions. EU Soil Strategy for 2030: Reaping the benefits of healthy soils for people, food, nature and climate. *COM(2021)*, 699.

EC. (2019). Communication from the commission to the European Parliament, the European council, the council, the European economic and social committee and the Committee of the Regions. *COM (2019)*, 640.

EC. (2022). Common agricultural policy for 2023–2027; 28 cap strategic plans at a glance. *Agriculture and Rural Development*.

EC. (2023). *EU missions—Soil deal for Europe—What is the EU mission—A soil deal for Europe*. Publications Office of the European Union. https://doi.org/10.2777/171313

EEA. (2022). Soil monitoring in Europe—Indicators and thresholds for soil health assessments. *EEA Report*, No 08/2022. https://www.eea.europa.eu/publications/soil-monitoring-in-europe

EU. (2023). Proposal for a directive of the European Parliament and of the council on soil monitoring and resilience (soil monitoring law). *Com(2023)*, 416.

Faber, J. H., Cousin, I., Meurer, K. H. E., Hendriks, C. M. J., Bispo, A., Viketoft, M., ten Damme, L., Montagne, D., Hanegraaf, M. C., Gillikin, A., Kuikman, P., Obiang-Ndong, G., Bengtsson, J., & Taylor, A. (2022). Stocktaking for agricultural soil quality and ecosystem services indicators and their reference values. *EJP SOIL Internal Project SIREN Deliverable 2*, Report. https://ejpsoil.eu/fileadmin/projects/ejpsoil/1st_call_projects/SIREN/SIREN_D2_final_report.pdf

Fielke, S. J., Botha, N., Reid, J., Gray, D., Blackett, P., Park, N., & Williams, T. (2018). Lessons for co-innovation in agricultural innovation systems: A multiple case study analysis and a conceptual model. *The Journal of Agricultural Education and Extension*, *24*, 9–27. https://doi.org/10.1080/1389224X.2017.1394885

Foldal, C. B., & Oorts, K. (2023). Soil threats and soil ecosystem services of interest in SERENA. *SERENA Deliverable D2.2, Report*.

Fossey, M., Angers, D., Bustany, C., Cudennec, C., Durand, P., Gascuel-Odoux, C., Jaffrezic, A., Pérès, G., Besse, C., & Walter, C. (2020). A framework to consider soil ecosystem Services in Territorial Planning. *Frontiers in Environmental Science*, *8*. https://doi.org/10.3389/fenvs.2020.00028

Goodman, L. A. (1961). Snowball sampling. *The Annals of Mathematical Statistics*, *32*, 148–170. https://doi.org/10.1214/aoms/1177705148

Heiberger, R., & Robbins, N. (2014). Design of Diverging Stacked bar Charts for Likert scales and other applications. *Journal of Statistical Software*, *57*, 1–32. https://www.jstatsoft.org/index.php/jss/article/view/v057i05

Heink, U., Hauck, J., Jax, K., & Sukopp, U. (2016). Requirements for the selection of ecosystem service indicators – The case of MAES indicators. *Ecological Indicators*, *61*, 18–26. https://www.sciencedirect.com/science/article/pii/S1470160X15005178

Hoffman, M., Lubell, M., & Hillis, V. (2014). Linking knowledge and action through mental models of sustainable agriculture. In *Proceedings of the National Academy of Sciences*, 111, pp. 13016–13021.

Höhler, J., Barreiro-Hurlé, J., Czajkowski, M., Dessart, F. J., Ferraro, P. J., Li, T., Messer, K. D., Palm-Forster, L., Termansen, M., Thomas, F., Zagórska, K., Zemo, K. H., & Rommel, J. (2024). Perspectives on stakeholder participation in the design of economic experiments for agricultural policymaking: Pros, cons, and twelve recommendations for researchers. *Applied Economic Perspectives and Policy*, *46*, 338–359. https://doi.org/10.1002/aepp.13385

Huber, S., Prokop, G., Arrouays, D., Banko, G., Bispo, A., Jones, R. J. A., Kibblewhite, M. G., Lexer, W., Möller, A., Rickson, R. J., Shishkov, T., Stephens, M., Toth, G., Van den Akker, J. J. H., Varallyay, G., Verheijen, F. G. A., & Jones, A. R. (Eds.). (2008). *Environmental assessment of soil for monitoring*. Office for Official Publications of the European Communities.

Ingram, J. (2014). Farmer-scientist knowledge exchange. In P. B. Thompson & D. M. Kaplan (Eds.), *Encyclopedia of food and agricultural ethics* (pp. 722–729). Springer.

