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European Joint Programme

Towards climate-smart sustainable management of agricultural soils

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Report on the current availability and use of soil knowledge

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ABSTRACT

This report provides a synthesis of stakeholders' perceptions of knowledge on and use of knowledge on sustainable soil management, as well as the knowledge needs. The report is based on interviews with 791 stakeholders in 23 European countries completed in the summer of 2020 in the context of the EJP SOIL project.

The analysis highlights a number of shortcomings in the current use and coordination of knowledge on sustainable soil management. For instance, insufficient communication and coordination between policymakers, researchers and farmers is reported. Most national reports stress that, currently, the promotion of knowledge on sustainable soil management towards stakeholders is ineffective. Challenges, for instance, arise because the theoretical knowledge produced at universities is considered irrelevant or inaccessible to farmers who have a practical approach to soil management. It is also reported that there is too little continuity in soil research due to project dependence, which is a challenge because soil research requires long-term investigations. Furthermore, current research insufficiently supports integrated decision-making of practitioners and policymakers, where different challenges and trade-offs continuously must be balanced. In some countries, this is partly due to insufficient funding for dissemination activities, whereas in other countries funding is not utilized correctly. Additionally, reports broadly agree that there is too little continuity in research due to project dependence, which is challenging because soil research requires long-term investigations.

In relation to specific areas, knowledge gaps regarding the loss of soil organic matter, carbon sequestration and exploring the effects of climate change, mitigation and preventive measures. were identified. A range of other areas also appear as highly important in certain regions – for instance, ensuring an optimal soil structure, enhancing soil biodiversity, water storage capacity, soil nutrient retention and use efficiency.

To overcome these challenges, stakeholders stress that it is important to improve the coordination between policy, research, industry, advisory services and farmers because knowledge about field activities and sustainable soil management is fragmented and poorly coordinated. Thus, stakeholders stress that it is important to strengthen intermediaries, such as the advisory service and farmers' associations, as they are important knowledge brokers, both in terms of improving knowledge availability and to provide feedback on knowledge gaps to research institutions. Additionally, the need for strengthening networks and peer-to-peer communication is emphasized because these are useful platforms for knowledge exchange. Furthermore, it is important to provide incentives for farmers and improve the visibility of soil challenges for stakeholders, for instance using decision support tools to highlight the benefit of adopting sustainable soil management.

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1. Introduction

The purpose of this report is to provide a synthesis of stakeholders' perception of knowledge on and use of knowledge on sustainable soil management, as well as the knowledge needs. The report is part of a series of stocktakes within the EJP SOIL Work Package 2 that inform the development of a roadmap for EU Agricultural Soil Management. Other deliverables include a report that identifies current policy ambitions and future soil aspirational goals (task 2.1) and a report that identifies knowledge availability and use (researchers' perspectives) (task 2.2.1), as well as an identification of barriers and opportunities by scenario development (task 2.3). Although each with a different focus, these reports are all based on feedback from a national group of researchers and stakeholders. The primary focus is on knowledge application as shown below. The task, therefore, concerns the knowledge application compartment of the EJP SOIL knowledge framework (see Figure 1).

The remainder of this report is structured as follows:

- Chapter 2 presents the methodology that has been used by partners to acquire data and in the compilation of results in this report.
- Chapter 3 presents a synthesis of stakeholders' perspectives on the status of national agricultural knowledge systems with respect to sustainable soil management.
- Chapter 4 presents a synthesis of stakeholders' perspectives on knowledge use and gaps in knowledge with respect to sustainable soil management.
- Chapter 5 summarizes the conclusions of the analysis.

The objective of this report is not to generalize results statistically beyond the national contexts where they appear. Rather, the issues that are brought forward in the national reports are important even when they only appear in one particular setting and not in others.

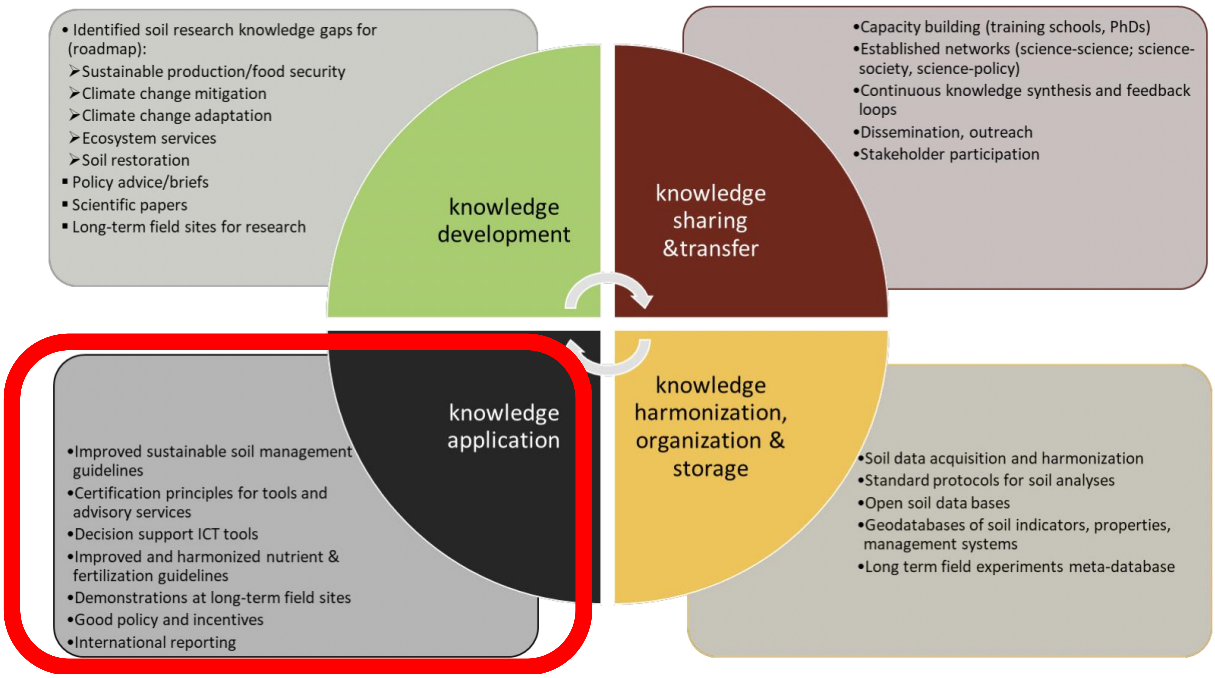

***Figure 1**: EJP SOIL Knowledge framework.*

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2. Methodology

The synthesis is based on national reports prepared by 23 EJP SOIL partners. Originally, we planned to use national workshops with stakeholder representatives as an input to these national reports. However, face-to-face meetings with stakeholders were impossible to organize in most countries due to the restrictions adopted to prevent the spread of Covid-19. Therefore, various approaches to represent stakeholders' perspectives were adopted by partners.

The social, institutional and environmental context varies considerably across the 23 countries that comprise the EJP SOIL consortia; therefore, it was important that the analytical setup reflects this diversity. To ensure comparability between all stakeholders and regions we developed a glossary and a soil concept framework, which was used across the three stocktakes; this was also used as the foundation of this report and is found in Ruysschaert et al. (2020: Annex 2).

Furthermore, due to variations in environmental conditions across national contexts and their implications for which soil challenges and knowledge gaps are relevant to address, challenges and knowledge gaps were grouped according to the respective environmental zone as classified by Metzger et al. (2005) (see Figure 2). In the current report, these environmental zones are again grouped into four European regions that are more broadly used in the EJP SOIL roadmap development (Central Europe, Northern Europe, Southern Europe (including Turkey) and Western Europe) (see Figure 3).

2.1 Identifying and recruiting key stakeholders for the analysis

Stakeholder representation is an important foundation for the work in EJP SOIL and a core group of stakeholders provide input for a number of tasks (National Hubs). Guidelines for selecting and recruiting stakeholders for the EJP SOIL was provided by EJP SOIL WP9. In acquiring data for this report, members of the national hubs were asked to provide information for this activity. However, the composition of stakeholders in the national hubs varies across countries due to differences in organizational landscape and stakeholder availability. Stakeholders who participated in this exercise also vary across countries.

A number of partners used existing stakeholder networks from related research projects as a platform for recruiting stakeholders for this analysis, but, generally, the basis for this report is a rather diverse representation of different groups of stakeholders. However, some partners also experienced a range of issues and delays as a result of lacking a network and contact with stakeholders as well as the restrictions on opportunities for face-to-face contacts that were adopted to prevent the spread of Covid-19.

2.2 Acquiring data for national reports

As a basis for the national reports, we recommended that partners conducted a series (5-10) interviews with key stakeholders. These interviews could be completed either face-to-face, by phone/Skype, email or as part of a focus group. Furthermore, we recommended that partners structured each interview according to the themes outlined below and planned for an open and explorative conversation (semi-structured). This enabled stakeholders to present their views and perceptions as openly as possible and it is inclusive towards unexpected inputs.

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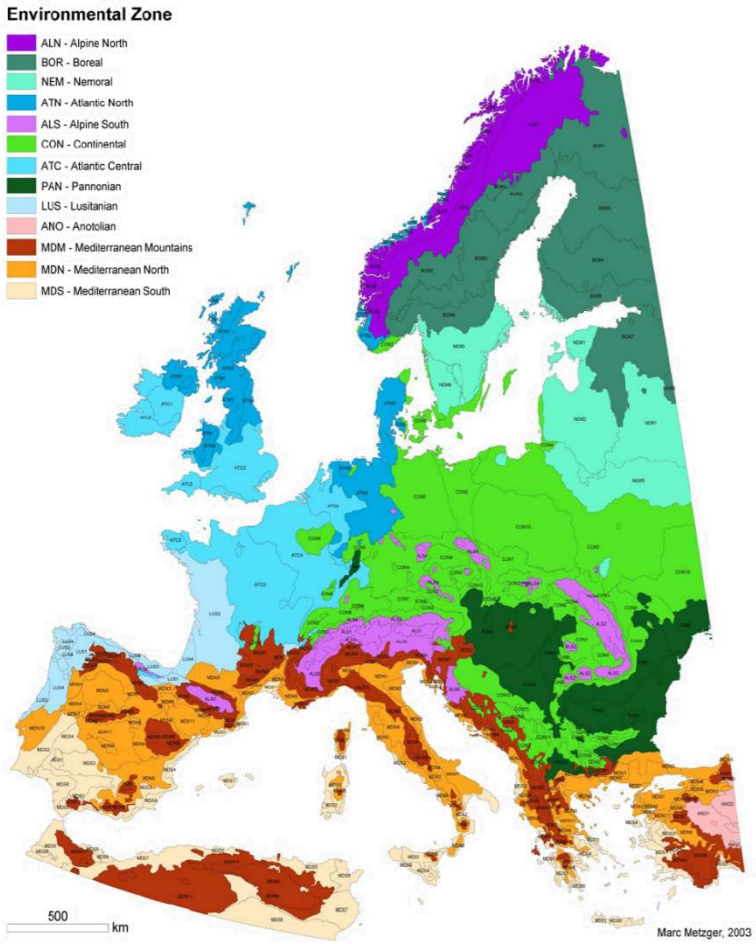

Figure 2: *Environmental zones of Europe according to Metzger et al. (2005): Alpine North; Boreal; Nemoral; Atlantic North, Alpine South; Continental; Atlantic Central; Pannonian; Lusitanian; Anatolian; Mediterranean Mountains; Mediterranean North; Mediterranean*

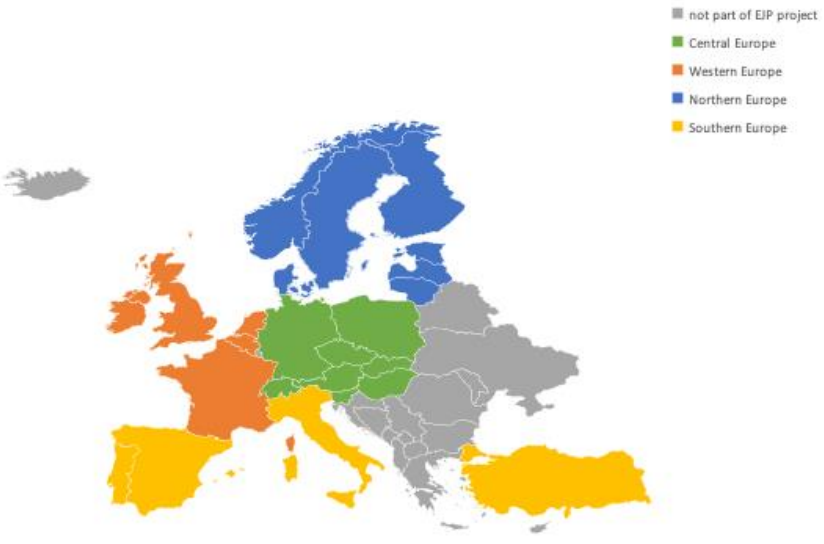

Figure 3: *Main European regions within the EJP SOIL project (StAGN 2020).*

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Interview themes:

1. Structure of the agricultural knowledge system in relation to sustainable soil management
2. Coordination of knowledge on sustainable soil management among key stakeholders
3. The ability of the knowledge system to influence farming practices
4. Status of knowledge on sustainable soil management relative to environmental zones
5. Knowledge gaps in relation to sustainable soil management relative to environmental zones

2.3 Data for this report

Based on these guidelines for stakeholder selection and interview themes, partners prepared a national report presenting each national context and the difference across environmental zones within each country. Each national team synthesized interviews for the present report in a web-based reporting tool (see Appendix A). Reporting requirements consisted of a range of open as well as closed questions that allowed for comparative analysis across the countries but also allowed partners to represent perspectives of individual stakeholders or specific national concerns and reflections. Besides, partners were encouraged to include diverging opinions regarding the need for action or importance of different knowledge gaps as these may differ across stakeholder categories.

The national reports are based on interviews with a total of 791 stakeholders, representing different perspectives on knowledge availability and use regarding sustainable soil management (see Table 1). Although the total number of respondents and stakeholder categories diverge across and within countries, the selection covers the diversity of European soils, and social and institutional contexts. However, for some countries, the number of stakeholders is somewhat limited considering the size of the countries, including France, Norway, Sweden and Turkey.

Most national teams acquired data for the report based on an online survey (see Table 2), developed around the questions outlined in Appendix A. However, some teams completed the task via online or phone interviews and others used a combination of methods. However, it is important to bear in mind that there are substantial social, cultural and institutional differences across countries that make it difficult to represent the views of stakeholders using the same methodology.

2.4 Data treatment

The reports from partners include qualitative and quantitative elements. This combination provides different types of information, offering a rich picture on the knowledge on and use of knowledge on sustainable soil management (Creswell, 2013). The qualitative and quantitative data were analysed in an iterative process providing complementary insights. The survey findings appear in tables, while open replies are used to deepen and discuss the insights and to highlight and unfold recurring themes. The tables containing replies to the closed questions represent an assessment of the national partners regarding the situation in the country or environmental zone based on the data acquired through the stocktake. We present quantitative elements using descriptive statistics and deliberately do not use advanced statistical models for the analysis as the total number of replies is low (N=23) and the contextual differences are notable across countries, so a statistical analysis would just disguise these differences. Furthermore, analysis of the open replies was used to highlight recurrent themes and broaden perspectives of the closed questions. Themes were grouped and regrouped in a process of constant comparison, developing distinct categories that account for the entire data set (Corbin, 1998; Silverman, 2011).

The content of the replies for the open questions differed slightly across national reports; therefore, in this report we have reorganized themes so they are presented in the same discussions, preventing

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redundancy. Replies to the open questions diverge across countries. Therefore, we refrain from emphasizing the country from where points originate as comments may also apply to a number of other countries. The first part of the result presentation (Chapter 3) presents a range of general conclusions regarding the differences across the countries that are part of the analysis. Further (Chapter 4), we emphasize the knowledge use and gaps that are most central in each of the environmental zones.

Table 1: *Stakeholder representation.*

	Policymakers	Research communities	Research funders	Educational institutions and agricultural colleges	Farmers & demonstration farms	Advisors	Farmers'	Agro-industry, supply & retail	Laboratories	National science testing and verification centers etc.	NGOs	Others	Total
Austria	1	4	0	3	0	2	1	0	0	0	0	0	11
Belgium Flanders	4	1	0	0	0	4	3	0	0	0	1	0	13
Belgium Wallonia	2	11	0	0	1	4	3	0	0	2	1	2	26
Czechia	1	3	1	1	1	0	1	0	1	1	1	0	11
Denmark	4	10	0	0	4	2	6	1	0	0	2	0	29
Finland	0	4	1	0	0	2	1	3	0	0	2	0	13
France	1	1	1	1	0	0	0	1	0	0	0	0	5
Germany	2	80	0	6	204	28	0	6	0	0	9	75	410
Hungary	2	3	0	2	1	2	2	2	2	1	1	0	18
Ireland	2	2	1	0	1	1	0	0	0	0	0	0	7
Italy	2	1	0	5	0	2	2	0	4	0	1	0	17
Latvia	5	2	0	1	41	0	4	1	0	0	2	0	56
Lithuania	1	3	0	1	2	2	0	0	0	0	1	0	10
Norway	0	0	0	1	1	2	1	0	0	0	0	0	5
Poland	2	1	0	0	5	2	0	1	1	0	0	0	12
Portugal	1	3	0	6	0	0	6	1	0	1	1	0	19
Slovakia	2	3	0	2	0	0	1	0	1	0	0	0	9
Slovenia	1	13	0	2	0	9	1	0	0	0	0	0	26
Sweden	0	0	0	0	1	3	3	0	0	0	0	0	7
Switzerland	9	7	0	4	0	3	3	4	0	1	0	0	31
The Netherlands	0	0	0	0	0	0	0	0	0	0	0	14	33
Turkey	0	4	0	0	0	0	0	0	0	0	0	0	4
United Kingdom	1	5	1	2	2	0	2	4	1	0	1	0	19
Total	43	161	5	37	266	68	37	40	10	6	66	89	791

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Table 2: *Interview types.*

	Face-to-face	Phone or video link	Focus group	Online focus group or webinar	Email or survey	Other	Total
Austria	5	3	0	0	3	0	11
Belgium Flanders	0	0	0	0	13	0	13
Belgium Wallonia	0	0	0	0	26	0	26
Czechia	0	0	0	0	11	0	11
Denmark	0	18	0	0	11	0	29
Finland	0	13	0	0	0	0	13
France	0	0	0	0	5	0	5
Germany	0	0	0	0	0	410	410
Hungary	6	4	0	0	6	2	18
Ireland	0	0	0	0	7	0	7
Italy	0	3	0	0	14	0	17
Latvia	42	4	0	0	10	0	56
Lithuania	6	4	0	0	0	0	10
Norway	0	1	0	0	4	0	5
Poland	0	11	0	0	1	0	12
Portugal	0	0	0	0	19	0	19
Slovakia	0	0	0	0	9	0	9
Slovenia	0	0	0	0	26	0	26
Sweden	0	5	0	2	0	0	7
Switzerland	0	0	0	0	31	0	31
The Netherlands	0	0	0	19	0	14	33
Turkey	0	0	0	0	4	0	4
United Kingdom	0	0	0	0	19	0	19
Total	59	65	0	19	187	457	791

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3. National agricultural knowledge and information systems

This section contains outcomes on stakeholders' general reflections on the structure and functioning of the agricultural knowledge and information system in relation to sustainable soil management in the partner countries.

The concept Agricultural Knowledge and Information/innovation System (AKIS) is widely used to characterize the exchange of knowledge and the institutions that support these exchanges (Klerkx et al., 2012; Knierim et al., 2015). The concept denotes a set of agricultural stakeholders, the links and interactions between them, engaged in the generation, transformation, transmission, storage, retrieval, integration, diffusion and utilization of knowledge and information, with the purpose of working synergistically to support decision-making, problem-solving and innovation in agriculture (Klerkx and Leeuwis, 2009). This approach to knowledge and innovation emphasizes the importance of systemic connections between different actors around farmers and their importance for the development of farms. These are highly embedded in local institutions and infrastructures and it is difficult to compare across countries. Therefore, in line with Knierim and Prager (2015), we distinguish between the coordination of the knowledge system (concerns the formal links between actors and cooperation) and the strength of the knowledge system (the presence of supportive actors, resource availability and that farmers are reached with interventions).

3.1 Coordination of knowledge on sustainable soil management

In a closed question, partners reported stakeholders' assessment of a range of factors related to the coordination of knowledge on sustainable soil management (see Table 3). Although considerable variation is reported across countries, particularly in relation to the performance of the advisory system, the majority of national reports indicate that, generally, farmers' access to knowledge was good and that farmers were well prepared to engage in sustainable soil management when graduating from agricultural college. However, most partners also reported shortcomings in the coordination between researchers, stakeholders as well as policymakers, and that initiatives to promote sustainable soil management were somewhat uncoordinated.

In an open question, partners were given the opportunity to provide their reflections of the coordination of sustainable soil management within the country. Generally, most partners indicated that coordination of knowledge use and knowledge production between stakeholders today is better than previously. However, national reports also documented that there is still considerable room for improvement and a number of barriers exist preventing the coordination of sustainable soil management. Below we summarized some of the themes that occurred recurrently in the national reports; for a detailed overview of specific countries, see Appendix B:

- Particularly reports from some of the large and heterogeneous countries documented a considerable **internal variation** in environmental conditions and conventions regarding coordination of sustainable soil management. Therefore, it is difficult to make generalized claims that apply throughout the country (and thus also across countries) or to specific production sectors. Hence, whereas the coordination of knowledge use and knowledge production was good in one region, it was not necessarily the case across the country. Besides, countries with variation in climate and soil types further report that this limits transferability and relevance of research and coordination across space. Additionally, often a mismatch between environmental zones and administrative boundaries is reported. Furthermore, across

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European countries, **the farming sector is often fragmented**. A number of countries reported that the farming sector both includes large-scale and professional producers that quickly respond to policy and market signals, as well as small-scale farmers rooted in traditional production methods and who may therefore be resistant to change and not supportive of sustainable soil management.

- Often **research activities are fragmented** due to disciplinary specialization, the participation of numerous actors in a research project and unclear focus and coordination. Some partners also stress that few researchers have a good overview of agricultural practice because they are specialized within a particular field. Furthermore, partners reported diverging views of what constitutes sustainable soil management, therefore, it is difficult to communicate and coordinate, when different claims regarding sustainable soil management exist and univocal terminology lacks. Besides, some research projects yield contrasting results. Additionally, the often short duration of research projects and the predefined scope imply that coordination is often not sufficiently prioritized.
- A number of partners report that **lacking communication** among researchers, policymakers and stakeholders is a hindrance to the coordination of activities and that this could be improved. Furthermore, partners also report that there is lacking coordination of activities and limited knowledge transfer within and across countries with comparable environmental conditions. This implies that research is redundant, or that research results that could benefit stakeholders in an entire region are not disseminated. Lacking communication across institutional boundaries may be due to a network scarcity or lacking will to engage stakeholders. Furthermore, lacking funding for dissemination is stressed as an important barrier to coordination of knowledge on and use of knowledge on sustainable soil management. Partners also reported that there is a tendency to allocate resources for knowledge production (scientific) rather than for dissemination and coordination. Hence, knowledge production targets a scientific audience, and whether results are useful for stakeholders or not is of secondary importance. Therefore, stakeholders do not build sufficient capacity to carry out sustainable soil management informed by scientific principles, and researchers have a fragmented picture of stakeholders' reality. A specific aspect relates to data availability and privacy. Often regulation designed to protect the privacy of farm data (GDPR) also implies that it is difficult for researchers to get an overview of the actual state of the soil and soil management issues because access to farm data is restricted.
- The **lack of coordinating institutions** is an important hindrance. Partners from a range of countries report that the advisory service is an important intermediary, but advisors' interest in sustainable soil management varies and the institutional setup around advisors also varies, implying that their ability to engage in the coordination of knowledge on sustainable soil management also differs. For instance, several reports emphasize the difference between commercial and public advisory services. Whereas the first group has good knowledge on sustainable soil management, others provide commercial advice and do not always have access to such knowledge but are often driven by short-term economic considerations. Some partners also report that advisors need to improve their skills in order to properly facilitate coordination of sustainable soil management and that more training is required for advisors to obtain skills in assessing farmers' soil management practices.

  Widely across countries, partners report **little interest in participating** in research and a lacking demand for knowledge on sustainable soil management among stakeholders. Some

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partners stress that stakeholders express little interest in participating in research projects. Furthermore, there is insufficient policy support and economic incentives for stakeholders to adopt recommendations, as stakeholders are more oriented towards the economy. Additionally, a number of West European partners emphasize that privatization of the advisory service implies that they must work on market conditions. Thus, they offer only such advice that farmers request and consequently they have little opportunity to promote new aspects of sustainable soil management beyond what is currently economically feasible. Additionally, many farmers across Europe are reported to be challenging to involve in the coordination of knowledge production and research activities due to seniority.

Table 3: *Stakeholders' assessment of a range of factors concerning coordination of knowledge on sustainable soil management. For the assessment, respondents were given a five-point Likert scale.*

	How good is farmers' access to relevant knowledge about sustainable soil management?	**How well are young farmers prepared for sustainable soil management in agricultural colleges?**	**How well is the advisory service prepared to promote knowledge on sustainable soil management to farmers?**	**How good is the overall coordination of knowledge production regarding sustainable soil management?**	**How well are research activities in relation to sustainable soil management coordinated with policy-makers?**
Austria					
Belgium Flanders					
Belgium Wallonia					
Czechia					
Denmark					
Finland					
France					
Germany					
Hungary					
Ireland					
Italy					
Latvia					
Lithuania					
Norway					
Poland					
Portugal					
Slovakia					
Slovenia					
Sweden					
Switzerland					
The Netherlands					
Turkey					
United Kingdom					

Legend	Very good/ Very coordinated	Good/coordinated	Neutral	Somewhat deficient/ Somewhat coordinated	Very poor/ Uncoordinated

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- **Insufficient link between researchers and policy-makers.** Several partners report that internally within governments, soil policies tend to be subdivided across different policy silos. Therefore, coordinating policy development is challenging and often soil policies tend to lack a comprehensive vision. Furthermore, policymakers are often not trained in soil management, and researchers, on the other hand, also lack knowledge about the constraints of policy design and implementation of public policies. Another hurdle is the lack of both top-down coordination and bottom-up initiatives because institutions and researchers work individually, competitively and are sometimes guided by personal interests.

Despite these shortcomings regarding the coordination of knowledge use and knowledge production between stakeholders, a number of replies also emphasize that the foundation for coordination of sustainable soil management is improving:

- **Increasing awareness about soil-related issues** is reported across countries and many events that disseminate sustainable soil management are organized although outreach can be improved. For instance, a number of partners report that much information is available and accessible in field demonstrations, communication in the agricultural press, seminars and workshops. In some countries, e.g., France, a range of platforms have been developed for the dissemination of knowledge that are also used internationally. Recent awareness of soil issues is important for the reach of such platforms. Furthermore, a number of countries including Denmark and Norway report increasing focus on sustainable soil management in agricultural colleges as several have initiated projects on soil health. The emerging focus on reducing GHG emissions also constitutes an important opportunity to improve conditions.

Overcoming challenges in the coordination of knowledge on and use of knowledge on sustainable soil management

In an open question, stakeholders were then asked to reflect how the coordination of knowledge production and use of knowledge on sustainable soil management can be improved. A number of points are raised in response to the challenges raised above.

- A number of stakeholders stress that it is important to **improve coordination between policy, research, industry, advisory services and farmers** because knowledge about land-use and sustainable soil management is scattered and for the moment poorly coordinated. There are linkages between all actors, but most are ad-hoc and project-based rather than systematic and long-term. Therefore, better integration of stakeholders would, in many countries, profoundly improve coordination. In order to do so, there is a need for a systemic, integrative long-term vision on agricultural soils. Partners report that for policymakers and researchers in some countries it is important to **improve the overview, availability and accessibility of soil data**. This could be ensured by preparing a continuous collection of activity data and setting up databases for various groups of stakeholders.
- Soil management is often not discussed directly at farm level and farm advisory services should emphasize this area of farm management and demonstrate the options available to solve the various soil challenges. Broadly, stakeholders stress that it is important to **strengthen intermediaries**, such as the advisory service and farmers' associations, as they are important knowledge brokers both in terms of making knowledge available to farmers and for providing feedback to research institutions. Therefore, they could play a more important role. However,

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across countries the organization of intermediaries differs substantially, therefore, approaches should be adapted to the local context. In countries with a fully or partly privatized advisory service, such as the Netherlands and Denmark, partners stress that it is important to ensure resources for dissemination of sustainable soil management because farmers do not request this information by themselves. Other partners stress that the advisory service lacks competencies to promote sustainable soil management (see Table 3) and stress the importance of improving such competencies to ensure that the advisory service is able to promote sustainable soil management. This could, for instance, be achieved by training advisors.

- Although often a requirement in European projects, local traditions for stakeholder involvement in research activities and policymaking differ. Several partners stress that it is important to **strengthen networks and farmers' inclusion in research projects** to enable better coordination within the knowledge system. Conducting this type of participatory research implies that knowledge producer should work directly with end-users, thus ensuring that research activities consider stakeholders' needs.
- A number of partners indicate the need for **a more coherent approach to sustainable soil management in environmental policy-making**, and that it is important to prioritize sustainable soil management in institutional programming.
- Furthermore, partners report that it is important to **strengthen farmers' awareness** about soil challenges and opportunities for sustainable soil management for engagement and improving participation in the coordination of sustainable soil management (see also next chapter for further details).

3.2 Strength of the knowledge system

Ways of communicating with stakeholders

In the communication with stakeholders, both commonalities and divergences across countries in the media use are seen (see Table 4). For instance, a number of communication channels are commonly used across all or most countries, including advisory service, peer-to-peer groups, printed media, as well as webpages and blogs. Furthermore, a range of communication channels are commonly not used in the communication with farmers, including scientific literature, technical reports and social media.

In addition to the platforms mentioned above, an open question enabled stakeholders to indicate additional information regarding communication. Replies reflected that a range of additional media were also used in the communication with farmers, including particular events, such as seminars, workshops and field days. Additionally, informal networks between colleagues or neighbours also play a role in communication between farmers.

Furthermore, several partners emphasize that often there is little information about sustainable practices in "traditional" agricultural media, but that such information is often found in more dedicated outlets; however, this largely restricts information access for farmers at large. Besides, although quite a lot of information is available via social media, much of this information is not controlled or quality-checked, thus implying that farmers are also exposed to misinformation. Furthermore, given the voluntary nature of many of these communication platforms, there is a risk that much critical information on sustainable soil management does not reach the farmers who need it the most.

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Table 4: *Stakeholders' replies to the question: "To which extent are different platforms used to disseminate knowledge on sustainable soil management to farmers?*

	Social media	Printed media	Electronic newsletters	Peer-to-peer groups	Farmer interest groups	Advisory service	Webpages and blogs	Scientific literature	Technical reports	Other
Austria										
Belgium Flanders										
Belgium Wallonia										
Czechia										
Denmark										
Finland										
France										
Germany[i]										
Hungary										
Ireland										
Italy										
Latvia										
Lithuania										
Norway										
Poland										
Portugal										
Slovakia										
Slovenia										
Sweden										
Switzerland										
The Netherlands										
Turkey										
United Kingdom										

Legend	Highly used	Used	Neutral	Somewhat used	Not used	No clear indication

Effectiveness of the communication and knowledge transfer

In a closed question, stakeholders assessed the effectiveness of the knowledge system in producing and communicating knowledge on and use of knowledge on sustainable soil management (see Table 5).

In relation to the overall effectiveness of the current knowledge system in communicating sustainable soil management to farmers there are divergences across countries (see Table 5). For a range of countries, stakeholders report that the current system is ineffective, including Italy, the United Kingdom, Austria, Portugal, Switzerland, the Netherlands and Lithuania and Latvia. However, in other countries, the perception is more positive, particularly for Denmark and Belgium (Wallonia), and furthermore, in a number of countries partners indicate a more neutral position.

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Table 5: *Replies to three questions regarding the strength of the knowledge system in the countries.*

	To which extent is the current knowledge system sufficiently effective in communicating knowledge on sustainable soil management to farmers?	To which extent are sufficient resources available for the dissemination of knowledge on sustainable soil management?	To which extent are sufficient financial resources available for the production of knowledge on sustainable soil management?
Austria			
Belgium Flanders			
Belgium Wallonia			
Czechia			
Denmark			
Finland			
France			
Germany			
Hungary			
Ireland			
Italy			
Latvia			
Lithuania			
Norway			
Poland			
Portugal			
Slovakia			
Slovenia			
Sweden			
Switzerland			
The Netherlands			
Turkey			
United Kingdom			

Legend	To a very high extent	To some extent	Neutral	To a small extent	Not at all

Some stakeholders report that current communication is ineffective, and they also indicate a lack in the resources available to the production and communication of knowledge on sustainable soil management. Furthermore, stakeholders in Slovenia, Slovakia, France and Belgium (Wallonia) also indicate a lack in either resources for production or dissemination of knowledge. However, with respect to resources available for the communication of knowledge, most stakeholders indicate a sufficient availability of resources for the communication of knowledge on sustainable soil

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management. Additionally, stakeholders indicate quite diverging positions regarding resource availability for the production of knowledge on sustainable soil management. However, there is also internal divergence within some of the countries, for instance reported for Belgium Flanders, where partners report that farmers' organizations and advisors rate the communication efficiency higher than policy and research stakeholders.

