Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture (CIRCASA)

Horizon 2020

Call: H2020-SFS-2016-2017 (Sustainable Food Security – Resilient and resource-efficient value chains)

Type of action: CSA (Coordination and support action)

Grant Agreement: 774378-CIRCASA

DELIVERABLE NUMBER: D2.3

DELIVERABLE TYPE: Report

DELIVERABLE TITLE: Synthesis report on knowledge demands and needs of stakeholders

Start date of the project: November 1, 2017

Due date of deliverable: M24

Actual submission date: M30

Organisation name of lead contractor: EI

Dissemination level: PU/~~PP~~/~~RE~~/~~CO~~

AUTHORS:

Frelih-Larsen, A.; Ittner, S.; Herb, I , Tarpey, J.;.Olesen, E.J.; Graversgaard, M.; Claessens, L.; Emoke Madari, B.; Razafimbelo, T.; Kontoboytseva, A.; Nciizah, A.; Swanepoel, C.; Katto, C.; Verchot, L.; Baldock, J.; Grundy, M.; Hongmin, D.; Li, Y.; McNeill, S.; Arias-Navarro, C.; Soussana, J., -F.; Tran, T. M.;Jouqet, P.; Demenois, J.

CITATION:

CIRCASA 2020. Deliverable D2.3: "*Synthesis report on knowledge demands and needs of stakeholders".* [Frelih-Larsen, A.; Ittner, S.; Herb, I , Tarpey, J.;.Olesen, E.J.; Graversgaard, M.; Claessens, L.; Emoke Madari, B.; Razafimbelo, T.; Kontoboytseva, A.; Nciizah, A.; Swanepoel, C.; Katto, C.; Verchot, L.; Baldock, J.; Grundy, M.; Hongmin, D.; Li, Y.; McNeill, S.; Arias-Navarro, C.; Soussana, J., -F.; Tran T. M.; Jouqet, P.; Demenois, J.]. European Union's Horizon 2020 research and innovation programme grant agreement N° 774378- Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture. https://doi.org/10.15454/Q0XVVD

DISCLAIMER OF WARRANTIES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **No 774378**.

This document has been prepared by CIRCASA project partners as an account of work carried out within the framework of the EC-GA contract No 774378. Neither Project Coordinator, nor any signatory party of CIRCASA Project Consortium Agreement, nor any person acting on behalf of any of them:

a. makes any warranty or representation whatsoever, express or implied,

   I. with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or
   II. that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or
   III. that this document is suitable to any particular user's circumstance; or

b. assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if Project Coordinator or any representative of a signatory party of the CIRCASA Project Consortium Agreement, has been advised of the possibility of such damages) resulting from your selection or use of this document or any information, apparatus, method, process, or similar item disclosed in this document.

Table of content

GLOSSARY

Carbon sequestration	Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide in plants, soils, geologic formations, and the ocean.
MRV	Measurement, Reporting and Verification (MRV) of greenhouse gas (GHG) mitigation.
SOC	Soil organic carbon (SOC) is one part in the much larger global carbon cycle that involves the cycling of carbon through soil, vegetation, oceans, and the atmosphere. SOC is the main component of soil organic matter.
SOM	Soil Organic Matter (SOM) also includes nutrients such as nitrogen, phosphorous and sulphur. It is divided into living and dead components and can range from very recent inputs such as roots and stubble to largely decayed materials that are thousands of years old.
SDGs	The Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations General Assembly in 2015 for the year 2030. The SDGs are part of Resolution 70/1 of the United Nations General Assembly, the 2030 Agenda.

FIGURES

TABLES

Executive Summary

Restoring degraded agricultural soils and raising Soil Organic Carbon (SOC) stocks has the potential to contribute to mitigation, and to support adaptation to climate change (e.g. by reducing yield variability) and sustainable intensification (higher productivity). Yet, soil degradation continues and farmers face various barriers in maintaining and enhancing SOC levels (in short, 'SOC management'). To date, a systematic review of these constraints and barriers is lacking. To tackle this gap, the CIRCASA project carried out a stakeholder dialogue on challenges, opportunities, and knowledge needs related to SOC management. This dialogue involved 11 workshops worldwide (235 participants), exchanges with a stakeholder advisory board, a global survey targeting farmers and other stakeholders including researchers, government authorities, farm advisors, policy makers and members of NGOs, associations and industry (1369 usable answers) and a survey with Danish farmers (1807 usable responses, representative of Danish farming structure).

Earlier analysis carried out in the CIRACSA project showed that stakeholders perceive a lack of knowledge around SOC management as a key barrier to scaling up beneficial practices and that improved knowledge creation and exchange is seen as a central solution to further the uptake of SOC management. In this report, we examine knowledge gaps identified by stakeholders. In this way, the findings support the creation of an international strategic research agenda for SOC, a central envisioned outcome of the CIRCASA project.

The most frequently mentioned knowledge gaps relate to farm-level management practices, their effects, economic costs and benefits, as well as questions on policy mechanisms, the enabling environment, and monitoring, reporting and verification for SOC. The following observations emerge as especially important.

Farmers' knowledge needs:

- Key gaps exist around management choices that benefit SOC levels, knowledge on costs and benefits of SOC management, including implications for productivity and yields (both quality and quantity of yields), financial returns and net income, and any other benefits (e.g. soil workability). Farmers need to know '*what's in it for me?*', including the potential risks and trade-offs, time and effort involved. Crucially, and inextricably linked to this question, farmers also require guidance and support in managing the transition, i.e. '*how do I get there*?'. For farmers, guidance is especially needed for crop choice (including rotation, crop combination, interactions and impacts on subsequent crops), which was the most frequently mentioned item in farm-level management. Other needs include questions about inputs of organic material, reduced tillage, machinery or testing of new measures (including biochar, or 'exotic' measures such as compost teas), and information on the effects of individual practices, interactions between practices, and management regimes (combinations of practices). The role of microorganisms, earthworms and more broadly interactions between soil microorganisms (fungi, bacteria), nutrients, and water were also mentioned.
- Farmers require contextual and regionally/locally specific knowledge: what are the best choices and practices in a given context. While there are similarities across regions in terms

of broad categories of knowledge needs, the required knowledge needs to be targeted at specific farming systems, soil type, climatic conditions, and socio-economic and policy environment within which the farmers operate. As one farmer put it: 'tailor-made packages are essential.'

- Moreover, the temporal dimension was also emphasized. Farmers need both short-term (annual) and longer-term (decadal) perspectives on the costs and benefits of SOC management.
- The availability of clear, 'simple' tools to demonstrate these contextually specific impacts and choices was stressed, and the role of advisory services in facilitating access to this knowledge.

Knowledge needs of other stakeholders:

- Stakeholders other than farmers pointed to the need to better understand and demonstrate broader societal and environmental benefits and potential trade-offs, and explore mechanisms for how to better incentivize SOC management. Policymakers require insights into where best to target public support and how to tailor approaches that maximize the returns on public investments (i.e. maximize beneficial outcomes). Mechanisms such as carbon credit payments and certification schemes were mentioned as worth exploring, although there were also critical voices over effectiveness and even potential negative impacts of these schemes. The potential effectiveness and design of these schemes in different conditions, and the conditions under which they are suitable or not, are questions that link very closely to the most important gap that stakeholders / policymakers identified – that of monitoring, verification and reporting (MRV) of SOC changes.
- A key theme in relation to monitoring is the need for improved reliability and standardisation of MRV methods with sufficient statistical relevance, yet at a reasonable cost. Most responses in relation to monitoring came from stakeholders other than farmers, referring to their own needs. However, about a quarter of responses related to monitoring referred to the need for systematic farm level monitoring, including the value of existing soil sampling and crowd sourcing, that would also enable the monitoring of effects in different conditions and soil types. This would also involve developing new cost-effective technologies for mapping SOC and monitoring SOC changes.
- Other important issues mentioned were leasing arrangements to incentivize SOC management, how to transition to valuing SOC as a capital asset (e.g. by financial institutions), enhanced communication and other aspects of the enabling environment for SOC restoration and sequestration. This also includes the questions of how to shift perception and willingness to pay for the real costs of food, to internalise the otherwise unaccounted costs of production to soil and other environmental media.

Access and creation of knowledge

- An important finding is that a large share of knowledge gaps were traced back not simply to 'research gaps' but to the lack of access to existing knowledge ('access-to-knowledge gap'). The access to knowledge gap was deemed important across all the themes, and in particular for farm-level management, as well as to a lesser extent for economic information.

- Themes where knowledge needs were perceived to be due to missing research included questions around: 1) societal costs and benefits, cost and benefits for farmers, including impacts on yield / productivity, as well as long-term economic effects; 2) policy and financial instruments (including carbon credits), and especially 3) MRV. There is a clear consensus that for the issue of MRV, the gap is not about access to already available knowledge and methods, but rather about creating new tools and methods that are realiable, credible and feasible in terms of costs.
- In this line, stakeholders call for efforts to improve knowledge exchange, communication and transfer, with a particular emphasis on complementing traditional 'top-down' modes of knowledge-dissemination with 'bottom-up' participatory knowledge creation. In this context, four modes of knowledge creation and dissemination – 'top-down', decision support tools, horizontal sharing of knowledge and participatory, co-creative knowledge production – are discussed.
- Stakeholders also stressed that there is often a mismatch in the timeframes between policy needs and the ability to deliver research outputs and outcomes. There is a need to develop mechanisms that better link policy development and research, so that research addresses the most appropriate questions thus reducing the potential mistmatch in timeframes.
- The stakeholder dialogue included especially strong responses from farmers and natural scientists. The perspectives of policy makers, farm advisory and non-governmental organisations were captured primarily through the stakeholder workshops. The perspectives of social scientists, including economists, on the other hand, were lacking. While this can in part be traced to the limitations associated with an international online survey and the total potential pool of interested respondents, in our view this also reflects the limited attention that the topic of SOC management has received in disciplines such as economics and social sciences more broadly, or also as an explicit topic in policymaking. While soil science research on SOC has expanded significantly over the last years, SOC management as such is still some ways from becoming a mainstream societal / policy topic.

To support a strategic international research agenda on SOC, this report outlines stakeholders' perspectives on key knowledge gaps and opportunities for how to address these.

Key points that have emerged from this analysis include:

- Of crucial importance are contextually specific knowledge and participatory, bottom-up processes to create and exchange knowledge. Farmers should also be understood as co-creators and not just receivers of knowledge. Participatory co-creation of knowledge is central to farm-level management and economics, as well as policy solutions that work in specific contexts. Individual solutions will need to be worked out in these contexts and be grounded in regional research and advisory infrastructures. However, an international research agenda can stimulate the setting up of these infrastructures, provide an impulse for different ways of working through the co-creation method or more transdisciplinary approaches that involve not just soil scientists, agronomists but also economists, legal expertise, and socio-economic, institutional sci-

entists. Methodological approaches such as living labs, or advances around communication and innovative incentive mechanisms can be essential to support enabling environments that are required for scaling up SOC management.

- International cooperation can also benefit from advances in methods applied for the assessment of costs and benefits, from farm level to societal scale (e.g. assessment of ecosystem services)
- Technological, institutional and regulatory advances related to MRV can be promoted through international cooperation, to develop and scale up rapid cost-effective assessment methods for SOC monitoring, reporting and verification. This may involve remote and proximal sensing technologies, but equally important in this context are farm-level monitoring tools and mechanisms, and the potential of crowd-sourcing farm level data.

An international research agenda on SOC needs to consider both the content of required new knowledge, as well as the question of how knowledge needs are identified, and how knowledge is created and exchanged. Bottom-up and top-down knowledge creation need to complement each other, and mechanisms need to be pursued that facilitate better coordination between farmers' needs, policy needs and research.

1. Introduction

The need to secure sustainable management of soils is recognized as central to climate mitigation and adaptation. The public profile of soil management has been raised by the Global Soil Partnership (GSP), the global soil week and the 4 per 1000 Initiative on Soils for Food Security and Climate (Minasny et al., 2017). The societal debate on soil management in the context of climate change spans multiple policy areas and a wide range of stakeholders with different, in part converging, agendas. Most directly, soil management is a key issue for climate mitigation and adaptation and for coping with increased demands on food production as well as environmental issues.

Agricultural soils carry a large potential for carbon sequestration, especially in degraded soils (Paustian et al., 2016). On the one hand, world soils contain a total organic carbon stock of about 1,500±230 gigatons carbon (GtC) (up to 1 m depth) (Scharlemann et al., 2014) which is the equivalent to twice the amount of carbon as CO_2 in the atmosphere (i.e. 829 GtC in 2015) (Quèrè et al., 2015). On the other hand, close to half of all agricultural soils are estimated to be degraded in soil organic carbon (SOC), which is a threat to food production because climate change is likely to further accelerate land degradation. Preserving soil organic matter (SOM), restoring degraded agricultural soils and raising SOC stocks is anticipated to provide adaptation to climate change (less variable yields) and sustainable intensification (higher productivity). Indeed, improved efforts for maintaining and enhancing SOC are considered central for achieving several of the Sustainable Development Goals (SDGs), and they also play an important role in meeting the objectives of the UN Framework Convention on Climate Change (UNFCCC), the UN Convention to Combat Desertification (UNCCD) as well as the Convention on Biological Diversity (CBD). These different but related foci create potentially synergistic drivers to advance societal action to maintain existing levels and enhance SOC sequestration, in particular because some of the measures that support this also support other ecosystem services.

Agricultural soil organic carbon management[1] appears as both a no-regret and an indispensable climate action. It is a no-regret action for its perceived contribution to climate change adaptation, food security, and to wider ecosystem service benefits potentially adding to overall climate resilience. It is considered indispensable for its climate mitigation and negative emissions characteristics, helping undo historical carbon emissions. However, there are some practical limitations to achieving this goal (Poulton et al., 2017) with biological, economic, social, political and institutional constraints hindering the implementation of management measures that benefit SOC levels.

A heavy focus of academic attention on technical issues has led to a neglect of non-biophysical barriers even though their importance has been convincingly documented (Schneider et al., 2009; Amundson and Biardeau, 2018). To date, a systematic review of these constraints and barriers is lacking. To tackle this gap, CIRCASA project carried out a dialogue with stakeholders

[1] For the purpose of brevity, we refer to the maintenance and enhancement of SOC levels as SOC management.

on challenges and opportunities related to SOC. The analysis focuses on the implementation of SOC sequestration options (D.2.1) and the barriers to implementation and potential solutions (D.2.2). This report (D.2.3) builds on deliverables D2.1 and D2.2, focussing in on knowledge demands and needs of stakeholders. The report first assesses *what* knowledge stakeholders identified to be lacking, i.e. 'knowledge gaps' (section 3.1). Secondly, it explores *why* this knowledge is lacking by distinguishing between a lack of research ('research gap') and a lack of knowledge transfer and exchange ('access-to-knowledge gap') (section 3.1). The finding that some knowledge exists but is inaccessible gave rise to a third question, which is *how* existing information can be made accessible (section 3.2).

Deliverable D2.2 (Claessens et al., 2019) established the importance of considering knowledge gaps around SOC. It analysed barriers and solutions to successful SOC management and found that the majority of the participants consider the statement that "information and knowledge support is not available" to be "most important" or "important" as a barrier to successful SOC practices. When compared to other barriers, knowledge gaps were ranked as the third and fourth most prevalent barrier (see Figure 1).