Jax, K., Furman, E., Saarikoski, H., Barton, D. N., Delbaere, B., Dick, J., Duke, G., Görg, C., Gómez-Baggethun, E., Harrison, P. A., Maes, J., Pérez-Soba, M., Saarela, S.-R., Turkelboom, F., van Dijk, J., & Watt, A. D. (2018). Handling a messy world: Lessons learned when trying to make the ecosystem services concept operational. *Ecosystem Services*, *29*, 415–427. https://www.sciencedirect.com/science/article/pii/S2212041617300177

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *Current. Journal of Applied Science and Technology*, *7*, 396–403. https://journalcjast.com/index.php/CJAST/article/view/381

Keeney, D. R. (1989). Toward a sustainable agriculture: Need for clarification of concepts and terminology. *American Journal of Alternative Agriculture*, *4*, 101–105. https://www.cambridge.org/core/article/toward-a-sustainable-agriculture-need-for-clarification-of-concepts-and-terminology/89E837DA2ED3961DAD3337909F852514

Keesstra, S. D., Chenu, C., Munkholm, L. J., Cornu, S., Kuikman, P. J., Thorsøe, M. H., Besse-Lototskaya, A., & Visser, S. M. (2024). European agricultural soil management: Towards climate-smart and sustainability, knowledge needs and research approaches. *European Journal of Soil Science*, *75*, e13437. https://doi.org/10.1111/ejss.13437

Lal, R., Bouma, J., Brevik, E., Dawson, L., Field, D. J., Glaser, B., Hatano, R., Hartemink, A. E., Kosaki, T., Lascelles, B., Monger, C., Muggler, C., Ndzana, G. M., Norra, S., Pan, X., Paradelo, R., Reyes-Sánchez, L. B., Sandén, T., Singh, B. R., … Zhang, J. (2021). Soils and sustainable development goals of the United Nations: An International Union of Soil Sciences perspective. *Geoderma Regional*, *25*, e00398. https://www.sciencedirect.com/science/article/pii/S2352009421000432

Leighton, K., Kardong-Edgren, S., Schneidereith, T., & Foisy-Doll, C. (2021). Using social media and snowball sampling as an alternative recruitment strategy for research. *Clinical Simulation in Nursing*, *55*, 37–42. https://doi.org/10.1016/j.ecns.2021.03.006

Leiner, D. (2019). SoSci survey (Version 3.1.06) [Computer software]. www.soscisurvey.de

Löbmann, M. T., Maring, L., Prokop, G., Brils, J., Bender, J., Bispo, A., & Helming, K. (2022). Systems knowledge for sustainable soil and land management. *Science of the Total Environment*, *822*, 153389. https://www.sciencedirect.com/science/article/pii/S0048969722004818

Mason, E., Cornu, S., & Chenu, C. (2023). Stakeholders' point of view on access to soil knowledge in France. What are the opportunities for further improvement? *Geoderma Regional*, *35*, e00716. https://www.sciencedirect.com/science/article/pii/S2352009423001128

Michel, K., Spiegel, A., Weninger, T., Goidts, E., Oorts, K., Sombré, L., Borůvka, L., Pálka, B., Pavlů, L., Pesch, C., Asins, S., Doñate, E., Molina, M. J., Cousin, I., Lemercier, B., Saby, N., Gedeon, C., Laborczi, A., Bondi, G., … Assennato, F. (2023). Currently available assessments of soil threats and ecosystem services: Data, metadata, and methodologies - update. *SERENA Deliverable* D3.1.2, Report, 224.

Montagne, D., Buttafuoco, G., Scammacca, O., Calzolari, C., Pindral, S., Foldal, C., Laborczi, A., Kukk, L., Anton, R., Medina, E., Stefanova, M., Oorts, K., Klimkowicz-Pawlas, A., Niedźwiecki, J., & Borůvka, L. (2023). Towards a cookbook to evaluate soil threats, soil-based ecosystem services and their associated bundles over scenarios of changes: A first identification of indicators for harmonisation at EU level. *EJP Soil Internal Project SERENA*, *Deliverable D.2.3.1*, *47*. https://ejpsoil.eu/knowledge-sharing-platform/deliverables

Osmond, D. L., Nadkarni, N. M., Driscoll, C. T., Andrews, E., Gold, A. J., Allred, S. R. B., Berkowitz, A. R., Klemens, M. W., Loecke, T. L., McGarry, M. A., Schwarz, K., Washington, M. L., & Groffman, P. M. (2010). The role of interface organizations in science communication and understanding. *Frontiers in Ecology and the Environment*, *8*, 306–313. https://doi.org/10.1890/090145

Paul, C., Kuhn, K., Steinhoff-Knopp, B., Weißhuhn, P., & Helming, K. (2021). Towards a standardization of soil-related ecosystem service assessments. *European Journal of Soil Science*, *72*, 1543–1558. https://doi.org/10.1111/ejss.13022

Power, A. G. (2010). Ecosystem services and agriculture: Tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*, 2959–2971. https://doi.org/10.1098/rstb.2010.0143

Prost, L., Martin, G., Ballot, R., Benoit, M., Bergez, J.-E., Bockstaller, C., Cerf, M., Deytieux, V., Hossard, L., Jeuffroy, M.-H., Leclère, M., Le Bail, M., Le Gal, P.-Y., Loyce, C., Merot, A., Meynard, J.-M., Mignolet, C., Munier-Jolain, N., Novak, S., … van der Werf, H. (2023). Key research challenges to supporting farm transitions to agroecology in advanced economies. A review. *Agronomy for Sustainable Development*, *43*, 11. https://doi.org/10.1007/s13593-022-00855-8

