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EJP SOIL
European Joint Programme

Towards climate-smart sustainable management of agricultural soils

Deliverable 2.8

Report on barriers and opportunities (knowledge and policy) at regional, national and EU levels for further harmonization and collaboration concerning research, data, training, and education

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ABSTRACT

The European Joint Program SOIL: "Towards climate-smart sustainable management of agricultural soils" (EJP-SOIL) aims at building a sustainable European integrated research system on agricultural soils, at promoting a climate-smart sustainable agricultural soil management, and at enabling an environment that will maximize the contribution of agricultural soil to key societal challenges such as food and water security, climate change adaptation and mitigation, biodiversity preservation and human health.

This report describes the work performed within the EJP-SOIL, WP2 task 2.3 *Identification of barriers and opportunities by scenario development* aiming at quantifying the current opportunities and barriers for soil knowledge (development, sharing and transfer, harmonization and storage, and application) to overcome the soil challenges in Europe, in the opinion of the stakeholders. The study involved 20 Countries and harvested the stakeholders' perception about knowledge and knowledge requirements related to the soil challenges, through national surveys. National results were collated and harmonized in a common database before the analyses.

According to stakeholders' perception on the most relevant soil challenges that research should address were "improving soil organic matter" for the Geographical Zones (GZs) of Northern, Western, and Central European "improving water storage capacity" in Southern Europe.

The main results showed that there are many areas of improvement of the soil knowledge sector as a whole, both by removing barriers and by enhancing opportunities to overcome soil challenges. Among the barriers, the stakeholders have indicated in detail the technical, cultural, organizational, legal/institutional, economic, and political obstacles, that hinder the exploitation of research efforts to solve soil-related issues. Among these are: the lack of funding for research and long-term experiments, low investments in education, a scarce relationship between researchers and other actors, the lack of knowledge networks and national infrastructure linked to those operating at European level, and the need to develop regional tailored soil management strategies.

The EJP SOIL already addresses some the identified issues, e.g,. by inventorying long-term experiments on sustainable management of agricultural soils, promoting their use and visibility (T7.3, T7.4, WP3), and favouring the creation of multi-actors and multi-disciplinary networks at national and European level. Concerning the need to develop regional tailored soil management strategies, the EJP SOIL makes use of the diversity of its partners within internal research projects, to consider the diversity of pedoclimatic conditions, specifically addressing organic vs mineral soils.

Identified opportunities ranged from the increase of financial resources for research, to be allocated mainly in multi- and trans-disciplinary research, to the creation of science-policy-society networks,

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improving communication among researchers and other soil stakeholders, creation of national infrastructures, encompassing databases created with standardised and harmonised methodologies at the European level using new ICT tools. The EJP SOIL includes the formation of young scientists in WP5, that will be targeted specifically on some of these issues.

Another important aspect outlined by respondents, concerns the transfer of the research outputs to agricultural soil managers, that should be based on the development of region-specific soil management strategies supported by appropriate policies and incentives. Some of the suggestions that came from the questionnaires will be specifically faced by the EJP SOIL WP8 Science to policy interaction.

The output of this research allows to identify in detail all those factors that should be removed to address the challenges of soil, but, at the same time, the immense opportunities listed by respondents, that implicitly enclose a “wish list” of how knowledge could contribute to tackle the soil challenges.

Hence, the highlighted elements can be viewed as an agenda of what needs to be done or avoided by soil stakeholders (scientists, farmers and farmer organisations, agro-industry and policy makers) to make soil research effective and responsive to the needs of soil conservation and sustainable development of the whole society.

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Annex 1: Guidelines EJP-SOIL Task 2.3

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List of acronyms and abbreviations

ALS	Alpine South
ANA	Anatolian
ATC	Atlantic Central
ATN	Atlantic North
BOR	Boreal
CON	Continental
EEZ	European Environmental Zone
GZ	Geographical Zone
LUS	Lusitanian
MDM	Mediterranean Mountains
MDN	Mediterranean North
MDS	Mediterranean South
NEM	Nemoral
PAN	Pannonian
PCs	Participant Countries
WP	Work Package

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Executive summary

The Deliverable D2.8 describes the work performed within the EJP-SOIL, WP2 task 2.3 *Identification of barriers and opportunities by scenario development*, aiming at quantifying the current opportunities and limitations for soil knowledge to overcome the soil challenges in Europe, in the opinion of the stakeholders.

The task was carried out by performing national surveys, collated in a template provided by the Task leader's team. The survey included two main sections: the first one related to the prioritisation of the soil challenges for each country, and the other one aimed to collect the information about knowledge contribution to overcome soil challenges. Soil knowledge was considered by using four main segments: i) development, ii) sharing and transfer, iii) harmonization and storage, and iv) application.