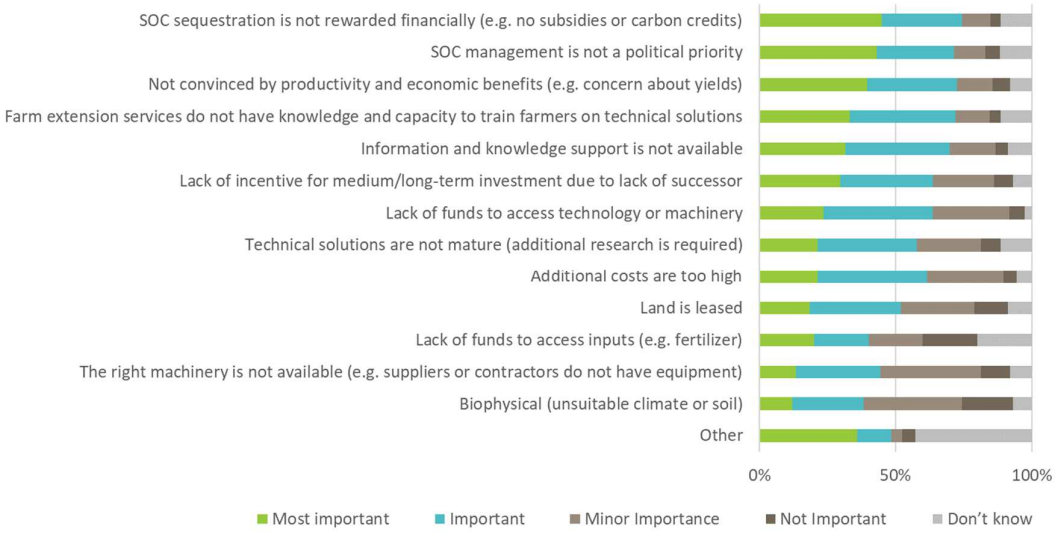


Figure 1: Global survey responses: Which barriers hinder successful SOC management?

Concerning potential solutions to barriers, farmers ranked knowledge transfer and exchange as the most important solutions: "Advisory services and knowledge exchange (in a variety of formats) are seen as the most important solution to barriers to implementation of SOC sequestration globally and consistently across regions and stakeholders." (Claessens et al. 2019, 23). Amongst global farmers the top four solutions all concern heightened efforts to create and disseminate knowledge successfully (see Figure 2). In the EU and Denmark, farmers show similar ranking patterns: 'tailored guidance and advice for farmers', 'improved awarenesss among the public', 'information to policy makers' and 'strengthening farm advisory services ranks' were all among the top five solutions. For EU farmers, the fourth place is taken up by 'payments for ecosystem services' while for Danish farmers, the second place is taken by 'indicators/tools for farmers/policy makers to measure progress in storing carbon storage in

soil". With minor variations, these findings were also reflected in the workshop discussions (see Claessens et al. 2019, p. 31).

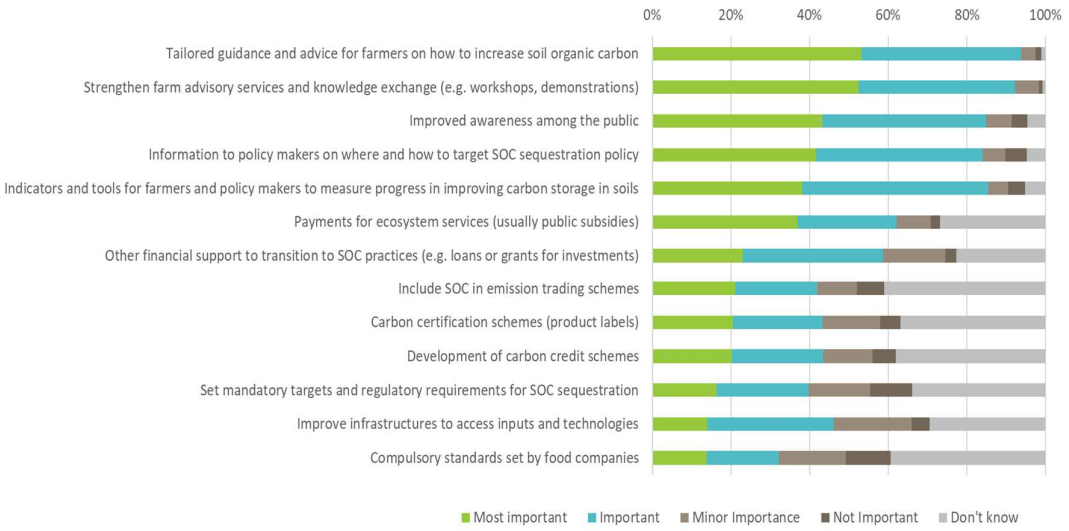


Figure 2: Ranking of the importance of solutions by farmers in the global survey

These findings that point to the importance of addressing farmers' and other stakeholders' knowledge needs as a means of scaling up SOC management are not surprising. The role of knowledge, learning and access to advisory services as factors facilitating farmers' uptake of sustainable soil management is well reflected in literature (see, for example, Fantappiè et al 2019, George et al 2018, Mills et al. 2019).

Knowledge creation and exchange/dissemination thus need to make up a central part of any policy mix for scaling up SOC maintenance and sequestration. Through exploring farmers' and other stakeholders' views on key knowledge gaps and opportunities for how to address these knowledge gaps, this report delivers valuable perspectives to support a strategic international research agenda on soil organic carbon.

2. Methods

To assess stakeholders' knowledge demands and needs around the role of SOC, stakeholders were consulted via online surveys and workshops. Moreover, a Stakeholder Advisory Board (StAB) was set up. The collected data was analysed utilizing a mixed-method approach, combining quantitative and qualitative elements.

2.1 Data Collection

The data collection included workshop dialogues with key stakeholders on SOC management and two online surveys. One survey ('global survey') was distributed globally to a diverse group of stakeholders working or having knowledge on SOC management, including researchers, farmers, public authorities, farm advisors, representatives of NGOs and industry, farmers' associations and the general public. To complement the global survey, which comes with the advantage of taking into account diverse views but cannot guarantee to representatively capture each country. Another survey was distributed among Danish farmers (Danish farm survey). Here, data availability allowed for more representativeness among farmers.

Moreover, a StAB was established, consisting of 12 representatives from farmers' organizations, conservation agriculture and land conservation interests, machinery and input providers, business and industry, landowners and land users, foundations, investment funds and NGOs. The StAB was involved in the piloting of the online survey, assisted with identifying and reaching stakeholders, and reflected on the results of the survey at a physical meeting in 2019.

2.1.1 Online surveys

Global Survey

The global online survey was made available in seven languages: English, German, Danish, French, Portuguese, Spanish and Russian, and it was disseminated via the regional hubs. The survey consisted of both open-ended and closed questions. A summary of the survey structure and the full list of questions can be found in Annex 1. In the global survey, questions were phrased around "SOC", rather than "carbon sequestration" as this can be an unfamiliar term for some stakeholders.

The survey consisted of seven main sections:

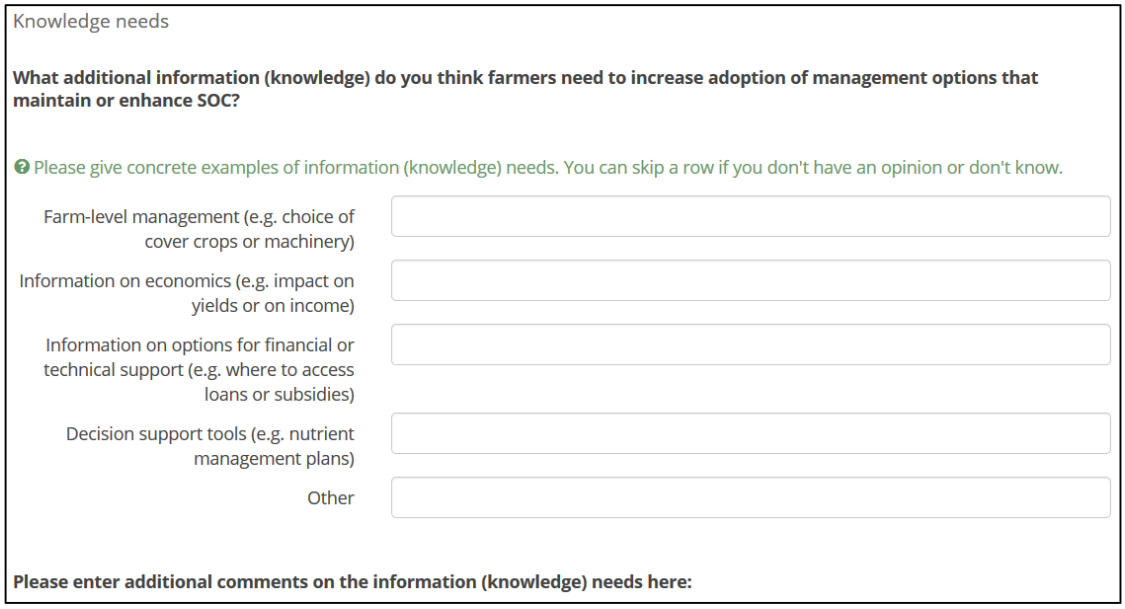
1. Background questions on SOC
2. Current management in relation to SOC
3. Barriers for implementing SOC management options
4. Solutions to address the barriers to implementation
5. Knowledge needs
6. Contribution of SOC management - sustaining and enhancing agricultural crop production and ecosystem services
7. Contribution of SOC management to climate and sustainable development.

This deliverable presents and discusses the results of section five. The findings of the other sections are reported in D2.1 (Olesen et al., 2019) and D2.2 (Claessens et al., 2019).

Two versions of the global survey were prepared: one for farmers and one for other stakeholders. Many questions overlapped, but there were also some differences. For example, farmers were asked for information on their social-economic background (primary farming system, ownership and employment conditions) and their knowledge about the SOC (e.g. SOC concentration of their soils). Section seven, on the other hand, was only included in the questions to "other stakeholders".

We drew the important distinction between knowledge that is lacking because it doesn't yet exist ('research gap'), and knowledge that exists but hasn't been transferred successfully to the relevant stakeholders ('access-to-knowledge gap'). In this line, the survey asked whether respondents deemed specific knowledge to be lacking research ('research gap') or to exist and lacking dissemination ('access-to-knowledge gap').

Farmers were asked to fill in knowledge needs in the survey as follows:


Knowledge needs

What additional information (knowledge) do you think farmers need to increase adoption of management options that maintain or enhance SOC?

Please give concrete examples of information (knowledge) needs. You can skip a row if you don't have an opinion or don't know.

Farm-level management (e.g. choice of cover crops or machinery)	
Information on economics (e.g. impact on yields or on income)	
Information on options for financial or technical support (e.g. where to access loans or subsidies)	
Decision support tools (e.g. nutrient management plans)	
Other	

Please enter additional comments on the information (knowledge) needs here:

Image 1: Survey question – Farmers' knowledge needs identified by farmers

Stakeholders other than farmers were asked to identify what concrete knowledge needs farmers and other stakeholders might have but are currently lacking. The survey differentiated between two sources for the lack of information, asking whether more research itself ('research gap') or better *communication* of existing research ('access-to-knowledge gap') is required.

What additional information (knowledge) do you think farmers need to increase adoption of management options that maintain or enhance SOC?

Please give concrete examples of information (knowledge) needs. You can skip a row if you don't have an opinion or don't know.

	Knowledge exists but needs to be communicated to farmers	Further research is required, including participatory research with farmers
Farm-level management (e.g. choice of cover crops or machinery)		
Information on economics (e.g. impact on yields or on income)		
Information on options for financial or technical support (e.g. where to access loans or subsidies)		
Decision support tools		
Other		

Image 2: Survey question – Farmers' knowledge needs identified by other stakeholders

What additional information (knowledge) do you think other stakeholders need to promote management options that maintain or enhance SOC?

Please give concrete examples of information (knowledge) needs. You can skip a row if you don't have an opinion or don't know.

	Knowledge exists but needs to be communicated to stakeholders	Further research is required
Farm-level management (e.g. choice of cover crops or machinery)		
Information on economics (e.g. cost-effectiveness of options)		
Policy solutions and design (e.g. where to target public support)		
Monitoring, reporting and verification (e.g. methods to verify sequestration)		
Enabling environment (e.g. how to organise knowledge exchange, or socio-economic issues)		
Other		

Please enter additional comments on the information (knowledge) needs here:

Image 3: Survey question – Knowledge needs of other stakeholders

To ensure that a broad range of perspectives around the globe is captured, 11 regional/national hubs were facilitated by regional/national coordinators. The global survey was disseminated through the 11 regional hubs and their networks, as well as through the network of the European Soil Partnership, the EIONET NRC Soil network and the 4 per 1000 initiative. The approach for interacting with stakeholders differed across the hubs, depending on the context and the resources available. The survey was available online from July 2018 until March 2019. In total, the global survey was visited 2057 times, of which 1369 answers could be used for

the analysis after data cleaning. The data cleaning excluded responses where no questions or only the background questions were answered.

We can observe differences in the response rate from different stakeholder groups and geographic regions. One third of responses came from "Research institute or university", another third from "Farmers" followed by "Public / government authority" with 9% (see Table 3 in Annex 2). The highest number of answers come from EU stakeholders (678), followed by Latin America (227), Africa (196) and Asia (112) and a limited number of answers from North America (76), Australia (44), Russia (16) and New Zealand (6).

Survey in Denmark

Danish farmers' views and perceptions on SOC management were surveyed using the same design as the global survey. The survey was translated into Danish, with some amendments that adapted it to Danish farming and agricultural conditions. For example, the farm type coffee-culture is not a production form in Denmark, so this option was excluded from the Danish farm survey.

In order to ensure that questions were comprehensible, the Danish farm survey was pilot-tested with a small group of farmers, as well as with researchers that have knowledge of farm surveys. The questions were then edited in consideration of comments from participants in the pilot group. This pilot resulted in some useful corrections for the final survey. To increase the response rate and for dissemination purposes a newspaper article was written and published in the national Danish farmers magazine (Landbrugsavisen), which introduced the project and stated that the survey would be distributed to Danish farmers (Olesen, 2018).

The survey respondents are representative of Danish farms both in terms of farm characteristics (farm type, farm size and agricultural practices), demographics (age and gender), and geographical distribution over the five regions in Denmark.

2.1.2 Workshops

Ten regional workshops were organised between July 2018 and March 2019 by Hub-Partners with a total number of 235 participants[2]. They took place in Brasil, Madagascar, Russia, South Africa, Colombia, EU, Australia, China, New Zealand and Vietnam, with further data coming from a similar workshop in Senegal[3].

The goal was to have at least 15–20 stakeholders present at the workshops to ensure that a range of perspectives were included. On average, each workshop was attended by 23.5 participants with the smallest workshop including nine (New Zealand) and the largest 35 participants (China) (see Figure 3).

[2] Note that due to the timing of workshops, this figure deviates from the number of participants considered in Deliverable 2.1 and 2.2 which were submitted earlier.