In an open question, stakeholders were given the opportunity to provide further reflections and their perspective on the opportunities for further improving the knowledge availability for stakeholders.

Generally, national reports also document that farmers are overloaded with farming, management and administration tasks, which makes them difficult to access in a communicational context. Therefore, it is important to improve knowledge availability for stakeholders by using a communication channel that farmers use and to ensure that the message is adapted to the farmer audience. The national reports emphasize a number of ways to improve knowledge availability for stakeholders (see Appendix E), including:

- Overall stakeholders across countries broadly agree that in research there is **too little continuity due to project dependence**, which is a challenge because **soil research requires long-term investigations**, and this issue therefore needs to be addressed in a number of countries. Further, in high-level European projects often sufficient resources are allocated for the production of knowledge, but these larger projects are not readily accessible to all stakeholders. However, in smaller projects, the budget for knowledge production and dissemination is mostly too limited. Moreover, stakeholders emphasize that a more holistic approach is needed for the assessment of measures and new tools to support integrated decision-making which is better suited to capturing the trade-offs and synergies of stakeholders decision-making. Many partners also note that financial support for dissemination is almost sufficient, but that resources are not always allocated appropriately. Therefore, the quality of dissemination is often poor and there is insufficient focus on sustainable soil management and important information only reaches a limited number of stakeholders.
- **Strengthening networks and peer-to-peer communication** is emphasized because networks are seen as a useful platform to exchange knowledge about sustainable soil management, especially networks between the research community and the farming sector. It is important for stakeholders to learn from fellow stakeholders who represent the practical reality and issues that farmers experience, and often recommendations from outsiders are not accepted. The most important source of information for farmers is someone's experience of solutions that are suitable for their conditions in practice. Although there are only few peer groups in soil related issues, as a general principle it is highly important for farmers to learn from their peers, because they experience many of the same challenges and are able to communicate to the practical reality of most farmers. In addition, peer-to-peer communication also offers opportunities for innovative first-movers to share their experiences with fellow enthusiasts. Dissemination involving producer or farmer associations is proposed as another effective communication channel and may help when addressing traditional practices that are highly ingrained. Therefore, establishing thematic groups for sustainable soil management could guarantee soil knowledge and research dissemination.
- Reports from stakeholders underscore that **demonstrations using real-life examples are a good form of dissemination** because farmers can see the results of experiments in practice. It

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is not enough for stakeholders to know that they damage soils, they also need workable and practical solutions; therefore, in the promotion of sustainable soil management demonstration fields, pilot farms or seminars for conservation and soil improvement practices are essential. Stakeholders propose that "experienced" farmers should be used (and possibly compensated) to disseminate knowledge, and it is also suggested as a way to transfer solutions from one country to the other.

- Stakeholders also stress that **participatory research** that includes farmers in the process should be promoted to increase coherence and to ensure that research projects lead to relevant outcomes. This could be done by securing financial support for projects that include farmers and providing a plan for how results of projects can be applied in practice.
- **Raising awareness** of sustainable soil management issues and improving farmers' understanding of their soil is emphasized as an important element, not only with farmers but also with the general public; without raising awareness there will be no pressure on politicians and scientists to invest in research. Furthermore, consumer awareness of sustainable soil management could be increased to strengthen the demand for "soil-friendly" products. Further, particularly for farmers in regions with a heterogeneous geography, it is important that advice and recommendations are specific to farmers' contexts to ensure relevance, accuracy and usability. Although likely diverging across countries, stakeholders across many contexts emphasize that digital communication is important to improve the availability of knowledge on sustainable soil management for stakeholders. Accessible and comprehensive web-based platforms for dissemination should be established for digital communication. Such platforms could include social media integration to facilitate digital networking. The national reports further indicate a number of elements that could be emphasized to improve site-specificity, including smartphone apps and other online decision support tools. Furthermore, soil analysis is an important element in targeting advice, particularly in regions with little overview or variation, but it is not always prioritized. Across a number of national reports, stakeholders express their concerns about the discrepancy between the theoretical research and the practical knowledge needed at the farm level. For instance, it is mentioned that **research from universities often lacks applicability in the everyday lives of farmers**. Further, stakeholders express that soil science is often presented in a complex language and it is difficult for farmers to understand and challenging for them to engage with researchers due to the complexity of the language used. **Overcoming the complexity of scientific communication** may be ensured by creating discussion forums that include both farmers, advisors, policymakers and scientists to discuss ideas or issues. For instance, information in digital soil maps is difficult to understand for outsiders. It should be easier for stakeholders to interpret the data that is already available and to understand the implications for their daily practices. In a number of national reports, stakeholders also emphasize that they need more focus on applied research and to ensure that research results are applicable. However, according to many national reports, often university research is too theoretical and not adapted to farmers' actual practices, but it is important that research projects take the needs of farmers into account. Further, knowledge on sustainable soil management is often fragmented across different groups of researchers or institutions, and broadly across countries stakeholders emphasize the need to make knowledge more accessible for stakeholders. This could be ensured, for instance, by developing decision support tools that provide comprehensive advice on farmers' field practice. Additionally, regarding resource allocations,

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stakeholders in Denmark stress that sometimes there is a temporal gap from when a new research need is identified (by stakeholders or government) and until funding is provided to document effectiveness by researchers. Because researchers cannot work without funding, this temporal gap prevents researchers from meeting immediate needs.

- It is important to **improve dissemination of knowledge produced in research projects** in order for it to be adopted by farmers. A part of this task involves the training or retraining of farmers and advisors. For instance, in the Netherlands, currently, courses are being developed to provide useful information regarding soil management to advisors (i.e., train the trainers) at several levels of intensity. This also implies using the communication platforms that are important for farmers, such as farm demonstrations, farm magazines, farming associations, web-based platforms and apps, etc. However, the relevant media for communication differ substantially across countries.
- National reports stress that although some stakeholders are passionate about sustainable soil management, many also experience challenges, which prevents a systematic adoption of sustainable practices and often farmers cannot implement recommendations due to economic constraints. Furthermore, often farmers' organizations are in charge of dissemination activities in research projects, but often sustainable soil management is not among the key priorities as communication activities focus on opportunities for improving productivity. Therefore, a shift in the attitude towards sustainable soil management within the public administration and farmers' associations is needed, including an emphasis on **economic incentives**. It is important for farmers' motivation that they can see a benefit of adopting sustainable soil management, otherwise, they have no incentive to engage in learning programmes. Initiatives can include taxes, but in motivating learning, it is also important to demonstrate the economic benefits of sustainable soil management. Countries also have the opportunity to utilize the Rural Development Programme to support the voluntary adoption of measures for sustainable soil management.

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4. Status of knowledge on and use of knowledge regarding sustainable soil management

This chapter contains a synthesis of stakeholders' reflections regarding the knowledge on and use of knowledge on sustainable soil management. To complete the task, each national team completed an assessment of stakeholders' perceptions of the knowledge on and use of knowledge regarding sustainable soil management of one or two environmental zones within each country according to the categorization developed by Metzger et al. (2005). In the analysis, we present perspectives from each of the environmental zones that are presented in the national reports as well as an aggregation of these on the four main European regions (Northern Europe, Southern Europe, Central Europe and Western Europe).

4.1 Challenges to sustainable soil management

Across all environmental zones, a number of challenges are generally perceived as either important or very important, including maintaining or increasing SOC, ensuring an optimal soil structure, enhancing soil biodiversity and enhancing soil nutrient retention or use efficiency (see Table 6). Furthermore, some challenges are primarily perceived as very important in certain regions, while not in others, including salinization and contamination in Southern Europe, erosion in Southern and Central Europe and improving water storage capacity in Central Europe.

Identifying knowledge gaps in sustainable soil management

Stakeholders were also asked to indicate the most important research needs (see Table 7). Across all regions, maintaining and increasing SOC is an area where stakeholders indicate the most important research needs. Furthermore, a range of other areas also appear as highly important, including ensuring an optimal soil structure, enhancing soil biodiversity, enhancing water storage capacity, enhancing soil nutrient retention and use efficiency.

Combining Table 6 and Table 7 reveals stakeholders' perception of the most critical knowledge gaps (important soil challenges with important knowledge gaps) (see Table 8). Generally, across all environmental zones, maintaining and increasing SOC is perceived to be a very important soil challenge with very important research gaps. The most critical knowledge gaps vary across regions, although there is also variation within regions. In Central Europe, soil erosion, enhancing soil nutrient retention and use efficiency and enhancing water storage capacity are assessed to be the most critical knowledge gaps. In Northern Europe, avoiding N_2O/CH_4 emissions, ensuring an optimal soil structure and enhancing soil nutrient retention and use efficiency are assessed to be the most critical knowledge gaps, although indications here are less pronounced. In Southern Europe, avoiding soil erosion, avoiding contamination and enhancing soil biodiversity are perceived to be the most critical knowledge gaps. In Western Europe, enhancing soil biodiversity, ensuring optimal soil structure and enhancing water storage capacity appear to be perceived as the most critical knowledge gaps.

Addressing knowledge gaps

National reports further contain stakeholders' assessment of a range of tasks to improve soil knowledge (see Table 9). The table generally illustrates that most tasks are assessed as either important or very important across partner countries, though particularly pronounced in Northern Europe. Generally, a number of tasks are considered as very important across all countries, including improving soil monitoring, increasing availability of existing research for stakeholders and improving

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coordination of knowledge production between stakeholders. Furthermore, with the exception of Central Europe, a range of additional tasks are emphasized, see elaboration below.

Table 6: *Stakeholders' replies to the question: "How important are the following challenges to sustainable soil management in the environmental zone according to the stakeholders?".*

		Maintain/increase SOC	Avoid N_2O/CH_4 emissions	Avoid peat degradation	Avoid soil erosion (e.g water/wind/tillage erosion)	Avoid soil sealing	Avoid salinization	Avoid contamination	Optimal soil structure	Enhance soil biodiversity	Enhance soil nutrient retention/use efficiency	Enhance water storage capacity
	AT (Alpine South)											
	AT (Continental)											
	CZ (Alpine South)											
	CZ (Continental)											
	DE (Atlantic North)											
	HU (Pannonian-Pontic)											
	PL (Continental)											
	SK (Continental)											
	SI (Alpine South)											
	CH (Continental)											
Northern Europe	DK (Atlantic North)											
	FI (Boreal)											
	LV (Nemoral)											
	LT (Nemoral)											
	NO (Boreal)											
	SE (Nemoral)											
Southern Europe	IT (Mediterranean North)											
	IT (Mediterranean Mountains)											
	PT (Lusitanian)											
	PT (Mediterranean South)											
	TU (Anatolian)											
Western Europe	BE (F) (Atlantic Central)											
	BE (W) (Atlantic Central)											
	FR (Atlantic Central)											
	FR (Lusitanian)											
	IE (Atlantic Central)											
	NL (Atlantic Central)											
	NL (Atlantic North)											
	UK (Atlantic North)											
	UK (Atlantic Central)											

Legend	Very important	Important	Neutral	Less important	Not important at all

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Table 7: *Stakeholders' replies to the question:" How important are research needs for the following soil challenges within this environmental zone?".*

		Maintain/increase SOC	Avoid N_2O/CH_4 emissions	Avoid peat degradation	Avoid soil erosion (e.g water/wind/tillage erosion)	Avoid soil sealing	Avoid salinization	Avoid contamination	Optimal soil structure	Enhance soil biodiversity	Enhance soil nutrient retention/use	Enhance water storage capacity
Central Europe	AT (Alpine South)											
	AT (Continental)											
	CZ (Alpine South)											
	CZ (Continental)											
	DE (Atlantic North)											
	HU (Pannonian-Pontic)											
	PL (Continental)											
	SK (Continental)											
	SI (Alpine South)											
	CH (Continental)											
Northern Europe	DK (Atlantic North)											
	FI (Boreal)											
	LV (Nemoral)											
	LT (Nemoral)											
	NO (Boreal)											
	SE (Nemoral)											
Southern Europe	IT (Mediterranean North)											
	IT (Mediterranean Mountains)											
	PT (Lusitanian)											
	PT (Mediterranean South)											
	TU (Anatolian)											
Western Europe	BE (F) (Atlantic Central)											
	BE (W) (Atlantic Central)											
	FR (Atlantic Central)											
	FR (Lusitanian)											
	IE (Atlantic Central)											
	NL (Atlantic Central)											
	NL (Atlantic North)											
	UK (Atlantic North)											
	UK (Atlantic Central)											

Legend Very important | Important | Neutral | Less important | Not important at all

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Table 8: *Identification of the most pressing research needs. This table overlays Table 6 and Table 7, identifying stakeholders' perception of the most important soil challenges with the most important gaps in research.*

		Maintain/increase SOC	Avoid N_2O/CH_4 emissions	Avoid peat degradation	Avoid soil erosion (e.g water/wind/tillage erosion)	Avoid soil sealing	Avoid salinization	Avoid contamination	Optimal soil structure	Enhance soil biodiversity	Enhance soil nutrient retention/use	Enhance water storage capacity
Central Europe	AT (Alpine South)											
	AT (Continental)											
	CZ (Alpine South)											
	CZ (Continental)											
	DE (Atlantic North)											
	HU (Pannonian-Pontic)											
	PL (Continental)											
	SK (Continental)											
	SI (Alpine South)											
	CH (Continental)											
Northern Europe	DK (Atlantic North)											
	FI (Boreal)											
	LV (Nemoral)											
	LT (Nemoral)											
	NO (Boreal)											
	SE (Nemoral)											
Southern Europe	IT (Mediterranean North)											
	IT (Mediterranean Mountains)											
	PT (Lusitanian)											
	PT (Mediterranean South)											
	TU (Anatolian)											
Western Europe	BE (F) (Atlantic Central)											
	BE (W) (Atlantic Central)											
	FR (Atlantic Central)											
	FR (Lusitanian)											
	IE (Atlantic Central)											
	NL (Atlantic Central)											
	NL (Atlantic North)											
	UK (Atlantic North)											
	UK (Atlantic Central)											

Legend		
	Very important soil challenge and very important research need	Very important soil challenge and important research need
	Important soil challenge and very important research need	Important soil challenge and important research need
	Other combinations	

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Table 9: *Stakeholders' replies to the question: "How important are the following tasks to improve soil knowledge in this environmental zone according to the stakeholders?"*

		New scientific knowledge on the prevalence of key soil challenges	New management strategies for sustainable soil management	Improve soil monitoring	Increase availability of existing research for stakeholders	Increase availability of existing research for policymakers	Improve the coordination of knowledge production	Other
Central Europe	AT (Alpine South)	Important	Important	Important	Very important	Very important	Very important	Very important
	AT (Continental)	Important	Important	Very important	Very important	Important	Very important	Neutral
	CZ (Alpine South)	Very important	Very important	Less important	Important	Important	Very important	Neutral
	CZ (Continental)	Very important	Very important	Less important	Important	Important	Very important	Neutral
	DE (Atlantic North)	Neutral	Important	Neutral	Very important	Neutral	Very important	Very important
	HU (Pannonian-Pontic)	Important	Very important	Very important	Very important	Very important	Very important	Neutral
	PL (Continental)	Important	Very important	Important	Important	Neutral	Very important	Not important at all
	SK (Continental)	Very important	Very important	Very important	Important	Very important	Very important	Very important
	SI (Alpine South)	Important	Very important	Important	Very important	Important	Very important	Very important
	CH (Continental)	Important	Very important	Important	Very important	Important	Very important	Very important
Northern Europe	DK (Atlantic North)	Important	Very important	Important	Very important	Important	Neutral	Neutral
	FI (Boreal)	Very important	Very important	Important	Important	Important	Important	Neutral
	LV (Nemoral)	Very important	Very important	Very important	Very important	Very important	Very important	Neutral
	LT (Nemoral)	Very important	Very important	Very important	Very important	Very important	Very important	Less important
	NO (Boreal)	Very important	Very important	Very important	Very important	Very important	Very important	Very important
	SE (Nemoral)	Important	Important	Neutral	Very important	Important	Neutral	Neutral
Southern Europe	IT (Mediterranean North)	Important	Important	Very important	Important	Very important	Very important	Important
	IT (Mediterranean Mountains)	Important	Very important	Very important	Important	Very important	Very important	Important
	PT (Lusitanian)	Important	Very important	Very important	Very important	Very important	Very important	Neutral
	PT (Mediterranean South)	Important	Very important	Very important	Very important	Very important	Very important	Neutral
	TU (Anatolian)	Very important	Very important	Very important	Very important	Very important	Very important	Not important at all
Western Europe	BE (F) (Atlantic Central)	Very important	Important	Important	Important	Important	Very important	Neutral
	BE (W) (Atlantic Central)	Important	Very important	Important	Very important	Very important	Very important	Neutral
	FR (Atlantic Central)	Important	Important	Very important	Very important	Important	Important	Not important at all
	FR (Lusitanian)	Important	Important	Very important	Very important	Very important	Important	Not important at all
	IE (Atlantic Central)	Very important	Very important	Important	Very important	Important	Very important	Neutral
	NL (Atlantic Central)	Important	Important	Very important	Very important	Important	Important	Important
	NL (Atlantic North)	Important	Important	Very important	Very important	Important	Important	Important
	UK (Atlantic North)	Important	Important	Important	Important	Important	Very important	Less important
	UK (Atlantic Central)	Very important	Important	Very important	Important	Important	Very important	Less important

Legend	Very important	Important	Neutral	Less important	Not important at all

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In a series of open questions, stakeholders were asked to detail these knowledge gaps, including scientific research gaps, gaps in soil monitoring, opportunities for improving knowledge availability for policymakers and stakeholders. In the following, we present the results of these open questions grouped according to the four regions. We focused on the recurrent themes but also included aspects that are emphasized locally and may have broader relevance. For a full overview of the contents of the national reports please see Appendices F-K.

4.2 Scientific research gaps

In an open question, stakeholders were asked to detail the most important scientific research gaps in the different environmental zones. A range of themes are emphasized; below we list the recurrent themes for each environmental zone (see Appendix F for a full overview of each report).

Most important scientific research gaps in Central Europe

- Several countries within central Europe reported a lacking focus on soil science, and particularly lacking funding for long-term experiments and increasing sampling point density, which is needed to document changes and long-term effects of agricultural practice, particularly documenting the effects of sustainable soil management on SOC dynamics.
- Several reports also stressed a lack in the communication and knowledge transfer from scientists to stakeholders, policymakers and across different scientific environments. Furthermore, specifically, missing knowledge on the effects of heavy machines on subsoil compaction and impact on soil fertility and yields, as well as mitigation strategies is noted as an important shortcoming.
- Austria specifically emphasized that almost no research is available in relation to soil structure, biodiversity, nutrient retention and water storage capacity.
- Switzerland specifically emphasized that an inventory of sustainable soil management practices is needed, rather than general principles regarding soil management. Furthermore, specifically in relation to draining, research is needed on how drainage can be optimized to minimize environmental impacts, for example by dynamic regulation of the groundwater level. Furthermore, documentation of long-term effects of chemical and mechanical crop protection strategies on soil quality is needed.

Most important scientific research gaps in Northern Europe

- Conservation agriculture and cultivation methods to implement cover crops are generally highlighted as important scientific knowledge gaps by stakeholders.
- Generally, across national reports, stakeholders emphasized the need for more integration, interdisciplinarity and collaboration between different research environments and with stakeholders in relation to soil research.
- SOC is mentioned as a specific issue to increasingly address in several reports, particularly methods to improve carbon sequestration and reliable methods to measure soil organic carbon and GHG emissions.
- Specifically for Denmark, the interaction between soil and modern technology is raised as an important issue.
- Specifically for Latvia, opportunities for sustainable soil management on medium-large farms are raised as a current shortcoming.

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- Particularly for Sweden, cultivation of cover crops and stimulation of soil biology to increase soil health is not addressed by current research programmes.

Most important scientific research gaps in Southern Europe

- Generally, the consequences of agricultural practices for soil quality and biodiversity are emphasized as a current shortcoming as well as the need for integrated agricultural management, effects of climate change and long-term soil quality monitoring programmes.
- Specifically for Italy, competition across knowledge institutions, a lacking focus on soils and poor coordination of research activities are highlighted as a major shortcoming. Furthermore, research is focused on academia and lacks a direct link with farmers' needs, especially in relation to communicating results.
- Specifically for Portugal, a range of specific issues are identified in different environmental zones, including the effect of agricultural practices on soil quality and biodiversity, strategies and techniques to improve soil fertility and reduce land degradation, identification and evaluation of emerging pollutants (drugs, microplast) in soils and drainage water. Additionally, a range of other elements are emphasized, see Appendix F for details.

Most important scientific research gaps in Western Europe

- Generally, across national reports from the region, there is a request for knowledge and new management strategies for sustainable soil management to maintain or increase SOC. There are a number of important unanswered questions regarding carbon sequestration potential of measures, for instance including novel crops, cover crops and the extent to which roots contribute to SOC. Furthermore, alternative options for the use of organic soils that are taken out of production are also emphasized as an important element.
- Several partners also note that there is a need for more research on soil biological quality indicators and the effect of different levels and related soil functions.
- Another research gap is the development of integrated approaches for assessment and documentation of sustainable soil management measures including in the dissemination of research results.
- Particularly for Belgium (Flanders), stakeholders indicate a shortcoming with respect to the potential of new technologies (soil scans, drones, satellite images, sensors, tractor data) and how they can be combined with other data (e.g., crop growth models, weather data) to map variations in soil quality and to increase crop yield potential; additional aspects are mentioned in Appendix F.
- Particularly for Ireland, it is emphasized that there is a critical research need on arable farming systems that retain soil structure and the productive function of soils through allowing efficient use of and retention of nutrients and water. Furthermore, there is a need for integrated decision support and assessment of best management practices to solve multiple challenges simultaneously.
- Particularly for the United Kingdom, nutrient use efficiency within plant-soil systems at the farm level and the role that liming or the introduction of multispecies swards may have on different soil ecosystem services are emphasized as current shortcomings.

Although research needs are somewhat regionally specific, among stakeholders across environmental zones, a number of gaps in current scientific research are emphasized as particularly important. This includes elements that are important to ongoing policy-making in relation to soils, such as perspectives

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regarding the loss of SOM and carbon sequestration and exploring the effects of climate change, adaptive and mitigative measures. Furthermore, national reports stressed the need for long-term research programmes, as changes to soil management practices are only visible in a long-term perspective and cannot be observed during ordinary research projects. Furthermore, many stakeholders make comments regarding research design, emphasizing the need for research activities that can inform the real-life situations and dilemmas of stakeholders. Therefore, increasingly including stakeholders in the research process, producing research that supports integrated management and decision-making in relation to soils and ensuring effective and broadly reaching dissemination of research activities are emphasized. Furthermore, across research environments, the need for better coordination of research activities across different research institutions and epistemic communities should be prioritized because this is currently lacking.

4.3 Gaps in current soil monitoring

In an open question, stakeholders were asked to detail the most important gaps in current soil monitoring systems in the different environmental zones. A range of themes are brought up detailing these more overall aspects; below we list the recurrent themes for each environmental zone (see appendix G for a full overview of national reports).

Most important gaps in current soil monitoring in Central Europe

- For several environmental zones, partners stressed that current soil monitoring is inadequate and needs to be improved as part of environmental monitoring, a problem which is partly caused by a lack of funding, low sampling density and lacking standardization of sampling procedures due to regional administrations.
- Particularly for Austria, there is no uniform monitoring system. The report suggests developing an easily accessible online tool allowing farmers to enter their data or to choose sites that are sampled regularly every 5-6 years. Moreover, it is questionable how representative experimental current sites are.
- Particularly for Slovakia, soil monitoring should be harmonized with surrounding countries, because there is a benefit in knowledge exchange. Furthermore, procedures for obtaining and evaluating data from forest soil monitoring are not harmonized and their connection to the monitoring of agricultural soils is missing.
- Particularly for Slovenia, results of soil monitoring are not available to the public and it is necessary that users are connected to databases.
- Particularly for Switzerland, the management (incl. drainage) of the monitoring sites should be described and assessed to evaluate management effects. Further, all sites should be evaluated with an integrated set of soil quality indicators instead of just single parameters.

Most important gaps in current soil monitoring in Northern Europe

- No commonalities are identified in the national reports for Northern Europe.
- Denmark has a strong tradition for monitoring, but improving the accuracy of soil monitoring is needed because of an ongoing transition to a more targeted approach to regulation. Therefore, it is important to improve site-specific databases for both precision agriculture and targeted regulation. Particularly, more site-specific measurements of soil carbon content are needed.
- Particularly for Latvia and Lithuania, soil monitoring is inadequate and relies on private initiatives.

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- Particularly for Norway, the most important gaps in soil monitoring include documenting the effect of various measures on carbon sequestration. There is also a need to monitor soil biology, e.g., how soil life is affected by food production under different production systems.

Most important gaps in current soil monitoring in Southern Europe

- National reports across Southern Europe broadly indicated that local monitoring activities are inadequate and are carried out without enough national or international coordination, particularly with respect to soil quality and biodiversity. Reported shortcomings include lacking definition of relevant indicators, baselines and thresholds, targets, reference system and monitoring plan. Therefore, it is difficult to evaluate trends, and mitigating measures cannot be undertaken.
- Furthermore, several partners reported difficult access to monitoring data. An online platform gathering standardized and georeferenced monitoring data would be a useful resource for stakeholders.
- Particularly Portugal and Italy reported an absence of historical data and functioning monitoring programmes that enable temporal data series to be developed.
- Turkey reported that the parameters used in soil monitoring are insufficient.

Most important gaps in current soil monitoring in Western Europe

- Across Western Europe, national reports stressed that improving soil monitoring is needed to fulfil policy objectives and to get a better understanding of the current soil status. A number of elements are emphasized, including monitoring chemical, physical and biological soil data and effects of sustainable soil management practices.
- Additionally, national reports indicated that monitoring data should also be comparable and stored in a central and accessible database, so stakeholders have easy access.
- Particularly for Belgium (Flanders), stakeholders expressed the need to investigate how satellite or other remote sensing data could be used to map soil challenges.
- Particularly for Belgium (Wallonia), there is little or no information on soil carbon stocks due to the lack of information on bulk density.
- Particularly for Ireland, indicators to capture spatial and temporal changes in soil carbon stocks are needed.
- Particularly for the Netherlands, monitoring programmes are fragmented and focused solely on one policy or soil aspect, which prevents general usability.
- Particularly for the United Kingdom, no comprehensive soil monitoring programmes are in place at the moment.

Inadequate monitoring is reported across most environmental zones, where much soil monitoring relies on uncoordinated private or regional initiatives, and without much national or international coordination. Furthermore, often monitoring systems lack proper definitions of relevant indicators, baselines and thresholds, targets and a detailed monitoring plan. This prevents model development and effective assessment of policy interventions. Therefore, it is important to ensure standardization of monitoring and the establishment of monitoring programmes, also beyond individual countries, ensuring comparability and making data available for stakeholders. Furthermore, it is important to improve site-specific databases to sustain targeted policymaking and to ensure opportunities for precision agriculture.

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4.4 Improving relevance for policymaking

In an open question, stakeholders were asked to detail how knowledge on sustainable soil management can be made more relevant for policymaking. A range of themes are brought up; below we list the recurrent themes and national specifics (see appendix H for a full overview of each national report).

Improving relevance in Central Europe

- Generally, all partners stressed that the communication between researchers and policymakers needs to be improved. It is essential to transfer knowledge from scientists to politicians in a clear and concise language adapted to the policy process, but uncertainties and complex language often lead to confusion and do not motivate solutions. Furthermore, relevant scientific output should be presented in summaries of findings written specifically for politicians (not just scientific abstracts).
- Furthermore, networks between researchers and policymakers are very important and thus could be established to improve communication between universities and ministries if not properly in place.
- Particularly for Hungary, development and application of indicators for sustainable soil management are needed to assess and communicate the relationship between land use and soil challenges.
- Particularly for Slovakia, soil policies detailing emission standards should be developed; if policies are not available, it is very difficult to develop emission projections. Furthermore, policymakers do not have enough knowledge nor enough tools to ensure sustainable soil management – this should be improved.
- Particularly for Germany, stakeholders – especially farmers – are concerned with economic and administrative issues as barriers to implementing sustainable and climate-smart soil management options, such as “insufficient financial support”, “insufficient willingness to pay by consumers”, “insufficient incentives”, “narrow framework in policy/legislation”. We conclude from the survey that new strategies for communication and knowledge transfer should address these issues.

Improving relevance in Northern Europe

- Generally, reports emphasized the need to improve the network between policymakers and researchers and to ensure funding for research that is relevant to policymaking in relation to sustainable soil management.
- Particularly for Denmark, reports emphasize that research should be more cross-disciplinary for policymakers to understand possible trade-offs and that there is a demand for policies that offer solutions to multiple challenges at the same time.

Improving relevance in Southern Europe

- There is a need to improve communication with policymakers about the benefits of sustainable soil management at a regional and national level, highlighting the detrimental effects of soil challenges and of not protecting soils from degradation processes with real examples. Furthermore, it is important to strengthen the science-policy interface regarding sustainable soil management, for instance with learning activities for policymakers in relation to soil challenges and mitigation measures.

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- Knowledge production should be linked to environmental and European policies to improve relevance for policymaking; currently, there is a lack of regulation that frames research activities and sustains the dialogue between researchers, farmers and policymakers.

Improving relevance in Western Europe

- Generally, raising awareness about soil-related issues among policymakers is emphasized as an important element to convey the local specifics of sustainable soil management and risk levels for various soil challenges.
- To improve knowledge gaps for policy development, there is a need for a long-term perspective in research activities. Furthermore, there is a need for indicators and benchmarks in soil policy to monitor soil quality in light of the soil challenges.
- In communication with policymakers, it is important to develop a synthesis of already existing soil knowledge because currently it is very fragmented and does not enable integrated decision-making.
- Particularly for Belgium (Flanders), stakeholders expressed the need for more practice-oriented and feasible policies with stimulating instead of controlling regulations.
- Particularly for France, it is important to improve the integration of social and economic elements to make knowledge more understandable and acceptable to stakeholders and policymakers.
- Particularly for Ireland, it is important to develop policy options that account for the variable capacity of soil types to deliver in terms of production and other soil-based ecosystem services such as climate regulation.

Generally, similar issues are raised in otherwise quite different social and political contexts. This includes the need to raise awareness among policymakers with respect to sustainable soil management and soil degradation. Across a number of national reports, stakeholders propose that this could be improved by developing networks between researchers and policymakers to extend communication between universities and ministries if not already in place. Furthermore, there is a need to improve communication of scientific results and translate findings into a language that is understandable for policymakers and that policy advice addresses concerns in ongoing policy processes. This implies that research results should be communicated in a clear and concise language and that relevant scientific output is presented in brief summaries targeted at policymakers. Finally, research activities and policymaking need to be increasingly aligned to ensure that research is able to yield policy-relevant knowledge and supports the integrated decision-making of policy processes, as currently soil research is too fragmented. This implies clear targets and indicators in policies and funding for more integrated and long-term research activities.

4.5 Gaps in the availability and use of knowledge on sustainable soil management according to stakeholders

In an open question, stakeholders were asked to detail gaps in the availability of knowledge on sustainable soil management. A range of themes was brought up; below we list the recurrent themes and national specifics (see appendices I and J for a full overview of each national report).

Gaps in the availability and use of soil knowledge in Central Europe

- Generally, national reports indicated that a lot of research is already produced, but also that transfer to the public, farmers, politicians and spatial planners is missing and acceptance

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among farmers is not ensured. Hence, too little attention is paid to capacity building, awareness-raising and advisory activities, and there is a lack of promotion of sustainable soil management. For communicating with farmers, practical workshops and popular articles are important means.

- It is important to promote information exchange between stakeholders, especially farmers. For instance, social networks are important, as a lot of knowledge can be shared. Furthermore, operational groups using farmer-to-farmer dissemination of sustainable soil management should be promoted to increase their reach.
- Several reports emphasize that the use of new technologies should be supported financially. For instance, the application of knowledge on sustainable soil management can be supported through lifelong learning and financial support, by making basic training a condition for direct payments, as mentioned in the national report for Slovakia. Furthermore, the Swiss national report emphasized the need for site-adapted and more flexible direct payments.
- Particularly for Austria, in the continental zone, there are many initiatives that promote farmers' knowledge and new practices on sustainable soil management. However, in the alpine region, there are no associations engaging in educating and connecting farmers, besides events by the agricultural chambers and farming schools.
- Particularly for Switzerland, an integrated, site-adapted perspective on sustainable soil management that accounts for complexity and trade-offs needs to be developed.