Identified barriers and opportunities were grouped, when possible, into a limited number of definitions and then harmonized, aiming to allow a qualitative and quantitative analysis.

Partners participant to the survey were 20 over 24: Austria, Belgium (Flanders and Wallonia) Denmark, France, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, The Netherlands, Turkey, United Kingdom - for a total of 329 stakeholders interviewed. Researchers, farmers, and farmer associations were the most represented groups within the stakeholders.

In the first part of the survey, the most relevant soil challenge for the four main GZs of Europe (i.e., Northern, Central, Western and Southern Europe) are reported. "Improving soil organic matter" was considered the first soil priority for all GZs except for Southern Europe, where the first priority considered was "Improving water storage capacity".

In the second part of the survey the main barriers and opportunities were identified for each knowledge compartment.

For knowledge development, 27 main barriers and 29 main opportunities were identified. The 5 most indicated barriers (by 41% of the participant countries-PCs) included: 1) an insufficient allocation of financial resources; 2) the lack of a link and a coordination between the main actors of knowledge development, namely researchers, advisors and farmers; 3) the deficiency of public-private partnership on soil research; and 4) the lack of training for advisors and farmers. The opportunities listed by the interviewees essentially represent possible solutions to remove the barriers identified previously. Therefore, the opportunities indicated by 48% of the stakeholders were: 1) the need to increase funds dedicated to research; 2) favoring multi and transdisciplinary research; 3) activation/funding/valorisation of long-term experiments; and 4) increase the number and improve the curricula of the soil science students.

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For knowledge sharing and transfer, 27 main barriers and 35 main opportunities have been identified. The most indicated barriers (56% of the Countries) were linked to the lack of networks between all actors, a poor communication and dissemination effectiveness, also as regards training for soil issues with contents not conveying useful information. As for the previous research segment, the opportunities in some way represent a solution to the barriers and were: 1) creation of national infrastructures, interactive and web-based, for the communication of soil data, 2) improving the communication on soil relevance for society; 3) activation of peer2peer training programs for farmers and advisors.

For knowledge harmonization, organization, and storage 21 main barriers and 16 opportunities were identified. Among the most indicated barriers (by 62% of the participating countries) three main areas were identified: uneven methodologies for soil sampling, analysis, mapping and storage; information on soil is outdated, dispersed, and fragmented; soil data policy is unevenly managed across Europe, without permission of data access in many countries for the general public. How to overcome these barriers is indicated by the 76% of the participating countries, in the following opportunities: 1) creation of national infrastructures and interactive web-based communication of soil data; 2) promotion of harmonization and standardization methodologies; and 3) validation and integration of large data sets by using new ICT tools.

For knowledge application, 27 main barriers and 28 main opportunities were identified. Respondent most indicated barriers (by 46% of the participating countries) were: 1) expectations on yields and profits might not be reached; 2) policies and incentives are not well designed;3) there are technological constraints (e.g., internet access in rural areas) and the preference of traditional practices or gender gaps); 4) the presence of institutional and legal barriers. The most indicated opportunities (by 60% of the participating countries) focused on the development of region-specific soil management strategies, the design of appropriate policies and incentives with effective policy measures; the availability for farmers of ICT tools and the knowledge to exploit them'.

Overall, our results showed that there are many areas of improvement of soil research to respond adequately to the soil challenges. Barriers are identified in cultural, organizational, legal/institutional, economic, and political obstacles, not allowing a proper development of new knowledge and exploitation of the efforts put in research. The main issues point to inadequate communication and exchange of information among actors, also linked to harmonization of terminology, methodology, data handling and sharing. The flux of knowledge along the 4 segments (i.e., development, transfer and sharing, harmonization, organization and storage, and application, Fig. 1) is slowed by several bottlenecks, whose removal appears as the main strategy to increase the opportunities.

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The increase of funding for research, long-term experiments, and education, together with the creation of knowledge networks and national infrastructure linked to those operating at European level, and the development of regional tailored soil management strategies can be promising opportunities to successfully overcoming soil challenges.

Some of the barriers/opportunities highlighted by the respondent are already encompassed in the different activities of EJP SOIL (long term experiment, creation of networks including science, policy and society, creation of harmonized databases on soil properties across Europe), several of the opportunities go beyond EJP SOIL scope (e.g. the creation of national soil infrastructures, improving communication between researchers and farmers) where the Program will offer a starting opportunity, and provide a basis for future European and national programs and projects.