[3] This workshop was funded through the EIT Climate KIC project 180507 "Action plan to scale out the 4 per 1000 Initiative" and organized by Cirad.

Half of the participants came from research institutions, followed by government representatives (17%), whereas agricultural advisory services (8%), international research initiatives/programs (1%), NGO´s (6%), farmers and farmer´s and landowner´s associations (3.4%) were represented by lower numbers.

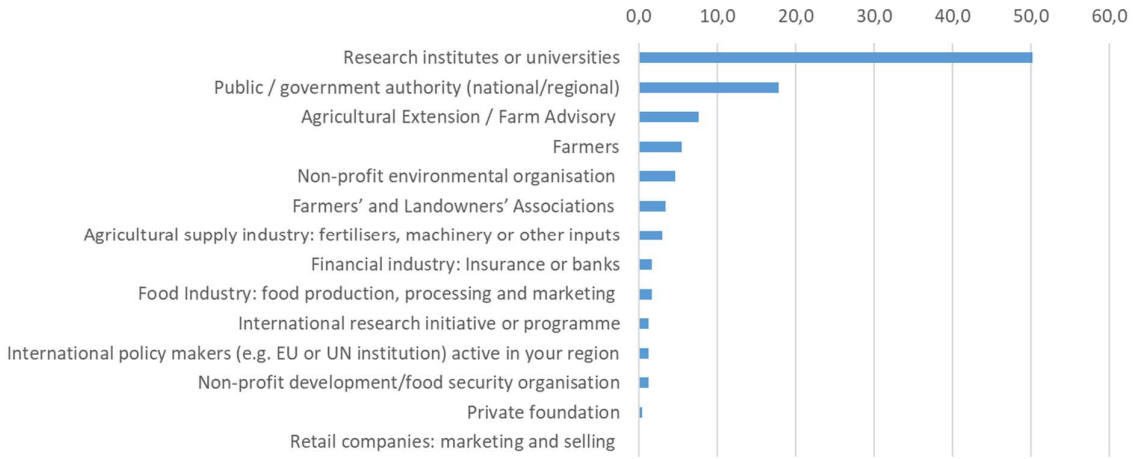


Figure 3: Stakeholder participation in the 10 regional workshops

The results need to be interpreted keeping in mind that we received different number of responses for different regions, and that different participation of different stakeholder types was possible. The results can nonetheless be interpreted as broadly indicative of the key issues and perspectives.

The overall aim of the workshops was to engage with regional stakeholders who have an interest and stake in soil management to gather their perspectives on SOC management. In particular, views were gathered on SOC management options, barriers and solutions for the implementation, and – which is the focus of this deliverable – knowledge and research needs to increase uptake of SOC management practices in their region.

The CIRCASA WP2 team provided a guideline for the workshops and briefed the partners. The guideline included a detailed description of the aim of the workshop, who should be involved, steps to select and invite participants, guidance on selecting the timing and the venue, the role of the facilitator as well as a detailed programme for internal use and an agenda. A reporting template was provided to ensure quality and consistency of reporting. The workshops were organized as full-day or half-day workshops, depending on capacities and nature of the event (e.g. side-event to conference).

The workshops covered two main thematic blocks with two sessions each (Table 1). Based on the workshop reports, the results of all workshops were summarized in a spreadsheet. In session 1, voting was applied in most of the workshops to identify most effective, most applied and most interesting but not well-known management options per region and globally. The pros and cons were categorized, and the important arguments for the most important practices analysed. The barriers and solutions were categorized as political, economic, social, and financial and knowledge issues, and analysed by region. The results of the workshops complement the results of the global survey.

Table 1: Structure of the regional workshops

Block	Session	Content
Current SOC management and barriers to implementation	1	First, all SOC management options which were identified in the literature and included in the online survey were presented to the participants. To complement these options portrayed in the literature, stakeholders were asked to complete the list of management options for their region. In a second step participants prioritized options according to: i) most effective, ii) most applied and iii) interesting but not implemented or not known. In smaller groups, participants discussed pros and cons of options in terms of the effect on SOC of the most relevant options identified before.
	2	After presenting the type of barriers from the survey, stakeholders discussed specific barriers to the uptake of SOC management in their region and prioritized these barriers by voting.
Solutions and knowledge needs for implementing SOC management options	3	After presenting the types of solutions identified in the literature and included in the online survey, stakeholders discussed which solutions for enabling the uptake of SOC management options are most important to address in the context of their region and how solutions can be effectively organized. All solutions were prioritized by voting.
	4	After presenting the types of solutions identified in the online survey, stakeholders discussed which solutions for enabling the uptake of SOC management options are most important to address in the context of their region and how solutions can be effectively organized. All solutions were prioritized by voting.

2.2 Data Analysis

The data collected in the workshops and surveys were analysed utilizing a mixed-method approach with quantitative and qualitative elements.

Qualitative research is well equipped to explore overlooked themes and explanations since it approaches data inductively, meaning that it moves from specific observations to broader generalizations, hypotheses or theories. It allows the researcher to be open to new insights and to develop generalizations bottom-up, which may precede or complement quantitative research and is of particular advantage when the aim is to include stakeholders' perspectives and relatively unexplored topics.

Data collected in the survey's open questions was analysed using the tools of qualitative text analysis (insprired by Mayring 1994 and grounded theory as proposed by Glaser and Strauss 1965 and Corbin and Strauss 1990). In a reiterative approach, a coding scheme was developed to reveal different themes running through the data from the open questions. To do so, in a first step, the meaning of each text sequence was condensed and key concepts were registered. In a second step, recurring themes and words were further analysed and grouped into several categories. Depending on the complexity of the categories, codebooks or lists of ex-

amples were developed to increase transparency and reliability of the coding process. To further increase reliability and validity, the coding went through several rounds with different researchers checking the coding.

The result of the qualitative analysis is a catalogue of important themes, which run through the subcategories of farm-level management (3.1.1), economic costs and benefits for farmers (3.1.2), policy solutions and design (3.1.3) and monitoring, reporting and verification (MRV) (3.1.4). These are elaborated below.

The qualitative analysis served to reveal *which* knowledge needs exist when it comes to SOC management. This was complemented by a quantitative analysis, which assessed how *prevalent* these different needs are. To do so, we counted how often participants in the workshops and in the survey statements mentioned the themes. A particular statement could be coded to one or more themes at the same time. Through cross-tabulations using excel, further information on differences across stakeholders were analysed.

Workshops generated supporting data that complement the survey data. The more flexible workshop setting enabled more interactive discussion and consensus seeking on the priority issues. Therefore, survey and workshop data follow a different logic and complement each other rather than being directly comparable. During the analysis, the workshop data was not included in the quantitative coding but was taken into account as a qualitative source of information. Therefore, figures, percentages and graphs apply to survey results only and the workshop data is used to exemplify and tease out points, which became apparent when synthesizing the findings from the different data sets. Importantly, the messages emerging from the survey and the workshops are very much complementary and reinforce each other.

3. Findings

This chapter discusses the findings. The structure of the chapter aligns itself with three main questions:

i) *What* information are stakeholders missing? (chapter 3.1). The analysis revealed four main 'knowledge gap' categories: farm-level management (section 3.1.1), economic costs and benefits for farmers (section 3.1.2), policy solutions and design (section 3.1.3) and monitoring, reporting and verification (MRV) (section 3.1.4).

ii) *Why* are stakeholders lacking information? (chapter 3.1). Non-farmer stakeholders were asked to differentiate between information that missing due to a lack of research ('*research gap'*) and information which exists but is inaccessible ('*access-to-knowledge gap*')[4]. This allows us to analyse *why* the knowledge gaps exist, i.e. why information is not available to the respective stakeholders. Across all 'knowledge gap' categories, stakeholders attribute the reason to a lack of research in 31% of responses (354 entries) and with accessibility-issues in 69% (774 entries)[5].

iii) *How* could knowledge gaps be addressed? (Chapter 3.2). An important finding that became apparent during the analysis of the survey is that respondents stressed that *making* existing information accessible and the question of *how* new knowledge is generated are of central concern (i.e. 'knowledge transfer & exchange'). More precisely, 24% of the coded entries in the survey were concerned with this issue (see Figure 4). Chapter 3.2 outlines different forms of knowledge communication as discussed by stakeholders and the literatuere.

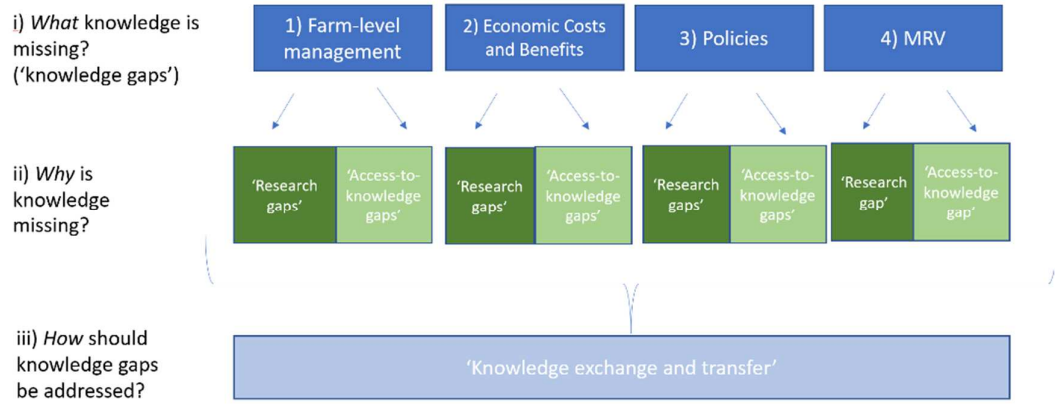


Figure 4: Visualization of the questions and structure in chapter 3.

[4] Farmers were not asked to differentiate between 'research' and 'access-to-knowledge' gaps.

[5] Note that figures do not correspond to the number of people that responded but to the number of comments concerning a specific theme. Hence, some respondents produced several entries and some entries also contained information which pertained to several subcategories and have thus been double-coded.

3.1. 'Knowledge Gaps' identified by stakeholders: What is missing and why?

This section describes *what* knowledge stakeholders are missing and why. First general observations are made on how frequently different themes were indicated to represent a knowledge gap, followed by further discussion of these different themes.

Figure 5 shows that knowledge gaps around *farm-level management* were mentioned most often (in 33% of the statements), followed by the question of the need to increase *access* and how existing information can be made accessible (24%), *economic issues* ranked third (20.5%), while less attention was given to knowledge gaps around *policy solutions* (12%) and monitoring, reporting and verification (MRV) (8%). Although stakeholders did not rank the different knowledge gaps in order of importance, different frequency with which themes were mentioned can be interpreted as indicating varying levels of concern.

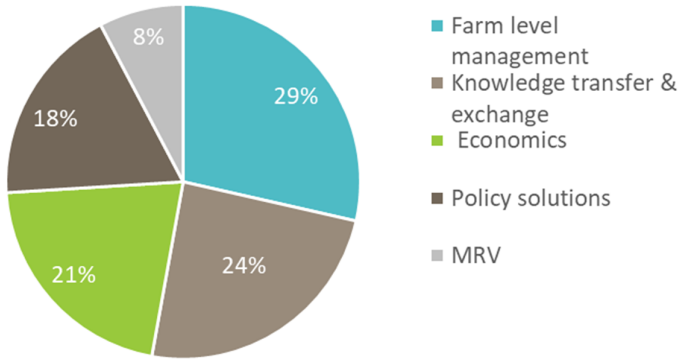


Figure 5: Share of responses per 'knowledge gap' category (global survey)

The findings of the workshop and the Danish survey mostly support these figures with some slight variation, which can be explained by the fact that, in contrast to the global survey and the workshops, the Danish survey only included famers.

	Global Survey	Danish Survey	Work-shops
The need to address knowledge transfer & exchange	24%	34%	24%
Knowledge gaps around farm level management	29%	38%	33,5%
Knowledge gaps around economic cost and benefits	21%	9%	20,5%
Knowledge gaps around policy solutions	8%	9%	12%
Knowledge gaps around MRV	8%	9%	8%

Figure 6: Variations between surveys and workshops regarding the share of responses according to 'knowledge gap' category

In terms of stakeholder groups, some variation can be observed across stakeholders. Figure 7 below gives an overview of the responses by stakeholder group. The findings will be discussed in more detail in the next subsections. Concerning the distribution of stakeholder groups in the survey it is worth noting that the survey produced 1128 valid entries. Of these, 29% re-

sponses concern stakeholders' needs identified by 'other stakeholders', 46% responses concern farmers´ needs identified by 'other stakeholders' and 26% responses concern farmers' needs identified by farmers themselves. This means that 'other stakeholders' opinion of farmers' needs is over-represented.

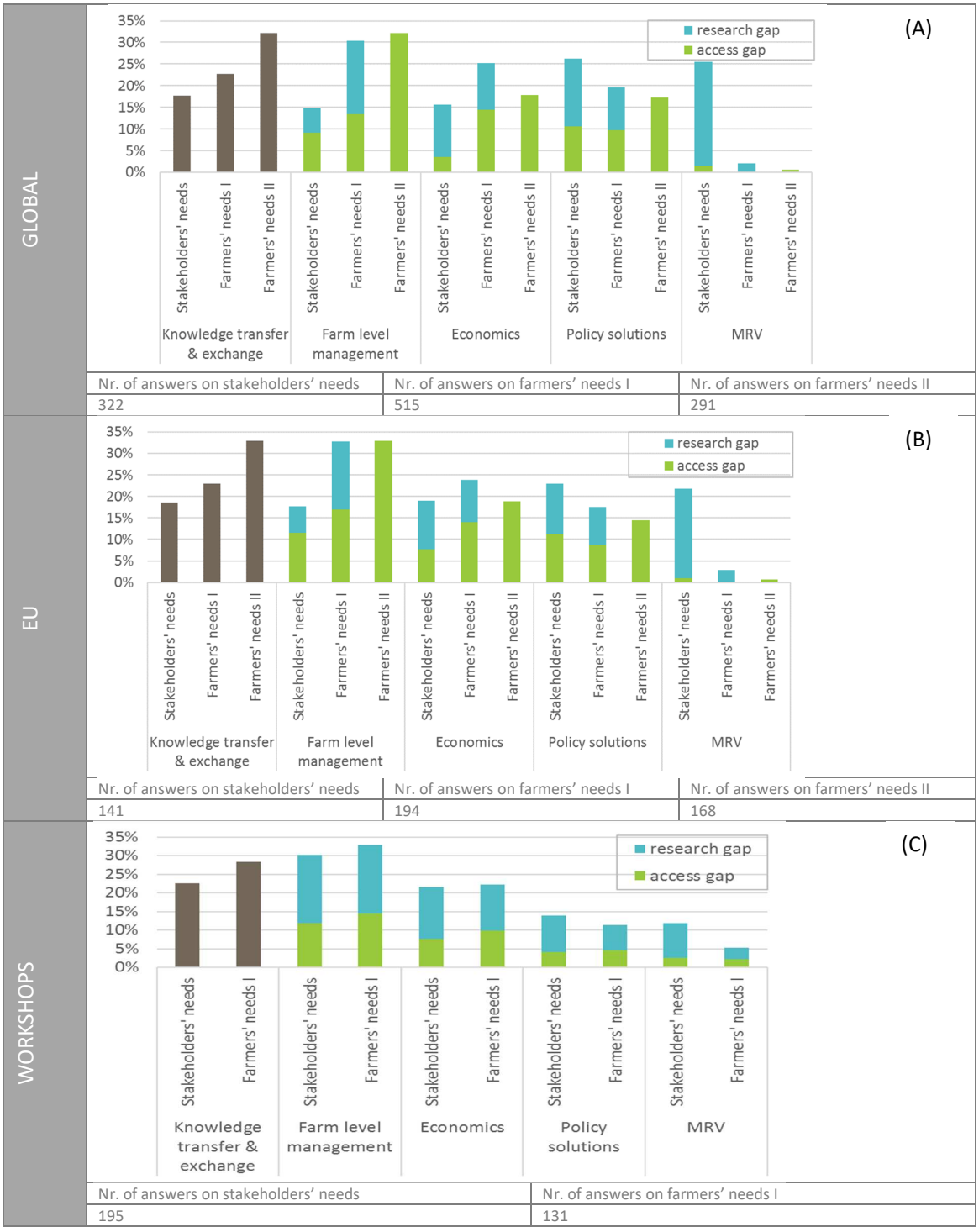


Figure 7: Share of responses per knowledge gap for farmers and other stakeholders

The bars sum up to a 100% within each stakeholder group and across knowledge gaps.
(Farmers'needs I = knowledge gaps of farmers identified by other stakeholders; Farmers' needs II = knowledge gaps of farmers identified by farmers)
The subcategory 'knowledge transfer & exchange' is displayed in brown to highlight that it does not focus on the content of knowledge gap but rather on the need to increase access and how to increase this access to knowledge.