Salvia, R., Simone, R., Salvati, L., & Quaranta, G. (2018). Soil conservation practices and Stakeholder's participation in research projects—Empirical evidence from southern Italy. *Agriculture*, *8*, 85. https://doi.org/10.3390/agriculture8060085

Schulp, C. J. E., Komossa, F., Scherer, L., van der Zanden, E. H., Debolini, M., & Piorr, A. (2022). The role of different types of actors in the future of sustainable agriculture in a Dutch Peri-urban area. *Environmental Management*, *70*, 401–419. https://doi.org/10.1007/s00267-022-01654-3

Schwilch, G., Bernet, L., Fleskens, L., Giannakis, E., Leventon, J., Marañón, T., Mills, J., Short, C., Stolte, J., van Delden, H., & Verzandvoort, S. (2016). Operationalizing ecosystem services for the mitigation of soil threats: A proposed framework. *Ecological Indicators*, *67*, 586–597. https://www.sciencedirect.com/science/article/pii/S1470160X16301200

Sullivan, G. M., & Artino, A. R. (2013). Analyzing and interpreting data from Likert-type scales. *Journal of Graduate Medical Education*, *5*, 541–542. https://doi.org/10.4300/JGME-5-4-18

Thorsøe, M. H., Keesstra, S., De Boever, M., Buchová, K., Bøe, F., Castanheira, N. L., Chenu, C., Cornu, S., Don, A., Fohrafellner, J., Farina, R., Fornara, D., da Conceição Gonçalves, M., Graversgaard, M., Heller, O., Inselsbacher, E., Jacobs, A., Mavsar, S., Meurer, K. H. E., … Munkholm, L. J. (2023). Sustainable soil management: Soil knowledge use and gaps in Europe. *European Journal of Soil Science*, *74*, e13439. https://doi.org/10.1111/ejss.13439

UN. (2015). Transforming our world: The 2030 agenda for sustainable development. A/RES/70/1.

van Beek, C. L., Tóth, T., Hagyó, A., Tóth, G., Recatalá Boix, L., Añó Vidal, C., Malet, J. P., Maquaire, O., van den Akker, J. J. H., van der Zee, S. E. A. T. M., Verzandvoort, S., Simota, C., Kuikman, P. J., & Oenema, O. (2010). The need for harmonizing methodologies for assessing soil threats in Europe. *Soil Use and Management*, *26*, 299–309. https://doi.org/10.1111/j.1475-2743.2010.00280.x

van den Elsen, E., Antón, R., Cousin, I., Fuchs, L., de Haan, J., Teuling, K., Klimkowicz-Pawlas, A., Nied'zwiecki, J., Pindral, S., Montagne, D., Scammaca, O., & Weninger, T. (2022). A framework to assess soil threats, soil functions and soil-based ecosystem services. *SERENA Deliverable D2.1, Report*.

Vanino, S., Pirelli, T., Di Bene, C., Bøe, F., Castanheira, N., Chenu, C., Cornu, S., Feiza, V., Fornara, D., Heller, O., Kasparinskis, R., Keesstra, S., Lasorella, M. V., Madenoğlu, S., Meurer, K. H. E., O'Sullivan, L., Peter, N., Piccini, C., Siebielec, G., … Farina, R. (2023). Barriers and opportunities of soil knowledge to address soil challenges: Stakeholders' perspectives across Europe. *Journal of Environmental Management*, *325*, 116581. https://www.sciencedirect.com/science/article/pii/S0301479722021545

Veerman, C., Correia, T. P., Bastioli, C., Biro, B., Bouma, J., Cienciala, E., Emmett, B., Frison, E. A., Grand, A., Filchev, L. H., Kriaučiūnienė, Z., Pogrzeba, M., Soussana, J.-F., Vela, C., & Wittkowski, R. (2020). Caring for soil is caring for life. *Interim Report of the Mission Board for Soil Health and Food*, *56*. https://era.gv.at/public/documents/4226/Soil.pdf

Wade, J., Beetstra, M. A., Hamilton, M. L., Culman, S. W., & Margenot, A. J. (2021). Soil health conceptualization differs across key stakeholder groups in the Midwest. *Journal of Soil and Water Conservation*, *76*, 527–533. http://www.jswconline.org/content/76/6/527.abstract

Zindler, M., Haensel, M., Fricke, U., Schmitt, T. M., Tobisch, C., & Koellner, T. (2023). Improving Agri-environmental schemes: Suggestions from farmers and nature managers in a central European region. *Environmental Management* https://doi.org/10.1007/s00267-023-01922-w

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Weninger, T., Ramler, D., Bondi, G., Asins, S., O'Sullivan, L., Assennato, F., Astover, A., Bispo, A., Borůvka, L., Buttafuoco, G., Calzolari, C., Castanheira, N., Cousin, I., van den Elsen, E., Foldal, C., Hessel, R., Kadžiulienė, Ž., Kukk, L., Molina, M. J., … Klimkowicz-Pawlas, A. (2024). Do we speak one language on the way to sustainable soil management in Europe? A terminology check via an EU-wide survey. *European Journal of Soil Science*, *75*(2), e13476. https://doi.org/10.1111/ejss.13476