Gaps in the availability and use of soil knowledge in Northern Europe

- Across national reports, the lack of practical experiences showcasing the beneficial effects of sustainable soil management is emphasized, as well as exchange of these demonstration farms and other peers. Furthermore, in promoting sustainable soil management it is important to make use of peer-to-peer groups, as these are important for farmers.
- Particularly for Denmark, currently the public debate is about opportunities to convert land use on organic-rich meadows that function as a source of CO_2. By changing management practices, these areas may potentially become sinks rather than sources, but this transition requires some basic knowledge on how this transition can be organized to become successful.
- Particularly for Sweden, stakeholders stressed that there is no easy access to the information published by SLU or other universities. Research has to be demonstrated and disseminated in popular science outlets.

Gaps in the availability and use of soil knowledge in Southern Europe

- Throughout the region, stakeholders expressed that there is a lack of demonstration activities involving stakeholders that promote sustainable soil management as stakeholders lack capabilities in that regard. Therefore, more field experiments and observations should be carried out, showing and quantifying the economic benefits of sustainable soil management. Greater involvement of farmers in the organization and dissemination of research is preferred because the best dissemination activities involve farmer-to-farmer learning. Generally, stakeholders express that they experience a lack of demonstration farms and that there are too few dissemination activities. Furthermore, researchers often use their results for scientific publications, which are irrelevant and often not disseminated to farmers.
- Showing and quantifying economic benefits and also using subsidies in the promotion of sustainable soil management should increasingly be prioritized. Courses involving all

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stakeholders focusing on specific territorial characteristics should be organized, also rewarding the participation as it is important to highlight site-specific conditions.

- Particularly for Italy, it is emphasized that digital platforms should be used more, also through the involvement of farmers' organizations. Information should be managed in web portals, making both basic and practical information available. Furthermore, knowledge on the following topics is reported as lacking by several Italian stakeholders: i) avoiding soil erosion and soil contamination; ii) correct SOM management; iii) the positive impacts of sustainable soil management; iv) the interaction erosion-crop; v) knowledge about the soil mineral matrix; vi) the interaction soil-machinery; and vii) the importance of intercropping. Furthermore, carbon sequestration and fertility recovery are aspects still to be developed.
- Particularly for Portugal, it is important to implement thematic network projects involving farmers and their organizations. Furthermore, a rural extension service is lacking or, alternatively, an accessible information repository could be developed. Generally, stakeholders expressed that research results are very poorly communicated towards stakeholders. Furthermore, there are specific knowledge gaps pertaining to the climate change that may lead to an increase in the following challenges to the soil: erosion, loss of organic matter, loss of biodiversity (soil and general), salinization, and eutrophication of surface waters.

Gaps in the availability and use of soil knowledge in Western Europe

- Across national reports from Western Europe, the importance of promoting the use of knowledge on sustainable soil management is emphasized. Therefore, soil knowledge must be understandable and adapted to the target audience. This requires the production of adequate communication and tools for farmers. Several ideas are listed for the promotion of knowledge application; most stress the need for more communication and networking between different stakeholders. Information about sustainable soil management does not reach farmers automatically, and gathering information is resource-demanding since the information is highly fragmented. Furthermore, farmers are already very busy and do not necessarily have time to read scientific reports. Therefore, popularized information (but technical enough for farmers to understand and be able to implement properly) would be welcome. Furthermore, demonstrations would allow farmers to see the positive effects on soils (but also their economic profitability). Furthermore, farm advisors should also play a role in the transmission of knowledge, as these are important in farmers' decision-making.
- Several reports also emphasized the need for developing tailor-made advice, providing an answer to the key question: which sustainable management practices are most (cost) effective and are most suitable for a specific farm type and what are the benefits and preconditions. Generally, the availability of regional-, soil-, farm-, or even field-specific information is lacking, making it difficult for farmers to judge the usefulness of the information and to make adequate management decisions.
- Finally, a number of reports stressed that an important precondition for the promotion of knowledge on sustainable soil management to farmers is to show how it will impact the long-term productive capacity of the soil and ideally to highlight the economic value of interventions.
- Particularly for Belgium (Flanders), stakeholders expressed the need for knowledge on soil biodiversity, e.g., what is the impact of crop rotation on soil biodiversity (and the extensive

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effects this has on, e.g., water availability, plant health). What is the effect of green manure and water availability on the next crop? What is the effect of no-till and weed management? How to enhance soil organic matter (in sandy soil)?

- Particularly for Belgium (Wallonia), research in organic conservation agriculture is lagging far behind compared to other countries. There may be inspiration from already innovative research in Switzerland and France, etc.
- Particularly for France, gaps in knowledge availability include: 1) Impact of different sustainable soil management practices on the biological quality of soils; 2) dynamics of bio-aggressors (ecotoxicity, plant diseases) according to the sustainable soil management practices implemented; 3) systematic campaigns for data acquisition to develop statistical modelling approaches to complement the use of deterministic models; 4) long-term observation and experimentation devices: support for the devices and proactive intervention for creation, monitoring and exploitation, and 5) construction of (typological) databases on sustainable soil management practices and on the nature of soil-related inputs.
- Particularly for Ireland, stakeholders emphasized knowledge gaps pertaining to management practices that enhance carbon sequestration, particularly the more stable carbon pools at depth; alternative options to manage and protect organic-rich soils that are under productive agriculture; the role of soil structure in reducing nutrient losses to the air or water; and quantifying how nutrients are lost.

Generally, national reports indicate that a lot of research is already produced, but also that transfer to the public, farmers, politicians and spatial planners is somewhat missing in most regions. Throughout Europe partners report that there is a lack of demonstration activities that promote sustainable soil management in a relevant way for stakeholders. For instance, stakeholders often express the need for practical experiences showcasing the beneficial effects of sustainable soil management. Furthermore, the level of information exchange between stakeholders is reported as insufficient. Generally, the availability of regional-, soil-, farm-, or even field-specific information lacks in most countries. Therefore, it is difficult for farmers to assess the usefulness of the information they receive, because it is considered too broad and generic, and therefore insufficient to make adequate management decisions. Finally, a number of reports emphasize the importance of highlighting economic implications of sustainable soil management for farmers and supporting the introduction of new technologies and practices with economic incentives, for instance using funding from the Rural Development Programme.

4.6 Divergences across stakeholder categories

In an open question, partners were asked to detail whether there are disagreements in reports across stakeholder categories. Even though most partners do not report any divergence in relation to this aspect, national reports present a rather diverse picture across different countries (see Appendix K). It is notable that the divergences that are reported in stakeholders' perception of challenges, knowledge gaps or how to address and prioritize these challenges relate to their perspective as stakeholders.

Generally, across some reports, stakeholders are concerned about the state of soils and are keen to preserve and improve it. However, a number of disagreements occur recurringly, which is not only due to different levels of knowledge or skills between stakeholders but to deep-rooted conflicts of interests and perspectives. For instance, farmers are often reported seeing things from a practical perspective and place a high value on the production potential of their farmland, and therefore they look at their soil as an important resource for their business. However, farmers are not uniform, and there are

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reports of divergences among different groups of farmers such as organic and conventional or stakeholders of Conservation Agriculture. Policymakers on the other hand focus on opportunities for intervention and for effective ways to monitor the progress of interventions. Other stakeholders such as environmental NGOs are reported to show a higher degree of concern for aspects that are not directly linked to the production potential of the farmland, such as ecosystem services, biodiversity, water quality, etc.

These different perspectives are expressed in reported divergences in relation to soil challenges, intervention opportunities and whether sufficient knowledge is available. For instance, a number of reports stressed that farmers and farmers' representatives prefer more flexible regulatory designs that enable a certain degree of freedom, while others are more concerned with policy enforcement, arguing that regulations should be simple, effective and controllable. Furthermore, there are also reports of disagreements on whether current research is sufficient or should be redesigned to reflect the needs of certain stakeholder groups − for instance, disagreements regarding whether sufficient knowledge is available for public interventions, and researchers argue that there is a scarcity of resources for research, while advisors and stakeholders argue that current knowledge is sufficient, but insufficient resources are available for dissemination.

However, all farmers care about soils because soils are important for farmers' ability to maintain or increase their agricultural production. This common interest in maintaining soils can be used as a lever for attention and action, depending on the efficacy of communication to bridge the different perspectives of stakeholders.

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5. Conclusions

The purpose of this report is to provide a synthesis of stakeholders' perceptions of knowledge on and use of knowledge on sustainable soil management, as well as the knowledge needs.

Generally, there is considerable variation in perception and use of knowledge across countries, but a number of shortcomings in the use and coordination of knowledge on sustainable soil management are documented. For instance, insufficient communication and coordination between policymakers, researchers and farmers is reported. Furthermore, some of the large and heterogeneous countries report a significant internal variation in environmental conditions, farming sectors and a lack of coordinating institutions.

Most national reports stress that currently the promotion of knowledge on sustainable soil management towards stakeholders is ineffective. Challenges for instance arise because the theoretical knowledge produced at universities is considered irrelevant or difficult to access and translate for farmers who have a more practical approach to soil management. Furthermore, current research insufficiently supports integrated decision-making of practitioners and policymakers, where different challenges and trade-offs need to be balanced. In some countries, this is partly due to insufficient funding for dissemination activities, but in other countries partners report that current resources are not utilized correctly. Additionally, reports document that according to stakeholders there is too little continuity in research due to project dependence, which is a challenge because soil research requires long-term investigations. This issue needs to be addressed in a number of countries.

To overcome these challenges, stakeholders stress that it is important to improve the coordination between policy, research, industry, advisory services and farmers because knowledge about field activities and sustainable soil management is fragmented and currently poorly coordinated. Therefore, across many countries, stakeholders stress that it is important to strengthen intermediaries, such as the advisory service and farmers' associations, as they are important knowledge brokers, both in terms of improving knowledge availability and to provide feedback on knowledge gaps to research institutions. Furthermore, several partners stress that it is important to strengthen networks and farmers' inclusion in research projects to enable better coordination of knowledge production and use. Additionally, improving networks and peer-to-peer communication are emphasized because these are seen as useful platforms to exchange knowledge about sustainable soil management. Furthermore, it is important for farmers' motivation that they can see a benefit in adopting sustainable soil management, so there is a need to change incentives with policymaking and improve the visibility of soil challenges for stakeholders, for instance using decision support tools.

In relation to knowledge availability and use, a number of gaps are emphasized as particularly important by stakeholders. These include elements that are important for policymaking, such as knowledge regarding the loss or sequestration of soil carbon and exploring the effects of climate change, and measures for mitigation and adaptation. A range of other areas also appear as highly important, particularly in some regions − for instance, ensuring an optimal soil structure, enhancing soil biodiversity, enhancing water storage capacity, enhancing soil nutrient retention and use efficiency.

Inadequate monitoring is reported across most environmental zones, where much soil monitoring relies on uncoordinated private or regional initiatives and monitoring standards are poorly coordinated across regions. Regional-, soil-, farm-, or even field-specific information is lacking in most regions. This implies that it is difficult for stakeholders to assess the usefulness of the information they receive,

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because it is considered too broad and generic and therefore insufficient for management decisions. Finally, a number of reports emphasized the importance of highlighting economic implications of sustainable soil management for farmers and supporting the introduction of new technologies and practices with economic incentives, for instance using funding from the Rural Development Programme.

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Appendix A: Template for national reports

This Annex contain the reporting template for EJP SOIL task 2.2.2 as provided to partners. Guidance for completing this template is found in the document: "Guidelines for work package 2 (task 2.1-2.2-2.3)".

Section #1 Background information

Which country do you report from here?

(1) ❑ Austria

(2) ❑ Belgium Flanders

(3) ❑ Belgium Wallonia

(4) ❑ Czechia

(5) ❑ France

(6) ❑ Denmark

(7) ❑ Estonia

(8) ❑ Finland

(9) ❑ Germany

(10) ❑ Hungary

(11) ❑ Ireland

(12) ❑ Italy

(13) ❑ Latvia

(14) ❑ Lithuania

(15) ❑ The Netherlands

(16) ❑ Norway

(17) ❑ Poland

(18) ❑ Portugal

(19) ❑ Slovakia

(20) ❑ Slovenia

(21) ❑ Spain

(22) ❑ Sweden

(23) ❑ Switzerland

(24) ❑ Turkey

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(25) ❑ United Kingdom

How were interviews for this task completed? (please note the number of interviews in each category)

Face-to-face	_____
Phone or videolink	_____
Focus group	_____
Online focus group or webinar	_____
Email	_____
Other	_____

How many stakeholders from different categories are included in the reporting of this task?

Policymakers	_____
Research communities	_____
Research funders	_____
Educational institutions and farm schools	_____
Farmers & demonstration farms	_____
Advisors	_____
Farmers' organisations	_____
Agro-industry, supply & retail	_____
Laboratories	_____
National science testing and verification centers etc.	_____
NGOs	_____

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Reflections regarding the selection and representation of stakeholders? (max 500 words)

_____

_____

_____

_____

_____

_____

Section #2: Structure and function of the agricultural knowledge system in relation to sustainable soil management

The following two sections present a range of general questions, to clarify the structure and functioning of the agricultural knowledge system in relation to sustainable soil management. Towards the end of each section you will be provided with a couple of open question that enable you to deepen your replies to the structured questions in the beginning.

2.1 Coordination of the knowledge system

Coordination of the knowledge system refer to the nature of the formal links between stakeholders and coordination of soil knowledge production and communication.

According to stakeholders how well is farmers access to relevant knowledge about sustainable soil management?

(1) ❑ Very good

(2) ❑ Good

(3) ❑ Neutral

(4) ❑ Somewhat deficient

(5) ❑ Very poor

According to stakeholders how well are young farmers prepared for sustainable soil management in farm schools?

(1) ❑ Very well prepared

(2) ❑ Well prepared

(3) ❑ Neutral

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(4) ❑ Somewhat poorly prepared

(5) ❑ Very poorly prepared

According to stakeholders how well is the advisory service prepared to promote knowledge on sustainable soil management to farmers?

(1) ❑ Very well prepared

(2) ❑ Well prepared

(3) ❑ Neutral

(4) ❑ Somewhat poorly prepared

(5) ❑ Very poorly prepared

According to stakeholders how well is the overall coordination of knowledge production regarding sustainable soil management?

(1) ❑ Very well coordinated

(2) ❑ Coordinated

(3) ❑ Neutral

(4) ❑ Somewhat coordinated

(5) ❑ Uncoordinated

How well are research activities in relation to sustainable soil management coordinated with policy-makers?

(1) ❑ Very coordinated

(2) ❑ Coordinated

(3) ❑ Neutral

(4) ❑ Somewhat coordinated

(5) ❑ Uncoordinated

Other reflections regarding the coordination of knowledge use and knowledge production between stakeholders? (max 500 words)

_____

_____

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_____

_____

_____

_____

How can the coordination of knowledge production and use regarding sustainable soil management be improved? (max 500 words)

_____

_____

_____

_____

_____

_____

2.2 Strength of the knowledge system

The strength of the knowledge system depends on the focus of resource allocations, public investments and engagement for instance in advisory service, knowledge production, knowledge exchange and that farmers benefit from such activities.

To which extent is the current knowledge system sufficiently effective in communicating knowledge on sustainable soil management to farmers?

(1) ❑ Highly effective

(2) ❑ Effective

(3) ❑ Neutral

(4) ❑ Somewhat effective

(5) ❑ Ineffective

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To which extent are different platforms used to disseminate knowledge on sustainable soil management to farmers?

	Highly used	Used	Neutral	Somewhat used	Not used
Social media	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Printed media	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Electronic newsletters	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Peer-to-peer groups	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Farmer interest groups	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Advisory service	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Webpages and blogs	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Scientific literature	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Technical reports	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑
Other	(1) ❑	(10) ❑	(11) ❑	(12) ❑	(13) ❑

Other platforms used and other reflections regarding media for communication? (max 500 words)

_____

_____

_____

_____

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_____

_____

To which extent are sufficient resources available for the dissemination of knowledge on sustainable soil management?

(1) ❑ To a very high extent

(2) ❑ So some extent

(3) ❑ Neutral

(4) ❑ To a small extent

(5) ❑ Not at all

To which extent are sufficient financial resources available for the production of knowledge on sustainable soil management?

(1) ❑ To a very high extent

(2) ❑ So some extent

(3) ❑ Neutral

(4) ❑ To a small extent

(5) ❑ Not at all

Reflections regarding the dissemination of knowledge on sustainable soil management (max 500 words)

_____

_____

_____

_____

_____

_____

How can knowledge availability for stakeholders be improved? (max 500 words)

_____

_____

_____

_____

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_____

_____

Section #3: Status on knowledge of sustainable soil management in relevant environmental zones

In this section we ask for stakeholders assessment of the knowledge needs in one-two most relevant environmental zone in the country. The soil and climatic conditions differ quite a lot across countries and the knowledge gaps may differ accordingly. Therefore, in this section we ask you to complete an assessment of the knowledge gaps in one-two most relevant environmental zones in the country. For each environmental zone you are asked to inform:

First pedo-climatic zone

Which pedo-climatic zones do you report for here?

(1) ❑ Alpine North

(2) ❑ Alpine South

(3) ❑ Atlantic Central

(4) ❑ Atlantic North

(5) ❑ Boreal

(6) ❑ Continental

(7) ❑ Lusitenean

(8) ❑ Mediterranean Mountains

(9) ❑ Mediterrenean North

(10) ❑ Mediterrenean South

(11) ❑ Nemoral

(12) ❑ Pannonian-Pontic

(13) ❑ Anatolian

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How important are the following challenges to sustainable soil management in the environmental zone according to the stakeholders?

	Very important	Important	Neutral	Less important	Not important at all
Maintain/increase SOC	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid N_2O/CH_4 emissions	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid peat degradation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil erosion (e.g water/wind/tillage erosion)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil sealing	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid salinization	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid contamination	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Optimal soil structure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance soil biodiversity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance soil nutrient retention/use efficiency	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

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	Very important	Important	Neutral	Less important	Not important at all
Enhance water storage capacity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

How important are research needs for the following soil challenges within this environmental zone?

	Very important	Important	Neutral	Less important	Not important at all
Maintain/increase SOC	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid N_2O/CH_4 emissions	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid peat degradation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil erosion (e.g water/wind/tillage erosion)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil sealing	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid salinization	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid contamination	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Optimal soil structure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

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	Very important	Important	Neutral	Less important	Not important at all
Enhance soil biodiversity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance soil nutrient retention/use efficiency	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance water storage capacity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

How important are the following tasks to improve soil knowledge in this pedo-climatic zone according to the stakeholders?

	Very important	Important	Neutral	Less important	Not important at all
New scientific knowledge on the prevalence of key soil challenges	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
New management strategies for sustainable soil management	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Improve soil monitoring	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Increasing availability of existing research for stakeholders	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Increase availability of existing research for policymakers	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

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	Very important	Important	Neutral	Less important	Not important at all
Improving the coordination of knowledge production between actors	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Other (please indicate below)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

What are the most important scientific research gaps in this environmental zone according to the stakeholders? (max 500 words)

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What are the most important gaps in current soil monitoring in this environmental zone according to the stakeholders? (max 500 words)

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How can knowledge on sustainable soil management be made more relevant ffor policy-making in this environmental zone according to the stakeholders? (max 500 words)

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What are the most important gaps in availability of knowledge on sustainable soil management in this environmental zone according to stakeholders? (max 500 words)

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How can the use of knowledge on sustainable soil management by farmers be promoted in this environmental zone according to the stakeholders? (max 500 words)

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Did you notice any disagreements in the issues raised by different stakeholder groups? (max 500 words)

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Other reflections regarding knowledge on and use of knowledge on sustainable soil management in this environmental zone? (max 500 words)

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Second pedo-climatic zone

Which pedo-climatic zones do you report for here?

(1) ❑ Alpine North

(2) ❑ Alpine South

(3) ❑ Atlantic Central

(4) ❑ Atlantic North

(5) ❑ Boreal

(6) ❑ Continental

(7) ❑ Lusitenean

(8) ❑ Mediterranean Mountains

(9) ❑ Mediterrenean North

(10) ❑ Mediterrenean South

(11) ❑ Nemoral

(12) ❑ Pannonian-Pontic

(13) ❑ Anatolian

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How important are the following challenges to sustainable soil management in the environmental zone according to the stakeholders?

	Very important	Important	Neutral	Less important	Not important at all
Maintain/increase SOC	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid N_2O/CH_4 emissions	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid peat degradation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil erosion (e.g water/wind/tillage erosion)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil sealing	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid salinization	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid contamination	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Optimal soil structure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance soil biodiversity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance soil nutrient retention/use efficiency	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

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	Very important	Important	Neutral	Less important	Not important at all
Enhance water storage capacity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

How important are research needs for the following soil challenges within this environmental zone?

	Very important	Important	Neutral	Less important	Not important at all
Maintain/increase SOC	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid N_2O/CH_4 emissions	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid peat degradation	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil erosion (e.g water/wind/tillage erosion)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid soil sealing	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid salinization	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Avoid contamination	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Optimal soil structure	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

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	Very important	Important	Neutral	Less important	Not important at all
Enhance soil biodiversity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance soil nutrient retention/use efficiency	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Enhance water storage capacity	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

How important are the following tasks to improve soil knowledge in this environmental zone according to the stakeholders?

	Very important	Important	Neutral	Less important	Not important at all
New scientific knowledge on the prevalence of key soil challenges	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
New management strategies for sustainable soil management	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Improve soil monitoring	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Increasing availability of existing research for stakeholders	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Increase availability of existing research for policymakers	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

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	Very important	Important	Neutral	Less important	Not important at all
Improving the coordination of knowledge production between actors	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑
Other (please indicate below)	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

What are the most important scientific research gaps in this environmental zone according to the stakeholders? (max 500 words)

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What are the most important gaps in current soil monitoring in this environmental zone according to the stakeholders? (max 500 words)

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How can knowledge on sustainable soil management be made more relevant for policy-making in this environmental zone according to the stakeholders? (max 500 words)

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What are the most important gaps in availability of knowledge on sustainable soil management in this environmental zone according to stakeholders? (max 500 words)

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How can the use of knowledge on sustainable soil management by farmers be promoted in this environmental zone according to the stakeholders? (max 500 words)

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Did you notice any disagreements in the issues raised by different stakeholder groups? (max 500 words)

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Other reflections regarding knowledge on and use of knowledge on sustainable soil management in this environmental zone? (max 500 words)

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Section #4: Ending

Other reflections regarding knowledge on and use of knowledge on sustainable soil management, or knowledge needs in your country? (max 500 words)

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Please note the name and email of the person who completed this form:

_____

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Appendix B: Reflections regarding the coordination and use of soil knowledge

The appendix contains replies to the question: ”Other reflections regarding the coordination of knowledge use and knowledge production between stakeholders? (max 500 words)”

Austria	The links between research, practice, counselling and agricultural schools are relatively weak. There is a consensus that research and practice are separate and that a lot of uncoordinated knowledge is produced. Scientific literature is often too specific, not practice-oriented and does not provide guidelines for practitioners. Reasons for this include the complex interrelationships, regional heterogeneity and the focus on the scientific community as target group. An essential aspect and at the same time a major difficulty for research is the identification / correct perception of the problems in the agricultural practice and their integration into research. Another hurdle is the lack of top-down coordination - institutions and people work individually, competitively and sometimes guided by personal interests. Everyone wants to stand out, neglecting the actual topic. The most effective channels for knowledge transfer to practitioners were identified as agricultural journals, advisory services, further training / courses, field days and publicly available information (e.g. webinars). In these channels, knowledge is prepared for practical application and up-to-date knowledge is conveyed and they find great acceptance among practitioners. In addition, further training for teachers (of agricultural schools) is an important aspect that is often neglected. Agricultural advisors are of great importance; farmers trust them. The advisors of the Chambers of Agriculture are well trained in sustainable soil management and have contacts to research. They draw on this knowledge in their advisory practice and reflect on shared knowledge with farmers. However, they have too little time to continuously follow and incorporate current research results. There is now an awareness about sustainable agricultural practices among parts of the farmers and, for example, there is now a greater range of courses on biodiversity. Farmers are usually interested and enthusiastic; their view is broadened in the trainings.
Belgium Flanders	(1.1) There is agreement that there is a lot of information available and accessible in field demonstrations, communication in agricultural press and seminars and workshops. Yet, the transition of knowledge to the individual farmers could be enhanced. Some stakeholders argue that only part of the farmers are reached and that independent on-farm advice is to a large extent lacking. Access to knowledge for individual farmers is also argued to be largely dependent on specific conditions of the farmer: socio-economic situation, educational level, willingness to adapt. More in general, the stakeholders advise to strengthen the network scientists-advisors-farmers-. (1.2) The stakeholders agree that, although young farmers are aware of the importance of soil quality, this topic should get a higher priority in farm schools. (1.3) The stakeholders point out that it is important to make a difference between public advising services and non-public (commercial) advisors. Whereas the first group has good knowledge on sustainable farming, the others providing commercial advice do not always have access to such knowledge and are often driven by short-term profitability. The stakeholders that indicated “somewhat poorly prepared” (25%) raise the importance to continue to raise awareness for slower long-term effects by soil management. They state that soil quality is a continuous work of many years. As listed in 1.1, these stakeholders emphasise the importance to structurally strengthen individual on-farm advice through a strong scientists-advisor-farmers network. (1.4)The stakeholders agree that cooperation between the stakeholders is increasing, but they emphasize the lack of coordination. A better coordination is needed to foster knowledge transfer between fundamental research, applied research, advisors and farmers.

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	It is suggested that a network of advisors specialized in sustainable soil management should be created with good access to the latest research insights. This would enable a transition from ad hoc project based knowledge transfer to a central contact point and databank. (1.5) There is agreement that soil policy is too dispersed and that we lack a comprehensive soil vision and research agenda. Due to this absence, there is little to no interaction between funding agencies. The program 'GRONDZAKEN' is listed as a recent program that tries to overcome the lack of interaction by linking all government agencies that are dealing with soils in order to improve interaction, knowledge exchange and to create a more coherent soil policy. (1.6) Overall, building on the previously mentioned elements, three general reflections are raised by the stakeholders: - The knowledge system lacks a holistic overview. For example, the economic effects are often not considered. - The knowledge system lacks policy coordination; soil policy is subdivided between sectoral divisions within the government. Soil management in agricultural land is both the responsibility of the policy department of Agriculture and Fisheries and the policy department of Environment, both even under a different minister. In addition, responsibilities are also divided between different policy agencies (e.g. mestbank at VLM). There is much work to be done to get these policy actors communicating, but things are in motion (see 'grondzaken' program in the next question). - There is a discrepancy between short term (economic) incentives and long term impact of sustainable soil management practices.
Belgium Wallonia	Funding is sometimes too focused on "trendy" themes without looking at the real problems/expectations of farmers. But research projects are often important for a better communication that is not often done. For example: communication of the results (what works and what doesn't) between different regions, different countries (Belgian and French farmers) Few scientists, researchers, field supervisors who have a global vision of agriculture, each working in 1 particular field (diseases, pests, varieties, phytos, etc.) and the soil issue is not part of their scope, Everything is linked. If you improve the sustainability of your soils, reduce diseases, and therefore treatments, improve profitability etc.. There is still a lot of contradictory discourse about sustainable soil management. experts do not agree with each other. For example, what solutions do I see for soil sustainability = conservation agriculture, (permanent) soil cover, as little mechanical work as possible, rational use of phytos. CA (conserv.agric) is still heavily criticized by many scientists. Universities and research centers are up to the task. Brake = professional organizations and people stuck in a spiral of agricultural intensification. Important knowledge in some EU member states. INRA in France capitalizes a lot of knowledge on soil management, but Wallonia does not draw much inspiration from it. Walloon farmers seek knowledge via for example INRA's YouTube channels, arvalis, etc. France is the leading European agricultural power and releases very large research budgets. Organize working groups, establish strategic and operational indicators and carry out actions. Coordination is mainly at the level of the geoportal (web based GIS). Why should all this be coordinated? In nature nobody coordinates and yet it works. Research data is not widely disseminated and disseminated. Especially to the agricultural world. Some researchers don't have the time / missions to come and disseminate them at a conference for farmers. There is no inventory of conventions and research projects. It is very difficult to know what has already been done. Often the reports are only known by the administrations (and members of the accompanying committees). A large part of the research, research results has not been archived and is therefore unfortunately lost. We really need to improve the conservation of data and results. It is of capital importance ! There is no more extension service. There was a time when each convention had to end with a booklet, a brochure, ... intended to be popularized.

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	The parties directly in contact with the agricultural world (laboratories, public agricultural advisers, ...) can give different advice to the farmers and they do not really know how to find their way around. A harmonization of discourses would be necessary. There is no (yet) clear scientific consensus on sustainable soil management, so it is complicated to coordinate actions and pass a clear message to farmers. Everyone works in their own corner, on their favourite subject (nitrogen, water, insects, specific crops) and there is little coordination between these structures, which prevents the implementation of global reflection. The development of knowledge on sustainable soil management is carried out by many actors without clear coordination. The production of knowledge is therefore very disparate in Wallonia.
Czechia	List of stakeholders comments: Comment 1: There is enough information about the sustainable soil management but it is problematic to apply them into policy decisions a and law and therefor it is problematic to force them. The research community provides enough information to policy makers, but the application of the knowledge fails due to political-economic reasons. Comment 2: Propagation of sustainable soil management is needed because of climate change. Comment 3: There is enough information about the sustainable soil management, but the key point is to better coordination and effectiveness of distribution of the information.
Denmark	Denmark has a system of government consultancy (myndighedsbetjening) which is mentioned by most stakeholders as crucial for the policy making to maintain integrity behind laws. This implies that the knowledge basis for policy making is not developed by government agencies, but by an independent third party, primarily Danish Center for Agriculture (DCA) and Danish Center for the Environment (DCE). Previously, research facilities were organized under the agencies as “sectoral research institutions”, but today the facilities have been merged with Aarhus University. The abandonment of the state owned research centers has strengthened the research facilities and extended the arm’s length principle according to a number of stakeholders. The advisory service is mostly cooperatively owned and have a high degree of legitimacy in the farming community and a close collaboration with researchers. The advisory service is organized in two levels, with a national center (SEGES) housing technical experts and also some test facilities and connecting the research to the local advisory services, which again disseminate knowledge to farmers, but SEGES also provide input to policy making and constitute the technical part of farmers association. Generally, stakeholders regard the advisory service as a very efficient way to disseminate knowledge between researchers and practitioners. As the local advisory service is cooperatively owned the national center is closely associated with the politically active interest group representing the farmers. Generally, there are a small concern about the interference that politics can have on the research scope and on the advisory service. Currently research is functioning as advisors to the government, however, the government in turn also influence the scope of the research by providing research funding and frame questions for researchers to explore. In a European context Danish farmers are well trained at farm schools before gaining access to farms. Farm schools are reported to show engagement in soil problematics and so are the young farmers, although both also sometimes lacking competencies in that regard. For instance by publishing books and teaching material on the area of soil conservation methods in practice. The Danish farming sector which is one of the most technically advanced in Europe, farmers have invested huge sums in the newest technology, furthermore, DK have a tradition for using RDP funding for technical support and farmers who are well trained in farming schools. Compared with other countries in Europe Danish farmers are highly skilled and professional in relation to technology, practice of farming. The double role of the Universities as researchers and advisors for the policy-makers was both praised and criticized. Praised as an effective way of making sound policies based on scientific knowledge. Criticized for the entanglement of politics and research. Research has also been criticized for collaborating with private industry and farmers, as this could be seen as a way of letting private interests interfere with research. On the other hand there is a strong interest from private industry to participate, and this is by many regarded as the only way to make research more relevant. The role of SEGES/L&F as both advisors and political organization for the farmers,

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	has been criticized for a similar entanglement of politics and professionalism, while others see this system as very effective at dispersing knowledge from research to farmers.
Finland	Please check summary of each interview (send via e-mail) on page 2 or 3 in section Task 2.2.2; subsection 2.1.
France	There are many interactions between stakeholders in France, due to structures (technical institutes, chambers of agriculture, etc.), specific actions or research programmes (Ecophyto, GESSOL, etc.). Recent strong awareness on soil issues has certainly also played a role (e.g. numerous events with stakeholders on soil and land use planning / artificialisation). However, the link between policy makers and knowledge producers remains insufficient: lack of training for policy-makers, but also lack of knowledge from knowledge producers on the constraints of design and implementation of public policies. Moreover, there is a lack of capitalisation of the produced knowledge. France has set up "platforms" to link the production and use of knowledge (GESSOL programme, RMT sol et territoire, RNEST network, GISSol). Despite this, much remains to be done to ensure that the knowledge from these platforms is used/mobilised by all stakeholders. The provision/dissemination of knowledge needs to be improved in order to reach farmers, advisors, etc. The format of the knowledge also needs to be adapted (e.g. extension work, ownership support, and training).
Germany	Stakeholders see other barriers than knowledge transfer much more important when it comes to implementation of sustainable soil management measures.
Hungary	Soil knowledge needs to be expanded among farmers. In particular, funding for climate change constraints and research to mitigate them should be encouraged. Development and application of indicators for sustainable soil management. Development and application of specific knowledge and assessment of the relationship between land use and soil challenges. Reduced communication sand awareness on the importance of soil in the society.
Ireland	According to stakeholders how well is farmers access to relevant knowledge about sustainable soil management? while the majority indicated somewhat deficient, this was not consistent with some indicating good and very good also. There is a general consensus that advisory services lack skills on this topic. The responses regarding knowledge coordination were split, ranging primarily from somewhat uncoordinated to somewhat coordinated. Whilst coordination was largely considered coordinated with stakeholders, this view was mixed across stakeholders. There are few bridging actors that can translate the scientific outcomes into practical recommendations. Also, there is insufficient basic education and training in relation to soil science offered in Ireland. More training required for advisors to deliver skills in assessing soil structure to farmers More solutions required to address problems when identified either in tillage or grassland Impact / results of applying soil solutions and economic benefit As soil management is such a vast area, it is difficult to answer whether knowledge acquisition, knowledge transfer and knowledge use are well coordinated. The situation is improving in terms of knowledge and general awareness concerning soil management but the need for action has increased as intensification in land use continues, organic matter on tillage soils declines and machine weight increases. There is a need for increased co-ordination, but in particular for soil management to be seen as a main-stream and embedded agricultural issue and not the preserve of soil 'enthusiasts' as leaving promotion to societies and groupings risks the development of polarized views and approaches which rarely achieves the required changes. So co-ordination across all stakeholder groups is essential and requires effort to get buy-in form each relavant sector. Research and policy are more aware of the options/knowledge that advisory, farmers and industry stakeholders. Better communication and dissemination of technologies and knowledge is require from the bottom up. There is recognised efforts where there is engagement between policymakers-research organisations and farmers on aspects of sustainable soil management. However, it is slightly disjointed with regards to what is sustainable soil management, who should care, why and how they can make the difference.