3.1.1. Farm-level management

What Knowledge is Missing?

The analysis revealed several knowledge gaps related to farm-level management. There are open questions and uncertainty around 1) what to do in management & how to do it, and 2) around the effects of specific farm-level management practices on SOC.

- *"Stakeholders need to see more knowledge, information and guidance … to choose the best management that maintains or improves SOC"*
- *"There is currently very little documentation for the effect of different management practices."*

The knowledge gaps in relation to farm-level management were grouped into six sub-topics. Figure 8 shows that globally, the choice of crops to enhance SOC is of most concern with around 50% of the statements on farm-level management mentioning it. Reduced tillage, machinery, and whole-farm management are given almost equal weight with around 12.5%. Inputs of organic material and local adaptation account for another 7% and 8% respectively. This shows on one hand that the biggest knowledge gap to be tackled is related to the choice of crops. On the other hand it illustrates that other topics need further attention and that both context-specific knowledge and knowledge around the interaction of elements within whole farm management are flagged as important.

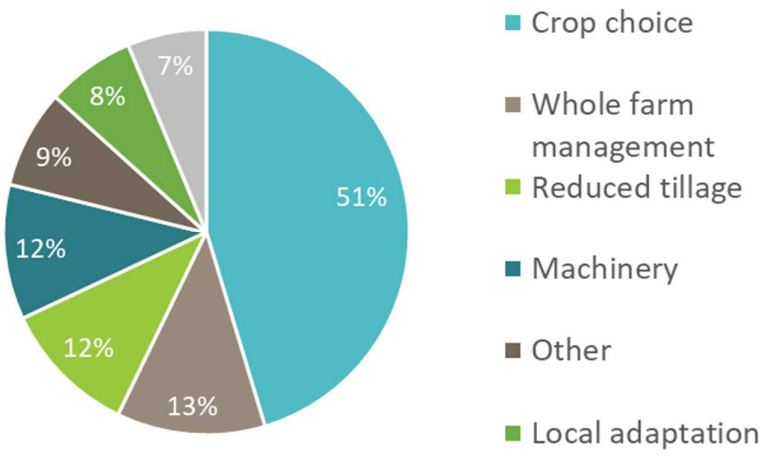


Figure 8: Share of responses related to farm level management per sub-topic (global survey)

Across stakeholder groups crop choice is consistently the sub-topic with the highest need for more knowledge creation and dissemination. Knowledge on reduced tillage (2) and inputs of organic materials (3) is considered more important for farmers (both by farmers and other stakeholders) while knowledge on machinery (4) is considered slightly more often for non-farmer stakeholders. Importantly, non-farmer stakeholders assessed farmers' needs for whole-farm management (6) as less important than farmers themselves, who mentioned the need for context-dependent knowledge in almost 20% of their responses. Apart from slight

differences, the results from the EU and the global level are comparable. What stands out is that farmers assessed their need for more knowledge around whole-farm management higher in non-EU regions than in the EU.

Indicative examples of knowledge needs per theme are outlined in Table 2.

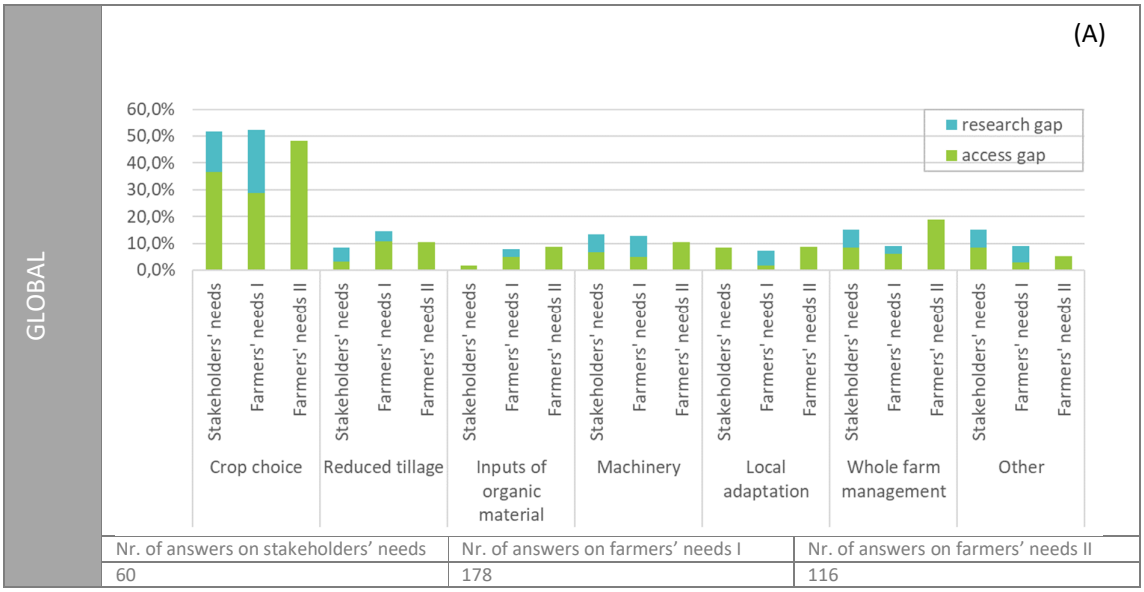
Table 2: Indicative examples of knowledge needs for farm level management

Theme	Knowledge needs
Crop choice	• Choice of crop (general) and cover crops / intercrops or underseeds / deep rooting crops (more specifically) for the region / time of year / place in rotation and effect on performance of the following crops, SOC formation • Crop types and SOC increase in low rainfall environments • Polycropping (silvopastoral systems, e.g.), multi-species fallow crops, mixed cropping and intercropping • Effects of crop rotation on SOC • Impact on the management/control of soil pathogenes • Intercrop mixtures (grasses + legumes + cruciferous plants) and area retting (superficial incorporation with rotary cultivator and inoculation with ferment bacteria) • Planting consortium of plants (e.g. corn and beans or corn and grass at the same time, intercropping) • Information on which management options have the most potential and are economically viable
Reduced tillage	• interactions between reduced tillage with other farming practices and soil conditions, e.g. interaction no-tillage system with different rotations • No-till systems and plant protection chemicals • Types of no drilling
Inputs of organic material	• Use of mulching systems • Composting systems on farm and in fields, compost tea and interaction with soil biology • Fertilisation planning and organic fertiliser use (storage) • Applying fertilizer pellets directly into the sowing bed; use of microorganisms (biological fertilization);
Machinery	• improved adaptation to the farming system, adaptation to local conditions and the need for adapted tillage systems. Improved access to and technical support with machinery is a further point of concern
Local adaptation	• Questions revolve particularly around what SOC practices are most appropriate in specific biophyisical regions, with varying weather conditions (rainfall patterns), soil types and varying local vegetation. For example, Danish farmers called for “more knowledge about what works on different soil types” and for “more experiments/trials at ‘fieldlevel’”. • ‘tailor-made packages are essential’ • To estimate potential SOC increase under specific practices in specific environment / soil type • “lots out there, bringing it back to a local scene often difficult, water drives it all’ • Producers need to have relevant and practical information that is appropriate at field level (practices with focus on sequestration, generation of emission factors per crop etc).
Whole-farm management	• Concerns over overly compartmentalized research which focusses merely on SOC, advocating for whole-farm management approaches

Theme	Knowledge needs
Other	• Information on the importance of soil content of microorganisms and earthworms for the sustained ability of the soil to be cultivated safely • Effect on pathogens and their effects oon soil • Potential of biochar in view of limited biomass availability • Holistic and medium-term CN calculation • How to interpret soil analyses on a wider basis than just NPK. • Stimulating soil profile correction • Interaction between fungi, bacteria, nutrients and water • Study the pH environment in the soil for microorganisms to develop – promoting the performance of beneficial organisms • Permanence, irreversibility of management measures

Why is knowledge missing? 'Research Gap' and 'Access-to-knowledge Gap'

Across the different subcategories of farm-level management, the access-to-knowledge gap was considered, on average, more important than the research gap (see Figure 9 below). This illustrates that there is significant knowledge on SOC farming practices that already exists, but that there is a need to make such information accessible and usable in the given context. An exception is machinery, where the need for more research is about as prevalent as the need for making such research accessible.



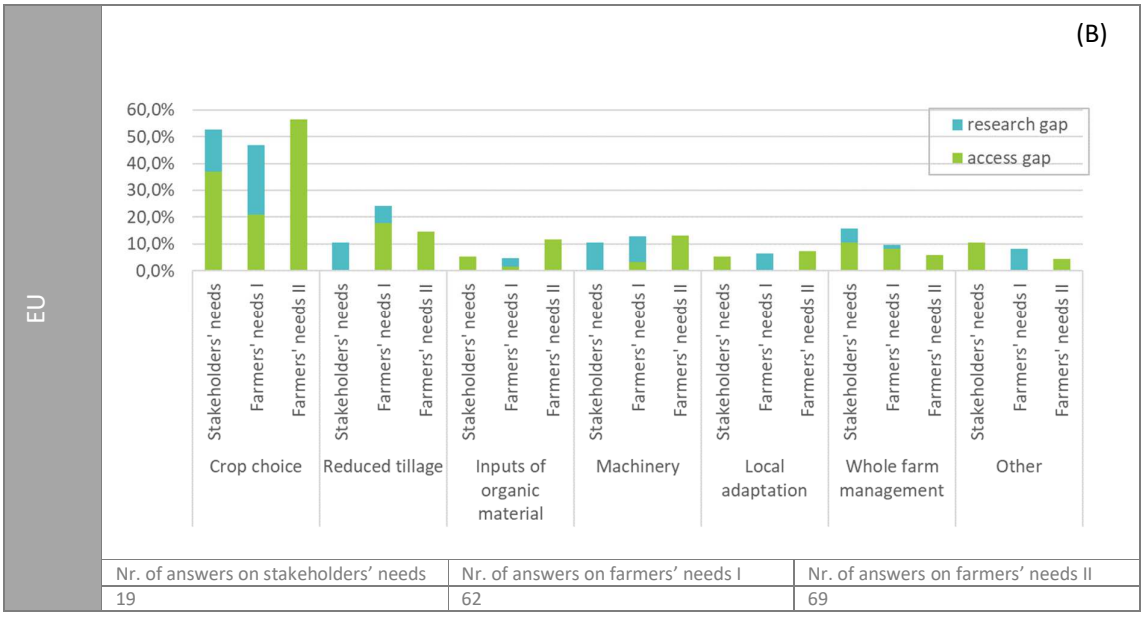


Figure 9: Share of responses per knowledge gaps concerning farm-level management for farmers and other stakeholders

The bars sum up to a 100% within each stakeholder group and across knowledge gaps. (Farmers'needs I = knowledge gaps of farmers identified by other stakeholders; Farmers' needs II = knowledge gaps of farmers identified by farmers)
The subcategory 'knowledge transfer & exchange' is displayed in brown to highlight that it does not focus on the content of knowledge gap but rather on the need to increase access and how to increase this access to knowledge

3.1.2 Economic costs and benefits for farmers

Knowledge Gaps: What Knowledge is Missing?

The analysis revealed several knowledge gaps in relation to economics. These can be grouped into five main sub-topics: 1) costs and benefits, 2) long-term economic effects, 3) impacts on yield / productivity, 4) impacts on water and 5) locally specific economic effects.

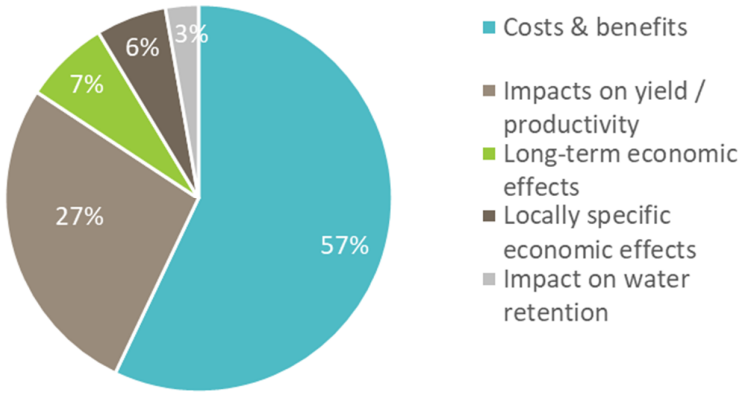


Figure 10: Share of responses related to economic costs and benefits per sub-topic (global survey)

Figure 11 shows that of most concern to all groups of stakeholders is knowledge regarding costs and benefits of SOC practices. Almost 80% of statements by non-farmer stakeholders on stakeholders' needs referred to the need of addressing costs and benefits, showing real uncertainties around the question of profitability of managing SOC. Given that economic uncertainties are a substantial barrier to farmers' uptake of farming practices (Van Herzele et al., 2013), this gap is crucial and will need to be addressed if farmers' uptake of SOC practices is to be increased. Even though long-term economic effects were mentioned less often, this theme nevertheless came up repeatedly, potentially illustrating some reservation regarding the usefulness of studies, which stress only short-term costs and benefits. The general uncertainty about economic costs and benefits of SOC is reflected by one Danish farmers' comment:

> *"I miss basic knowledge of the economic benefits of both carbon management and the use of catch crops. I am driven by the subsidy for catch crops, as well as a belief (also knowledge) that it benefits the soil. But have only seen few examples where there is put a size (+ and -) on the financial gain."*

The second most frequently mentioned theme is the question of how SOC impacts yield productivity, indicating that stakeholders miss credible basic information on the benefits of SOC management, both in the short and longer term. Lacking basic knowledge around the impacts of SOC on yield productivity and water retention (the latter was mentioned the least frequently), renders SOC practices a risky business for farmers, which is reflected in the fact that this theme was particularly prevalent among farmers. A particular challenge for the future will be locally specific knowledge around cost-benefit analyses.

Table 3: Indicative examples of knowledge needs for economics

Theme	Knowledge needs
Costs and benefits	• Information on which management options have the most potential and are economically viable • Translating science benefits to farm financial activity complex

Theme	Knowledge needs
	• Soil investigation results that illustrate economic efficiency • A shift from contribution margin accounting to a focus on total operating considerations, including long-term analyses of the advantages of higher humus contents • Time of application – which process has the highest degree of efficiency • Cost of brown/green manuring legumes ; economics of adopting cover-cropping, loss of yield in following cereal crop • If I spend more on cover crop seed, will I get a return from increased nutrients sequestered ? • Show different options in cost accounting for the user • Concrete numbers not projections and assumptions • The cost-benefit of increase in SOC in nearer and longer terms • How to monitor cost-effectivenss and rapidly the impacts? • Quantification of ecosystem services • Understanding of cascading effects
Impacts on yield and productivity	• Business plan with productivity information obtained from SOC conservation trials and estimates on return from investment • The economic effect of SOC on crop yield • It must be demonstrated that the yields will be maintained over time, and in the case of recovering deteriorated soil, demonstrate the increase in yields • Yield differences on wet organic soils • There is a demand in understanding the long term effects on yield stability and soil fertility • Differentiation between economic results and yields
Impact on water retention	• Water capture/infiltration and SOC yield benefits • Specification of water retention capacity at different humus percentages and yield effects • With 5% humus each farm gets by with 400 ml of water/year. Dry periods could be bridged with winter humidity in this way
Long-term economic effects	• Farming community not prepared to adopt new systems until the long-term financial reliability can be demonstrated • Studies on the economic feasibility in the short, medium and long term
Locally specific economic effects	• Local farming systems economic analyses of different scenarios • Analysis in small farms • Good to develop more of this by crop type • The effectiveness of various measures in the local soil-climate zone must be defined.

Why is knowledge missing? 'Research Gaps' and 'Access-to-knowledge Gaps'

As mentioned earlier, for farmers the survey did not distinguish between research gaps and access-to-knowledge gaps. Stakeholders distinguished between these and considered both gaps to play a role. For yield productivity and water retention, knowledge gaps on long-term economic effects and field observations were almost equal with research and access limitations. Concerning costs and benefits, survey respondents saw the research gap to be a bigger issue when it came to other stakeholders' needs, but the access-to-knowledge gap of greater importance when considering farmers' needs.

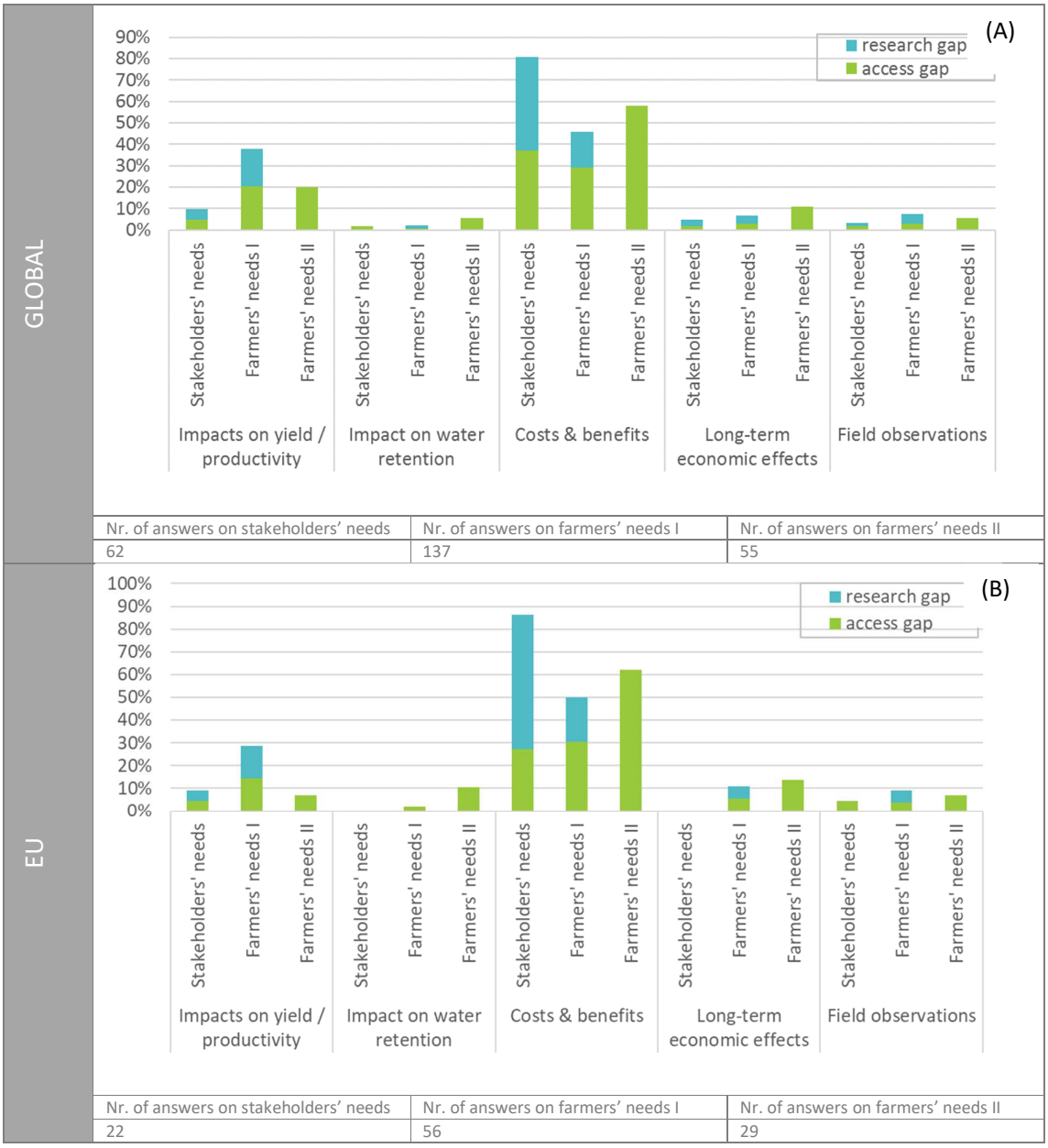


Figure 11: Share of responses per knowledge gaps concerning economic costs and benefits for farmers and other stakeholders

The bars sum up to a 100% within each stakeholder group and across knowledge gaps. (Farmers'needs I = knowledge gaps of farmers identified by other stakeholders; Farmers' needs II = knowledge gaps of farmers identified by farmers).
The subcategory 'knowledge transfer & exchange' is displayed in brown to highlight that it does not focus on the content of knowledge gap but rather on the need to increase access and how to increase this access to knowledge.

3.1.3 Policy solutions and design

Knowledge Gaps: What Knowledge is Missing?

The consultation points to several knowledge gaps in relation to policy solutions and design. These were grouped into four main themes: adding value/markets; financial support access/policy; land access and rent and certificates, pricing and taxes. The category 'other' includes statements which did not fit one category neatly.

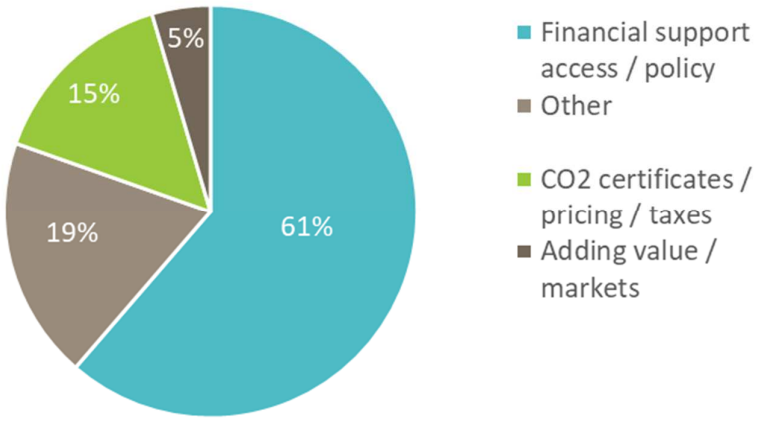


Figure 12: *Share of responses related to policy design per sub-topic (global survey)*

Most statements referred to access to financial support and policy options. Many statements referred to missing information about what schemes / support are already available, and that access to financial support is crucial in encouraging uptake, but knowledge on how to design policies and mechanisms was not always available. Financial support could refer to loans with long-term payback, possibly also financial instruments offered by banks that recognize the value of existing SOC or somehow make conditions attached to SOC maintenance and improvement mandatory for receipt of loans. One specific type of mechanism that was mentioned were economic instruments, in particular carbon credit schemes (CO_2 certificates), pricing of C at a level that provides an incentive, and issues around feasibility of taxes. Scaling up of SOC solutions will require a range of financial mechanisms, both from public and private funding. How to design and best roll out effective mechanisms, while ensuring equitable and targeted access, is a question which policy-oriented research can help to guide.

A further 15% of entries concerned CO_2 certificates, pricing and taxes, 5% of the addressed knowledge gaps refer to adding value/markets and 2% to land access/rental.

Stakeholders also mentioned the importance of creating opportunities and access to markets in order to add value to farm products. References were made to issues such as traceability, increasing consumer awareness through improved information, communication of the value of SOC to consumers (e.g. what role / potential labels can have in this context). Moreover, in some regions access to land and issues of land rental are key barriers and addressing these effectively remains an open question.

Table 4: Indicative examples of knowledge needs for policy solutions and design

Theme	Knowledge needs
Financial support access / policy development	• Public acceptance of measures, they must be adapted regionally • What should policy makers promote, create concrete subsidy frameworks • Barriers in current system and levers for solutions • Unintended consequences beyond immediate context, leakage • Where to place AND how to implement public support • Government policies at the macro-region and country levels to come up with new plans financial incentives for wetter organic soils still too low • analysis of existing public policies: identification of inconsistencies and proposal for improvement by integrating the different levels of action of public policies • Private-public schemes that work; development in concert with farmer loan bodies is important; work with banks and other financial institutions • Research for political communication of the SOC • How to reward "natural capital" and putting a price on ecology are key. • Subsidy and Incentive need to be linked with SOC • Linkage between soil carbon and human health • Understand drivers behind uptake • Research on effective means of ensuring equitable access to financial support is needed. Research should examine not only access by small-scale and remote farmers but also within these communities to address any disparity in access between men/women and for marginalized populations.
CO2 certificates / pricing / taxes	• Setting up CO2 price, and how to reward the services provided • Effective design and implementation, enabling factors for these schemes • How to set up carbon credits and markets, profitability, efficiency concerns • Concrete implementation of, e.g. CO2 certificates, must be worked out • Peer discussion groups, e.g. of farmers, could be part of carbon credits to help each other to make and decide on which crop is best to grow on their soil in their area • If a carbon or SOM label were to be introduced, how would this affect the already existing labels, how would it fit and what works best as labels? This is new knowledge that needs to be developed by social scientists.
Adding value / markets	• Policy based on incentives and social benefit combined with premium returns for producer acheivement such as reduced taxes, reduced land rates, investment allowances, incentive funding and brand premiums • Food system transition • Emissions (LCA) for products across territories / supply chain – data and inclusion of SOC in LCA

All stakeholders agree that the most important gap is financial support access/policy for farmers, while this is less important for other stakeholders. Similarly, CO_2 certificates/pricing/taxes were seen to be more important to farmers than other stakeholders. Responses in the EU and globally were mostly comparable. The only noteworthy difference is the higher need for more knowledge on financial support access/policy among non-farmer stakeholders in the EU. This difference may be explained by the higher visibility of the topic and the established CAP framework within the EU context.

Why is knowledge missing? 'Research Gaps' and 'Access-to-knowledge Gaps'

Both research and access-to-knowledge gap were considered relevant by stakeholders, indicating that further efforts concerning both knowledge creation and communication is needed.

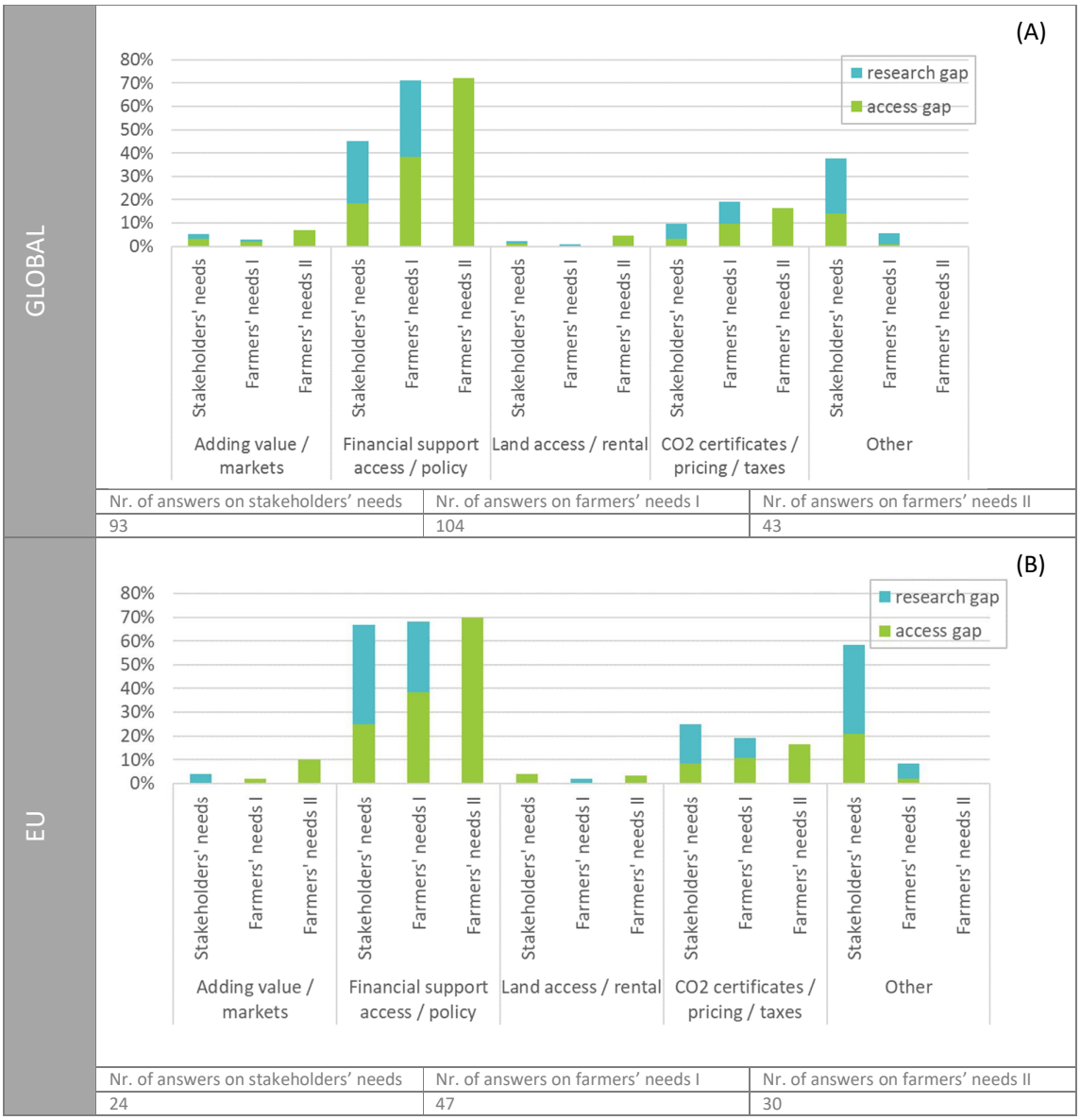


Figure 13: Share of responses per knowledge gaps policy design for farmers and other stakeholders

The bars sum up to a 100% within each stakeholder group and across knowledge gaps. (Farmers'needs I = knowledge gaps of farmers identified by other stakeholders; Farmers' needs II = knowledge gaps of farmers identified by farmers)
The subcategory 'knowledge transfer & exchange' is displayed in brown to highlight that it does not focus on the content of knowledge gap but rather on the need to increase access and how to increase this access to knowledge

3.1.4 Monitoring, reporting and verification

Knowledge Gaps: What Knowledge is Missing?