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	It does exist but needs improvement
Italy	Italian reality is very complex and diversified among Regions, and only few Regions have an adequate knowledge system. Most respondents report that sufficient knowledge exists, but it is not much utilized, also for a lack of coordination among institutions producing knowledge and (few) disseminators. Coordination of knowledge production and use is considered scarce for: i) the mean old age of most Italian farmers, even if it became lower in the last years and young farmers often have a specific education; ii) "competition" with other sources of information for farmers; iii) scarce support from national and regional policies. In general, starting from the Universities, there is little interest in transferring knowledge, since dissemination activities are not adequately evaluated, and no recognition is given to disseminators. Knowledge production by research is strongly aimed at scientific literature production, and if the results are useful or not for stakeholders is of secondary importance. Available resources are more used for knowledge production than for dissemination: several research projects about soils carry out experiments for a greater environmental, economic and social sustainability, but Italian farmers (except for organic and biodynamic ones) are not motivated in improving their knowledge about soil, aiming at profits and not at environmental protection. This also because policies do not adequately reward soil improving actions: it is difficult to access to European funds for increasing soil fertility, especially for small farms. Soil sustainable management was a strategic priority in RDPs for 2014-2020, but the return to stakeholders was not satisfactory. Demonstrative projects (e.g. LIFE Helpsoil) can help in transferring knowledge to stakeholders. But a bridge between research and agricultural production, that could really allow farmers to benefit from experimental results, is missing. Specific projects for transferring knowledge from research to the farm should be enhanced. Often the involvement of farms is end in itself, instead of representing a model for attracting farmers' interest. Dissemination activities are often little focused and effective, thus knowledge and innovation are exclusive rights of few people. Despite of a project financed by the European Community (Reg. CE 270/79) for technical assistance and dissemination centres in Italy, several experts in pedology and soil conservation are no longer employed in this role. Knowledge on soil – particularly related to climate change dynamics – is widespread in a scientific context, but can be also easily accessible for farmers through advisory services, nevertheless it is not sufficiently correlated with Italian law. Research results, especially about climate, are usually not considered by law, and this lack of connection creates several problems in the definition of both corrective measures and incentives for GAP. This regards not only soil quality (SOM, SOC, contaminants, etc.), but also soil consumption (sealing, desertification), for which suitable policies are not yet been adopted. Someone reported that a clear definition of priorities in institutional programming is lacking.
Latvia	Some of farmers mentioned that there is need for clarification and education about sustainable soil management.
Lithuania	We interviewed different stakeholder's groups: farmers, scientists, policy maker, agriculture advisors, mass media representative, and representative of NGO's. The response from them was different, but reflection to some problems was rather similar. The persons interviewed were well acquainted with agriculture in general and in soil in particular.
Norway	Farmers' access to relevant knowledge depends e.g. on the region. In western Norway, the climate is wetter than in Eastern Norway. The available literature is often knowledge regarding dry conditions. Thus, the information might not be relevant to Western Norway. Furthermore, advisors' interest in sustainable land management varies across Norway. The farmer interviewed, who are interested in the topic, mainly gathers information from abroad. Knowledge has mainly concerned soil chemistry, not biology. According to most stakeholders, there is an increasing focus on sustainable soil management in farm schools. Several farm schools have initiated projects on soil health. Still, a lot of the increased focus seems to be attributed to committed teachers. However, a new curriculum has an increased focus on sustainability. As previously mentioned, the promotion of sustainable land management by the advisory service depends on the individual interests and region. Some regions have initiated several projects,

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	which emphasises on e.g. soil health. Furthermore, several courses are held on the topic. Still, there are divergent opinions within the service. According to stakeholders, knowledge needs to be transferred. The large variation in e.g. climate limits the transferability of the research/knowledge. Moreover, research projects of only a few years could limit the production of reliable/useable knowledge - especially regarding e.g. SOC. It is important to test new tillage methods etc. to attain optimal soil health. Research on soil biology is lacking in Norway.
Poland	Agricultural policy makers evaluate the coordination of soil knowledge use as very effective. Policy makers are strongly supported by the linked research institutes. There is a group of State Research Institutes supporting a policy maker - Ministry of Agriculture and Rural Development in development and evaluation of policy instruments and selection of administrative units for CAP support. That support undergoes under 5 y long term programs. Policy makers understand that designing any policy is not possible without knowledge. Currently it is especially needed to design policy concerning organic soils and adaptation to climate change or assessing soil contribution to GHG balance. The strong example was recent delineation of Area with Natural Constraints.
Portugal	Regarding the coordination of knowledge use and knowledge production between stakeholders, all the interviewed agree that the coordination of the use of knowledge as well as the production of knowledge is very deficient, and needs improvement. There is an expression of interest in many cases, but overall, the coordination is deficient and, fundamentally, dependent on services and information transmitted by companies and commercial agents (eg. machinery, agrochemicals, irrigation systems). The rural extension/technology transfer policy remains insufficient. It will be necessary to create simple content for practical application to promote adoption by farmers. The creation of synergies between stakeholders for the transfer and use of available knowledge is insufficient, including concerning private companies. Although there was an effort of an informal congregation of public and private entities in the Portuguese Partnership for Soil (39 members, among which 16 are entities of research and teaching, 3 centers of competence, 7 associations of production, 3 federations, 3 companies, 3 regional public entities, and 4 national ones), there is still little coordination in the use and especially in the production of knowledge. Despite having been established by the Partners of the Partnership, an innovation agenda, and guidelines for the sustainable management of soils, as it is a voluntary partnership, individual interests still often overlap. There is a lack of something to coordinate the production of scientific knowledge according to needs and the dissemination and transfer of scientific knowledge. Portugal is still very much rooted in traditional soil sciences and needs to expand to other frontier sciences that can greatly contribute to sustainable and precision agriculture. It must be established that the transfer of knowledge to producer organizations and private companies (factors of production, equipment, consultancy, projects, and others) will be privileged. Also, the production of knowledge based on the needs of agricultural production should be privileged. Producer organizations, reference farmers, production factors, equipment, and consultancy companies should always be heard about knowledge production needs. For this purpose, formal, simple, inexpensive, and agile protocols for collaboration between different stakeholders may be established. A platform could be created where agricultural production will insert knowledge needs. We speak of multidisciplinary subjects, of a multiplicity of situations, in which the effective knowledge of stakeholders on the totality of subjects is reduced. So, there must be strong, practical, and objective coordination. No entity or site brings together all knowledge. Professional farmers follow the practices encouraged by the Agricultural Policy, as well as those dictated by the market. Medium and smaller farmers, (mostly) with a low level of professionalism, often do not perceive knowledge and use what the seller provides them. Given the characteristics of our agriculture and farmers, it is necessary to encourage associativism based on knowledge. Lately, associativism for the market has been encouraged, which is important, but given the current challenges, namely scanning and precision agriculture, to deal

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	with climate change and the reduction of plant protection products, it is essential to encourage the associativism as the basis for knowledge transfer.
Slovakia	Slovakia lacks the concept of good farming practice, which would focus on sustainable agriculture mangment. There is a lack of society support, including financial support, for the coordination of the use of knowledge. Farmers must prefer a market-based approach, regardless of sustainable management, if they would like "survive". There is very little measurable data in this area. There is a lack of data collection on what techniques farmers use in practice to reduce the environmental burden on agricultural land. At present, research and education are no longer centrally managed, so it is important to have information on potential researchers and to specifically support the exchange of experience and knowledge by public administration governing bodies and to ensure information within the department. Improving the cooperation of academic and scientific institutions of the Slovak Republic in the process of evaluating the achieved knowledge and establishing corrective measures as well as coordinating the application of the acquired knowledge in practice.
Slovenia	According to 48 % of stakeholders the coordination of knowledge use and knowledge production is coordinated and 39 % of stakeholders have an opinion of good coordination between knowledge use and production.
Sweden	The interest in conservation agriculture is rather low and farmers rather continue with their business as usual. If there is no compensation for specific actions, there is no reason to spend time on it. Those that are interested can get information very easily in the form of presentations and seminars. Local associations are usually dominated by standard topics (e.g. nitrogen fertilization, herbicides etc.), while topics such as soil preparation and cover crops are rather "out of the box". Among the most important is the social system (conformity principle) and people who think differently and appear in the media easily stand out negatively. In the end it is the money that decides and so far, farmers cannot apply for compensation when it comes to carbon sequestration or "conservation agriculture". The compensation for cultivating cover crops given by the Board of Agriculture is according to some advisors not recommended to use, as the conditions are rather stiff and it lacks the technical equipment to establish cover crops effectively. Without better technical equipment, planting cover crops after the harvest of the main crop means a lot of work for the farmers in a period when there is a lot to do on the farm/field.
Switzerland	A common terminology on SSM needs establishment to attain a fruitful coordination of stakeholders. Some stakeholders use different terms and concepts when they talk about SSM related topics. Furthermore, this common terminology needs to be adapted to three languages (French, German, and Italian).
The Netherlands	Although the general interest in the soil condition is increasing, stakeholders accurately remark the high variability in the knowledge level of farmers, advisors and education programmes. The interviewees indicate that although information on sustainable soil management is available, information is highly dispersed and does not reach farmers automatically. They say that some farmers are well aware of various soil challenges and gather information themselves, albeit only on a few soil aspects. Others only have a limited interest in soil management and rather focus on other farming topics. In general, farmers are in need of decision tools/customized advice related to their soil condition and challenges. However, farm visitants (e.g. salesmen, advisors, contract workers etc.) often provide incoherent and contradictive advice. The privatization of farm advice and the presence of commercial advisors is often mentioned as a bottleneck. Additionally, some stakeholders state that many farm advisors only have a limited understanding of soil processes, which is crucial for appropriate advice on sustainable soil management. Additionally, integrated knowledge on the effects of management practices on soil challenges and the trade-offs is insufficient. The interviewees point out that research projects are fragmentated and that different interests are involved. They lack an overview of projects regarding knowledge development and sharing related to soil management. Besides they lack the translation of (fundamental) research into management practices. At the same time, the quality of many subsidized (non-scientific) research

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	projects is considered as discutable, the methodologies of applied research are often inappropriate and the results are poorly processed. Nevertheless, hard conclusions are often being drawn and communicated. Another issue includes data-availability and privacy. A lot of data is collected in research projects and by farmers, but often not available for others to follow up.
Turkey	The current strategies on coordination of knowledge use and knowledge production should be stregnthened and developing a communication strategy to ensure information exchange and research findings are shared with all stakeholders. Dissemination of sustainable soil management information through scientific publications, media publications, posters, educational materials, web sites, workshops, field days, etc. should be supported.
United Kingdom	The key message is that farmers have good access to relevant knowledge about sustainable soil management and young farmers are well prepared but in general coordination of knowledge and communication between various stakeholders (scientists, farmers, policy-makers) is not great and could be greatly improved.

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Appendix C: Improving coordination of sustainable soil management

The appendix contains replies to the question: ”How can the coordination of knowledge production and use regarding sustainable soil management be improved? (max 500 words).”

Austria	The coordination of knowledge must be strengthened between research, practice, advice and schools and the implementation of research results into practice must be improved (unanimous consensus). Therefore, organisational changes are needed, institutional coordination is necessary, possibly also an interface where knowledge is processed / transformed / passed on to multipliers. Different stakeholders (from education, advisory services, practice, science, politics) should work together from the beginning on ("multi-professional teams"). Other perspectives should be included already in the process of finding research questions and different stakeholders could take on an advisory function in research projects. For example, the cooperation of consultants and scientists could be structurally predetermined. Scientific results are often lost since they are not disseminated outside the scientific community. Hence, there should be a structured and/or institutionalised dissemination; communication channels should be created. Target group specific dissemination should be part of research projects. Sufficient funds must be available for this. The scientific knowledge must be translated/adapted in order to be understood easily by farmers. Advisors have an important function here, as well as publicly available data and modern communication channels (easy dissemination via digital and social media). Since the advisors are trusted persons, they should be convinced by sustainable land management. The most important source of information for farmers is the exchange of experience with other farmers. It is therefore necessary to bring knowledge and new practices to farms (pioneer projects, best practice examples) and create platforms to learn from each other. Farmers need to see for themselves that management practices work. Recommendations from people with no relation to agriculture will not be accepted. Other ways of conveying knowledge are magazines, awareness-raising, but for implementation concrete examples are needed. For soil and humus issues, more impulses should be given through training courses to stimulate knowledge transfer. Teaching and training methods should continue to be used to transfer knowledge. To this end, the use of digital media can/should be expanded, simplifying the access to farmers. Examples are webinars and instructive short videos that do not require physical participation and allow flexible time investment. The digital offer is currently well accepted, especially by modern / educated farmers (not so much by traditional farmers). Another possibility for knowledge transfer would be a public soil database, fed with soil analyses of the farmers (exact data would be available).
Belgium Flanders	The stakeholders listed a set of key elements that should be solved, to improve knowledge production and use: - More coordination between policy, research, advisory services is necessary because knowledge is scattered and for the moment poorly coordinated. There are linkages between all actors, but most are ad-hoc and project-based rather than systematic. There is need for a systemic integrative long-term vision on agricultural soils. A potential step forward is recently initiated by the “Grondzaken” program. Grondzaken aims at more interaction and a systematic collaboration between different governmental policy and research organizations. This program is key to come to a more coherent soil policy and knowledge base. For Grondzaken to succeed it is important that a clear mandate is given to employees of different institutes and departments to work together in an open culture. - A better connection, collaboration and coordination between fundamental research, applied research and advisory services is needed in order to create a better knowledge flow from research to farmer and farmer to researcher.

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	- Soil knowledge should be centralized and be accessible for all stakeholders. - A network of advisors that are specialized in soil management and whom can provide individual farm support should be established. This network should be well connected with research to transfer new knowledge to farmers. It would probably help if the role of different organizations would be better defined and a formal collaboration that is a win-win for all could be established in an open knowledge exchange culture and based on trust. This is often hindered by competitions for the same funding. - Reward innovative farmers for their knowledge transfer. A strong partnership with incentives for knowledge sharing would enable pioneer farmers to transfer their experience and farmer knowledge to researchers. A possible approach would be to create a cost-free monitoring system for pioneers.
Belgium Wallonia	'- Bottom-up" and better inclusion of farmers in research projects - communication of the results concerning sustainable soil management and all the positive repercussions on the other axes of agriculture. - it is necessary to promote an independent agricultural council, well aware of sustainable practices (and independent of vendors of products, seeds, etc.). - Clear legislation, but above all a system that informs what the farmer actually does in the field. - Do not reinvent the wheel, use existing data under comparable pedoclimates and complete them. Dedicate agricultural training courses to this theme and above all include it in a preponderant way in the curricula of universities and colleges that teach agronomy. Behavioral changes come not from education. Use the pilot centers to popularize scientific information in this field. Obtain data from REQUASUD, the pilot centers concerning product analyses related to soil quality (reasoned manuring, organic, etc.). See if over time, significant differences in Oligo reduction are measured, for example. Set up a system of agricultural advisors with sustainable soil management as a field of competence or add this competence to an already existing network of advisors (e.g. Natagriwal). The coordination of projects remains imperfect and is strongly linked to dialogue between people within the institutions and particularly within the SPW. No clear trans-actor strategy to date. What is missing are information catalysts, disseminators, extension workers, etc. To continue with my metaphor with nature: energy. And last but not least: that farmers (and extension workers) have time. Give more time to researchers to allow them to disseminate this knowledge. Inventories: Better coordination between institutions, but avoid creating a heavy administrative burden for the "primary producers of results". Too many requests for information sheets, hinders cooperation and the desire to respond correctly. Training should be done on the farms. Farmers must be stakeholders in research. Research results must be brought to political decision-makers to ensure the implementation of ambitious policies in terms of soil protection and soil life. Develop a stronger link between research actors - administration - policies. Develop clear and coherent research themes with well-defined political and societal objectives. On the basis of the results, develop a coherent extension and support policy for farmers. In the Walloon Region, we observe the multiplication of actors which is detrimental to a coherent production of knowledge and a harmonization of actions.
Czechia	There were no comments from stakeholders for this question.
Denmark	By and large coordination works quite well at the moment, but stakeholders stress that participatory research, which include farmers in the process should be promoted further to increase coherence. This could be done by securing financial support for projects that include farmers, and provide a plan for how project results can be applied in practice. Often dissemination of results are not supported Some stakeholders argue that it is an issue that the research community is somewhat

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	fragmented in that each researcher tend to focus on his or her own perspectives. However, according to some stakeholders this sometimes constitute an issue in relation to regulation and practice, therefore, a holistic approach is advocated that take into account mutual benefits or trade-offs of different instruments are needed. Furthermore, research is often perceived as too theoretical to some of the practitioners. They ask for more focus on making applied research and to make sure that research results are realistic to use in practice. Generally, this is seen as a barrier because when the knowledge is theoretical, then it is difficult for famers to adopt directly, because it does not relate to their daily life and practice. Both farmers, advisors and NGO's show an interest in having a more active role in research. They need more resources to take more active part though as often farmers are enrolled in research projects without being funded for their participation and therefore it is difficult for farmers to spend their time participating in research projects. Generally research funding from national programmes or the government ensures that research on sustainable soil management may be carried out. Some stakeholders express their dissatisfaction regarding the time it takes to document and approve new measures to be financed under the RDP that are approved in other and comparable countries. In Denmark in general, the advantage is that first it has to be proved that a measure will actually have an effect, before the measure can be implemented, but a problem is that it can be difficult to get the funding for research analyzing whether a potential measure will have an effect because no general funding is allocated for innovative initiatives. However, regarding resource allocations a number of stakeholders stress that sometimes there is a temporal gap from when a new research need is identified (by stakeholders or governement) and until funding is provided to document effectiveness by researchers. And because researchers cannot work without funding, this temporal gap prevents needed research from being carried out. There are a concern from advisors that a lot of time is spend with rules and regulations instead of technical assistance – this has led to a neglect of issues concerning healthy soil. Generally, farmers contract advisors and use them for administrative work more than technical support. Hence, when something is not directly forbidden farmers tend to think that it is not harmful. However, in principal advisors could play a much more active role in promoting sustainable soil management, but often they are unable to fulfill this role because it is not the task that farmers request. Furthermore, advisors are expensive for the farmers, so most farmers try to reduce the use of advisors to save money, therefore the cost of using the advisory service is also an important hindrance for some.
Finland	Please check summary of each interview (send via e-mail) on page 2 or 3 in section Task 2.2.2; subsection 2.1.
France	Researchers who produce knowledge on sustainable soil management need to work directly with those who will use the knowledge. Knowledge producers must be able to respond to the direct needs of users. This requires that knowledge production projects involve all stakeholders to ensure that produced knowledge is useful, usable and used. Co-constructed work, participatory approaches, should be proposed to connect stakeholders and interest them right from the start of the knowledge production. Moreover, communication and dissemination of knowledge is essential. It is also necessary to continue to raise the awareness of all stakeholders (especially locally) for a better understanding of the challenges of sustainable soil management, while developing cross trainings. Taking into account social sciences would make it easier to promote transfers. If research cannot do the communication and dissemination of knowledge on sustainable soil management, intermediate coordination structures (more or less independent) must be involved. The structures could organise recommendations and advices so that the knowledge is usable and used. In the financing of research projects, providing for additional funding of 1 to 2 years, possibly for a "valorisation" phase or more operational additions, would help improve the link between knowledge producers and users. This has been done in the National Soil Research Programme in Switzerland.

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Germany	Within another study (SoilAssist; not yet published), curricula and media used in farmers' education systems appeared to be rather old fashioned and new topics/technologies are rarely pushed forward. Especially, we suggest improvements in the sector 'smart soil management' focusing digital technology and young professionals.
Hungary	Introducing measures based on relevant research and monitoring whether it really has an impact. Increasing stakeholder participation, there would be a willingness to participate and share knowledge, even from farmers. Improving the interactive web-based sharing of soil data. Create ready-to-use technologies, be open and build a connection between the soil community and society: I think this can be improved, because there can be a willingness to do it from both sides, we just need to find a framework
Ireland	Better horizontal integration of actors in the AKIS. Also, greater inclusion of end users in knowledge production prcoesses. More on farm demo's to firstly show where soil compaction can be a problem and secondly solutions to rectify the problem We need a sustained applied research programme which will provide practical and useable soil management knowledge appropriate for the farming systems being practiced. In addition to generating knowledge, this research should act as a demonstration and knowledge transfer portal. Allied to this is the need to ensure that soil management is seen to be a key element of sustainability which will impact on the future viability of all agricultural production. Consequently all technology transfer practitioners need to have an increased level of knowledge about soil management supported by knowledge transfer specialists in this area. Finally farmers need enough awareness to seek knowledge and information on soil management to ensure protective actions are undertaken. Soil management is often not discussed directly at farm level and farm advisory services should emphasize this area of farm management and demonstrate the options available to solve the various problems / soil challenges or threats Advisory could bring soil management advice higher up on the agenda when advising farmers A recognised network of stakeholders is needed so that there is coordinated oversight and a systematic approach that is inclusive of all stakeholders where knowledge is flows are designed upon a feed-back system. So that it is always targeted at the right group, at the right time and that efforts remain sustained and effective. Ensuring better collaboration, development of AKIs in the next CAP should enhance this
Italy	In Italy the third mission of research is not adequately evaluated, thus it is difficult to directly address stakeholders' practical problems. But a direct approach to farmers' expectations, with focused actions and professional disseminators, together with a greater collaboration and information exchange among research institutions and farmers' organizations was indicated as highly desirable. Demonstration farms and the example of virtuous farms that already have a sustainable management, presenting and practically showing the obtained benefits, are fundamental, especially for disseminating positive impacts of sustainable soil management on the environment and on food security, up to the final consumers (e.g. via social media). In research projects, specific dissemination plans should be addressed to technicians that could later transfer the knowledge to farmers. Communication and dissemination of knowledge should involve the single farmers, by means of advisors, farmers' associations and other organizations with a direct contact with them. Qualified intermediate figures are needed, with continuing education, to support stakeholders for agricultural and environmental issues. Also coordination tables and mixed groups among researchers and farmers - with more farmers than researchers - should be important. Policies referring to the environmental and climatic impacts on soil and the correct soil management should be linked to the research results. Soil sustainable management should become one of the priorities in institutional programming. Dissemination of knowledge to farmers should occur through a development of advisory services and actions highlighting the advantages for agricultural enterprises – incentives for GAP or products certification.

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	Aiming to improve the connection among research and farmers, these latter should be more involved in research projects, and farmers' organizations in the dissemination phase, promoting sustainable soil management also among consumers. In Italy there are also significant experiences of collaboration, and recently the Operative Groups of European Partnership for Innovation started in several regions. Establishing thematic groups for sustainable soil management could guarantee the transfer of soil knowledge and research results to the users. A greater soil culture is needed, together with more financial support for farmers' education. For some respondents, in each Region an institution collecting soil knowledge – and producing it if lacking – should be present.
Latvia	Making workshops and some other information exchange event including farmers, policy makers, advisors and other, to establish consistent information exchange.
Lithuania	The farmers (practitioniers) are looking at soil as the source of making their business. Modern farmers understand that their life depend on soil fertility, its capability to grow crop and produce good yields. Due to this, their are willing to solve any problem if it will be profitable of farming at the end. Not practioniers also agree that the soil is important for food production, while stronger express concern on environmental and social soil servise. To get close these two points in to one, would be great achievenment of EJP Soil activity in Europe.
Norway	Incentives such as different instruments and subsidies do promote sustainable land management. Informational 'campaigns' are also important. More demonstration farms/fields showing successful implementation of e.g. soil-improving cropping systems could be useful. Research, where farmers are more involved, could provide possible trade-offs. More interaction between organic and conventional farming - both in research and in e.g. field days.
Poland	In order to improve the coordination of knowledge production it is necessary to sustain the programs of cooperation between institutes and ministry, better coordinate work of different institutes. Also to continue strategic programs in the area of agriculture under National Centre for Research and Development. There was a strategic program BIOSTRATEG covering soil and other agricultural issues several years ago but it has not been repeated until now. Policy makers emphasize the need for basic science in soil processes, e.g. C sequestration in subsoil or erosion driven changes in SOC and GHG. Knowledge use will be limited without producing basic science. Soil issue need to be lobbied in basic science centre calls. The other needed knowledge is on how agricultural practices shall change under climate change and whether policy instruments are keeping pace with climate change and environmental challenges. The need for knowledge covers also scale of wind erosion, balance of water in various rotations, including catch crops or intercropping.
Portugal	Increase simplified information, convey information more perceptible to farmers, technical training and advice, dissemination of knowledge to extension and advisory structures, and stakeholder associations. Promote more testing and experimentation actions as applied and concrete as possible. That is, for production systems in use in each region, involve farmers and some companies and service providers for these production systems. Keep these demonstration tests for several years, in order to be able to repeat every year dissemination and demonstration actions capable of reaching the largest possible number of farmers, and to be able to clarify the doubts and be able to face the climatic variability that inevitably occurs year to year. To be able to have teams to support farmers who adhere to new practices until they feel they have mastered the techniques and can make appropriate decisions for the conditions they may have to face. Streamline workgroups and focus groups to bridge the gap between researchers and users. Opening places of coordination and production of knowledge to the production structures (farmers, associations, among others); holding meetings; establishment of partnerships that allow better communication between all stakeholders. Through the training of technicians (private and public) and producers; by reinforcing the

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	work in a network (for example through greater involvement of public and private stakeholders in the Portuguese Partnership for Soil). Implementation of a unified soil monitoring system based on stakeholder contributions, accessible to all public and private institutions, with centralized management in partnership. In charge of the Technical-Scientific Community for the creation of Regional Pilot Explorations. Use this initiative of the constitution of the National Hub and transmit it to the whole scientific community, farmers, and also to the general public. Databases are crucial and starting their development is an added value. Developing new (bio) monitoring tools will certainly translate the functional component of soils more effectively. There should be joint initiatives by entities from the National Scientific and Technological System, the Ministry of Agriculture (INIAV, DGADR), and stakeholders - namely farmers and their organizations - capable of disseminating existing knowledge - possibly through the Partnership Portuguese for Soil, and Competence Centers. At the same time, it will be important to ensure the availability of public funding for the promotion of these initiatives. APOSOLO (Portuguese NGO), has been promoting the dissemination of knowledge about soil conservation practices and their economic, social, and environmental benefits to farmers, agricultural technicians and society in general, but recognizes the need to facilitate the connection between the production of knowledge and their use/users by defining initiatives that have access to public funding. The procedures must be simple, agile, and inexpensive. Through a coordinating entity, thematic presentation/discussion forums, and a knowledge dissemination structure. Promoting meetings with good presenters, very practical and with unscientific fluidity, promoting technologies, paths, ways of seeing or reviewing strategies. Implementation of updated knowledge platform and dissemination of information. Using the organizations, namely the farmers and forest producers, to collaborate in the preparation of the content to be disseminated.
Slovakia	Coordination of the creation and use of knowledge in the field of sustainable land management can be improved, for example, by combining theory with practice and pointing to positive examples in practice, by financially supporting sustainable land management. Improvement can also be achieved by preparing a continuous collection of activity data so that all relevant parties (ministries, agricultural research institutions, universities, NGOs ...) are involved in its preparation. Furthermore, we recommend working systematically at the level of the Ministry of Agriculture and other public organizations to coordinate the creation of knowledge about sustainable land management, support research and development in this area and subsequently in the use of acquired knowledge. Last but not least, this is possible through better promotion of the comprehensive advice available. Pay increased attention to this issue already in the process of studying future farmers, which will be able to apply in practice.
Slovenia	23 % of stakeholders did not answer to how to improve coordination between knowledge use and production. Meanwhile 73 % of stakeholders have opinion, that coordination can be improved. According to them, there should be more presentations of good agricultural practices with workshops for farmers and with demonstrations on farms. Also educational training for farmers is important and knowledge dissemination about soil among society. Training involves agricultural advisors and knowledge transfer to farmers. Stakeholders suggest more research on sustainable soil management and including this topic more in educational institutions. Results of research and data should be presented to the farmers and available. Some also suggest incentives.
Sweden	The most efficient way to increase the interest in sustainable agriculture and increase the knowledge regarding sustainable soil management is suggested to be a more determined education of the younger farmers/successors. For example, if new strategies or management options are not specifically dealt with, they are normally not being applied (e.g. cover crops or stimulating soil biology using compost). Besides education, media is a strong driver when searching for help, news or information. There are facebook groups for

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	farmers and those that are interested in sustainable agriculture can find information and exchange experiences. However, the universities are strongly encouraged to conduct more research on specific topics and even though the communication between the university and the advisors is in general considered good, more research should be done directly in Southern Sweden where the food production happens.
Switzerland	A national strategy to SSM dissemination and advisory could be developed. SSM communication and outreach could be harmonized. A national or regional SSM network could be established. The network should involve all relevant stakeholders, such as farmer groups and organizations (e.g. Swiss No-Till and the regenerative farming movement), advisors, researchers, existing networks (e.g. Forum Ackerbau), contracting companies and agricultural cooperatives. Furthermore, the network should be easily accessible. The network should provide the opportunity to exchange knowledge and experience on SSM. This network could host web-based platforms, apps and events. Shared content should involve information for farmers, advisors as well as authorities (e.g. Ressourcenprojekte). The coordination of this network should be adequately and permanently funded (e.g. Agridea). This proposed network could help to increase cooperation between producers (e.g. between potato, vegetable and sugar beet producers), increase cooperation and exchange between research and practitioners, and insure better linkage between research and policy makers and authorities. By the increased exchange, soil research shall be more strongly aligned with the needs of farmers and policy makers. Therefore, such research can provide effective support to advisors and farmers. Within the network it could also be decided what approaches, techniques and machines are to be assessed and later on promoted. The network could also facilitate common use of resources and competences among research activities. On the governmental level, soil protection agencies could be further involved in the agricultural policy framework and its enforcement.
The Netherlands	Regional governments subsidize various knowledge development projects. These projects often not involve a (scientific) researcher, provoking debatable methods and results. Discutable research projects are considered to be inherent to the way the provision of subsidies is organized, and provides room for improvement. In general, knowledge obtained in research projects should be better integrated and communicated. Farm visitants, farm magazines and farm interest groups are important sources of information for most farmers. Retraining farmers and advisors is often mentioned as part of the solution. Currently, courses are being developed to provide useful information regarding soil management to advisors (i.e. train the trainers) at several levels of intensity (short course of a few days and a more extensive training program of >20 days).
Turkey	Establishing effective policies and strategies to develop a strong national soil information system and support sustainable soil management for decision makers, researchers, academic community, non-governmental organizations, farmers and other stakeholders.
United Kingdom	Overall our evidence from the questionnaire is that lack of communication remains a big issue for all stakeholder groups. The stakeholders suggest that there should be a more cohesive approach to managing soils. Improving the sustainable management of soils will necessitate a collaborative effort from diverse stakeholders (growers, governments, academia, industry, public sector bodies etc.). Need to put in place a system which promotes communication (also the use of demonstration farms together with the organization of regular workshops)

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Appendix D: Reflections regarding dissemination

The appendix contains replies to the question: ”Reflections regarding the dissemination of knowledge on sustainable soil management (max 500 words)”

Austria	Knowledge of sustainable management is apparent and used in ÖPUL (Austrian agri-environmental programme). Farmers who are participating in ÖPUL follow the rules completely. There are some measures (e.g. organic farming) for which farmers are obliged to complete courses. Much information of different agricultural topics are available for free (e.g. at advisory service, research institutions). Nevertheless, the knowledge doesn’t or not often reach the farming community. In general, farmers like to exchange among themselves. They accept and apply new strategies if they can see the experiments on site/in reality. Pilot farms/trial plots for dissemination of knowledge are very effective, but participation depends on age and interest. Especially for organic farming there is still too little teaching. However, many working groups exist which are often specialized on certain topics, where farmers can obtain information and exchange experiences and know-how. The coordination of knowledge production guided by an organization is well done in general. Drawback: only farmers which have interest are participating (ones who should participate to sustain their land might not bother). There are also initiatives at which scientists and practitioners develop new methods (e.g. to mitigate erosion) or new/innovative cropping systems (e.g. with ammoniumsulfate-solution injections into the soil) with agricultural engineers. Due to changing climatic conditions, more awareness is raised e.g. at soil water storage capacity due to the lack of rainfall, extreme rainfalls inducing soil loss, etc. However, some topics are lacking interest e.g. aggregate stability: agricultural machines are getting heavier and bigger (e.g. sugar beet harvester up to 60 tons) which leads to soil compaction in the metre range. Traffic in the field must be reduced leading to reduced tillage, results in CO2-savings (fuel savings) and soil acts as a huge C sink. A lot of information and knowledge is communicated via communication platforms (e.g. WhatsApp, chat rooms, forums). Also newsletters, meeting in working groups, educational training courses (free/compulsory) are available for many soil issues. Negative: this is often informal and voluntary. Also many farmers have only little capacity to adapt new knowledge on sustainable soil management, mainly due to economic and time constraints.
Belgium Flanders	(2.1) There is no agreement between the stakeholders on the effectiveness of knowledge communication. The answers range from effective (50%) over somewhat effective (23%) to not effective at all (8%). Farmers organizations and advisors rate the communication efficiency higher than policy and research stakeholders. The stakeholders agree that there exists a lot of communication on diverse channels. Yet, some argue that the group of farmers reached through the different channels is similar. This means that it is difficult to reach all farmers. Others argue that the information is often topic-specific and dispersed, which causes farmers to struggle with the overall implementation. (2.3) Most stakeholders indicate that to some extent (64%) resources are available for the dissemination of knowledge on sustainable soil management. However some stakeholders point out that scientific literature is not always accessible, when not open access. And more in general that, although information can be available, this doesn’t mean that there is a coordinated action towards enhancing sustainable soil management. (2.4) There seems to be an equal division between the stakeholders, with 42% indicating to some extent and 42% indicating to a small extent. Although the opinions of the stakeholders is divided, overall the stakeholders agree that there is too little continuity due to project dependency. In high level European projects there is sufficient budget available for the production of knowledge, but these mostly larger projects are not accessible for all stakeholders. In smaller

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	projects the budget for knowledge production is mostly too limited. Moreover, since soil research requires long term investigations there is a structural need of co-financing, which is not possible for all stakeholders.
Belgium Wallonia	Maintain a variety of dissemination methods in view of the diversity of the public, but the risk is to have too great a heterogeneity of knowledge. CA farmers are very active on YouTube and social networks (compared to the average agri). Poor quality of the media communication must be renewed, be didactic and direct. Dissemination in the media is one thing, but it is necessary above all to emphasise feedback, field corner visits, de-dramatise changes in practices, etc. Dissemination of explanatory or technical sheets via soil analysis laboratories. These laboratories have an advisory role to play in addition to the analytical results of products or soil. According to FUGEA, on-farm agricultural advice is, according to FUGEA, an untapped (barely existing) resource that would allow effective dissemination to farmers of scientific and technical knowledge on sustainable soil management. Research is underfunded. We are working with a soil map that is more than 60 years old, some data are very difficult to update (carbon content) even though they exist. We have an extraordinary basis at the global level but still many research questions in relation to major societal issues. Communication towards farmers and the public is negligible in research projects. This constitutes a vicious circle. Without awareness-raising, no pressure on politicians and scientists to develop research, and so on... etc. We can never disseminate enough. If the budget is constant, reallocating part of the resources used for knowledge production towards the dissemination of knowledge seems judicious to me. This dissemination is essential and the researchers responsible for a study concerning the agricultural environment should be able to disseminate it to the 4 corners of Belgium via conferences aimed at farmers, or visits to their trials, etc, ... Sustainable soil management cannot be an isolated goal of the sustainability of agricultural systems. Thus conservation agriculture and no-till farming, often highlighted to improve soil sustainability, are or could be in many ways harmful to the environment through the production of greenhouse gases (INRA work, ...). To want to preserve the soil to the detriment of the atmosphere and the climate will be absurd. It is necessary to have a global approach and to integrate the dissemination of knowledge into a production systems approach. Communication must be based on soil management that links the different subjects: geology, pedology, agronomy. Knowledge must first be produced before being disseminated. The Walloone agricultural research center could be a centralising body of knowledge but the website is not hyper user friendly.
Czechia	Comments from stakeholders: Comment 1: Many new information prospects and channels, both commercial and non-commercial, was produced. The farmers can use the advisors and consultants for improvement of the sustainable management. , Comment 2: The best way how to disseminate the knowledge is brochures, short videos, CDs. Comment 3: The general knowledge about sustainable soil management exist, but the availability of the information to farmers is the weak point.
Denmark	The two-level advisory service in DK is a very strong and well-functioning system to disperse theoretical knowledge from researchers to farmers – but also the reverse movement of knowledge is facilitated by the system (farmers to researchers). However, the innovative first movers among farmers experience to stand alone. Peer-to-peer groups (ERFA-grupper) are important for these innovative first movers and in general for the dispersion of practical knowledge. Denmark has an extensive network of peer-to-peer groups (farmer to farmer, sometimes moderated by an advisor) organized around particular issues or themes offering good transfer of the more practical knowledge and skills. The use of such groups is a very effective way to disseminate knowledge about sustainable soil management to farmers and also offer opportunities for the innovative first-movers among farmers to share their experience with fellow enthusiasts. Although few of such groups exists that deal directly with soil related issues, as a

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	general principle it is highly important for farmers to learn from their peers, because they deal with many of the same challenges and are able to communicate to the practical reality of most farmers. Furthermore, stakeholders stress that participatory research, which include farmers in the process should be promoted further to increase coherence. This could be done by securing financial support for projects that include farmers and provide a plan for how the results of the project can be applied in practice. Farm demonstration/pilot projects were mentioned as a good initiative to document effects. There are e.g. some projects running under 'Partnerskab for præcisionsteknologi'. E.g. graded spreading of nitrogen based on intelligent maps, avoidance of overlapping through section divided sprayer etc. Some stakeholders would like to have more projects of that kind to test measures – an example could be nitrogen fixating crops. There is a risk that it does not work, but sometimes we need to test. Some advisors and practitioners express concern about the link between the theoretical research and the practical knowledge needed at the farm level. It has been mentioned that the research from universities sometimes lack applicability in the everyday lives of farmers. There has been expressed an interest in getting involved more actively in the research projects by serving as test farms
Finland	Please check summary of each interview (send via e-mail) on page 2 or 3 in section Task 2.2.2; subsection 2.2.
France	Dissemination of knowledge on sustainable soil management is lacking. When disseminated, knowledge is not always specific nor directly usable. Knowledge dissemination is not sufficiently considered and funded in the research sector.
Germany	We suggest a lack of experts on the field of target-group specific communication within soil and agronomy sciences.
Hungary	NA
Ireland	The approach to soil management is fragmented. A more holistic approach is required and tools to support integrated decision making that could better capture the trade offs and synergies of different decisions. A lot of interest from advisors / industry to up skill and improve knowledge on assessing soil structure More advisory time required to give to assessing soil structure While dissemination is practiced, it is uneven. Some interest groups are passionate about soils and occasionally promote and adopt soil management practices that might not be optimal for regional climate and production systems. This can polarize opinions and prevent logical systematic adoption of appropriate soil management. Soil management must become more mainstream by being an integrated part of production systems. To help this, the attribution of future economic benefits to the adoption of soil management systems, has a role to play. Advisors must see soil management as being a key role. Awareness of the soil issues and demand for information from farmers and advisory services is low and therefore the information available is not fully utilized or adopted by farmers. Advisory services need to engage researchers to develop their knowledge and raise awareness and demand for knowledge among farmers The dissemination of knowledge and principles of sustainable soil management in this area is strong. However, due to the large spatial variability of soils in Ireland. Dissemination of soil specific knowledge management means that farmers in particular may not see the applicability to them Sustainable soil management is only a small part of the advice on production being disseminated to farmers
Italy	Someone from Academic world reported a lack of knowledge, not of dissemination. For several respondents sustainable soil management is only marginally treated. Financial support for dissemination is considered almost sufficient by most respondents, but badly utilized in most cases - dissemination is not widespread, reaching a limited number of stakeholders, and only little knowledge arrives to farmers. Several respondents think that with more financial resources dissemination could be improved, by means of dedicated events and expert professionals. Knowledge should be translated in good practices and incentivized to increase farmers' economic interest, because there are too few practical applications of sustainable management practices.

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	Too often farmers' organizations are in charge for dissemination, and despite of the presence of specialistic structures, sustainable soil management is not among the priority issues. Lacking a tecnical assistance and dissemination services, dissemination is often left to the web, open only for experienced and curious users. Communication should carefully utilize social media or other digital platforms, since journalists have an inadequate education about these issues, thinking that the concepts must be simplified for the common reader, but such simplification often trivializes the topics and not favours the comprehension. Other respondents think that often disseminators keep a highly complex level, scarcely relevant for farmers. Operative Groups of European Partnership for Innovation should be an opportunity, but a regional, national and European coordination is missing. All research projects should always foresee the active participation of farmers or farmers' associations, during both the experiments and the result dissemination phase. Someone thinks that if knowledge is effectively used by a leading company, would quickly spread to other companies.
Latvia	Dissemination of knowledge about sustainable soil management is provided mostly by advisory services and farmer organisations, even policy makers if needed. Researches about sustainable soil management are made by scientific community and then this information is spread to stakeholders. Sometimes there are available workshops or lectures about this topic.
Lithuania	Social media information, web page information, practical seminars, field days etc. are popular way to make dissemination of knowledge in Lithuania.
Norway	Resources seem adequate. More important is the shift in attitude in administration and research towards sustainable soil management. According to one stakeholder, farmers are loyal to the management system. Thus, an increased focus on sustainability in the administration might increase awareness among farmers. Although, one stakeholder representing the Agricultural Extension Service answered resources were scarce. Other stakeholders, argued that resources were sufficient. According to stakeholders, funding to the Agricultural Agency has increased in recent years. Farmers can apply for funding to The Agricultural Agency. However, the process can be difficult. The support schemes for farmers willing to test sustainable soil management should become simpler.
Poland	The dissemination effectiveness might be different depending on the target group. There is very good dissemination among policy makers through existing channels of ministry support by research institutes. Ministry asks for support like data or development of policy instruments almost on daily basis. There are frequent discussion meetings organised in ministry facilities. Dissemination of knowledge among farmers is diverse depending on region and farm size. Agricultural Research Stations belonging to institutes disseminate knowledge among local farmers on soil management, liming, sustainable fertilisation, straw management, tillage simplification, etc. through seminars and field demonstration. In general farmers are aware how important is regular soil analysis. The analysis can be easily done in reginal Agrochemical Stations. Important channel, especially in case of young farmers are internet, agricultural practical journals, demonstrations by companies supplying equipment. Very effective channel of knowledge spread is exchange between local farmers, especially demonstration. It can be said that awareness of young farmers is increasing. They are dedicated to farming and soil management since they decided to treat farming as the major business. There is a kind of natural selection between young farmers – only these most aware and knowledgeable can survive due to economic issues. The problem is access to knowledge by small size farms. They are not that open and eager for new knowledge and dissemination through existing advisory or research structures is limited. State Advisory Network does not have institutional and staff resource capacity to deliver the knowledge on soil to most of farmers. Some large farmers cooperate with IT teams and develop knowledge together. They play important demonstration role.
Portugal	All the interviewed agree that more research and knowledge dissemination focused on sustainable soil management is still lacking. Existing information must be more perceptible to farmers and transfer tools that facilitate the use of knowledge are needed. There is a large gap on the subject, given that the dissemination of scientific knowledge is not transferred by extension to

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	stakeholders. There is also a need for great interaction between academic and research institutions with the dissemination and advisory structures, as well as with sectoral organizations or associations. More workshops, more specific training of short duration between the scientific community and farmers in all areas of the country is crucial. The dissemination of knowledge remains based on traditional cultures and often little integrating new technologies now available to farmers. The dissemination of knowledge about sustainable soil management is relatively limited, although there has recently been a growing interest in the subject, mainly following '2015 - International Year of Soil' and the visibility it has given to the theme of soil. However, information about the soil appears in electronic publications of general agricultural scope. A specific publication on the soil would be desirable with subjects that are of specific interest to the different production systems (agricultural, agroforestry, agroforestry and pasture, annual and permanent crops, rainfed and irrigated crops). Producers are aware there is still a lack of widespread knowledge about the soil and its sustainable management, indicators, and ways of obtaining data. It is only possible if it is demonstrated (Regional Model/Pilot Explorations). The dissemination of knowledge must, from the beginning, reach the young public, in order to captivate this public to desire sustainable agriculture. Disseminating information to the older audience is also crucial because from there we can obtain very important information about older sustainable practices. Still very weak on the part of the investigation and larger on the part of producer organizations, needing promotion and improvement. Those who produce information are more interested in the quality of what they produce and not so much in the degree of perception of the message by the farmer. At the moment, most research funding requires actions to disseminate the results obtained, yet the dissemination to broader groups is deficient. It cannot be generalist or too much technical. The end-users still have and will continue having, low perceptions about some subjects, and the economic component has too much weight on the options of change. Communication in general, mainly social communication, misinform. There is a lot of scattered information, sometimes contradictory, political measures disregard the specificities of the regions and legislate for the whole based on a part. The dissemination of knowledge will have to be done at the level of producer associations, which is necessary to encourage, as our farmers are also very individualistic and convinced of the techniques they have always used.
Slovakia	Dissemination of knowledge about sustainable land management is not a sufficiently effective means if it is in some way at odds with production and the market on which farmers are financially dependent. The solution is the financial support for the implementation of sustainable land management, as it is a society-wide requirement. There is probably a lot of information available on sustainable land management. Perhaps international conferences could be held more often in Slovakia, in which foreign farmers would talk about the experience in their countries in introducing sustainable agriculture. To make the issue of working with the public visible - to focus information activities on a specific topic of sustainability in the field, a specific locality or in a region. Few farmers will seek new knowledge in the field of sustainable soil management, so it is necessary to increase awareness, promotion and advisory activities in this area, from which there will be very clear outputs for farmers, not just speeches that no one understands. Involve experts from practice, farmers' associations, SUA, climate club in this activity.
Slovenia	According to stakeholders the dissemination of knowledge about sustainable soil management in Slovenia is very important. And besides dissemination observing the state of dissemination efficiency should be considered.
Sweden	In general, the communication and dissemination of knowledge and results are considered good, one advisor noted that it is not always easy to know whom to ask when it comes to specific questions from the farmers. What is needed is a more open dissemination of knowledge, for example in the form of a magazine, in order to update both farmers and advisors on what the universities are working on.
Switzerland	In general, the public awareness on the importance of SSM must be raised to increase consumer demand and political pressure for SSM dissemination. Consumer awareness for SSM should be

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	increased to strengthen the demand for “soil-friendly” products. Wherever possible this approach should be coordinated with existing initiatives and labels. The recent rise in climate attention could be used as a catalyst to SSM dissemination.
The Netherlands	Apart from the platforms used to disseminate knowledge to farmers, respondents were asked to numerate the platforms they consult and the most common bottlenecks. The most consulted platforms include printed media, websites, expert networks, technical reports, scientific litrature, digital soil maps and newsletters. An overview of the importance of the bottlenecks is provided below. In general, information is considered as dispersed. The lack of uniform soil analyses is mentioned as a bottleneck in monitoring systems and digital soil maps. Additionally, information in digital soil maps is difficult to understand for outsiders. To a lesser extent, information in technical reports and websites is considered as outdated. The costs and limited access (to data) is mentioned as a bottleneck for printed media (i.e. journals) and scientific literature. Bottleneck Percentage Information is dispersed 33% Soil analyses are not uniform 13% Information is outdated 10% Data is not available 8% The costs 5% Difficult to understand 5% Integration between management options is missing 3% Limited access 3% Customized advice is impossible 3% No bottlenecks 18% Sum 100%
Turkey	A multistakeholder " national soil information system" which can contribute to needs of sustainable soil management and provide data for conventions of climate change, desertification and biodiversity should be established in the country. The system has to collect actual and updatable soil data consistently for use of all stakeholders.
United Kingdom	According to stakeholders a key to successful engagement is through engaging progressive farmers and providing them with the key information needed to inform others. Farmers find engagement with researchers challenging due in part to the language used. We need to break down the barriers between farmers and researchers so each will be listened to and engaged with. A clear, simple message is also critical with ALL researchers focussing on the key topics. Sometimes messages can be lost due to multiple different messages which can cause confusion. We need a joined up approach to both engagement and messages.

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Appendix E: Improving knowledge availability for stakeholders

The appendix contains replies to the question: ”How can knowledge availability for stakeholders be improved? (max 500 words)”

Austria	It is important to display the knowledge better. This could be achieved e.g. through more networking, on all levels: between farmers, advisors, scientists, policy makers. Financial support for networking activities (e.g. trainings, working groups) should be available no matter which governmental party is in power. Also the establishment for pilot farms with demonstration fields should be supported as this would be a very effective was to disseminate knowledge. With regard to soil analysis: to get more farmers participating in soil analysis, a reward or benefit could be offered to make it more attractive for the farming community. Also knowledge production has to be coordinated effectively. The coordination of knowledge production should be guided e.g. by an organization. Often implementation is slow and should be dealt with through education and demonstration, not by laws and ordinances as this is the most effective way to reach young and also elder farmers (e.g. good experience exists with lecture series e.g. organic farming training courses). However, the effectiveness of the mentioned methods can be improved by financial support or funding. However, this needs the willingness of the general public to pay for.
Belgium Flanders	Knowledge on sustainable soil management is fragmented and policy regulations are sometimes even opposing each other. This makes it difficult for farmers to put knowledge into practice. There is a need for an integral vision and associated communication and management strategies and enhanced collaboration. Communication on all levels is highly necessary and urgent. Several stakeholders also raise the need of a central (single point) communication platform to share knowledge and practical guidelines. Such a platform should not only contain knowledge from Flemish research, but should also put international knowledge in the Flemish perspective (examples of such platforms already exist for pigs, cows etc.).
Belgium Wallonia	a common platform? Organise field visits, disseminate clear information in the media traditionally read by the farming community, raise awareness among advisers it must be possible to establish economic indicators of the risk of poor soil management (erosion, etc.). Without economic indicators, farmers will not be sensitive to the issue. It should be possible to evaluate, for example, for erosion (average of 5t/ha.year) the monetary value of soil lost over 10 years if nothing is done (topsoil has an important monetary value linked to the number of years it took to create it and to agricultural land). Continue the move towards open access for all soil-related data, develop a neutral coordination body between all producers and users of soil data. Establish a concerted multi-year research plan over time with all these players, and include soil education in this approach. It will not cost more but it will be more effective than what is currently being done. Give them time for training. Forcing them to train is a first step towards a solution (cf. phytolicence) but you must also be ready with good information, pre-digested. Farmers often lose precious time in meetings because the speakers are not impacting enough. It is also often forgotten that most of the knowledge is already with the farmers and that we can help them to bring it out. That "knowledgeable" farmers should be used (and paid) to disseminate knowledge seems to me to be a path to explore. Reduce the top down, create the down top in agriculture. This dissemination is essential and the researchers responsible for a study concerning the agricultural environment should be able to disseminate it to the 4 corners of Belgium via conferences aimed at farmers, or visits to their trials, etc, ... By working with support structures such as pilot centres, Biowallonie (organic), Famer groups, agricultural education establishments, etc... Even if the various media are used to disseminate knowledge, it is clear that alternatives to chemical crop management solutions are given very little prominence in the agricultural press. A sustainable soil is a soil that is given time to achieve its own balance. The life of the soil is essential

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	to its resilience. As long as sustainable solutions are drowned out in the midst of pesticide lobbying, sustainable soil management will not make any headway !
Czechia	Comments from stakeholders: Comment 1: I consider the knowledge about sustainable soil management sufficient, a media campaign cloud even improve it. Comment 2: It is important to focus on big farmers (companies) . To produce information materials such booklets, videos and others. Comment 3: Make a one central hub for the information distribution. Comment 4: To build a platform that would be the head of the of the information platform.
Denmark	It is mentioned that some research funds could ear-marked for application of results as often resources are required to implement and test for the first group of farmers who adopts a new technology or a research result. This testing is often not funded by research programmes. Furthermore, stakeholders stress that participatory research with farmers and/or NGO's, as mentioned above, would be great to ensure that research results can be implemented directly by the stakeholders. In general, stakeholders stress that there is an opportunity in providing farmers with a broader palette of measures, because farmers are heterogeneous – what matches the preferences of one farmer does not match the preferences of his neighbor. Therefore, a broad pallet ensures that each farmer is able to tailor solutions to the particular challenges that appear at his farm not only in terms of practical measures, but also in terms of advise. However, it is important for motivation of farmers that they can see a benefit of changing their practice. If they can't, they won't implement if they can avoid it. Often regulation is adapted to the average farmer, but that can be a barrier for development. Those farmers who believe that nutrient reductions is a good idea – some don't – can be moved, if they can see a purpose of what is being implemented.
Finland	Please check summary of each interview (send via e-mail) on page 2 or 3 in section Task 2.2.2; subsection 2.2.
France	Knowledge availability for different stakeholders can be improved in several ways. First of all, there is a need to foster a change of perspective in the scientific community, by considering usable knowledge availability as an integral part of research. Scientists should be encouraged to produce specific, directly usable advice. This requires that knowledge production projects are co-constructed with all stakeholders to ensure that produced knowledge is useful, usable and used. The popularisation of research results should also be encouraged by providing dedicated and specialised human resources and means to ensure the dissemination of popularised results (should be part of the research funding). A mean would be to create a resource centre (in the form of a digital sharing platform) which would bring together all available knowledge and information.
Germany	Implementation of target-group specific communication between research, advisory services and farmers.
Hungary	Create ready-to-use technologies, be open and build a connection between the soil community and society: We think this can be improved, because there can be a willingness to do it from both sides, we just need to find a framework.
Ireland	Better training of the advisory cohort in relation to sustainable soil management is necessary. To make part of open days Work more with discussion groups to improve knowledge transfer and get down to giving local advice for the soils in particular areas More knowledge needs to be generated; its a huge area so a co-ordinated approach to knowledge generation is needed. This knowledge needs to be appropriate for the soils climate and farming systems of different regions and cannot be simply parachuted in without validation. All actors concerned need to be aware of the knowledge and technology transfer deficits that exist and work together to address these deficits. It must be a main-stream and integrated process that is not left to enthusiastic individuals or groups to promote, but equally it must be underpinned by sound research and good specialist technology transfer experts. There in particular is a need to develop practical, feasible and economic soil management actions from research which are applicable at farm level. It is not enough to know that we are damaging our soils; we need workable solutions. EU or other support for appropriate farm adoption may be appropriate but only if it does not deflect from the acquisition of soil management knowledge by growers.

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	Awareness raising: Training and education of farmers on the soil challenges and impacts. Training and education of advisory services on the impacts and the solutions/ management options available. Improved intensives for farmers to focus on sustainable soil management through Agri-Environmental Schemes Ensure it's a key syllabus subject at secondary and tertiary education across all Ag programmes, Link it as a subject training course as part of scheme payments. Increase the level of advisory knowledge in this area Utilise online platforms Ask for feedback and improve Tailoring the communication approach to the targeted audience
Italy	Knowledge should be linked to farmers' economic interests, and research projects should take into account their real necessities. Knowledge and data should be simpler, more useful and more easily accessible, and specific technical reports - focused on the objectives - should be available. The use of more effective media, like webinars or videos in dedicated channels, is important, involving organizations, advisory consultants and technicians for a widespread intervention in different territories. A greater awareness is necessary, and if sustainable soil management would be considered a priority in landscape planning and management, also more knowledge would be produced and disseminated. Examples are the best form of dissemination, thus farmers should directly see the results of experiments, having a practical and concrete demonstration of real situations. Scientific disseminators are necessary, who not trivialize the matter but make it understandable despite its complexity. Moreover, a greater humility and communication capacity of scholars would be fruitful. Knowledge production occurring in different institutions should be better coordinated, and should be more supported by national authorities. Advisory services, which have the main role in dissemination, should be strengthened and perform a continuing education. Also farmers' organizations should be in charge for dissemination, and peer-to-peer groups should be more effective, if adequately supported by researchers and local policy makers. If financial support for dissemination would be better utilized, it could be increased. With a big effort for coordination and organization, a huge website should be set up collecting all the available information. European Partnership for Innovation should be recognized as a strategic sector of intervention for Ministries, Universities and Research institutions.
Latvia	By improving communication between farmers and their peers that are participating in some funded research projects. With these kind of experience exchange there will be much more proven and practically used practices that can be used in wider scale. For other group of farmers that are much less active and interest with such experience exchange, we can use other mechanisms to let them participate more.
Lithuania	Practical seminars, visiting long-term field trials in research institutes and financial support of demonstration farms is a way to improve knowledge availability and practical experience gaining.
Norway	Knowledge availability for stakeholders can, according to one stakeholder, be improved through educating advisors on sustainable land management, increased attention in the media (larger papers). Moreover, the use of shorter webinars. Overall, close collaboration between farmers, researchers, advisors would be beneficial for all. Including field days.
Poland	Regarding production of knowledge there is a need for better focusing the research needs. Exchange of ideas between policy makers, science, advisors and farmer organisations. Such forum of discussion would be helpful. There is also a need for coordination of dissemination activities among researchers and advisory systems and establishing better knowledge sharing between these two players. Applied research shall be more focused on major challenges e.g. adaptation of agriculture to new targets and climate change. Better focus of basic science on current challenges would be also helpful. Access of farmers to knowledge must be improved, especially to demonstration. New technologies in dissemination develop quite well. Very important would be exchange between practitioners and researchers on the knowledge needs. Regarding availability of knowledge existing advisory networks are underfunded and staff is limited. There is a strong need for developing IT tools in knowledge based advisory, like "digital advisors".
Portugal	Increasing research and knowledge dissemination focused on sustainable soil management, with information and language adapted to farmers, increasing training programs, and technical advice to

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	the farmers. To create and to improve (the existing ones) extension structures that transfer scientific and technological knowledge to users. The restoration of the former Rural Extension will be needed as a way to promote knowledge. Also, more communication between all sectors is needed. Increase the case studies in demonstration units, including new technologies in soil and crop monitoring and management of cultural operations. Keep these demonstration fields for several years, to be able to repeat every year field days to disseminate and demonstrate actions capable of reaching the largest possible number of farmers and to be able to clarify doubts and be able to face the climatic variability that inevitably occurs year to year. Once again, the farmer likes to see and believe, so the creation of demonstration fields for conservative and soil improvement practices is essential. Dissemination can also be improved through farmers' associations and involving services providers (companies) of materials and services. However, there is a fundamental difference between disseminating information and motivate each farmer to change his usual practices, especially on a larger scale. There is the necessity to be able to have support teams for farmers who adhere to new practices until they become familiar with them, and can make appropriate decisions for the conditions with which they may have to confront. Training of technicians (public and private), producers; implementation of a monitoring system; implementation of networks of demonstration farms supported by technicians/educational entities; aggregation of existing knowledge in an easily accessible and durable location. The availability of this information must be done by people with knowledge in this area of science management, and in an appropriate manner considering each of the stakeholder groups. In the opinion of APOSOLO (NGO), there is some effort to disseminate knowledge to stakeholders, mainly by associations and producer organizations in events such as field days and farmers' meetings; through extension forms/brochures and newsletters and information available on websites and news published on social networks and specialty magazines. However, there is still necessary information that should be disseminated through research/experimentation and through farmer networks/organizations. They believe that the immediate transfer of research/experimentation results to stakeholders should be mandatory. Producer organizations, companies of production factors, equipment and others, and also consultancy companies should be called for scheduling knowledge transfer. The implementation of electronic platforms, training actions, and seminars is also needed.
Slovakia	It is necessary to start in schools, primary, secondary, higher. It must also continue in practice, motivate farmers with proper land management and preserve it for future generations. By focusing on specialized areas of problems, specific solutions and a targeted group of experts and entrepreneurs.
Slovenia	Knowledge can be improved by online lectures, with more agricultural practice presentations on TV and radio, with workshops for farmers and advisors, field experiments and demonstrations, cooperation between research community and farmers/advisors (network establishment), common database with available data about soil.
Sweden	See above: For example a magazine that is released for farmers and advisors and shows what current research is about and what new knowledge has been established.
Switzerland	In general, stakeholders stated that knowledge accessibility is good. However, researchers and progressive farmers tend to disagree. The following approaches came up, when stakeholders were asked for ways to increase the knowledge availability for stakeholders and farmers. An accessible and easy to understand web based platform for SSM knowledge dissemination should be established to allow digital learning. Such a platform could include social media integration to facilitate digital networking. Multimedia products could be disseminated on this web-based platform. The development and maintenance of integrated digital Tools (i.e. Apps) could improve knowledge availability and use. A tool in which farmers can autonomously analyze the properties of their fields was said to be crucial for site-adapted soil management. Soil and SSM should become an attractive cornerstone of agricultural education. Education on soil should be strengthened at all levels; this includes an efficient exchange with professional

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	colleagues, consultants and researchers, and systematic learning from professional colleagues. Teachers and consultants (but also application-oriented researchers) must also be able to deepen their knowledge of the subject and continue to train. For advisors, agricultural soil science related training could be organized, for example by Agridea. Furthermore, SSM should be specifically addressed in farmers' continued education. Practical education and demonstrations, such as field days, inspections of strip treatments and machine demonstrations need strengthening. They should be held on a regional basis to be accessible to farmers. These educations and events could be guided but also accessible autonomously (e.g. by panels or QR codes).
The Netherlands	Networks are seen as an useful platform to exchange knowledge about sustainable soil management, especially networks between the research community and the sector. Additional suggestions include: - Knowledge sharing as a mandatory part of public financed projects; - More efficient communication methods; - Establishing a network of independent advisory services, who are annually retrained on the basis of scientific findings; - Collaborations focussing at specific topics; - Involving teachers and students in research programmes (i.e. improving the relation between education and research); - The establishment of regional demonstration farms to efficiently share knowledge; - Farmers often consult the internet. Information on the internet should be better available, for example in one portal in which integrated information becomes available; - Many (decision) tools are being developed, those should be better integrated to foster efficient communication.
Turkey	Establishing effective strategies to develop a strong national soil information system and support sustainable soil management for decision makers, researchers, academic community, non-governmental organizations, farmers and other stakeholders.
United Kingdom	Two routes to improve dissemination are: a) to have the activities that generate the knowledge to be co-constructed with farmers and stakeholders to ensure both buy-in and an understanding of the issues being addressed; and b) use a common language that facilitates understanding. Too many times researchers use language that is alien to farmers and stakeholders. A more co-ordinated message is needed. Although there is lots of knowledge available, especially on-line, it is done disparately and there sometimes appear to be contradictions in the messages provided.

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Appendix F: Scientific research gaps

The appendix contains replies to the question: ”What are the most important scientific research gaps in this environmental zone according to the stakeholders? (max 500 words)”

	Central Europe
AT (Alpine South)	The most important research gaps are concerning knowledge in soil structure, biodiversity, nutrient retention and water storage capacity. In these areas, there is almost no research available. Soil sealing is a very important issue for the Alps, but research needs about this issue are smaller. Knowledge regarding emissions is still needed. Generally, the main issue is the lack of communication and knowledge transfer from scientists to practitioners/politicians/special planners. The implementation of knowledge is not working!
AT (Continental)	Generally, important issues are soil biodiversity and the impact of climate change on the whole soil system. Foremost, research in erosion and nutrient retention/efficiency is needed. Moreover, there are research gaps regarding maintenance of SOC and avoidance of N2O and CH4 emissions for the continental environmental zone. When it comes to doing research aiming to fill these gaps, it needs to be noted that the communication between institutions is missing in Austria. Many times, federal states and universities are conducting research individually. A combined approach to tackle research needs is missing.
CZ (Alpine South)	Stakeholders comments: Comment 1: The main focus should be to soil organic matter. SOC cycles and its relevance to improved fertility and water storage capacity. Comment 2: Not all soil contamination aspects are solved (biocontaminants – pesticides, drugs residuum). Comment 3: There is need for better connection between research (universities and research institutes) and farmers. Comment 4:More focus is needed for local aspect of the proper management.
CZ (Continental)	Stakeholders comments: Comment 1: The main focus should be to soil organic matter. SOC cycles and its relevance to improved fertility and water storage capacity. Comment 2: Not all soil contamination aspects are solved (biocontaminants – pesticides, drugs residuum). Comment 3: There is need for better connection between research (universities and research institutes) and farmers. Comment 4:More focus is needed for local aspect of the proper management.
DE (Atlantic North)	concrete options and research needs were chosen out of 17 agricultural management options and with a total of 410 ticks, stakeholders chose “diversity of crop rotations” (82 ticks), “continuous soil cover” (70 ticks), “intensity of soil tillage” (51 ticks), “establishing agroforest and hedges” (35 ticks), and “use of organic fertilizers” (25 ticks).
HU (Pannonian-Pontic)	As soil is in many cases thought of "only" as a frontier science, there is often no call for proposals specifically dealing with soil science as a science. Examining soil as a natural integrator can in many cases only be examined with a complex approach In the '60s and' 90s we were a great power of long-term experimentation, but today the long-term long-term experiments have been almost completely reduced. These need to be planned for the long term so that the specific causal relationships can be examined with sufficient rigor. Even at the moment, there is (would be) a great need for such experiments to perform various management and ministry tasks.
PL (Continental)	Concerning the knowledge gaps such issues were mentioned as: status and monitoring of organic soils and their management, SOC stock including subsoil, wind erosion and related degradation processes, effective water management and full evaluation of catch crops and intercropping in relation to climate change and scarcity of water. There is still a gap in development of precision agriculture.