A key theme in relation to monitoring is the need for MRV methods for SOC that have improved reliability and are standardized with sufficient statistical relevance, yet at a reasonable cost. Most responses referred to different improvements in MRV, either specific aspects or improvements in general. Less frequently there was also explicit reference to whether these improvements are to occur at farm level (improved soil sampling, measurements, analysis, understanding of impact) or through the application of remote sensing. In relation to farm level monitoring, some commentary included reference to monitoring transition processes or transition farms, i.e. how the overall farm management and economics of farms evolves along with improved SOC management. Responses also emphasized the issue of developing affordable and lower-cost methods than what is currently available.

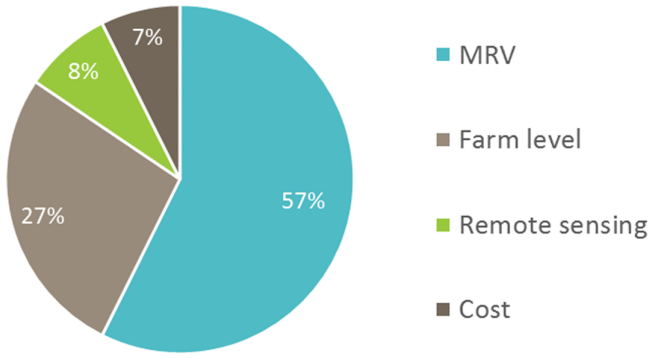


Figure 14: *Share of responses related to MRV per sub-topic (global survey)*

Most responses in relation to monitoring came from stakeholders other than farmers, referring to their own needs. This is of course not surprising, since 'other stakeholders' are the group responsible for the design of schemes and the need to to evaluate, demonstrate, and account for changes in SOC stocks and how they relate to achieving climate policy objectives.

Only two farmers responded directly to 'monitoring'. However, farmers are certainly interested in understanding what to apply to increase the SOC content, which is also reflected by reference to decision-support. Farmers tend to speak about monitoring of effects as such more with reference tothe choice of methods, and direct decision support, rather than using terms such as sampling or monitoring over time. When stakeholders spoke about farmers' needs in relation to monitoring, they spoke about monitoring in relation to SOC levels, as well as economic impacts, or relevance of monitoring as a means of demonstrating the impact.

Table 5: Indicative examples of knowledge needs for monitoring per theme

Theme	Knowledge needs
Monitoring, reporting, verification	• Systematic monitoring is required to understand different practices synergies under different environmental conditions and different soils • Plot networks and long-term trials for C and N monitoring • Being able to accurately measure SOC in alkaline soils • Changes in SOC are site specific and often long-term so monitoring techniques are needed to evaluate the impact of changes in land management • There is no consensus on how to account for c-seq and various methods can provide very different results, hence more need for harmonise and getting consensus is needed. • Further research is required here, as current monitoring schemes really focus on topsoil carbon • Detailed monitoring showing where demonstrable soil degradation occurs (in this case OM decline), instead of presenting generic risk maps which are hardly convincing. • Tier 3 modelling compatible for national and project scale
Farm level	• Need grassroots level network for assessment • Business plan with productivity information obtained from SOC conservation trials and estimates on return from investment • Monitoring productivity and long term SOC levels • Need to fund economic transition assessment programs by monitoring transition or transition farms • Equipments to test for carbon easily should be available so data can be reliable e. g a carbon refractometer • On our soil types we have not been able to demonstrate increases in SOC with different practices - difficult to measure and takes a long time to see differences. Despite zero/minimum tillage and stubble retention, SOC levels are still declining in our low rainfall region. We are not testing consistently enough, and we are not confident in the test itself. • Need to develop in-field, user-friendly, easy to interpret indicator of C dynamics • Comparison of target/actual status • Farmers need to be placed in the centre of knowledge production
Remote sensing	• Monitoring by satellite and soil samples necessary. Must be set up and defined as a requirement 5, 10, 15 years soils tests (standardised) on SOC, as well as previous cropping history!) Spy in the sky! • Research is indeed required on this specific topic because EO observations can only really address vegetation cover and not soil
Cost	How can changes be monitored with sufficient statistical power and affodable expenditure Rapid and cheap techniques would enhance adoption and improve credibility

A critical comment on monitoring was included by a stakeholder about the cost of MRV and the relevance of carbon credits as the most effective method to incentivize SOC management at farm level:

> *"Verification of SOC is only needed if payments are going to be made for carbon sequestration. Don't do this. It is a waste of scarce resource. Spend the money on promotion to lift adoption of technologies for the right reason. (New Zealand) ".*

While this was a single comment, it does echo concerns expressed by stakeholders in grey literature on the risks associated with the development of carbon credits and the differentiated costs and benefits to different groups, with possible disadvantages to smaller farmers. The results for the EU mirror the results for the global responses with minor differences.

Why is knowledge missing? 'Research Gaps' and 'Access-to-knowledge Gaps'

There is a clear consensus in the responses that for the issue of MRV, the gap is not about access to available knowledge and methods but rather about creating new tools and methods that are reliable, credible and feasible in terms of costs.

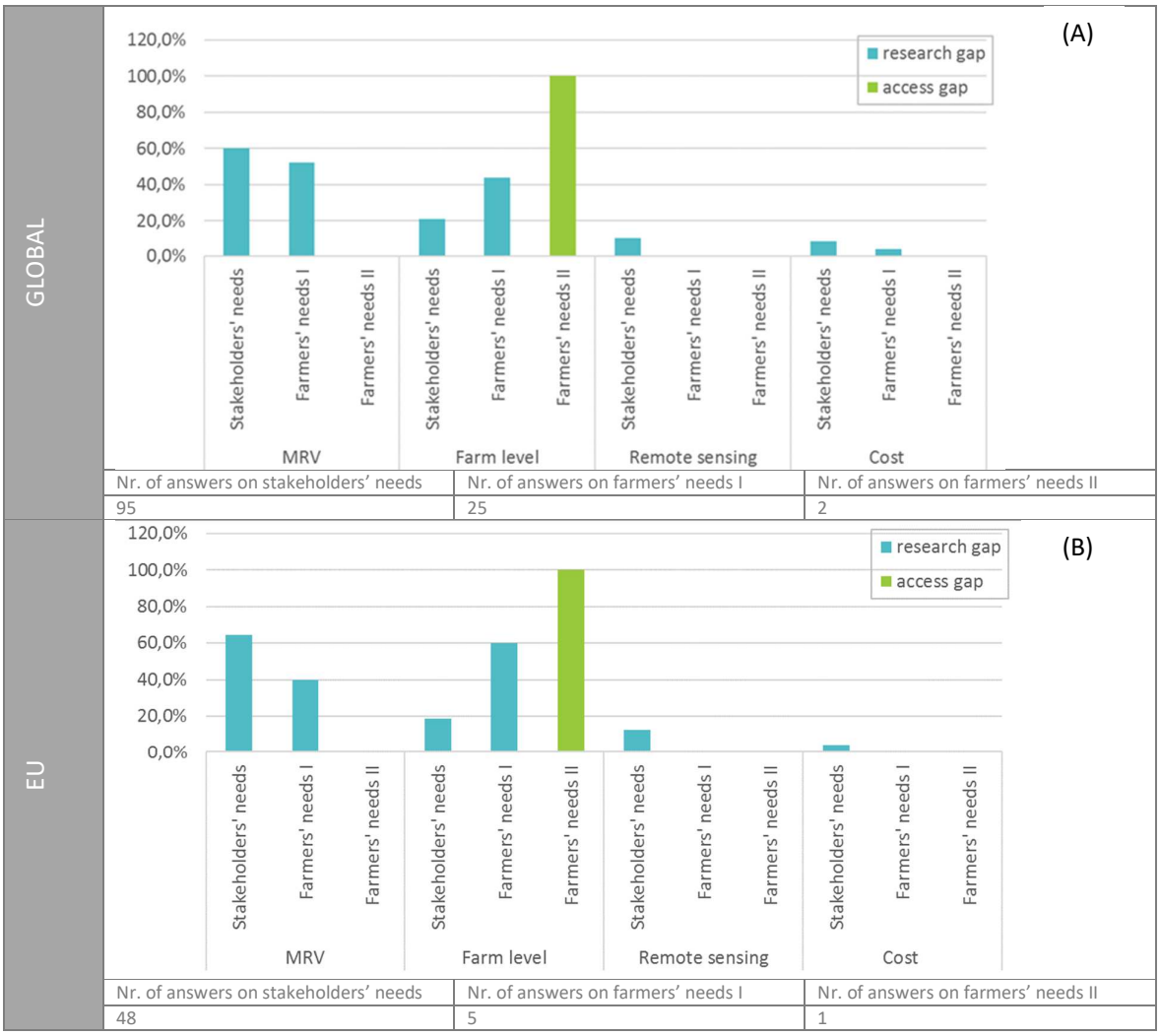


Figure 15: Share of responses per knowledge gaps concerning MRV for farmers and other stakeholders

The bars sum up to a 100% within each stakeholder group and across knowledge gaps. (Farmers'needs I = knowledge gaps of farmers identified by other stakeholders; Farmers' needs II = knowledge gaps of farmers identified by farmers)

The subcategory 'knowledge transfer & exchange' is displayed in brown to highlight that it doesn't focus on the content of knowledge gap but on the need to increase access and how to increase this access to knowledge

3.2 How could the 'access-to-knowledge gap' be addressed?[6]

The previous sections have illustrated the types of themes and questions where more research around SOC management is needed. In this section, we take up the other key issue: translating, transferring and exchanging knowledge. Hence, the question is *how* to make existing knowledge accessible to farmers and other stakeholders. While one of the survey questions explicitly prompted respondents to think about the "organisation of knowledge exchange", the worry of how to organise knowledge exchange was a theme running through many of the open responses, illustrating the overarching relevance of the topic.

The need to consider *how* knowledge is transferred varies slightly across stakeholder groups. Perhaps unsurprisingly, farmers and 'other stakeholders' believe that special attention needs to be geared towards how to communicate with farmers, while communication with non-farmer stakeholders is considered less of an issue.

The in-depth analysis of the open questions in both the survey and workshop data revealed several themes around the question of *how* to transfer and exchange existing knowledge. We grouped them into four main types. In the following sections, these types will be briefly outlined. Subsequently, their quantitative prevalence will be discussed. The implications and their resonance with existing academic literature is covered in the next subchapter.

3.2.1 Four modes of making knowledge accessible

i) Top-down knowledge transfer

One way of disseminating information which comes up in the workshop and survey can be categorized as 'top-down knowledge transfer'. Keywords included:

- Dissemination and distribution of information
- (free) access to information
- training
- farmers' schools
- education
- better advisory services
- awareness raising

While some of these keywords do not strictly imply top-down knowledge transfers, the coding was done erring on the side of caution. Coding conservatively, it was assumed that knowledge transfer was understood as a top-down process unless explicitly stated otherwise. For example, 'training' was coded as top-down unless contextualised, for example, as 'horizontal training'.

[6] Note that in this section, we were able to include further data from a workshop conducted in Senegal within a separate project from CIRCASA and which yielded data on knowledge transfer and exchange which is compatible with our data. The workshop was funded through the EIT Climate KIC project 180507 "Action plan to scale out the 4 per 1000 Initiative" and organized by Cirad. See https://www.researchgate.net/publication/326258978_PROJECT_Action_plan_to_scale_out_the_4_Initiative_Project_type_Partner_Accelerator_Report_2-Workshop_n2-Africa

ii) Usability of information: Decision-Support-Tool

A second theme goes a step beyond stressing the need for top-down knowledge transfer by also stating that knowledge needs to be presented in a way that makes it 'usable'. This is considered particularly important given the wealth of information potentially available and the complexity of the issue at stake. Quests for simple knowledge and a decision support tool were particularly prevalent in this context. Keywords that came up frequently included:

- Decision support tool
- online database
- excel
- calculation
- evaluation scheme

iii) Horizontal sharing of knowledge

While the previous two categories were concerned with vertical knowledge transfer, participants also expressed the need for horizontal sharing of knowledge, including farmer-to-farmer channels but also increased *interaction* (as opposed to 'transfer') between stakeholders and farmers and stakeholders in general. A key concern was that vertical knowledge transfer, while important, is not enough to ensure uptake by farmers and to improve performance. In this line of thinking, successful carbon sequestration not only depends on well-functioning linear information channels but also on encouraging farmers to exchange their knowledge and to interact with other stakeholders on an equal footing. This point resonates with the latest research showing that farmers already hold substantial knowledge but lack the channels to share it with other farmers and stakeholders (MacMillan, Benton 2014). In this category, the following key words came up repeatedly:

- Demonstration plots
- demonstration farms/ field demonstrations
- networks
- conferences
- seminars
- good examples
- "seeing is believing"
- knowledge exchange
- cheaper ways of analysis

iv) Participatory knowledge co-creation

While the previous category dealt with horizontal *sharing* of knowledge, this one is concerned with the horizontal *creation* of knowledge. While this may at first seem unrelated to the issue at hand here, which is how to tackle the knowledge *transfer* gap, the latest academic research, as well as this project, stress the advantage of thinking about the creation and the transfer of knowledge together rather than as two separate processes (see discussion below). In other words: the way knowledge is created matters since it can already be part of knowledge transfer.

In the survey and workshops, key words included:

- Trial areas
- local/location adapted
- lighthouse farms
- 'tests in all areas', individual farms/needs…
- case studies
- pilot farms
- holistic
- 'practical research'
- group actions

3.2.2 Prevalence of the four types of knowledge exchange

The four types of transferring and exchanging knowledge show different degrees of prevalence, which also varied across stakeholder groups.