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SK (Continental)	Within the soil research in Slovakia, there is insufficient support for research, long-term lack of interest in agriculture, lack of conceptual research and long-term intentions. As a result, research projects cannot be implemented in the context of the perception of the landscape structure and research solutions should be aimed at optimizing the use of the capacities of the researched area. For example, the monitored amount of carbon in the soil and the number of sampling points or samples is insufficient for relevant data for the whole SR. Also, indicators for maintaining the amount of organic matter in the soil are not available and control mechanisms are not currently set up to check the content of organic matter in the soil. In addition to solving specific problems of agricultural land, due to landscaping, the whole problem of land is not solved comprehensively in terms of its use and implementation of the latest knowledge so as to create added value for society. Another shortcoming in scientific research is the lower level of cooperation of workplaces dealing with scientific research of soil, few joint projects of scientific institutions with the university environment. In Slovakia, there are enough experts in research (whether Slovak Academy of Sciences or academic community). The biggest shortcomings is finance for research and direct state support to soil-oriented research.
SI (Alpine South)	According to stakeholders the main research gap is lack of research on sustainable management (economic point of view). We pay too little attention to adapting agricultural practices to heavy soils. There is much done on of soil acidity and the advantages of liming. But it is necessary to upgrade the knowledge on maintaining/increasing organic matter, on the preservation of soil structure and thus better water retention properties of soil. Monitoring of nutrient leaching (various forms of nitrogen) would also be needed. Also there should be more long-term experiments on different agricultural practices.
CH (Continental)	A general finding of our survey is that soil research must be more oriented toward the needs of the practice. For example, farmers and advisors need a catalog with specific practices or systems and not generalities or principles on soil management. Furthermore, research needs to be more system oriented. It needs to go beyond single factor assessment (e.g. erosion, SOC). For example, soil challenges need to be assessed and addressed on the catchment-scale and with a value chain perspective. Other aspects of the system orientation are: What are the effects of SSM practices and systems on productivity, yields and profits? What are the long-term effects of SSM practices and systems on soil quality? Are today's SSM practices future and climate proof? Are the assessed new techniques applicable and feasible on the farm level? To address these system oriented questions, transdisciplinary research approaches including farmers and specific agricultural systems, such as conservation and organic agriculture, needs to be fostered. A main open research question seems to be: "What are site-adapted SSM practices at a specific location or region?" Site characteristics are diverse (e.g. organic and mineral soils), thus their sustainable management are diverse too and need to account for the interaction of multiple soil challenges. Efficient, holistic and easy-to-apply soil quality indicators need establishment to assess the suitability of SSM practices and systems. According to stakeholders concerned with drainage systems, there are many open question regarding efficient and effective drainage. How to sustain, reinstate and improve drainage systems? Can drainage systems be optimized to minimize environmental impacts, for example by dynamic regulation of the ground water level? What are the overall effects of drainage systems on production, soils and environment? Many stakeholders were concerned with knowledge gaps linked to specific soil challenges. Knowledge on avoiding soil compaction and the restoration of compacted soils was stated to be missing. The effect and impact of heavy machines and subsoil compaction on soil fertility and yields, strategies to avoid subsoil compaction in grasslands and strategies to reverse soil compaction were asked for. Management factors of SOC dynamics are not documented well enough. Advise to effectively and efficiently increase and maintain SOC stocks is needed. The function, impact and state of soil biology seem understudied. Methods to easily assess

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	soil biological status and management strategies to improve soil biology are lacking. Furthermore, one stakeholder mentioned that effect of microbial amendments (e.g. compost-teas) are understudied. The processes, activities and timescales for the restoration of degraded soils (e.g. compacted, contaminated or low SOC soils) are unknown according to stakeholders. Some stakeholders were asking for deeper understanding on the long-term effects of chemical and mechanical crop protection strategies on soil quality.
	Northern Europe
DK (Atlantic North)	The answers are varying. For the most part stakeholders argue that no more theoretical knowledge is needed on the basic properties of soil threats. Rather, it is crucial that the available knowledge is put into practice, however the preferred mode of action depends on the particular theme in question and according to stakeholders different types of actions are important to varying degrees – either through policies (especially on compaction, i.e. by setting weight limits on machinery) or through participatory research to create coherence between practitioners and researchers (especially on carbon seq.) is needed. Currently, there is much talk about the opportunities for improving carbon sequestration policymakers currently negotiate about a forthcoming climate act that likely implies stricter requirements on farmers in relation to carbon sequestration. Practitioners, policy makers and advisors ask for more holistic knowledge on soil management, as they perceive the research system as highly fragmented, therefore there is a need to integrate the knowledge produced by different research communities in integrated recommendations for practitioners and policymakers, because often it is difficult for these actors to make this balancing. Stakeholders from all levels are interested in the broader question of what create a healthy and robust soil and the positive synergies between soil biology, chemistry and geology. Furthermore, the stakeholders request more knowledge on the interaction between soil and modern technology. For instance, larger farms require streamlined management and have difficulties encompassing all the variations between and within different parts of their farm on the increasingly large farms. The larger within variation in soil types of modern farms creates a demand for technology within the area of precision agriculture and for easy-to-use tools for measurements of soil carbon.
FI (Boreal)	Please check summaries of the interviews on page 2/3 section T2.2.2; subsection 3.
LV (Nemoral)	There are lot of science based practical knowledge in our environmental zone, but the main problem starts with implementing these practices in farms. Some of farmers discussed the need of studies about sustainable farm management in medium or medium-large farms.
LT (Nemoral)	Soil organic matter conservation (improving), water storage capacity (improving), nutrient retention or use efficiency (improving), salinisation and acidification (avoiding), and soil compaction (avoiding) were top-mentioned soil problems. Practitioniers especially noticed SOM increase, soil water storage improvement, nutrient retension and acidification, while others – soil erosion, soil biodiversity or GHG emision. Disease suppression was not a problem especially mentioned. In general, the farmers noted more practical, more economically related soil problems. The scientists, advisers and others – more environmental and social related soil service problems. These problems above-mentioned have to be solved.
NO (Boreal)	There is a need for research on cultivation methods to implement cover crops. From the research, a guide to successfully implement cover crops can be developed. Further, more research is needed on conservation agriculture in Norway - methods, and effect. According to one stakeholder, reliable methods to measure soil organic carbon are needed. Another stakeholder emphasized that soil biology has been downgraded both in research and in management. Interdisciplinarity and collaboration between different research environments in Norway should be prioritized.
SE (Nemoral)	Cultivation of cover crops and stimulation of soil biology to increase soil health
	Southern Europe

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IT (Mediterranean North)	There are different institutions producing knowledge, with different scopes and often in competition, without any coordination. Research is often limited to academic world, and is not available for stakeholders. A clear idea of the national dynamics is lacking, since research is too sectoral, analysing problems only in local contexts, difficult to be generalized. Scholars report as the main problems a limited importance of third mission of research, insufficient education of agronomist and other experts in pedology and soil science, the lack of financial support, of field studies, and the limited availability of PhD grants. Advisors report the lack of financial support, too, but also that research is not capable to listen to the real needs of the farmers, and a weakness in the dissemination of results. In general, the lack of a direct link with farmers' needs, especially in communicating results is reported. A greater availability of results for advisors and farmers is desirable. Applied research, e.g. on soil conservation, should be valorized. Pedology is not taught in most Italian universities.
IT (Mediterranean Mountains)	There are different institutions producing knowledge, with different scopes and often in competition, without any coordination. A clear idea of the national dynamics is lacking, since research is too sectoral, analysing problems only in local contexts, difficult to be generalized. Scholars report as the main problems the lack of financial support (reported also by advisors), of suitable education, of field studies, and the limited availability of PhD grants. Advisors report that research is not capable to listen to the real needs of the production world, and a weakness in the dissemination of the results. In general, the lack of a direct link with farmers' needs, especially in communicating results, is reported. A greater availability of results for advisors and farmers is desirable. Applied research, e.g. on soil conservation, should be valorized. Pedology is not taught in most Italian universities.
PT (Lusitenean)	Need for research on the consequences of agricultural practices on soil quality and biodiversity. Need for integrated agricultural management and soil quality monitoring programs. Strategies and techniques to improve soil fertility and reduce land degradation. How to manage and measure the effects of soil biodiversity. The component of (bio) monitoring, efficient (precision) fertilization, effects of the prolonged application of pesticides in crops. Identification and evaluation of the presence of emerging pollutants (drugs, microplastics) in soils and drainage waters.
PT (Mediterranean South)	The need for an integrated agricultural management. The interaction between soil structure, organic matter and biodiversity, for the purpose of using resources. Need for a regional soil information and monitoring system in its different aspects (physical, chemical and biological). The sustainability of some production systems face to current climate change scenarios that can lead to an increase in the following threats to the soil: erosion, loss of organic matter, loss of biodiversity, salinization and also eutrophication of surface waters. There is also a lack of long-term studies on the evolution of pedogenetic processes associated with more intensive systems and in some soils. Lack of interaction between areas of knowledge. Indicators of soil quality. Absence of specific programs to finance research proposals. Strategies and techniques to improve soil fertility, reduce land degradation, to manage and to measure the effects of biodiversity and to reach a precision fertilization. Impact of extensive livestock production systems on soil management. Monitoring the soil with expeditious methods (physical, chemical and biological characteristics and health). The investigation/experimentation of sustainable soil management techniques in different cultures of interest to farmers: conservation mobilization and conservation agriculture techniques, namely conservation mobilization and non-mobilization practices; types of permanent soil cover and its management with spontaneous vegetation, crops, straw, and

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	stubble; mobilization equipment and conservation agriculture; precision farming equipment; other forms of ecosystem services. Absence of applied research/communication of data and results in readable and extensible forms/economic impact of the measures resulting from the research in the farmer's crop/income account. Research without a territorial base and not adapted to the reality of farmers. Absence of information for rational fertilization of forest stands; impacts of mechanization on different soil families. Soil biodiversity, soil erosion, slope soil systematization to minimize slope movements, slope stabilization, alternatives to herbicides for embankments management.
TU (Anatolian)	The soil problems listed above vary depending on the geographical structure, they should be examined regionally and the current status of these problems should be revealed first, and then research should be done to control each of them to ensure sustainable soil management.
	Western Europe
BE (F) (Atlantic Central)	The stakeholders agree that the most important research gaps are on soil life and biodiversity, carbon sequestration potential and water storage capacity. In more detail the following elements are raised: - There remain plenty unanswered questions on the carbon sequestration potential. Some examples are: What is the potential of different (new) crops, cover crops and the extent to which roots are contributing to SOC (eg. Root:shoot ratios)? What is the relationship between soil organic carbon content and plant-available water. How much water is being stored? What is the relevance for crop growth? What is the difference in water holding capacity between different carbon fractions? What is the potential of increasing soil organic carbon content by means of organic amendments and what is the risk for increasing nutrient leaching. What is the carbon sequestration potential in arable and grassland soils in Flanders? What is the effect of grassland management (I.e. reseeding, rotation) on carbon sequestration? How much carbon can be stored? Which soils are saturated? - There is a knowledge gap on the potential of new technologies (soil scans, drones, satellite images, sensors, tractor data) and how they can be combined with other data (eg crop growth models, weather data) to map variations in soil quality and to increase crop yield potential. - There is a knowledge gap on soil biodiversity, how it impacts soil functioning and what are bench mark values. What is the effect of a.o. crop rotation, soil cultivation, pesticides and climate on soil biology. - There is a knowledge gap on N2O emissions and its variability. - There is a knowledge gap on the effect of minerals, micro nutrients on soil health (plant health).
BE (W) (Atlantic Central)	Soil biology Contaminant dynamics ants Study agricultural problems in a global way and not only in a given position/axis Many soil research projects have erroneous basic hypotheses You don't do TCS just by stopping ploughing a field, you have to change your way of working globally. you don't sow a ploughed field and a TCS field at the same time, you don't intervene at the same time, and so on. Lack of listening/time to listen to policy makers (we talk in a vacuum) to better understand the impact of organic matter in soil fertilisation (and therefore also mineral fertilisers), in order to better manage their use to understand the long-term impact of phyto products and chemical fertilisers to develop agronomic techniques by respect for soil biodiversity - Popularisation and policy making - Lack of financial means Sometimes gap between research and current agricultural practices Extension to final stakeholders (farmers and policy makers). coordination between the different themes Dissemination of information.

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	Training of counsellors. Listening to the needs of the field. How many tools produced by research are actually used by farmers? DISSEMINATION! Innovative research in agro-ecology or organic farming. The research is very conventional. Lack of coordination too affected and influenced by the media coverage of "stupidities" of scientific untruths such as "dead soils", "ploughing is more harmful than pesticides", "soil life that can be seen (with the naked eye)", soil biodiversity theories, disregarding flows and the confusion between soil biodiversity and habitat biodiversity (the two are not synonymous, sometimes antagonistic). The bigger it is, the more provocative it is, the more it gets in the media, and then perishes. ... lack of duration: to be serious, research needs duration, multi-year repetitions often research is funded for short periods of time whereas agricultural systems, whose soils are sometimes slow to react and fluctuate according to climatic factors. Need for duration, and conservation, accessibility of data. The implementation of real solutions resulting from research, in all fields. Interpretation of biological soil analyses Lack of coordination between studies. Lack of vision on the questions that the different studies want to answer and how to articulate them. For example, the GSOC map resulting from the CARBIOSOL convention is a map frozen in time. It cannot be used in the analysis of regulating ecosystem services for this reason. Research is not at all sufficiently responsive to the issues at stake in the field. It almost never leads to agronomic innovation and often serves simply to consolidate what is already known. Impact of agricultural practices on carbon storage. Advantages/disadvantages of agricultural practices. Lack of an integrated indicator of soil quality. Potential for C storage in agricultural soils .
FR (Atlantic Central)	The most important scientific research gaps in Atlantic Central in France are: - Interpretation of organic matter levels and determination of desirable levels by soil type and cropping system - Determination of desirable levels of soil biological quality indicators - Development of knowledge on soil biodiversity and its associated functions - Assessing soil evolution in relation to climate change Another general research gap is the development of integrated approaches with the soil as a central component. For example: soil and food systems, land use change, soil and bio-economy, soil and one health, soil in a circular economy (recycling of elements, energy, water, ...).
FR (Lusitenean)	The most important scientific research gaps in Lusitenean are: - Interpretation of organic matter levels and determination of desirable levels by soil type and cropping system - Determination of desirable levels of soil biological quality indicators - Development of knowledge on soil biodiversity and its associated functions - Assessing soil evolution in relation to climate change Another general research gap is the development of integrated approaches with the soil as a central component. For example: soil and food systems, land use change, soil and bio-economy, soil and one health, soil in a circular economy (recycling of elements, energy, water, ...).
IE (Atlantic Central)	Alternative options for the use of organic soils is taken out of production. Carbon sequestration at landscape scale where interactive processes are more prevalent. Gaps in nutrient use efficiency research. Solutions for specific soil types Management after applying soil solution Impact / results from fixing soil structure issues Alerts related to soil SMD's in terms of soil traffic ability In the crops area, farming systems which retain soil structure and the productive function of soils through allowing efficient use of and retention of nutrients and water are critical. This comprises many elements: 1. the retention or augmentation of soil C through crop

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	rotations, cover crops, organic manure amendments, and tillage system. 2. The prevention of structure damage through reduced axle loads, reduced ground pressure, better machine turning systems on headlands, controlled traffic, better timing of operations, reduced cultivations, more targeted cultivation actions etc. Knowledge on the effects of Soil type x Management on the different soil challenges. Research to identify the best management options to solve multiple challenges simultaneously. Assessing the agronomic, environmantal and cost benefit of these management options - soil specific advice New management strategies for sustainable soil management to Maintain / increase SOC, Avoid N2O/CH4, to improve Soil nutrient retention/use efficiency, structure and biodiversity. Improving soil biology to reduce dependence of artificial inputs on farms
NL (Atlantic Central)	Other (please indicate below): long-term experiments are considered important. The question regarding the research needs was formulated as an open question during the questionnaire and the interview (no differentiation between climatic zones was made). In contrast to the question above (research needs per soil challenge), respondents note the importance of the coherance and trade-offs between soil challenges. In general, the effects of various management options on the soil condition and functions are not sufficiently clear. Furthermore, methodologies to test the effect on the soil condition are complex (e.g. due to variations in time and space, representative sampling and validation), and target values are lacking. In addition to information about the effect on the soil condition, there is a need for information about investments of the management options and the related (long-term) returns. Moreover, information about business cases and the availability of (regional) best practices is limited. Additional gaps as formulated by stakeholders include: o Relation between management practices on the soil condition: § The effect of the watertable on peatland degradation and CO2 emissions; § The effect of soil cultivation on the soil structure; § Management options to improve the water availability in the soil; § The effect of management options on soil organic matter and the time it takes before the effects become noticable; § Management options to stimulate soil biodiversity in a useful way; § The effect of crop (varieties) on the soil quality; § Management options to improve nutrient use efficiencies and the quality of products. o Soil processes: § Characteristics of organic matter and the associated effects on various soil functions; § Mineralisation of organic fertilizers (when combined with artificial fertilizer); § The effect of the soil structure on the nutrient availability; § Interactions between chemical, biological and fysical soil aspects. o Other: § The potential to increase soil organic matter on sandy soils; § Methodologies to assess soil compaction; § The effect of soil compaction on yields; § The use of organic fertilizers and its climate impact; § The variations in rooting depth and associated resilience to droughts in grasslands; § The financial consequences of sustainable soil management; § Difference in the effects of management options between the regional and farm level.
NL (Atlantic North)	Note: in the questionnaire and the interviews no distinction was made between climatic zones, as the distinction was not relevant in the Netherlands. Therefore, answers given for Atlantic North also apply to Atlantic Central.
UK (Atlantic North)	A better understanding of (1) nutrient use efficiency within plant-soil systems and at the farm level, (2) mechanisms responsible for changes in GHG emissions from managed soils, (3) management effects on soil compaction, (4) the role that agricultural liming or the introduction of multispecies swards may have on different soil ecosystem services.

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UK (Atlantic Central)	A better understanding of (1) nutrient use efficiency within plant-soil systems and at the farm level, (2) mechanisms responsible for changes in GHG emissions from managed soils, (3) management effects on soil compaction, (4) the role that agricultural liming or the introduction of multispecies swards may have on different soil ecosystem services.

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Appendix G: Gaps in soil monitoring

The appendix contains replies to the question: ”What are the most important gaps in current soil monitoring in this environmental zone according to the stakeholders? (max 500 words)”

	Central Europe
AT (Alpine South)	Questions relevant asking are, if the methods used for monitoring are accurate. What is the method really measuring? Are the right parameters measured? Moreover, it is questionable how representative experimental sites are. For example, on most managed grassland sites, machinery is harvesting and fertilizing fields up to 30 times a year, leading to soil compaction. Most experimental fields never experience these realistic conditions and therefore do not show signs of compaction. Generally, there is no proper monitoring for soils in the alps, only results from LTE’s and field experiments are available. Currently the soil protection working group of the Alpine Convention is working on a unified monitoring of the alpine region.
AT (Continental)	In the continental zone and ,overall in Austria, there is no proper soil monitoring, as there is no uniform monitoring system for the whole country. The competences are distributed to the federal states, which is the reason for the non-uniform structure. A national monitoring would be of benefit. For Lower Austria, the project LUCASA (LUCAS SOIL AUSTRIA) the LUCAS data is tested and will offer a good basis for further discussions about how to set up monitoring systems for the future. It is questionable, if a national effort to monitor soil properties is reasonable, or a European wide approach should be waited for (European Soil Partnership). The federal agency for water management is working on the project ErosAT, which aims to calculate the national soil erosion by water. Persistent organic pollutants are monitored nationally within the project “AustroPOPs” by the Environment Agency Austria. Austria does not have a monitoring system for soils. Data which is generated within projects or experiments is usually collected and later evaluated for monitoring purposes. A proper monitoring is therefore needed. An idea would be to develop an easily accessible online tool to allow farmers to enter their data. Another option is to choose sites which are sampled regularly every 5-6 years.
CZ (Alpine South)	No comment.
CZ (Continental)	No comments.
DE (Atlantic North)	Issues on soil monitoring and better data availability were not mentioned in the free-text fields. However, we suggest that every stakeholder is concerned about the fact that monitoring and data are of high importance. It must be added, that there is no harmonized monitoring of soil erosion.
HU (Pannonian-Pontic)	There is currently no functioning soil information monitoring system in Hungary that would be able to examine the correlations between load and condition. Though data collection structures have been around for a long time, there is either not enough money to maintain them or no one to operate them with expertise.
PL (Continental)	The most important gaps refer to monitoring and evaluating status of peat soils. The existing spatial databases of organic soils come from the 1970s. Assuming impact of climate change and groundwater level on transformation of organic soils, it is difficult to delineate areas to be covered by new policies on protection of organic soils. Obviously there is knowledge gap on CAP impacts however such monitoring has been initiated and shall bring some answers in long term perspective.
SK (Continental)	It is necessary to focus on increasing the capacity provision for soil monitoring and on increasing the density (network) of soil monitoring, for example, continuous analysis of soils with lysimeters. Soil monitoring have to be provided as part of environmental monitoring. At the same time, it must also build on soils outside the agricultural sector within the Slovak

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	Republic, but it should be must also harmonized with soil monitoring, especially in the surrounding countries. Due to the lack of funds, the nationwide monitoring of soil contamination within the agrochemical testing of the soil was limited to risk areas. In soil monitoring in Slovakia, it is necessary to switch to non-destructive methods as much as possible, as the development and production of such devices will only allow. It is a solution using permanently located sensors and downloading data online. The current sampling basically presents changes in space and not changes in time. At present, the procedures for obtaining and evaluating data from forest soil monitoring are not harmonized and their connection to the monitoring of agricultural soils is missing. In soil monitoring, it will be necessary to ensure a comparison of procedures and to ensure the collection and processing of monitoring data so that we achieve compatible outputs usable in specific local or regional conditions.
SI (Alpine South)	Barriers to soil monitoring, according to stakeholders, are as follows: the results are not available to the public and it would be necessary to connect databases and access data for different users; not only overall concentrations but also accessible ones should be determined; comparability of sampling methods and analytical procedures should be required; monitoring should be regulated by law and stable funding should be provided.
CH (Continental)	In Switzerland, there is the Swiss Soil Monitoring Network (NABO) and multiple cantonal soil monitoring networks (KABOs). The existence of these networks is based on the Soil Protection Ordinance [1]. Some stakeholders said that the existing monitoring networks should coordinate more effectively and that outputs could be more targeted towards farmers and other stakeholders. Furthermore, the number of sites should be increased to represent the diversity of soils and soil management practices found in Switzerland. For example, the number of sites on organic soils ought to be increased and the site selection should allow the comparison of drained and undrained sites. The survey participants named many additional aspects that could be monitored in the future. The management (incl. drainage) of the monitoring sites should be described, and assessed to evaluate management effects. Further, all sites should be evaluated with an integrated soil quality indicator, instead of just single parameters. The list of additional soil properties to examine is relatively long. Besides subsoil properties in general, it includes physical soil parameters, soil compaction, soil biology, SOC stock changes in the whole profile, peat degradation status, contamination by micro plastics and other 'toxic' compounds. The national inventory of the quantity and quality of the prime cropland with 'FFF'-quality is a requested feature of a future soil monitoring system. Furthermore, the stakeholders asked how the findings of the monitoring networks can be used to draw conclusions for the state of all soils. Especially, as for some regions there are no soil maps existing. For further validation, the above mentioned should be cross-referenced with a yet unpublished NABO foresight study [2] [1] SPO. Soil Protection Ordinance. Access: https://www.admin.ch/opc/de/classified-compilation/19981783/index.html. [2] Gubler A., Meuli R. G. & Keller A., 2020. Bedürfnisse der Kantone und des Bundes rund um ein Monitoring der Ressource Boden: Erfassung und Beurteilung von Risiko, Zustand und

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	zeitlicher Entwicklung durch flächenhafte Erhebungen (Kartierung) und langfristige Beobachtung. Agroscope, NABO, Im Auftrag des Bundesamtes für Umwelt (BAFU), Zürich-Reckenholz. IN PREPARATION
	Northern Europe
DK (Atlantic North)	Denmark is currently transitioning to a more targeted approach to regulation, which sets some important requirements for the monitoration of soil data. DK has a strong tradition for keeping track of many agricultural processes. This is in general a resource to researchers and advisors, but less directly so for the practitioners, which experience it as a burden to file too many registrations. There is a wish across all stakeholders to improve site-specific knowledge databases for both precision agriculture and targeted regulation. There is a large gaps in the site-specific knowledge on soil carbon, but the knowledge on nutrient loss also needs to be more precise. Precision agriculture makes way for very precise measurements of soil traits and this is needed for the development of a targeted regulation on climate impact of agriculture. Therefore, much knowledge has been gathered and synthesized based on a general regulation paradigm, and when moving towards a more targeted regulatory paradigm then, stakeholders argue there is a lack in the knowledge available to support the transition. More site-specific measurements of soil carbon content are needed according to both farmers and advisors. The argument are that practitioners will gain more interest in the topic if they are able to see effects on their own land. This calls for better equipment for monitoring carbon content on field and farm scale. This data are also called for to create better foundation for targeted regulation which, both advisors, interest groups and policy makers are working towards. Furthermore, for a number of years farmers have questioned the legitimacy of the models (particular those that are used to predict nutrient leaching) that are employed in the regulation of famers arguing in favor of measurements which would be a more grounded data to use as a basis for the regulation of famers. Therefore, improving the measuring basis for the regulation is emphasized as important for many stakeholders.
FI (Boreal)	Please check summaries of the interviews on page 2/3 section T2.2.2; subsection 3.
LV (Nemoral)	In Latvia we have only some parameters/areas that are monitored (for example, nitrate sensitive areas), and even if monitoring is made, it is not easy to get information about it. Some farmers are making monitoring for their farms (but it is not mandatory).
LT (Nemoral)	Soil monitoring is a weak point. Soil mineral N monitoring is performed in Lithuania every year. Unfortunately, no other soil chemical and physical properties are not monitored.
NO (Boreal)	According to stakeholders, the most important gaps in soil monitoring include measuring the effect of various measures on carbon sequestration. There is also a need to monitor soil biology. E.g. how soil life is effected by food production under different systems, the use of pesticides. In addition to chemical analysis, biodiversity needs to be included.
SE (Nemoral)	no information
	Southern Europe
IT (Mediterrenean North)	In Italy there is not a specific law on soil monitoring, thus it is attributed to different actors depending on the monitored parameters. There is not a national monitoring network with repeated measures, and some Regions monitor soils with different criteria and different methods, while other Regions do not monitor soils at all. Such local monitoring activities are carried out without a national coordination. For this reason, a temporal trend is difficult to individuate, and eventual corrective actions cannot be undertaken. A national scale monitoring is performed only for soil consumption. Several respondents report a difficult access to databases, that are also not uniform, and the lack of coordination among monitoring technicians and among national and regional administrations. There is a lack of structures dedicated to monitoring activities c/o local authorities. A web platform collecting certified and georeferred monitoring data should be useful. A lack of education is also reported - specific expertise is lacking, professionals should improve their expertise in studies and data interpretation - and financial support is considered scarce. A better

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	arrangement of available monitoring information for an easier use by policy maker would be desirable.
IT (Mediterranean Mountains)	In Italy there is not a specific law on soil monitoring, thus it is attributed to different actors depending on the monitored parameters. There is not a national monitoring network with repeated measures, and some Regions monitor soils with different criteria and different methods, while other Regions do not monitor soils at all. Such local monitoring activities are carried out without a national coordination. For this reason, a temporal trend is difficult to individuate, and eventual corrective actions cannot be undertaken. A national scale monitoring is performed only for soil consumption. Several respondents report a difficult access to databases, that are also not uniform, and the lack of coordination among monitoring technicians and among national and regional administrations. A lack of education is also reported - specific expertise is lacking – and financial support is considered scarce. A better arrangement of available monitoring information for an easier use by policy maker would be desirable.
PT (Lusitenean)	Deficient monitoring of soil quality and biodiversity. The question of the level of soil organic matter, salinity and acidification. The almost total absence of monitoring systems, including the definition of relevant indicators, baselines and thresholds, targets and monitoring plan. Lack of efficient legislation in terms of soil contamination, monitoring biodiversity, functional monitoring through the research of nutrient cycle, soil microbiota, microbiology, ecotoxicology.
PT (Mediterrenean South)	The lack of monitoring systems, identification of indicators, baselines and thresholds, and adequate reference systems. The monitoring that has existed has been in the context of European initiatives (eg Biosoil, Lucas) but these, being adequate for the European scale, are insufficient at the national and regional scale. There is a lack of an environmental monitoring network. There is a need for updated soil mapping. Absence of current/recent analytical data from soil properties. Absence of historical data, inexistence of expeditious methodologies, and availability/access to data/information such as productivity maps and differentiated distribution of inputs for easy/accessible use. An expeditious and consensual way of monitoring the soil; key points of results; evaluation timings; regionalized reference points. Timely information and concrete proposals for improvement. Expeditious fertility and structure monitoring tools. Biodiversity of the soil, soil erosion, organic matter fixation.
TU (Anatolian)	The most important gap is that on soil monitoring, there are different soil information system under different institutions, there is a need a comprehensive national soil information system which consists of their databases. The number of parameters used in soil monitoring is insufficient. For example, there is no any criteria for the biological structure of the soil. Data should be collected every 5-10 years and with this data should be used for future forecast / model studies and policy revisions etc.
	Western Europe
BE (F) (Atlantic Central)	Soil monitoring needs are very high in Flanders, most basic data are outdated by at least 50 years. Yet, monitoring is needed to fulfil (inter-)national obligations and to get insight in the current soil status. For carbon stocks a monitoring network is designed and monitoring will start soon, but for all other soil challenges there is no scientific sound monitoring. The SOC monitoring network should be extended to also measure other soil properties. Additionally, the stakeholders indicate that monitoring data should also be comparable and stored in a central and accessible database. Some stakeholders also mention the need to investigate how satellite or other remote sensing data could be used to map soil challenges.

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BE (W) (Atlantic Central)	Soil biology We can always do better, but I do not think that allocating additional resources to monitoring is appropriate. These means could be more efficient elsewhere. Lack of a global soil monitoring system Lack of legislative tools (soil decree just for contamination issues) Soil biodiversity, the OM rate with more data than at present, + develop quality indicators (structure, permeability, clay-humus complex, etc.). To draw up soil maps of a given element more frequently and to compare them; i.e. to be able to draw up maps more easily and quickly on the evolution of the soil. Analyses of sewage sludge and biomethanisation digestates should systematically test and quantify the presence of antibiotics and plastics (in addition to the analyses already carried out: heavy metals, hydrocarbons, pathogens, etc.) and subject them to demanding standards. To my knowledge, these points are not currently analysed. the dynamics of monitoring in parallel with the dynamics of the evolution of the monitored variables the coordination between the actors some data that are very difficult to access although they exist Dissemination of information. I know everything is available on the net, but the task must be further preached by regularly extracting small pieces of information that are easy to understand and disseminating them. There is almost none left? For contaminations, traceability must be strengthened, we must prevent agriculture and its soils from becoming society's dustbin, and then strengthen legislation and sanctions. Too much reliance on models and maps, not enough field knowledge. Farmers are hardly included in the process. Apart from accounting for agricultural land and Mo content, there is as far as I know no soil monitoring. No information on structure, biodiversity, etc. We have a good idea of the C content of soils via the soil analyses carried out by the provincial laboratories of the requasud network. On the other hand, we have little or no information on C stocks in soils due to the lack of information on bulk density.
FR (Atlantic Central)	The most important gaps in current soil monitoring in Atlantic Central in France are: - Have indicators of the biological quality of the soil - Monitor chemical, physical and biological soil data according to the sustainable soil management practices implemented in the field to establish the impact of the implementation of a practice as well as a combined set of practices on soil. This would be in order to have data on sustainable soil management practices to be implemented according to soil characteristics - Finalise soil mapping campaigns to complete the full coverage of France - Develop proxi-detection tools
FR (Lusitenean)	The most important gaps in current soil monitoring in Lusitenean are: - Have indicators of the biological quality of the soil - Monitor chemical, physical and biological soil data according to the sustainable soil management practices implemented in the field to establish the impact of the implementation of a practice as well as a combined set of practices on soil. This would be in order to have data on sustainable soil management practices to be implemented according to soil characteristics - Finalise soil mapping campaigns to complete the full coverage of France - Develop proxi-detection tools
IE (Atlantic Central)	Indicators to capture spatial and temporal changes in soil carbon stocks. Certain managements lack a management factor that can be incorporated into inventories.
NL (Atlantic Central)	Soil monitoring systems can apply to the National-, regional- and farmlevel. In general, monitoring systems are considered as fragmented, dispersed and inconsistent. Most monitoring tools focus solely on one policy or soil aspect, limiting its usefullness. Because of the variation in scale, indicators and methodologies, results are difficult to interpret and compare between monitoring systems. Soil testing at field level is common, but values do

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	not necessarily reflect the effect of management options and farmers' understanding of all parameter values is limited.
NL (Atlantic North)	Note: in the questionnaire and the interviews no distinction was made between climatic zones, as the distinction was not relevant in the Netherlands. Therefore, answers given for Atlantic North also apply to Atlantic Central.
UK (Atlantic North)	There is basically no soil monitoring programmes in place at the moment. A lot of work is needed to plan and implement monitoring, reporting and verification platforms at regional and national levels.
UK (Atlantic Central)	There is basically no soil monitoring programmes in place at the moment. A lot of work is needed to plan and implement monitoring, reporting and verification platforms at regional and national levels.

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Appendix H: Improving relevance for policymaking

The appendix contains replies to the question: ”How can knowledge on sustainable soil management be made more relevant for policymaking in this environmental zone according to the stakeholders? (max 500 words)”

	Central Europe
AT (Alpine South)	It is essential to transfer knowledge from scientists to politicians in an adequate language with precise acting instructions and clear goals. Insecurities and complex knowledge is leading to confusion and does not motivate politicians to adapt suggestions. The same is relevant for spatial planners!
AT (Continental)	On a national policy level, the communication between universities and ministries should be improved. When research projects are not funded by the ministries but other funding organisations, ministries have no insight into the current research activities and most relevant findings. An accessible summary of these activities or annual meetings would help policy makers and funding institutions to have an overview of the national available knowledge. On a federal state level, the issues are similar, as communication with research institutions is missing as well. The biggest points of contact between knowledge on soil management and implementation of policies are local authorities. For example, modelled data for mean soil erosion is available on local scale and policies can be implemented within those communities. Unfortunately, also most problems arise within this area. But not only local authorities, but also chambers of agriculture act as important communication and implementation interfaces. To solve this issue, not only agricultural policies but also regional and municipal politics are needed.
CZ (Alpine South)	Stakeholders comments: Comment 1: There is lack of connection between research and farmers. Comment 2: Fragmentation of the information is the weakest point. More harmonization and specification according local conditions are needed. Comment 3: Harmonization of information.
CZ (Continental)	Stakeholders comments: Comment 1: There is lack of connection between research and farmers. Comment 2: Fragmentation of the information is the weakest point. More harmonization and specification according local conditions are needed. Comment 3: Harmonization of information.
DE (Atlantic North)	Much stronger than knowledge transfer, stakeholders, especially farmers, concerned economic and administrative issues as barriers to implement sustainable and climate-smart soil management options, such as “insufficient financial support”, “insufficient willingness to pay by consumers”, “insufficient incentives”, “narrow framework in policy/legislation”. We conclude from the survey that new strategies for communication and knowledge transfer should include these issues.
HU (Pannonian-Pontic)	Development and application of indicators for sustainable soil management. Development and application of specific knowledge and assessment of the relationship between land use and soil challenges. Introducing measures based on relevant research and monitoring whether it really has an impact. Create ready-to-use technologies, be open and build a connection between the soil community and society: I think this can be improved, because there can be a willingness to do it from both sides, we just need to find a framework Improve coordination between ministries, regions and national agencies in the research chain.
PL (Continental)	In general relevance of knowledge on soil management for policy-making is at good level. The channels of supporting policy at national level are effective and it can only be improved by better coordination of new knowledge production with current and future challenges and defining research questions in line with policy needs.

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SK (Continental)	Knowledge on sustainable soil management should be part of all strategic and conceptual materials of the ministries of agriculture and environmental protection, which are the basis of policy-making in these areas. Soil is one of the basic natural resources, which has irreplaceable value. It is necessary to protect and manage it so that its quality is not lost and degradation processes do not occur on it. This knowledge of land management should be relevant in policy-making. Politicians should understand the importance of knowledge about sustainable land management and the change of personalities or political parties should not affect long-term intentions and measures. Training courses should be introduced to talk about the value of the land and sustainable land management. The transfer of scientific knowledge on sustainable soil management to those responsible for drafting legislation can take place through the participation of these employees in project solutions. For example, emissions and emission balances as one of the indicators of sustainable management are policy-dependent; if policies are not available, it is very difficult to produce emission projections. Effective soil protection in the Slovak Republic could be implemented through revised legislation based on research results. Taking into account and accepting the results of soil research in legislation will increase the sustainability of land management. For example, good monitoring and data on the state of carbon in soils could also serve to ensure compliance with Directive 2001/2018 on the promotion of the use of energy from renewable sources, Art. 29, point 2.
SI (Alpine South)	All stakeholders agree, that better knowledge of sustainable soil management would help to understand the issue of sustainable use of agricultural land in Slovenia. Lack of coordination among national institutions should be improved. Network between researchers and policy makers is very important and thus should be established.
CH (Continental)	Knowledge on SSM could be made more easily available to decision-makers by targeted educational courses (e.g. by FHs or Agridea). Furthermore, relevant scientific output should include brief summaries of findings written specifically for politicians (not just scientific abstracts). With increased inter- and transdisciplinary exchange and cooperation the knowledge of practitioners, advisors and researchers alike could influence the policy design. However, some stakeholders mentioned that political framework conditions and political influence in participatory processes can ‘dilute’ the impact of regulatory measures.
	Northern Europe
DK (Atlantic North)	Some stakeholders argue that it is an issue that the research community is somewhat fragmented in that each researcher tend to focus on his or her own perspectives. However, according to some stakeholders this sometimes constitute an issue in relation to regulation and practice, therefore, a holistic approach is advocated that take into account mutual benefits or trade-offs of different instruments are needed. Policy makers emphasize that research should be more cross-disciplinary for policy-makers to understand possible trade-offs. There are a demand for policies that can offer solutions to multiple challenges at the same time. More long-term experiments on soil carbon content and the effects of instruments (like conservation agriculture or set aside of lowlands) are needed.
FI (Boreal)	Please check summaries of the interviews on page 2/3 section T2.2.2; subsection 3.
LV (Nemoral)	As most of stakeholders mentioned, there is lack of hearings between policy makers and small or medium sized farms. Most impact and lobbying comes from large farm owners and other stakeholder who are holding very big impact over policy makers.
LT (Nemoral)	Politicians has to be well informed concerning soil situation first of all due to make right decision making. Financial support for soil research activities, long-term field trials financing should be activated.
NO (Boreal)	According to stakeholders, inviting policymakers to field days, etc., could contribute positively. Demonstration farms succeeding with sustainable soil management, documenting improved soil health, could mobilize policymakers to push for sustainable policies.

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SE (Nemoral)	No information
	Southern Europe
IT (Mediterranean North)	Policy makers need simpler and concise information about the huge benefits of sustainable soil management at regional and national level, highlighting the bad effects of soil threats and of not protecting soils from degradation processes with real examples. Nonetheless, an excess in simplification of complex phenomena regarding soil often trivializes the problems or is not effective. Research world should find the way to talk with policy makers for supporting them, with more available researches finalized to the policy demand. A continuous coordination between research and policy, highlighting the importance of research, should be important, and knowledge should be linked to environmental and European policies. A cultural evolution of policy makers is necessary, through focused education and information about environmental dynamics, strictly linked to climate change and with soil in the foreground. Data for sustainable soil management should be made easily usable for policy makers, since most data are not readily available, and technical solutions should be presented together with an economic evaluation. Field visits, continuing education for managers, interactions among researchers, farmers and policy makers are important issues. A greater coordination among individuals interested in soils is desired, defining a common strategy to be shared with decision makers. Someone suggests to use information materials and more discussion among stakeholders.
IT (Mediterranean Mountains)	Policy makers need simpler and concise information about the huge benefits of sustainable soil management at regional and national level, highlighting the bad effects of soil threats and of not protecting soils from degradation processes with real examples. Nonetheless, an excess in simplification of complex phenomena regarding soil often trivializes the problems or is not effective. Research world should find the way to talk with policy makers for supporting them, with more available researches finalized to the policy demand. A continuous coordination between research and policy, highlighting the importance of research, should be important, and knowledge should be linked to environmental and European policies. A cultural evolution of policy makers is necessary, through focused education and information about environmental dynamics, strictly linked to climate change and with soil in the foreground. Field visits, continuing education for managers, interactions among researchers, farmers and policy makers are important issues. A greater coordination among individuals interested in soils is desired, defining a common strategy to be shared with decision makers. Someone suggests to use information materials and more discussion among stakeholders.
PT (Lusitenean)	Long-term projects involving farmers' organizations should be implemented. Implementation of technical itineraries and information dissemination actions demonstrating the effect of good agricultural policies and practices on the quality of the environment and human health. Depending on the problems identified in a region, it can help to define corrective measures that can minimize the weaknesses of the region and thus motivate farmers to adopt them, to help achieve the objectives of the national and European strategy. To train technicians from public and private entities; by strengthening partnership work (for example through Soil Partnership), by implementing a monitoring system and by the disseminating of knowledge. There is lack of efficient legislation in terms of soil contamination, monitoring of soil biodiversity, functional monitoring through investigation of the nutrient cycle and soil microbiota, microbiology, ecotoxicology. Through sharing and dialogue between researchers, farmers, and decision-makers.
PT (Mediterranean South)	Long-term projects involving farmers' organizations should be implemented. Dissemination of scientific knowledge. Updated Cartography. Contributing to legislation, be it restrictive and/or conditioning, but more adjusted to the regional reality.

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	Creation of an expert group that integrates the definition of policies. Depending on the problems identified, it can help to define corrective measures that can minimize the weaknesses of the region and thus motivate farmers to adopt them, to help achieve the objectives of the national and European strategy. Mitigating the process of real desertification of inland areas. Training technicians from public and private entities; by strengthening partnership work (for example through Portuguese Soil Partnership), by implementing a monitoring system, and by disseminating knowledge. Through regional pilot demonstration explorations. Soil fits into the policies as it is a determinant factor, among others, of the sustainability - economic, environmental and social - of agricultural activity, namely of the productivity of the crops, being recognized the capacity of carbon storage, and of 95% of world food production. The soil can be a tool for adapting to climate change, providing ecosystem services and guaranteeing the maintenance and improvement of biodiversity. Therefore, the knowledge that promotes the improvement of the soil organic matter content, reduction of erosion, correction of the soil pH, the increase of its fertility, the retention of water in the soil, the protection of air and water and maintaining biodiversity will contribute to policy formulation. Policies that respond to the needs listed above and that are easily implemented by agricultural production should be privileged, establishing support for a quicker adhesion of farmers who may see their income affected by the implementation of certain measures. Talking regionally with stakeholders, involving them in the process and asking them to formulate their policy measures (inversion of thought, accountability for decisions). Translating the knowledge into a language that policy makers understand and taking a more proactive attitude in preparing information before it is requested by legislators and forcing its presentation when it is not requested. Crossing scientific knowledge with regional specificities through the representatives of farmers, and talking together with the "makers" of public policies.
TU (Anatolian)	Science-policy interface should be improved regarding SSM. To train experts who know both subjects on the interface of "sustainable soil management-policy development" is very important and these experts should be with communication with Universities-public-farmers. Good expression of expected results of the studies should be made for policy makers, the case study number increased.
	Western Europe
BE (F) (Atlantic Central)	The stakeholders formulate a need for more practice oriented and feasible policy with stimulating instead of controlling regulations. Specific needs discussed are: - Need for CAP payments research focused towards farm or field parcel monitoring. - Need for result-based payments as incentive for sustainable farming practices. An accurate and cost effective method for carbon accounting should be established and certified by the government. - Need for a long-term perspective and an integral approach. - Need for harmonized holistic non-opposing policies. - Need for indicators and benchmarks in soil policy to monitor soil quality in light of the soil challenges.
BE (W) (Atlantic Central)	Drawing up synthetic and pragmatic reports (regular) Raising political awareness quantify them in terms of greenhouse gas savings, food quality, etc. take them into account in the new CAP Make the link between this management and the various threats to the soil. raise awareness among policy makers. Scientific research must be able to identify emergencies and lobby politicians for rapid integration. Creating a central knowledge platform

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	dialogue between researchers, land users and policy makers Knowledge is so huge and politicians' time so small. They have to be given the task beforehand and cut the puzzle into pieces. They are all on Twitter, let's take them on their playground with short news. But not only that. I refuse to sum up the science to a few Twits. Twitter is just a gateway. Politicians need to make useful and practical decisions that relate to the realities on the ground and not just to satisfy their electorate . By better integrating them into the sustainable management of agricultural systems. Wanting to store carbon only makes sense by maintaining production levels. Otherwise, we would no longer heat up (acidification reduces biological activity, mineralisation of the organic C in the soil), we could even pollute it with loaded WWTP sludge (heavy metals, pardon the trace metal elements) can also by their toxicity reduce the mineralisation of the C in the soil and the soils polluted in this way can become marvellous biotopes for botanical or enthomological rarities such as ancient metallurgical sites converted into natural reserves. More link between agricultural and environmental materials. Coordinating agents at the SPW to relay to the different Ministries concerned, in a coordinated manner? Show politicians the economic interest (especially in the short term) in moving towards sustainable soil management (since politicians see money above all else, this may influence them in the right direction). Bringing politicians to the field The positive or negative impacts of sustainable soil management techniques should be well demonstrated and validated. On this basis it would be possible to establish a coherent policy.
FR (Atlantic Central)	To be relevant, knowledge on sustainable soil management must be known and understood by policy-makers. This requires the establishment of coordinated monitoring and the pooling of knowledge already produced. The gathered information must be synthesised in order to produce sufficiently clear-cut and enlightening scientific opinions and syntheses for public policies. Syntheses must provide exhaustive coverage of soil information. Good communication, transfer of research results and awareness raising among policy-makers are essential processes to make knowledge on sustainable soil management more relevant. Knowledge must be easily implemented and/or interpreted by stakeholders. This requires the integration of social and economic elements, through work carried out on farms by exchanging with farmers on the socio-economic difficulties encountered (importance of the social and family context, history of the territory). Moreover, the dispersion of soil considerations in different policies should be concentrated in a specific soil policy (in relation to the Soil Framework Directive).
FR (Lusitenean)	To be relevant, knowledge on sustainable soil management must be known and understood by policy-makers. This requires the establishment of coordinated monitoring and the pooling of knowledge already produced. The gathered information must be synthesised in order to produce sufficiently clear-cut and enlightening scientific opinions and syntheses for public policies. Syntheses must provide exhaustive coverage of soil information. Good communication, transfer of research results and awareness raising among policy-makers are essential processes to make knowledge on sustainable soil management more relevant. Knowledge must be easily implemented and/or interpreted by stakeholders. This requires the integration of social and economic elements, through work carried out on farms by exchanging with farmers on the socio-economic difficulties encountered (importance of the social and family context, history of the territory). Moreover, the dispersion of soil considerations in different policies should be concentrated in a specific soil policy (in relation to the Soil Framework Directive).
IE (Atlantic Central)	Develop options that account for the variable capacity of soil types to deliver in terms of production and other soil based ecosystem services such as climate regulation. Then this could help support incentivisation or development of instruments that would enhance soils for meeting societal needs.

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	To high the role of soils in reducing nutrient losses to water / air There is a need to consider all soil management on a region and site specific basis from a policy perspective. It is not a one case fits all situation. Soils, climate, cropping systems and other regional or site specific factors impact on the needs and policy must reflect this. This will only occur if the research is available to support this and the expert knowledge which allows research to be translated into useful sustainable soil management actions is also in place. Equally our research needs to be translated for policy makers to in-particular demonstrate the long term impact of soil management actions (or the lack of them!). In our region, our climate has a huge impact and many of the practices which may impact positively on soils in another region may have a different effect here. Policy makers need to consider that different soils may have different levels of risks for impact form soil challenges. Policy needs to be more adaptive to variability between soil types and farming systems and allow more autonomy to the farmer to select the best options for their situation /context. Knowledge is vital to help understand what realistic targets can be set to achieve the desired effects within these environmental goals Knowledge will help understand how these can be met, if additional legalisation, strategies and/or funding is required to research and/or implement measures either mandatory or voluntary. Demonstration/explanation of science into practical application
NL (Atlantic Central)	Policy development is often based on existing knowledge. However, research projects do not always meet the knowledge needs of policy development. Contradictions in current policies and regulations are often mentioned as a bottleneck in the transition towards sustainable soil management. An integrated approach is needed to prevent contra-productive policies. Knowledge on the coherence and trade-offs between management practices and soil challenges are required for successful policy development.
NL (Atlantic North)	Note: in the questionnaire and the interviews no distinction was made between climatic zones, as the distinction was not relevant in the Netherlands. Therefore, answers given for Atlantic North also apply to Atlantic Central.
UK (Atlantic North)	There is a danger in treating the knowledge exchange as unidirectional (i.e. from researchers / government to farmers), when many farmers are very well informed and highly invested in the health of their soils. Co-development of programmes with farmers, asking about their needs / opinions / barriers to uptake & actually incorporating them into activity design is critical. Appropriate incentives for participation may also help (many KE activities depend upon farmers giving up their time / resources).
UK (Atlantic Central)	There is a danger in treating the knowledge exchange as unidirectional (i.e. from researchers / government to farmers), when many farmers are very well informed and highly invested in the health of their soils. Co-development of programmes with farmers, asking about their needs / opinions / barriers to uptake & actually incorporating them into activity design is critical. Appropriate incentives for participation may also help (many KE activities depend upon farmers giving up their time / resources).

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Appendix I: Gaps in availability of soil knowledge

The appendix contains replies to the question: ”What are the most important gaps in availability of knowledge on sustainable soil management in this environmental zone according to stakeholders? (max 500 words)”

	Central Europe
AT (Alpine South)	Again, transfer of knowledge is the main problem. There is a lot of research available but transfer to the public, farmers, politicians and special planners is missing.
AT (Continental)	As explained in the question above, the communication between the ministry (and policy makers on federal state level) and universities is missing. Moreover, there is already a lot of knowledge available. The goal should be to use this knowledge and put it into practice. As Austria has proposed for the mission “Soil Health and Food” in Horizon Europe, not the generation of new knowledge is necessary but the transfer of available knowledge into practice.
CZ (Alpine South)	Stakeholders comments: Comment 1: Improve education about SSM at high schools and universities. Put more emphasis of SSM propagation for farmers (seminars, fairs). Comment 2: Production of information materials for both farming community and public. Comment 3: Increase financial resources for research. Comment 4: Raising long-term awareness among farmers and public about SSM and its impact. Comments 5: Found local centers for SSM propagation.
CZ (Continental)	Stakeholders comments: Comment 1: Improve education about SSM at high schools and universities. Put more emphasis of SSM propagation for farmers (seminars, fairs). Comment 2: Production of information materials for both farming community and public. Comment 3: Increase financial resources for research. Comment 4: Raising long-term awareness among farmers and public about SSM and its impact. Comments 5: Found local centers for SSM propagation.
DE (Atlantic North)	To improve knowledge on sustainable soil management, stakeholders were asked to give their ideas in a free-text field. Out of 29 replies on this topic, “support multi and trans-disciplinary research” (11 times) was the most important; followed by “increase training for farmers, advisors and other actors involved in soil subject” and “increase number of soil science students and improve curricula” (both 9 times), and “switch from top down to bottom-up research” (7 times).
HU (Pannonian-Pontic)	The soil itself, so soil science is a very complex system, a science. This complexity must therefore be taken into account in soil and soil-related research. Despite the fact that there are few calls for proposals dealing with the purely soil research topic, research related to soil science should also be increased. The more people have well-established knowledge of soil science, the more supportive the practical solutions and aspects to be taken into account would be in favor of soil knowledge. The impartiality of science becomes questionable. Partly lacking dissemination, partly lacking interest.
PL (Continental)	Some stakeholders raised that advisory is not sufficiently effective in reaching the farmer. Also the effective channels for sharing knowledge/needs between science and advisory shall be developed/improved. There is existing network of state advisory system so this structure shall be better supported financially and more effectively used. The major gap is still development and availability of IT advisory tools. Many farmers raise that they lack demonstration proving effectiveness of soil management and calculation/explanation of economic and environmental benefits.

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	Leading farmers shall ne somehow incorporated into the knowledge dissemination and advisory structures. They shall play s role of demonstration centres.
SK (Continental)	One of the most important shortcomings in the availability of knowledge is the low level of attention paid to awareness-raising and advisory activities - there is a lack of promotion and awareness of agriculture. Likewise, many scientific papers are published in professional domestic and foreign journals, which are sometimes difficult to access. There is a lack of connection with practice and research is done only at the local level without connection to larger units. The popularization of science is currently not focused on soil protection and sustainable soil management. Currently, the economic problems resulting from the current economic crisis prevail. For a change in society to acquire and interest in land in terms of its sustainability, it is necessary to prepare for long-term communication activity at various professional levels. In order to make information more accessible, it is also necessary to go to EU projects, which are aimed at disseminating scientific knowledge and subsequently popularizing it with the general public. In agricultural operations, managers are primarily market-oriented so that they can meet the financial needs of employees, sustainable land management is second only to them. Governance - politicians in office do not have enough knowledge but not enough tools to ensure sustainable management
SI (Alpine South)	According to stakeholders the most important gaps in availability of knowledge are that we have a lack of practical workshops for farmers, a lack of popular articles on the subject and a lack of knowledge transfer into practice. Social networks are important, where a lot of knowledge could be shared, the importance of soil could be promoted and different groups of people could be linked.
CH (Continental)	"A great deal of knowledge is already available - the challenge is its communication and acceptance among farmers! We need a paradigm shift in soil management. This rethinking must start at the basis; it needs to be bottom up. This is why basic training for farmers is extremely important. However, first, the trainers' awareness for sustainable soil management must be increased." This statement of a Swiss No-Till member summarizes the findings of our survey. Effective approaches and methods for dissemination SSM knowledge and practices need to be developed and established. A transdisciplinary approach to identify and address possible conflicts of goals and trade-offs related to SSM (environmental, economic, social, traditional etc.) needs to be considered. This approach should be able to account for farm level constraints to SSM adaptation, such as affordability, available labor, timing and prioritization. Furthermore, the complexity of SSM practices and systems needs to be addressed. If the application of SSM knowledge is difficult to manage from an organizational point of view, the implementation will remain limited. Therefore, the participatory development of new solutions and decision support tools is important.
	Northern Europe
DK (Atlantic North)	Particular three themes emerge as important gaps to be addressed in this environmental zone. First of all, the need to reduce carbon loss is emphasized as an important theme because all stakeholders expect that in the future farmers will have to reduce their CO2 loss. However, at the moment, there is uncertainty regarding which measures that may in practice be adopted to mitigate CO2 loss. Currently, the public debate is about how to exempt farming on the organic rich meadows that settle due to drainage and therefore function as a source of CO2. By changing management practices these areas may potentially become sinks rather than sources, but this transition requires some basic knowledge on how this transition can be organized to become successful. Furthermore, in Denmark cover crops and catch crops are measures that are highly used in relation to nutrient management, but these may also provide an additional benefit to sequester carbon, however, knowledge regarding this is still needed by the stakeholders. Secondly, in a longer term perspective a number of stakeholders emphasize the need to

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	organize phosphorous recirculation from wastewater in an appropriate way, because current reserves are running out and the remaining are of a poor quality that are unsuitable to improve soil quality. Finally, some stakeholders argue that in Denmark, there has been an overemphasis on nutrient management (particularly N) as opposed to other soil management issues. Therefore, it is argued that the extensive focus on nutrient management have implied that other soil related issues have not been prioritized in knowledge production and political interventions.
FI (Boreal)	Please check summaries of the interviews on page 2/3 section T2.2.2; subsection 3.
LV (Nemoral)	Most of the stakeholders pointing out the lack of farmer initiative to learn new farming practices and gather knowledge of better soil organic matter management or limiting greenhouse gas emission practices.
LT (Nemoral)	Deeper knowledge on different types and textured soils management to increase soil sustainability and economic profitability.
NO (Boreal)	According to one stakeholder, farmers might apply too little lime to the soil to develop microbial activity. This has been extensively researched internationally. They operate with different amounts of lime and pH values than in Norway. A national program for soil health, namely, “Nasjonalt program for jordhelse”, was recently published emphasizing issues related to soil health. Current agricultural policy causes a surplus of nutrients in areas with grassland/dairy production systems, while the availability of manure in areas with cereal production is lacking. Thus, a circular system should be set in place. Some knowledge exists on this topic. However, are not utilized.
SE (Nemoral)	No easy access to information published by SLU or other universities. Research has to be presented more applied and in popular science terms.
	Southern Europe
IT (Mediterrenean North)	The main problems reported are the fragmentation of knowledge and the lack of knowledge sharing, thus there is not a common view. Anyway, different territories should be actively involved in the knowledge production process. In some cases data are missing, while in other cases only their availability and the expertise for interpreting them is missing. There is a lack of demonstration farms, and dissemination activities are too few. Researchers often use their results for scientific publications, which are not disseminated and arrive too late to farmers. A pedological national database, collecting all certified and georeferred soil data is missing, as well as a decision support system providing policy makers, stakeholders and end users with access to information derived from such data. Soil ecosystem services should be economically valorized. Knowledge on the following topics is reported as lacking by several respondents: i) avoiding soil erosion and soil contamination; ii) a correct SOM management; iii) the positive impacts of sustainable soil management; iv) the interaction erosion-crop; v) knowledge about soil mineral matrix; vi) the interaction soil-machinery; vii) the importance of intercropping. Carbon sequestration and fertility recovery are aspects to be still developed in Italy, boosting the attention on the residues recycling (including zootechnical effluents and biogas digestate), as well as on the struggle against climate change and soil degradation.
IT (Mediterranean Mountains)	The main problems reported are the fragmentation of knowledge and the lack of knowledge sharing, thus there is not a common view. In some cases data are missing, while in other cases only their availability and the expertise for interpreting them is missing. There is a lack of demonstration farms, and dissemination activities are too few. Researchers often use their results for scientific publications, which are not disseminated and arrive too late to farmers. Soil ecosystem services should be economically valorized. Knowledge on the following topics is reported as lacking by several respondents: i) avoiding soil erosion and soil contamination; ii) a correct SOM management; iii) the positive impacts of sustainable soil management; iv) the interaction erosion-crop; v) knowledge about soil mineral matrix; vi) the interaction soil-machinery; vii) the

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	importance of intercropping. Carbon sequestration and fertility recovery are aspects to be still developed in Italy, boosting the attention on the residues recycling (including zootechnical effluents and biogas digestate), as well as on the struggle against climate change and soil degradation.
PT (Lusitenean)	Lack of simple information and quick consultation. The involvement of farmers' organizations must occur from the beginning of the projects and not only in the knowledge dissemination phase. The lack of demonstration of practices that promote sustainable soil management. There is still a lot of ignorance in this matter. Strategies and techniques to improve soil fertility, reduce land degradation; Biodiversity - how to manage and measure its effects; precision fertilization. Integration that can transmit coherent information to different stakeholders.
PT (Mediterrenean South)	The involvement of farmers' organizations must occur from the beginning of the projects and not only in the knowledge dissemination phase. The lack of experimental systems. The lack of updated cartography and associated soil properties databases. They are the same ones mentioned for the research gap, namely the sustainability of some production systems face to current climate change scenarios that can lead to an increase in the following threats to the soil: erosion, loss of organic matter, loss of biodiversity (soil and general); salinization; eutrophication of surface waters. There is also a lack of long-term studies on the evolution of pedogenetic processes associated with more intensive systems and in some soils. Improve the coordination of knowledge production/transfer between researchers and stakeholders. The lack of demonstration practices that promote sustainable soil management. There is still a lot of ignorance in this matter. Need for more research; lack of resources to carry it out. Strategies and techniques to improve soil fertility, reduce land degradation; biodiversity - how to manage and measure its effects; precision fertilization. Constitute regional pilot demonstration areas. The absence of a rural extension service or alternatively an accessible information repository. Very poor disclosure to stakeholders of the results achieved by research that can promote greater and better sustainable soil management. There is a huge silence between entities, universities, stakeholders, each one goes by itself without an agglutinating strategy (the operational groups are improving the situation!). Timely information and concrete proposals for improvement. Soil biodiversity, soil erosion, slope soil systematization in order to minimize slope movements, embankments stabilization, alternatives to herbicides for slope management.
TU (Anatolian)	Problems in transferring existing knowledge to local users (lack of interest of farmers, lack of "agricultural communication expertise" departments in universities and insufficient trained human resources) Information users are not sufficiently aware of the available information. Those who have knowledge about sustainable soil management must have enough awareness about importance of topic, Studies on raising awareness should be increased in different way
	Western Europe
BE (F) (Atlantic Central)	Farmers need tailor-made advice, providing an answer to the key question: which sustainable management practices are most (cost) effective and are most suitable for a specific farm type and what are the benefits and preconditions? To answer this, a systemic vision including all farming aspects is needed. Specific questions listed are: Need for knowledge on soil biodiversity, e. g. what is the impact of crop rotation on soil

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	biodiversity (and the extensive effects this has on e.g water availability, plant health). - What is the effect of green manure and water availability for the next crop? - What is the effect of no-till and weed management? - How to enhance soil organic matter (in sandy soil)?
BE (W) (Atlantic Central)	Soil biology Contaminant dynamics Some of the data used are several decades old Some regions are under-sampled Either everything is known and poorly communicated, or there is still a lot of work to be done through research and we need to catch up with other member states that are well advanced. The long-term competitiveness of agriculture in Wallonia is at stake. To our knowledge, there are no scientific studies of the impact of biomethanisation digestates on soil microbial life. In fact, the spreading of digestate brings anaerobic microbial flora to the soil, whereas its surface is essentially composed of aerobic micro-organisms; it seems relevant to question the harmlessness of these practices on soil life. structure dynamics, storage (and release of C) They are too big and too complex. Again, the puzzle must be cut into very small pieces. Innovative research in agro-ecology or bio. The research is very conventional. We do not know enough about the long-term global effects of the practices recommended today. An example in animal husbandry methods: for the animal welfare of pigs, biomaitrized bedding was once proposed as the solution (less NH3 emissions, less lung disease in pigs, less odours, ... everything seemed perfect until the day when the production of greenhouse gases was measured (it is more difficult, more expensive) and then disaster struck ... Since then, we don't talk about this type of farming anymore. It could be the same with some techniques promoted today as wonderful for the soil. Studies may be less numerous but more complete and of longer duration. Research in organic conservation agriculture is lagging far behind in Belgium compared to what is being done in other countries. Knowledge in organic soil management, with simplified techniques that disturb soil life as little as possible, should be documented abroad and disseminated in Wallonia. There is no need to reinvent the gunpowder, we might as well draw inspiration from already innovative research in our neighbours (Switzerland, France, ...). basic knowledge of innovative techniques. It would be necessary to make an inventory of the available knowledge and to gather it in the same database .
FR (Atlantic Central)	The most important gaps in availability of knowledge on sustainable soil management in Atlantic Central in France are: - Impact of different sustainable soil management practices on the biological quality of soils - Dynamics of bio-aggressors (ecotoxicity, plant diseases) according to the sustainable soil management practices implemented - Systematic campaigns for data acquisition to develop statistical modelling approaches to complement the use of deterministic models - Long-term observation and experimentation devices: support for the devices and proactive intervention for creation, monitoring and exploitation - Construction of (typological) databases on sustainable soil management practices and on the nature of soil-related inputs
FR (Lusitenean)	The most important gaps in availability of knowledge on sustainable soil management in Lusitenean are: - Impact of different sustainable soil management practices on the biological quality of soils - Dynamics of bio-aggressors (ecotoxicity, plant diseases) according to the sustainable soil management practices implemented - Systematic campaigns for data acquisition to develop statistical modelling approaches to complement the use of deterministic models - Long-term observation and experimentation devices: support for the devices and

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	proactive intervention for creation, monitoring and exploitation - Construction of (typological) databases on sustainable soil management practices and on the nature of soil-related inputs
IE (Atlantic Central)	Management practices that enhance carbon sequestration, particularly to enhance the more stable carbon pools at depth. Alternative options to manage organic rich soils that are under productive agriculture. Role of soil structure on reducing nutrients losses to the air or water. Quantify how much nutrient are been lost It is the same as the research gaps i.e. In the crops area, farming systems which retain soil structure and the productive function of soils through allowing efficient use of and retention of nutrients and water are critical. This comprises many elements: 1. the retention or augmentation of soil C through crop rotations, cover crops, organic manure amendments, and tillage system. 2. The prevention of structure damage through reduced axle loads, reduced ground pressure, better machine turning systems on headlands, controlled traffic, better timing of operations, reduced cultivations, more targeted cultivation actions etc. But for knowledge transfer, this information must be packaged and integrated with other aspects of production advice. Knowledge on soil C sequestration rates for different soils and management options. This is needed for soil C inventories and for farmers to get credit for storing more carbon. Knowledge on the soil biodiversity and how management practices change soil biodiversity including the impacts on agronomy, environment and economics. Under the Green Deal we need research ton how to sustain agricultural production levels with less fertilizer and pesticides and to improve nutrient use efficiency Network of trained Experts to deliver knowledge specific to soil type and its relevance to the environmental zones. Demonstration/explanation of science into practical application
NL (Atlantic Central)	Information about sustainable soil management does not reach farmers automatically, and gathering information takes a lot of effort since the information is highly dispersed. For an overview of the bottlenecks, see question 16.
NL (Atlantic North)	Note: in the questionnaire and the interviews no distinction was made between climatic zones, as the distinction was not relevant in the Netherlands. Therefore, answers given for Atlantic North also apply to Atlantic Central.
UK (Atlantic North)	Increased funding for research on sustainable soil management is the pre-requisite. Often there is little funding for basic research that can then be brought through to stakeholders and farmers.
UK (Atlantic Central)	Increased funding for research on sustainable soil management is the pre-requisite. Often there is little funding for basic research that can then be brought through to stakeholders and farmers.