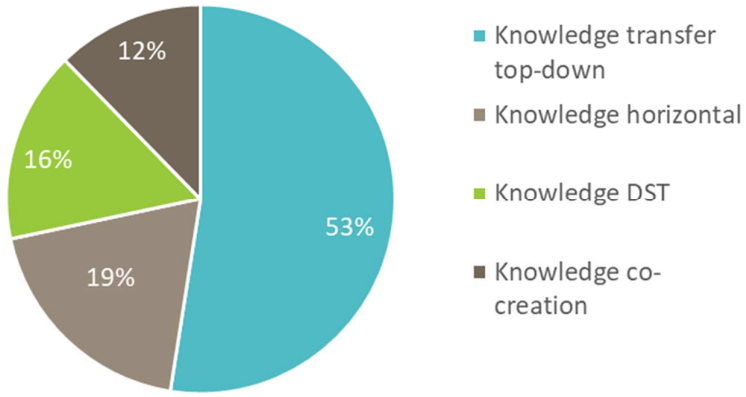


Figure 16: *Share of responses related to 'knowledge exchange' per sub-topic (global survey)*

As shown in figure 16, the importance of making knowledge available top-down was stressed particularly often (54% in the survey, 61% in the workshop), showing a real need for channels and support to transfer and translate academic findings into accessible knowledge. The need to provide decision support tools to make information usable (16% and 10%), to estabish horizontal channels of knowledge transfer (19% and 16%), and to invest in participatory knowledge creation (12% and 12%) were all considered similarly important.

While these figures have not been statistically evaluated and should thus serve as indications rather than generalizable results, it is already an important finding that as many as 24% of the coded entries were concerned with knowledge transfer and exchange, many of them drawing attention to the different ways knowledge is created and transferred and the necessity to complement top-down knowledge transfer with more participatory approaches.

Stakeholder groups differ in their mentioning of different ways to make knowledge accessible. Farmers mentioned top-down knowledge to farmers in 60% of their responses, while other stakeholders did so less often with 45%. Similarly, farmers mentioned the necessity of knowledge decision tools and simple language in about 20% of their responses, compared to about 10% of non-farmers. The need for co-creative knowledge is similarly prevalent among stakeholder groups. Interestingly, horizontal exchange of knowledge is slightly more strongly advocated for amongst non-farmer stakeholders than amongst farmers.

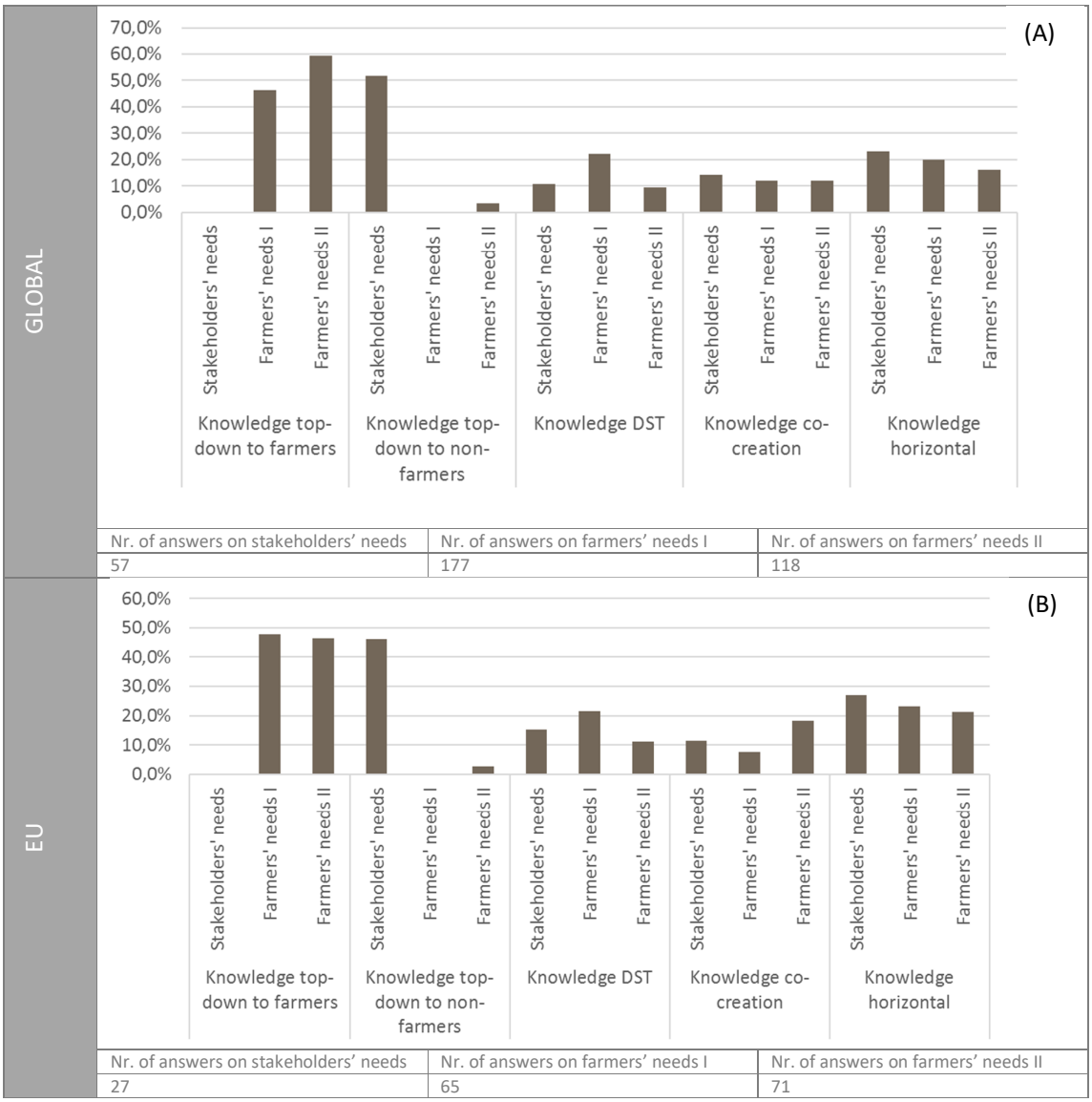


Figure 17: Share of responses related to 'knowledge transfer and exchange' – per sub-topic and stakeholder group

(Farmers'needs I = knowledge gaps of farmers identified by other stakeholders; Farmers' needs II = knowledge gaps of farmers identified by farmers)

3.2.3 Discussion: Embedding the survey findings in existing literature on participatory approaches to knowledge exchange and transfer

Stakeholders stress the need to make knowledge available. While channels operating according to a linear 'top-down' logic are frequently mentioned, other aspects were also flagged. Given that the horizontal sharing (point iii in section 3.2.1) and creation (point iv in section 3.2.1) of knowledge is still neglected in practice yet extensively discussed in academic literature, we tease out some key points on participatory approaches to knowledge exchange and transfer from this literature.

Horizontal *sharing* of knowledge (point iii in secton 3.2.1): A substantial amount (about 20%) of the survey comments on knowledge exchange and transfer addressed the need to share knowledge horizontally. This is a point that receives more and more attention in academic literature and the policy area too. For example, Rose and colleagues advocate for "good knowledge exchange and education initiatives, ideally delivered in a face-to-face manner or making the most of active demonstrations", stating that such activities "were identified as key factors in influencing behaviour" (Rose et al., 2018, 3). In a similar line, the European Commission emphasises the key role of "networks of experimental and demonstration farms and forest sites" in its strategy paper *"A strategic approach to EU agricultural research & innovation"* (2016): "Joint activities of researchers with advisors, innovation support services, farmer / foresters and their groups and other private actors will be crucial to facilitate knowledge exchange." (European Commission, 2016, 35).

Participatory knowledge *co-creation* (iv in section 3.2.1): Combining the insights from our project and those of the latest research, several reasons emerge for the need to complement centralized top-down knowledge production with more participatory co-creative approaches.

Different arguments for participatory research and knowledge transfer proposed in the literature and our survey may be distinguished along two dimensions: some arguments center on 'pragmatic' reasons ('it will support better outcomes'), and others on 'normative' reasons ('groups and invididuals have a right to be included in research') (for a similar distinction, see Reed, 2008; Reed, 2009). Pragmatic reasons that are particularly important within the context of soil are, firstly, that participatory research needs to produce the right knowledge. Therefore, questions have to address topics of real relevance on the ground (1a). Furthermore, some of the knowledge farmers need has to be locally specific (1b). Additionally, many environmental challenges show a high degree of complexity and interdependence (1c). Finally, participatory research facilitates the uptake of new knowledge and practices.

Concerning the first 'pragmatic' question **(1a)**, the survey and workshop responses from farmers and other stakeholders show that it is crucial to consider the kind of knowledge farmers actually need. Here, farmer-led participatory research is attuned to picking up issues with real relevance at the farm-level. In this line, SCAR (Standing Committee on Agricultural Research) stresses: "Agenda setting by farmers and food business is more important than just more research dissemination." (EC, SCAR 2012, 7) and Liebig and Doran remarked as long ago as 1999

that “agriculturists should seek out farmers' knowledge of soil characteristics as a first iteration to pointscale evaluation of soil quality.” (Liebig and Doran, 1999, 11). Ingram and colleagues add to this point by remarking that academic research runs the risk of compartmentalizing problems, thereby producing knowledge that cannot easily be applied: “information on a single aspect, such as soil carbon, is not helpful since in soil management, physical, biological and chemical considerations overlap.” (Ingram et al., 2016, 122). In line with the literature, several participants in our project stressed the importance of participatory research. For example, one stakeholder from South Africa explicitly stated the need to “promote more farmer-driven research that aligns better with each farmer’s situation and needs.”

Furthermore, our data analysis revealed that not only is it crucial to include farmers in research to detect questions of relevance but also because SOC renders one-size-fits-all approaches limited in their applicability (**1b**). Again, this is supported by previous research:

> *“Taking into account varied stakeholder views about what constitutes credible and salient information and their associated preferences for different information formats, it was clear that a one-size-fits-all approach to decision support was not appropriate.”* (Ingram et al., 2016, 123).

Dougill and colleagues (2006) note that participation is necessary to account for various perspectives and ideas without which local specificities will be overlooked. Survey participants noted that locally specific knowledge is particularly sought after. For example, in our survey, a stakeholder from Europe required “decision support tools co-created by farmers rather than research, look to integrate with existing rather than starting from scratch” and a stakeholder from an African country added: “Small-scale experiments by farmers should always be part of the extension process when working with small-scale farmers.”

Similarly, participatory research has been seen as a way of dealing with the complexity and interdependency of environmental challenges and agricultural systems **(1c)**, which compartmentalized and reductionist science may not always be able to do justice to. In this line, it is argued that participatory approaches may increase the quality of research dealing with highly complex and context-depenent questions (see for example Fischer, 2000; Beierle, 2002; Koontz and Thomas, 2006; Newig, 2007; Reed, 2008) to which carbon sequestration arguably belongs.

While the previous paragraphs dealt with the more general point of asking the right questions and ensuring high-quality research processes, the second point is concerned more specifically with the issue of knowledge exchange, dissemination and uptake. The advantages of participatory research when it comes to creating and packaging knowledge to be taken up and successfully implemented by farmers, centers around two angles: How can existing knowledge of farmers be utilized (2a) and how can the uptake of knowledge be facilitated (2b)? Regarding **2a**, scholarly literature supports the finding that a substantial amount of farmers’ knowledge comes from their own efforts. Yet, a lack of cooperative research structures means that such information is not accessible to other farmers. For example, in their *Nature* article, MacMillan and Benton (2014) show how farmers are already active in finding innovative solutions and

are running small-scale experiments. They conclude: "Some of the best returns can come from helping farmers to assess their own ideas. […] It is not only productive to include farmers' knowledge but it could also "reap big rewards for minimal extra cost." The finding that good practices regarding innovative agriculture exist but often remain implicit or lack dissemination (Cooreman et al., 2018, 91) has led international sources such as the IAASTD (2009, 483) to call for ways of producing knowledge in which farmers are empowered to contribute. In 2019, the European Commission stated: "Sharing and building knowledge in an open way that creates space for actors to meet and develop ideas, is essential to generate innovation accessible to all" (European Commission, 2019a: 5). Farmer-led participatory research is a means of creating structures in which implicit or hidden information becomes accessible to a wider network and can be further disseminated. This pertains not only to the simple fact that participatory research enables farmers to 'get their message out' through knowledge exchange with their group partners, but also the more long-term process of fostering trust. As EIP-Agri notes, "trust needs to be built to transform a farming system which is based on competition into one where knowledge is created and shared cooperatively" (EIP-Agri, 2015; see for a similar argument also Schneider et al., 2009, 487).

Against the backdrop of the European Commission's finding that "[o]n average, twenty years separate the start of research from the mainstream application of its outcomes in agriculture." (EC on AKIS, 2019a, 2), it is crucial to reflect on the uptake of knowledge **(2b)**. Farmer-led participatory research has the potential to decrease the research-implementation gap for at least four reasons:

i) 'Self-produced' knowledge is taken up most reliably: Previous research, for example by Ingram and colleagues has shown that farmers rank real life examples the highest and count more on their own and peer's experiences than scientific explanation as proof (Ingram et al., 2016, 121). Mills and colleagues add: "Encouraging the uptake of sustainable soil management practices often requires on-farm experiential learning and adaptation over a sustained period, rather than the traditional knowledge transfer processes of identifying a problem and implementing a solution." (Mills et al., 2019: 195).

ii) Legitimacy, credibility, and salience: As Ingram and colleagues (2016) note, farmers in the EU often hesitate to implement science on soil carbon. This is because farmers perceive such information to lack legitimacy (perception that farmers' knowledge/needs aren't considered), to furthermore lack credibility (perception that scientists themselves do not yet fully understand soil carbon dynamics) and to lack salience (missing everyday relevance and economic viability or a 'whole-farm perspective'). Amongst others, Ingram and colleagues argue that participatory research may increase the perceived legitimacy, credibility and salience of information for farmers.

iii) Peer-to-Peer learning: Scholars have shown that farmers "tend to be most influenced by proof of successful farming methods that is showed and explained by other farmers (Hamunen et al., 2015; Kilpatrick and Johns, 2003; Schneider et al., 2009;

Warner, 2007). In this line, "research on the adoption and diffusion of innovations has consistently confirmed that one of farmers' most commonly cited sources of information and ideas are other farmers (Oreszczyn et al., 2010; Rogers, 1995). "When farmers produce knowledge, they are more likely to adopt new practices, and their insights are more likely to be relevant to local conditions." (MacMillan and Benton, 2014)

iv) Increasing buy-in through trust: It has been repeatedly pointed out that participatory research has the potential to increase farmers' buy-in and therefore the uptake of new knowledge. For example, Reed argues: *"By establishing common ground and trust between participants […] participatory processes have the capacity to transform adversarial relationships and find new ways for participants to work together […].Depending on the nature of the initiative, this may significantly reduce implementation costs."* (Reed, 2008: 2420)

Further claims focus on normative benefits of participatory research (**3**). For example, Reed argues that "stakeholder participation reduces the likelihood that those on the periphery of the decision-making context or society are marginalized" (Reed, 2008: 2420). A farmer in the Thames Water project, facilitated by the Living Lab network *Soil Association* states: "We ought to have more say of what we ought to be doing"[7]

[7] Soil association: https://www.soilassociation.org/farmers-growers/innovative-farming/)

4. Conclusions

Overall, 'knowledge gaps' were identified particularly with regard to farm-level management with questions revolving first and foremost around the question of crop choice, but also around specificities of reduced tillage, machinery, inputs of organic material, local adaptation and the need to adopt a whole-farm approach. A theme that deserves highlighting as it calls for challenging changes in knowledge production is the need for locally specific, context-dependent knowledge rather than one-size-fits-all solutions. Overall, when it comes to farm-level-management, stakeholders are more concerned about an 'access-to-knowledge-gap' than 'research gaps'.