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Appendix J: Promoting use of knowledge on sustainable soil management

Replies to the question: ”How can the use of knowledge on sustainable soil management by farmers be promoted in this environmental zone according to the stakeholders? (max 500 words)”

	Central Europe
AT (Alpine South)	It is important to promote information exchange between stakeholders, especially farmers. Moreover, past experiences in consulting showed that forcing farmers to visit workshops, field days or courses as obligatory requirements to, for example receive grants, is not beneficial, as their interest is mostly very low. It is suggested to host open events and charge adequate fees to attract interested farmers. In the alpine region there are, besides events by the agricultural chambers and farming schools, no associations engaging in educating and connecting farmers. BIO Austria, a network for organic farming, is offering a soil practitioner certification course, which is successfully training farmers in sustainable soil management and improving communication skills. In Styria (Alpine South environmental zone) a new centre, the “Humus Soil Centre”, was founded. Here are Experts and farmers working together to improve soil resilience towards climate change and sequester carbon as soil organic matter.
AT (Continental)	In (the continental zone of) Austria there are already many initiatives that promote farmer’s knowledge and new practices on sustainable soil management. The association „Bodenleben“ (English: soil life; https://www.bodenistleben.at/verein/) is a good example of a successful bottom-up approach, transporting knowledge from farmers to farmers and others, like universities. This association is working on innovative practices (f.e. SOC saturation through different management approaches or monitoring of land with satellite data) on a national scale. Moreover, the Upper Austrian “Boden.Wasser.Schutz.Beratung” (https://www.bwsb.at/) department is educating and training farmers in sustainable soil management practices. There are regular working group meetings hosted, to connect those trained farmers and keep them up to date. Moreover, those meetings aim to bring trained and untrained farmers together. The association is also hosting field days with over 500 participants. On a federal state level, the Chambers of Agriculture are hosting working groups for practitioners.
CZ (Alpine South)	Stakeholders comments: Comment 1: By organization of seminars and popularization of the SSM among farmers. Comment 2: Increase motivation of farmers by law and subsidies settings. Comment 3: By project and grants. Comment 4: Popularisation of results of SSM pratices. Comment 5: By increase of financial support (subsidies, research projects)
CZ (Continental)	Stakeholders comments: Comment 1: By organization of seminars and popularization of the SSM among farmers. Comment 2: Increase motivation of farmers by law and subsidies settings. Comment 3: By project and grants. Comment 4: Popularisation of results of SSM pratices. Comment 5: By increase of financial support (subsidies, research projects)
DE (Atlantic North)	see above
HU (Pannonian-Pontic)	Soil knowledge needs to be expanded among farmers. A farmer who has been working with a certain technology for many years will not necessarily switch technology, especially if that method is not financially advantageous either.
PL (Continental)	This question was most difficult. Only there were suggestions that in order to facilitate production of the needed knowledge on soil management, there is a need for coordination of strategies research programs between ministries and centres coordinating research

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	programs and calls. There is also a need to link farmer organisations with research institutions. Research call on innovation sin agriculture would be very helpful sine they would connect industry, SMEs with research institutions. Some funds in CAP devoted innovative advisory systems would be also effective and would promote delivery of new knowledge to practice.
SK (Continental)	The use of knowledge on sustainable management by farmers can be supported through lifelong learning and applications for support / direct payment should be conditional on this basic training. In practice, farmers could apply this knowledge to the land they farm. Farmers may make available their land which they own or use for scientific purposes. Based on these findings on sustainable management, they can apply the proposed changes. Farmers can organize professional, cultural and traditional activities linked to either the region or the agricultural seasons. The compilation of a calendar of events will create an opportunity to prepare for the presentation of professional events focused on PR soil care and also the presentation of knowledge about sustainable land management. The use of knowledge can also be promoted by creating a system of support (subsidies) that will favor farmers using agricultural practices that are based on knowledge of sustainable land management.
SI (Alpine South)	According to stakeholders the use of knowledge on sustainable soil management could be promoted through education and workshops for farmers. There are opportunities in online events, with individual counseling, with TV contributions, demonstration videos, with incentives and with short online lectures by pedagogical lecturers and researchers. However, practical field demonstrations are also very important.
CH (Continental)	Operational groups to use Farmer-to-Farmer dissemination of SSM knowledge should be promoted to increase their reach. Operational groups are said to be successful due to the social learning processes, the collective encouragement as well as the common achievement of objectives. Such operational groups could use organizational, methodological and informational support by a secretariat and experts. Such a scheme would need adequate and stable funding. Transparent information on SSM practices needs to be accessible and useful to farmers. This information should show benefits but also costs and disadvantages. Furthermore, it should increase the visibility of best practice examples. An integrated, site-adapted perspective on SSM that accounts for complexity and trade-offs needs to be developed. Such a perspective needs to include site characteristics, plant protection, nutrient management, soil biodiversity, soil biological activity, soil health, nutrient and water retention, etc. A major barrier to SSM application was mentioned by P. Weisskopf, a research group leader at Agroscope: “If the application of SSM knowledge on the farms is not economically viable, this knowledge is not implemented and effective, therefore: economic incentives are important and organizationally clever options for action are helpful.” Some ideas to increase the incentives for SSM were mentioned by stakeholders. These ideas are summarized below. SSM should be addressed more strongly in agricultural policy and its instruments. For example SSM and soil quality maintenance could be included in the PEP and targeted direct payments (e.g. REB, RP) can be further improved to facilitate SSM dissemination. Furthermore, direct payments could be linked to continued SSM training. Many ideas about site-adapted or more flexible direct payments were voiced. Direct payments could be linked to soil and site properties (site-adapted management). More flexible contribution systems, without overly specific requirements, were said to enable the farmers to make better use of their knowledge and expertise. Furthermore, not specific practices should receive subsidies, but the long-term achievement of soil quality objectives should be rewarded. Stakeholders also mentioned that such soil quality objectives need to be realistic, i.e. site-adapted. However, a stakeholder concerned with agricultural policy execution at the cantonal level

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	advised that (new) regulations must be efficient and effective to enforce and control. Another stakeholder added that control-based systems tend to become too complex to handle. Existing or new labels could put more emphasis on SSM and thus create economic incentives for farmers to adopt SSM practices. Concluding the survey, a stakeholder mentioned that current efforts need to be continued, as "constant dripping wears away the stone".
	Northern Europe
DK (Atlantic North)	Denmark has an extended network of peer-to-peer groups and farmer field schools, in which farmers share experiences with each other in relation to particular topics. These are a popular way for farmers to share knowledge and skills among each other and furthermore, by sharing and obtaining knowledge from peers it is easier for farmers to put new knowledge into practice and other farmers have a higher status and legitimacy in the farming community. Researchers and advisors can join and promote new knowledge, but it is important that this is coordinated with the farmers to that there is an emphasis on the practical aspects of adoption. Therefore in promoting sustainable soil management it is important to make use of the peer-to-peer groups, as these are important for farmers.
FI (Boreal)	Please check summaries of the interviews on page 2/3 section T2.2.2; subsection 3.
LV (Nemoral)	Stakeholders agreed that there is need for some practice experience exchange between these demonstration farms and other peers. Especially pointing out the value of practices and how can it help in soil management also not reducing farms output.
LT (Nemoral)	Field days, seminars, educational-practical events and mass media information are the right way to improve soil management knowledge.
NO (Boreal)	According to stakeholders, the use of knowledge on sustainable soil management by farmers can be promoted by showcasing the beneficial effects of sustainable soil management. Moreover, to arrange demonstration trials, arrange meetings, collaborate (researchers, farmers, advisors, policymakers, etc.). The Norwegian agricultural extension service arranged a competition to engage with farmers. The competition had a positive impact on cover crop implementation among farmers...
SE (Nemoral)	Interested farmers can get information via facebook groups or other media. However, more direct information and involvement in research that is conducted at the universities (especially SLU) should be provided, for example in the form of a farmers magazine.
	Southern Europe
IT (Mediterranean North)	Actions at all levels (also administrative ones), involving farmers' organizations and production districts are necessary, together with specific education of farmers performed by dedicated technicians. More field experiments and observations should be carried out, showing and quantifying the economic benefits of sustainable soil management. A greater involvement of farmers in the dissemination system, together with technicians and territorial organizations operating together with farmers, should be realized. Farmers should be more involved also in research projects. A stable collaboration among researchers, farmers' organizations and advisory services is necessary both for choosing the research topics and for the dissemination of results. Examples are the best dissemination activity, e.g. with demonstration farms. Raising awareness should be performed through leading farms, showing and quantifying economic benefits, also increasing public subsidies. Digital platforms should be more used, also through farmers' organizations activities. Information should be managed in web portals, making both basic and practical information available. Also a decision support system could provide useful information. Courses involving all stakeholders focused on each specific territory should be organized, also rewarding the participation. Someone suggests to use information materials and more dedicated technical support. Public subsidies should be increased.
IT (Mediterranean Mountains)	Actions at all levels (also administrative ones), involving farmers' organizations and production districts are necessary, together with specific education of farmers performed by dedicated technicians. More field experiments and observations should be carried out. A

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	greater involvement of farmers in the dissemination system, together with technicians and territorial organizations operating together with farmers, should be realized. Farmers should be more involved also in research projects. A stable collaboration among researchers, farmers' organizations and advisory services is necessary both for choosing the research topics and for dissemination of results. Examples are the best dissemination activity, e.g. with demonstration farms. Raising awareness should be obtained through leading farms, showing and quantifying economic benefits, also increasing public subsidies. Information should be managed in web portals, making both basic and practical information available. Someone suggests to use information materials and more dedicated technical support. Promotion of labels for products reporting soil sustainable management practices was proposed by one of the respondents.
PT (Lusitenean)	Improving simple and targeted information through the media. Implementation of technical itineraries and information dissemination actions. Implement thematic network projects that involve farmers and their organizations. Through field experimentation and respective demonstration actions. Work in partnership bringing together the various stakeholders (definition of needs on the part of the production and meet demand and supply of knowledge). Through training and demonstration. Realizing farmers' needs and basic knowledge in order to provide information in an objective and efficient way. Through advisory services/offices; training actions; dissemination of research results.
PT (Mediterrenean South)	Implement thematic network projects that involve farmers and their organizations. Creation of demonstration systems and creation of dissemination tools. Through the display of demonstration fields, technology transfer and competence centers. To promote more testing and experimentation actions as applied and concrete as possible. That is, for production systems in use in each region, involve farmers and some companies and service providers for these production systems. Keep these demonstration experiments for several years, in order to be able to repeat every year the dissemination and demonstration actions capable of reaching the largest possible number of farmers and being able to clarify their doubts and be able to face the climatic variability that inevitably occurs year to year. To be able to have support and support teams for farmers who adhere to new practices until they feel they have mastered the techniques and can make appropriate decisions for the conditions with which they may have to confront. Promotion of training/awareness actions. Through Regional pilot demonstration explorations. Through field experimentation and demonstration actions: workshops, short courses, more extension by the competent entities. Work in partnership bringing together the various stakeholders (definition of needs on the part of production and meeting demand and supply of knowledge); training and demonstration. At events such as field days and farmers' meetings; through webinars, extension forms/brochures and newsletters, information available on websites, news published on social networks and in specialty magazines. Promoting the results of the knowledge in training actions and educational institutions. Promotion of more effective ways of disseminating knowledge, both by public entities (ex. Ministry of Agriculture) and private ones (producer organizations, companies of production factors, equipment, services, consultancy, investment projects and other). Training promoters in the associative world, recommend universities and professors to help with the extension and official services to speak with associations. Awareness actions, demonstration fields, technical and economic evidence. Through local producer organizations, a contribution from the beginning in the preparation of the content to be transmitted up to the form and model of transmission. Through working together with the technical associations that represent farmers.

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TU (Anatolian)	The interest and participation of farmers and land users in regulations and activities related to SSM should be increased. Sustainable agricultural communication should be provided in the triangle of University-Public-Farmer / land user. Depending on the global and local socio-economic changes, it must be worked on increasing the effectiveness of the Agricultural Extension System Explanation of the study results should be made through direct information meeting and social media and a sample studies. SSM Implementations should be increased through more incentives and support. Increasing or expanding the number and scopes of projects such as "Agricultural Academy" for farmers to include issues such as SSM and sustainable agricultural water management Soil ethics (that the land is not only property, it should be protected that it is alive) the concept should be more considered by all stakeholders.
	Western Europe
BE (F) (Atlantic Central)	Several ideas are listed to promote the use of knowledge, most stress the need for more communication and participation between the different stakeholders. Specific ideas listed to improve the use of knowledge on sustainable soil management are: - Individual farm advice by advisors that are well connected to research and have the latest research insights. - A closer collaboration with all actors in the value chain. - A stimulating consistent policy - A two-way communication and cross-sharing between farmers and policy makers - Knowledge is one aspect, but also an integral approach (as provided by the green deal) is needed for effective knowledge application . - Maybe a “soil license” (after the phyto-license) could be introduced?
BE (W) (Atlantic Central)	Setting up networks, avoiding the multiplication of communication channels. cfr previous answers linking sustainable management and the farmer's portfolio Create a single platform (a single website centralising all soil information (maps, analytical data, management advice, legislation, etc.) Dissemination of knowledge through all possible communication channels: Media, dedicated YouTube channel, agricultural advisor, pilot centre, compulsory or voluntary training (a bit like phytolicence) Use all actors directly linked to farmers (e.g. analysis labs, FWA, articles in the agricultural press, etc.). Farm advisory services, the most effective method of reaching farmers and initiating changes in practices, is still the most effective way to reach farmers hear their questions and the proven technical barriers to the theoretical solutions identified by the research This is THE good question. Attract curiosity? Highlighting the economic gains that can be made by taking care of the soil? Make farmers proud of good soil rather than good yields? Highlight the working comfort, the reduction of stress that can be obtained when one's system becomes resilient (to drought for example)? Here I'm pushing a little ... By going to meet farmers and independent advisors. By organising days of visits to the trials that took part in the research. By popularising and discussing (at a conference, for example) the research with farmers. As already mentioned, through the pilot centres and other support structures Going to farms, giving demonstrations. Farmers are already very busy and don't necessarily have time to look at scientific reports. Popularised information (but technical enough for farmers to understand and be able to implement it properly) would be welcome. Demonstrations would allow them to see the positive effects on their soils (but also their economic profitability). A more important legal framework for the preservation of agricultural soils with clear objectives, validated and coherent measures and specific aids would be needed.

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FR (Atlantic Central)	To promote the use of knowledge on sustainable soil management by farmers, soil knowledge must be understandable and adapted to the target audience. This requires the production of adequate communications and tools for farmers. The promotion of knowledge can be done directly through journals read by farmers. Another way to promote the use of knowledge would be to work with associations in charge of the production and dissemination of knowledge. Farm advisers should also play a role in the transmission of knowledge.
FR (Lusitenean)	To promote the use of knowledge on sustainable soil management by farmers, soil knowledge must be understandable and adapted to the target audience. This requires the production of adequate communications and tools for farmers. The promotion of knowledge can be done directly through journals read by farmers. Another way to promote the use of knowledge would be to work with associations in charge of the production and dissemination of knowledge. Farm advisers should also play a role in the transmission of knowledge.
IE (Atlantic Central)	The key to promotion to farmers is to show that it will impact on the long term productive capacity of the soil and ideally to tabulate what the economic vale of that will be. Farmers are very much driven by two things: the need to be profitable to be sustainable and the desire to leave the farm and land in a better productive state than they got it! By dealing with soil management in these terms, farmers will adopt appropriate practices. But there is a need to have an integrated approach where it is dealt with as an embedded part of their farming system, but supported by expert knowledge and research. Through better advice and knowledge transfer from advisory services /extension services. Improved education on the soil challenges and demonstration of the benefits (agronomy, environmental and cost benefit). Decision support tools to help farmers identify the problem/issues on their soils and to select the appropriate management practices Use of farmer knowledge on soils local to them to better mange soil resources Their knowledge should be part of the feedback for use in further research, design of dissemination and communication plans to other stakeholders and peers. Through farm walks, peer to peer demonstration and webinars
NL (Atlantic Central)	Farmer interest groups, on farm demonstrations, journals and websites are the most used platforms to disseminate knowledge about soil management. The dissemination of general information about soil management via these platforms is considered to be sufficient. In contrast, the availability of region-, soil-, farm-, or even field specific information is lacking, making it difficult for farmers to judge the usefulness of the information and to make adequate management decisions. The most used platforms are inadequate to disseminate this type of knowledge. Advisory services is often mentioned as an opportunity. However, customized advise requires a high level of expertise. Therefore, training advisors specifically on soil processes and soil management options is often mentioned as an useful addition to current platforms. However, it needs to be mentioned that the availability of knowledge is not seen as the only barrier in the transition to sustainable soil management. According to the stakeholders, a lack of (financial) stimulation and contradictive policies are considered as important.
NL (Atlantic North)	Note: in the questionnaire and the interviews no distinction was made between climatic zones, as the distinction was not relevant in the Netherlands. Therefore, answers given for Atlantic North also apply to Atlantic Central.
UK (Atlantic North)	Further training at school/college/advisory level. Further KE at science-advisory level. Buy-in from advisory level.
UK (Atlantic Central)	Further training at school/college/advisory level. Further KE at science-advisory level. Buy-in from advisory level.

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Appendix K: Disagreements between stakeholder groups

The appendix contains replies to the question: ”Did you notice any disagreements in the issues raised by different stakeholder groups? (max 500 words)”

	Central Europe
AT (Alpine South)	See general disagreements below
AT (Continental)	Stakeholders did disagree on the topic of farmer’s motivation regarding soil health. The advisor argued that the majority of practitioners are not motivated in learning about soil health and improving agricultural measures. The national policy stakeholder had a different view, saying that the farmer’s knowledge as well as their drive to keep their soils healthy is underestimated. Other disagreements were found in the questions regarding the challenges to sustainable soil management. In the continental zone, contamination was evaluated as important and less important by stakeholders. Research needs in enhancing soil biodiversity and water storage capacity was perceived as very important and neural. Regarding research needs, stakeholders had different opinions on the importance of soil erosion in the continental zone, which was viewed as a very important and less important research need. Moreover, generating new knowledge on water storage capacity and soil biodiversity were seen as neutral and very important by stakeholders.
CZ (Alpine South)	Stakeholders comments: Comment 1: Yes, there is many disagreements between farmers/policy makers/research. Often a political/economical reasons is a barrier why the SSM practices are not applied. Comment 2: Yes. The policy makers are focused on the methods of possible control rather that to effects of the SSM practices. Comment 3: Absolutely yes. There is often low interest from the farmers to apply new methods. Many farmers are sceptic about the results from research. Comment 4: No.
CZ (Continental)	Stakeholders comments: Comment 1: Yes, there is many disagreements between farmers/policy makers/research. Often a political/economical reasons is a barrier why the SSM practices are not applied. Comment 2: Yes. The policy makers are focused on the methods of possible control rather that to effects of the SSM practices. Comment 3: Absolutely yes. There is often low interest from the farmers to apply new methods. Many farmers are sceptic about the results from research. Comment 4: No.
DE (Atlantic North)	no
HU (Pannonian-Pontic)	In Hungary, the level of social communication related to soil is basically low, despite the fact that one of our greatest natural resources is a significant part of our national wealth. There has also been an increase in the demand for soil knowledge among those working in agriculture in the last decade, recognizing that the basis of crop production and animal husbandry is good quality soil. The social awareness of the soil should be developed from a very early age, but it should definitely play a more prominent role in primary schools. There is a major gap between researchers and farmers, which generally prevents the co-design based on the mutual knowledge and the adaptation of the proposed measures to local conditions. Other identified factors are the lack of appropriate communication of scientific results, cultural barriers, and inadequate regulations or incentive policies.
PL (Continental)	Not too much disagreement between different stakeholder groups. More or less all groups raised the need for better integration of their activities to improve the effectiveness of sharing knowledge.

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SK (Continental)	We did not notice any discrepancies
SI (Alpine South)	Disagreements or dissenting opinions among different stakeholder groups were not found. All survey participants are committed to better use and dissemination of knowledge among people. They agree, that knowledge sharing is important, especially between researchers, advisors, farmers and policy makers. Establishment of permanent national network among them is needed.
CH (Continental)	Yes, there were major and minor disagreements. The major ones, according to our judgment, are described below. In general, teachers and advisors evaluated the capacity of the knowledge system to promote SSM knowledge to be higher than progressive farmers and researchers did. Some, rather visionary, stakeholders urged the need for more flexible regulations while others, more concerned with policy enforcement, stated that regulations need to be simple and effectively controllable. Many stakeholders argued for more cooperative and transdisciplinary research and policy development, while others, concerned with soil protection enforcement, stated that political influence can 'dilute' the effectiveness of policies.
	Northern Europe
DK (Atlantic North)	Although, generally there is quite a good communication between the different stakeholder groups in relation to the design of policy interventions and that these are often debated among all stakeholder groups before they are agreed politically, there are also divergent views across the different stakeholder groups when it comes to the challenges that need to be addressed and how to address and prioritize these challenges. We have interviewed farmers – which see things from a practical perspective and place a high value on the production potential of their farmland. They regard themselves as being more influenced by decisions in the political system more than the other way around. This is an issue because they feel that they are sometimes exposed to regulation that they do not think is relevant, and that monitoration and sanctions, especially in relation to breaching of EU requirements under the cross compliance regulation is unnecessarily hard. They find that regulations are often passed that constitute a nuisance to their daily life as farmers and often they are unable to see the benefit of the requirements they are exposed to. So generally when talking with farmers about regulation this is perceived as a negative element and their replied reflect this situation. The advisors interviewed see themselves as the binding force between the research and the practitioners, they are very skilled in relation to the perspective of the farmers, but also knowledgeable about the practical realities of regulation. In spite of these controversies all stakeholder groups including the farmers are agreeing on which challenges to soil that are most important, however there are also divergences. This is for instance reflected in diverging views regarding drainage. From a practitioner's perception of issues about draining, which is a very central concern for the farmers because it influences the production potential of farmland. However, other stakeholder groups argue that drainage cause environmental problems such as degradation of organic matter and nutrient leaching and rather than supporting further drainage, they support rewetting to restore the environmental state.
FI (Boreal)	'- compared to most stakeholders a stakeholder from industry mentioned that some players may misuse lacking knowledge about sustainable soil management for their own benefit...
LV (Nemoral)	Communication between different stakeholder groups should be better. Each group are trying to protect their own interests, that was clearly seen during the interviews.
LT (Nemoral)	The farmers (practitioners) are looking at soil as the source of making their business. Modern farmers understand that their life depend on soil fertility, its capability to grow crop and produce good yields. Due to this, their are willing to solve any problem if it will be profitable of farming at the end. Not practitioners also agree that the soil is important for food production, while stronger express concern on environmental and social soil service.

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NO (Boreal)	There was some disagreement on the degree of severity of e.g. soil challenges. For peat degradation, one stakeholder emphasized the importance of research on CO2-emission on peatland, while the other stated that research exists on the area.
SE (Nemoral	Yes, especially when it comes to the accessibility of information did the perceptions of the advisors differentiate
	Southern Europe
IT (Mediterrenean North)	Scholars are obviously reporting that knowledge is lacking, and there is a need for more financial support for knowledge production. Advisors instead think that knowledge is sufficient and sufficiently financed, but not enough available for professionals and farmers, and financial support is insufficient only for dissemination.
IT (Mediterranean Mountains)	Scholars are reporting that knowledge is lacking, while advisors think that knowledge is sufficient but not enough available for professionals and farmers, and financial support is insufficient for dissemination.
PT (Lusitenean)	No we didn't. The interviewed stakeholders from the different groups agreed with each other even in complaining about the extension of the questionnaires. In resume, stakeholders agree that in Portugal there is an urgent need of long term demonstration fields of practices that promote sustainable soil management by region, to reduce soil threats, including desertification, long term monitoring campaigns, organization of existing knowledge in an accessible and easily understandable way, more training and divulgation actions, increasing rural extension services, more connection between researchers and farmers associations, need of updated soil maps and associated databases of soil properties, need of a soil information system updated and validated on soil, due to different cartographic and analytical methodologies, data dispersion, the lack of monitoring programs and harmonized methodologies, as well as national information infrastructures. There is the need of crossing scientific knowledge with regional specificities through the representatives of farmers, and talking together with the "makers" of public policies, translating the knowledge into a language that policy makers and farmers understand and taking a more proactive attitude in preparing information before it is requested by legislators and forcing its presentation when it is not requested. There is a lack of some structure/organization to coordinate the production of scientific knowledge according to needs, and to disseminate and transfer scientific knowledge. Portugal is still very much rooted in traditional soil sciences and needs to expand to other frontier sciences that can greatly contribute to sustainable and precision agriculture. We speak of multidisciplinary subjects, of a multiplicity of situations, in which the effective knowledge of stakeholders on the totality of subjects is reduced. So, there must be strong, practical and objective coordination in the entire process. Also, there is lack of an entity or site that brings together all knowledge. Professional farmers follow the practices encouraged by the Agricultural Policy, as well as those dictated by the market. Medium and smaller farmers, (mostly) with a low level of formation, often do not perceive knowledge and use what the seller provides them. Given the characteristics of our agriculture and farmers, it is necessary to encourage associativism based on knowledge. Although there was an effort of an informal congregation of public and private entities in the Portuguese Partnership for Soil (39 members, among which 16 are entities of research and teaching, 3 centers of competence, 7 associations of production, 3 federations, 3 companies, 3 regionals, and 4 national public entities), there is still little coordination in the use and especially in the production of knowledge. Despite having been established by the Partners of the Partnership, an innovation agenda, and guidelines for the sustainable management of soils, as it is a voluntary partnership, individual interests still often overlap.
PT (Mediterrenean South)	No we didn't. The interviewed stakeholders from the different groups agreed with each other even in complaining about the extension of the questionnaires. In resume, stakeholders agree that in Portugal there is an urgent need of long term demonstration fields of practices that promote sustainable soil management by region, to reduce soil threats, including desertification, long term monitoring campaigns, organization

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	of existing knowledge in an accessible and easily understandable way, more training and divulgation actions, increasing rural extension services, more connection between researchers and farmers associations, need of updated soil maps and associated databases of soil properties, need of a soil information system updated and validated on soil, due to different cartographic and analytical methodologies, data dispersion, the lack of monitoring programs and harmonized methodologies, as well as national information infrastructures. There is the need of crossing scientific knowledge with regional specificities through the representatives of farmers, and talking together with the "makers" of public policies, translating the knowledge into a language that policy makers and farmers understand and taking a more proactive attitude in preparing information before it is requested by legislators and forcing its presentation when it is not requested. There is a lack of some structure/organization to coordinate the production of scientific knowledge according to needs, and to disseminate and transfer the scientific knowledge. Portugal is still very much rooted in traditional soil sciences and needs to expand to other frontier sciences that can greatly contribute to sustainable and precision agriculture. We speak of multidisciplinary subjects, of a multiplicity of situations, in which the effective knowledge of stakeholders on the totality of subjects is reduced. So, there must be strong, practical and objective coordination in the entire process. Also, there is lack of an entity or site that brings together all knowledge. Professional farmers follow the practices encouraged by the Agricultural Policy, as well as those dictated by the market. Medium and smaller farmers, (mostly) with a low level of formation, often do not perceive knowledge and use what the seller provides them. Given the characteristics of our agriculture and farmers, it is necessary to encourage associativism based on knowledge. Although there was an effort of an informal congregation of public and private entities in the Portuguese Partnership for Soil (39 members, among which 16 are entities of research and teaching, 3 centers of competence, 7 associations of production, 3 federations, 3 companies, 3 regionals, and 4 national public entities), there is still little coordination in the use and especially in the production of knowledge. Despite having been established by the Partners of the Partnership, an innovation agenda, and guidelines for the sustainable management of soils, as it is a voluntary partnership, individual interests still often overlap.
TU (Anatolian)	Projects/users using soil data should easily benefit from the information system. Supports should be provided to ensure that the public and local producers benefit from soil data systems sufficiently. There is a need for a new formation that accommodates the requirements and changes of the era (knowledge and information technologies, mass communication-distance education, use of information-data systems, etc.) between university-public-users. For examples, the "Department of Agricultural Communication, Education, and Leadership" can be located in Agricultural Faculties in the country.
	Western Europe
BE (F) (Atlantic Central)	There is relatively little disagreement between the stakeholder groups on the knowledge gaps.
BE (W) (Atlantic Central)	[N.B. based on stakeholders point of view, some stakeholders does not report any differences] Yes disagreement between organic, conventional and CA farmers disagreement between scientists There are not very objective statements on the cultivation systems favourable/unfavourable to the soils of Wallonia. The best example is the no-till agriculture defended by some in complete opposition (and not very rational) to ploughing, even though it has undeniable benefits. And conversely, a denigration of these techniques by the leaders of "traditional" agriculture without recognising the contribution of the diversification of production techniques to the improvement of soil fertility. This is regrettable. yes, particularly in the fight against soil erosion, where "obvious" scientific solutions encounter proven obstacles, particularly with regard to market laws. There should be a

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	policy dialogue to resolve this. (e.g. potato contracts). Everybody agrees to reduce GHG emissions but in reality nobody does. In fact we are all climate sceptics who ignore each other. Yes as explained before between the rationalists and the "fashionable" ones like certain gurus of soil life and non-ploughing", the "Claude Bourguignon and Konrard Schreder". Research must be based on measured and verifiable, reproducible facts and therefore free itself from groups that are sometimes too media-oriented. In the field of agricultural management.
FR (Atlantic Central)	No disagreement was noticed among different stakeholder groups. The same type of ideas/response was raised when answering to an open question or when selecting on scale.
FR (Lusitenean)	No disagreement was noticed among different stakeholder groups. The same type of ideas/response was raised when answering to an open question or when selecting on scale.
IE (Atlantic Central)	The highest scoring result was presented however, this was not unanimous in most cases so opinions varied on these topics.
NL (Atlantic Central)	There is some differentiation between the stakeholder groups in the prioritization of soil challenges. Increasing/maintaining SOC is seen as a more important challenge by governmental organizations and research communities than by farmers' organizations and the agro-industry. Surprisingly, water retention is also seen as a more important soil challenge by governmental organizations and research communities than by farmers' organizations and the agro-industry. Furthermore, there is some disagreement in whether sufficient resources are available for knowledge development and sharing, see the table below. Researchers in consider the resources as insufficient while the industry and farmers' organizations are neutral. Governmental stakeholders claim that the financial resources are sufficient, but an overview of the results is missing. The relevance of developing a shared knowledge agenda is acknowledged, which is also the aim of the National Program on Agricultural Soils. Research/education Policy makers Industry/farmers' organizations Advice Insufficient 91% 56% 100% Sufficient 9% 100% 44%
NL (Atlantic North)	Note: in the questionnaire and the interviews no distinction was made between climatic zones, as the distinction was not relevant in the Netherlands. Therefore, answers given for Atlantic North also apply to Atlantic Central.
UK (Atlantic North)	Surprisingly stakeholders showed significant agreement across most aspects related to access that farmers have to relevant knowledge about sustainable soil management. Stakeholders also agree the key issue remains communication among different players and the lack of support to implement changes in a way that farmers feel protected and at low risk when taking on board and experimenting innovative practices.
UK (Atlantic Central)	Surprisingly stakeholders showed significant agreement across most aspects related to access that farmers have to relevant knowledge about sustainable soil management. Stakeholders also agree the key issue remains communication among different players and the lack of support to implement changes in a way that farmers feel protected and at low risk when taking on board and experimenting innovative practices.

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[i] Data reported here are from a different survey (N=56)

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