Second in line was the concern that knowledge often exists but does not reach the stakeholder needing it. This indicates that concerted efforts must be made to make knowledge accessible. As discussed in the discussion section, it is necessary to employ different communication and dissemination channels, including top-down methods, creating decision support tools, horizontal sharing and horizontal, participatory co-creative knowledge production. The latter two particularly call for substantive efforts to create innovative structures for knowledge production and distribution. The need to tackle the 'access-to-knowledge gap' is further underlined by the fact that this is particularly important for farm-level management.[8] This indicates that efforts of knowledge dissemination have so far been insufficient.

The topic addressed third most often is knowledge gaps around economic costs and benefits of SOC for farmers without which SOC practices are a risky business. There is a real need for farmers to have more information on the general costs and benefits of SOC but also more generally about the impact of SOC on farming outcomes such as yield productivity and water retention. As with the other topics, a theme that came up here was the need to overcome one-size-fits-all solutions and to encourage locally specific knowledge.

Policy solutions were addressed fourth most often. What farmers and other stakeholders mentioned here underlines concerns raised in the section on economic costs and benefits: the majority of comments concern knowledge gaps around financial support and CO_2 certificates, pricing and taxes. Interestingly, here, stakeholders found knowledge gaps to be caused mostly by a lack of 'research', which may be interpreted as a need to invest more research into which policies would support an increase of SOC well.

A key theme in relation to monitoring is the need for improved reliability and standardization of MRV methods with enough statistical relevance, yet at a reasonable cost. Most responses in relation to monitoring came from stakeholders other than farmers, referring to their own needs. However, about a quarter of responses related to monitoring referred to the need for systematic farm level monitoring, including the value of existing soil sampling and crowd sourcing, that would also enable the monitoring of effects in different conditions and soil types.

[8] The survey did not ask farmers to distinguish between knowledge which does not exist ('research gap') and that which is not accessible to them ('access-to-knowledge gap'). Therefore, an overall estimate of whether 'research' or 'access gaps' are more prevalent would refer to the responses from 'other stakeholders' only.

Through exploring stakeholders' views on key knowledge gaps and opportunities for how to address these, the report outlines stakeholders' perspectives to support a strategic international research agenda on soil organic carbon. Given the importance of contextually specific knowledge and the role of participatory, bottom-up processes to create and exchange this knowledge, where farmers are also co-creators and not just receivers of the knowledge, the question arises: what can be the contribution of an international research agenda for SOC?

Key points that have emerged from this analysis include:

- Participatory co-creation of knowledge is central to farm-level management and economics, as well as policy solutions that work in specific contexts. Individual solutions will need to be worked out in these contexts and be grounded in regional research and advisory infrastructures. An international research agenda should stimulate the setting up of these infrastructures and provide an impulse for different ways of working through the co-creation method or more transdisciplinary approaches that involve not just soil scientists and agronomists but also economists, legal experts, and socio-economic, institutional scientists. Methodological approaches such as living labs, or advances around communication and innovative incentive mechanisms can be essential to support enabling environments that are required for scaling up SOC management.
- International cooperation can also benefit from advances in methods applied for the assessment of costs and benefits, from farm level to societal scale (e.g. assessment of ecosystem services)
- Technological, institutional and regulatory advances related to MRV can be promoted through international cooperation, to develop and scale up rapid cost-effective assessment methods for SOC MRV. This may involve remote sensing, but equally important in this context are farm-level monitoring tools and mechanisms, and the potential of crowd-sourcing farm level data.
- Research that aims to support scaling up of SOC management has to balance concerns related to farm level management, economics, policy and monitoring.

An international research agenda on SOC needs to consider both the content of required new knowledge, as well as the question of how knowledge needs are identified, and how knowledge is created and exchanged. Bottom-up and top-down knowledge creation need to complement each other, and mechanisms that facilitate better coordination between farm level needs, policy needs and research should be emphasised. This requires strategic thinking for improving collaboration and networks that connect scientists, farmers, and other stakeholders to "spaces where these actors regularly meet and collectively develop new knowledge and strategies" (Schneider et al. 2009). Finally, an international research agenda needs to consider carefully the role of knowledge brokers, independent advisory systems, and research infrastructure that focus on sustainability rather than profit-orientation.

5. References

Beierle, T.C., 2002. The quality of stakeholder-based decisions. Risk Analysis 22, 739–749.

Claessens, L.; Frelih-Larsen, A.; Ittner, S.; Tarpey, J.; Olesen, J.E.; Graversgaard, M.; Emoke Madari, B.; Razafimbelo, T.; Kontoboytseva, A.; Nciizah, A.; Swanepoel, C.; Katto, C.; Verchot, L.; Baldock, J.; Grundy, M.; Hongmin, D.; Li, Y.; McNeill, S.; Arias-Navarro, C.; Soussana, J.-F. 2019. "CIRCASA Deliverable 2.1: Assessing barriers and solutions to the implementation of SOC sequestration options. European Union's Horizon 2020 research and innovation programme grant agreement No 774378 - Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture. https://doi.org/10.15454/SYP4PE.

Cooreman, Vandenabeele, Debruyne, Ingram, chiswell, Koutsouris, Pappa, Marchand. 2018. "A conceptual framework to investigate the role of peer learning processes at on-farm demonstrations in the light of sustainable agriculture". International Journal of Agricultural Extension: 91-103.

Corbin, J., Strauss, A.L., 1990. „Grounded theory research: Procedures, canons and evaluative criteria". Qualitative Sociology 13, 3–21.

Dougill, A.J., Fraser, E.D.G., Holden, J., Hubacek, K., Prell, C., Reed, M.S., Stagl, S., Stringer, L.C., 2006. Learning from doing participatory rural research: lessons from the Peak District National Park. Journal of Agricultural Economics 57, 259–275.

European Commission. 2016 : A strategic approach to EU agricultural research & innovation. https://ec.europa.eu/programmes/horizon2020/en/designing-path-conference-eu-agricultural-ri-videos-presentations-and-outcomes.

European Commission. 2019a. BUILDING STRONGER AGRICULTURAL KNOWLEDGE AND INNOVATION SYSTEMS (AKIS) to foster advice, knowledge and innovation in agriculture and rural areas. https://ec.europa.eu/eip/agriculture/en/news/building-stronger-akis

EC SCAR AKIS. 2012. Agricultural Knowledge and Innovation Systems in Transition – a reflection paper. doi: 10.2777/34991.

EIP-Agri. 2015. "EIP-AGRI Seminar 'Promoting creativity and learning through agricultural knowledge systems and interactive innovation'" SEMINAR REPORT 3-4 DECEMBER 2015. https://ec.europa.eu/eip/agriculture/en/event/eip-agri-seminar-promoting-creativity-and-learning.

Fischer, F., 2000. Citizens, experts and the environment. The Politics of Local Knowledge. Duke University Press, London.

Fantappiè, M.; Lorenzotti, R.; De Meo, I.; Costantini, E.A.C., 2019. How to improve the adoption of soil conservation practices. Suggestions from farmers' perception in western Sicily. Journal of Rural Studies.

George, A. D.; Clewett, J.F.; Lloyd, D.; McKellar, R.; Tan, P. Howden, M.; Rickards, L.; Ugalde D.; Barlow S. 2018. Research priorities and best practices for managing climate risk and climate change adaptation in Australian agriculture. Australasian Journal of Environmental Management.

Glaser, Barney; Strauss, Anselm. 1965. Awareness of Dying. Transaction Publishers.

Hassan, Zaid (2014): The Social Labs Revolution. A New Approach to Solving our most Complex Challenges. San Francisco: Brett-Koehler Publishers.

Ingram, Julie; Mills, Jane; Dibari, Camilla; Ferrize, Roberto; Ghaley, Bhim B.; Hansen, Jens G.; Iglesias, Ana; Karaczun, Zbigniew; McVittie, Alistair; Merante, paolo; Molnar, Andras; Sánchez, Berta. 2016. "Communicating soil carbon science to farmers: Incorporating credibility, salience and legitimacy." Journal of Rural Studies 48: 115-128.

International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). 2009. Agriculture at a Crossroads. Global Report. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwi73Oa7o-nlAhXHMewKHTyiAGYQFjAAegQIBRAC&url=https%3A%2F%2Fwww.weltagrarbericht.de%2Ffileadmin%2Ffiles%2Fweltagrarbericht%2FIAASTDBerichte%2FGlobalReport.pdf&usg=AOvVaw3uYldQay0rhAlfbwy1qwxq.

Koontz, T.M., Thomas, C.W., 2006. What DoWe Know and Need to Know about the Environmental Outcomes of Collaborative Management? Public Administration Review 66, 111–121.

Liebig, Mark A.; Doran and John W. 2009. "Evaluation of farmers' perceptions of soil quality indicators." American Journal of Alternative Agriculture 14(1): 11-21.

MacMillan, Tom and Benton, Tim G. 2014. Agriculture: Engage Farmes in Research. *Nature* 30.4.2014. https://www.nature.com/news/agriculture-engage-farmers-in-research-1.15108

Mayring, P. (1994), 'Qualitative Inhaltsanalyse', in A. Boehm, A. Mengel, and T. Muhr (eds.), Texte verstehen: Konzepte, Methoden, Werkzeuge (Konstanz: Universitäts-Verlag Konstanz), 159–75.

Mills, J.; Reed, M.; Skaalsveen, K.; Ingram, J. 2019. "The use of Twitter for knowledge exchange on sustainable soil management". Soil Use Management (35): 195-203.

Mills, J., J. Ingram, C. Dibari, P. Merante, Z. Karaczun, A. Molnar, B. Sánchez, A. Iglesias & B. Bahadur Ghaley (2019) Barriers to and opportunities for the uptake of soil carbon management practices in European sustainable agricultural production, Agroecology and Sustainable Food Systems, DOI: 10.1080/21683565.2019.1680476

Minasny, B., Malone, B.P., McBratney, A.B., Angers, D.A., Arrouays, D., Chambers, A., Chaplot, V., Chen, Z.-S., Cheng, K., Das, B.S., Field, D.J., Gimona, A., Hedley, C.B., Hong, S.Y., Mandal, B., Marchant, B.P., Martin, M., McConkey, B.G., Mulder, V.L., O'Rourke, S., Richerde-Forges, A.C., Odeh, I., Padarian, J., Paustian, K., Pan, G., Poggio, L., Savin, I., Stolbovoy, V., Stockmann, U., Sulaeman, Y., Tsui, C.-C., Vågen, T.-G., van Wesemael, B., Winowiecki, L., 2017. Soil carbon 4 per mille. Geoderma 292, 59-86.

Newig, J., 2007. Does public participation in environmental decisions lead to improved environmental quality? Towards an analytical framework. Communication, Cooperation, Participation. Research and Practice for a Sustainable Future 1, 51–71.

Olesen, J.E.; Graversgaard, M.; Frelih-Larsen, A.; Ittner, S.; Tarpey, J.; Emoke Madari, B.; Razafimbelo, T.; Kontoboytseva, A.; Nciizah, A.; Swanepoel, C.; Katto, C.; Verchot, L.; Baldock, J.; Grundy, M.; Hongmin, D.; Li, Y.; McNeill, S.; Claessen, L.; Arias-Navarro, C.; Soussana, J.-F. 2019. « CIRCASA Deliverable 2.1 : Stakeholder views on the role of SOC for limate change mitigation, adaptation and SDGs ». European Union's Horizon 2020 research and innovation programme grant agreement No 774378 - Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture. https://doi.org/10.15454/8XFF8D

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G.P., Smith, P., 2016. Climate-smart soils. Nature 532, 49-57.

Poulton, P., Johnston, J., Macdonald, A., White, R., Powlson, D., 2018. Major limitations to achieving "4 per 1000" increases in soil organic carbon stock in temperate regions: Evidence from long-term experiments at Rothamsted Research, United Kingdom. Global Change Biology 24, 2563-2584.

Reed, Mark S. 2008. „Stakeholder participation for environmental management: A literature review. Biological Copnservation (141): 2417-2531.

Reed, Mark S.; Graves, Anil; Dandy, Norman; Posthumus, Helena; Hubacek, Klaus; Morris, Joe; Prell, Christina; Quinn, Claire H.; Stringer, Linday C. 2009. "Who's in and why? A typology of stakeholder analysis methods for natural resource management". Journal of Environmental Management (90): 1933-1949.

Scharlemann J.P., Tanner, E.V., Hiederer, R., Kapos, V., 2014. Global soil carbon: understanding and managing the largest terrestrial carbon pool. Carbon Management 5, 81-91.

Schneider, Flurina, Patricia Fry, Thomas Ledermann, and Stephan Rist. 2009. Social Learning Processes in Swiss Soil Protection—The 'From Farmer - To Farmer' Project. *Human Ecology* 37: 475–489. doi:10.1007/s10745-009-9262-1.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., 2007. Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agriculture, Ecosystems and Environment 118, 6-28.

Annex 1: Responses by stakeholder type in the global survey

Answers of the global survey by stakeholder for all countries (global) and for the EU in percentage

STAKEHOLDER TYPE	ANSWERS - GLOBAL [%]	ANSWERS - EU [%]
RESEARCH INSTITUTE OR UNIVERSITY	33,5	25,3
FARMER	30,1	34,0
PUBLIC / GOVERNMENT AUTHORITY	9,1	11,6
AGRICULTURAL EXTENSION / FARM ADVISORY	5,9	6,7
OTHER	5,3	6,8
NON-PROFIT ENVIRONMENTAL ORGANISATION	4,1	4,5
AGRICULTURAL SUPPLY INDUSTRY: FERTILISERS, MACHINERY OR OTHER INPUTS	2,8	3,1
NON-PROFIT DEVELOPMENT/FOOD SECURITY ORGANISATION	2,0	1,0
FARMERS' ASSOCIATION	1,8	1,3
GENERAL PUBLIC	1,7	1,6
FOOD INDUSTRY: FOOD PRODUCTION, PROCESSING AND MARKETING	0,8	0,9
INTERNATIONAL RESEARCH INITIATIVE OR PROGRAMME	0,7	0,6
PRIVATE FOUNDATION	0,5	0,6
INTERNATIONAL POLICY MAKER (E.G. EU OR UN INSTITUTION)	0,5	0,7
RETAIL COMPANIES: MARKETING AND SELLING	0,4	0,3
FINANCIAL INDUSTRY: INSURANCE OR BANKS	0,4	0,0
LANDOWNERS' ASSOCIATION	0,2	0,4
PUBLIC FUNDING MECHANISM	0,2	0,4

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **No 774378**