1. Introduction

Soils can provide most of the ecosystem services to humankind. These include provisioning services (e.g., food and fuel), regulating services (e.g., flood mitigation and water purification), supporting services (e.g., soil formation and nutrient cycling) and cultural services (e.g., recreation, aesthetic value) (http://www.millenniumassessment.org/en/Framework.aspx). There is a consensus that healthy soils are pivotal for food security (Amundson et al., 2015). Soil health is an integrative property that reflects the capacity of soil to respond to agricultural intervention, so that it continues to support both the agricultural production and the provision of other ecosystem services. The major challenge within sustainable soil management is to conserve ecosystem service delivery while optimizing agricultural yields. The United Nations put food security (end poverty and hunger, in all their forms and dimensions) as the most critical challenge facing humankind. In 2015. 193 World Governments at the General Assembly of the United Nations adopted, for achievement by 2030, Seventeen Sustainable Development Goals (SDGs) (United Nations, 2015, THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT). The soil plays a primary role in the SDGs addressing hunger, water quality, climate mitigation and biodiversity preservation, and a secondary relevance for other SDGs (Visser et al., 2019, Bouma and Montanarella, 2016). Soils, and their ability to support the sustainable intensification of agriculture, will play a central and critical role in delivering food security.

In this context, advancing soil science research presents various challenges and the discrepancy between societal needs and state-of-the-art on soil knowledge need a mutual effort to improve soil knowledge (Mol and Keesstra, 2012). "*The question then has to move from 'how farmers learn a new technique most efficiently, to how farmers, scientist and advisors can collaborate, re-negotiate existing and co-create new meanings for soil erosion and soil conservation*" (Schneider et al, 2009).

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The European Joint Program EJP-SOIL aims to boost the contribution of soil to tackle the key challenges for society: climate change mitigation and adaptation; sustainable agriculture production; enhanced ecosystem services provisioning, regulating, and supporting; soil restoration and avoiding degradation. EJP-SOIL considers the creation of an integrated framework for soil research in Europe as pivotal, to support harmonization of capacity, capability, and knowledge for all EJP SOIL Countries, enabling all countries to use the knowledge about soil to face the global challenges. Within the WP2-*Developing a Roadmap for EU Agricultural Soil Management Research*, the specific objective of Task 2.3 is the identification and prioritization of barriers[1] and opportunities[2] for the enhancement of knowledge on agricultural soils. The task contributes to the general objective of the program by favouring the integration of research (WP3), data harmonization (WP6), collaboration in training and education (WP5) and integration of knowledge into policy development (WP8) across partner organizations and participating countries. Task 2.3 contributes also to the roadmap, defining the knowledge needs/gaps and expectations of each European Environmental Zone (EEZ) and Geographical Zone (GZ), implemented annually, as well as a 10-year strategic research agenda which will support the sustainability of the developed EJP framework beyond the project time.

Knowledge can be defined as the sum of what is known on a specific matter. To make this broad concept usable for EJP-SOIL, a knowledge framework has been developed. The four segments of knowledge are: i) knowledge development, ii) knowledge harmonisation, organisation & storage iii) knowledge sharing & transfer, and iv) knowledge application (modified from the Knowledge management framework by Dalkir (2005[3]). These four segments are part of a cyclic process to enhance the development and use of knowledge on agricultural soils (Fig. 1).

In detail knowledge development refers to the provision of new knowledge and innovation, in our case related to agricultural soil.

Knowledge sharing & transfer refers to the enhancement of scientific capacities and cooperation, soil networks for scientists' establishment, science-policy and science-society interactions, and capacity building for young soil scientists and societal stakeholders, i.e., farmers and advisors, policy makers, landowners and managers, civil society and industry.

[1] A barrier is any element or action that hinders the achievement of an aspiration. In our specific case, we focus on the barriers that hinder the achievement of aspirations in the soil challenges by knowledge and knowledge use on agricultural soils.

[2] an opportunity is any element or action that favour the achievement of an aspiration. Specifically, we focus on the opportunities that enhance and favour the achievement of aspirations in the soil challenges by knowledge and knowledge use on agricultural soils.

[3] Dalkir, K. (2005). Knowledge Management in Theory and Practice (1st ed.). Routledge. https://doi.org/10.4324/9780080547367

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Knowledge harmonization, organisation, and storage of soil information. In details it refers to (i) improvement of data harmonization and standardisation of soil sampling methods, analysis and mapping; (ii) methods to monitor soil fertility and quality; (iii) improvement of inventories, reporting and accounting activities at different scales; (iv) improve EU contributions to global soil mapping activities, and (v) facilitate sampling and further development of LUCAS.

Knowledge application refers to the use of available knowledge on agricultural soil to make decisions and develop guidelines, decision support systems, certification systems. This knowledge framework has a direct relation with the workflow in EJP SOIL.

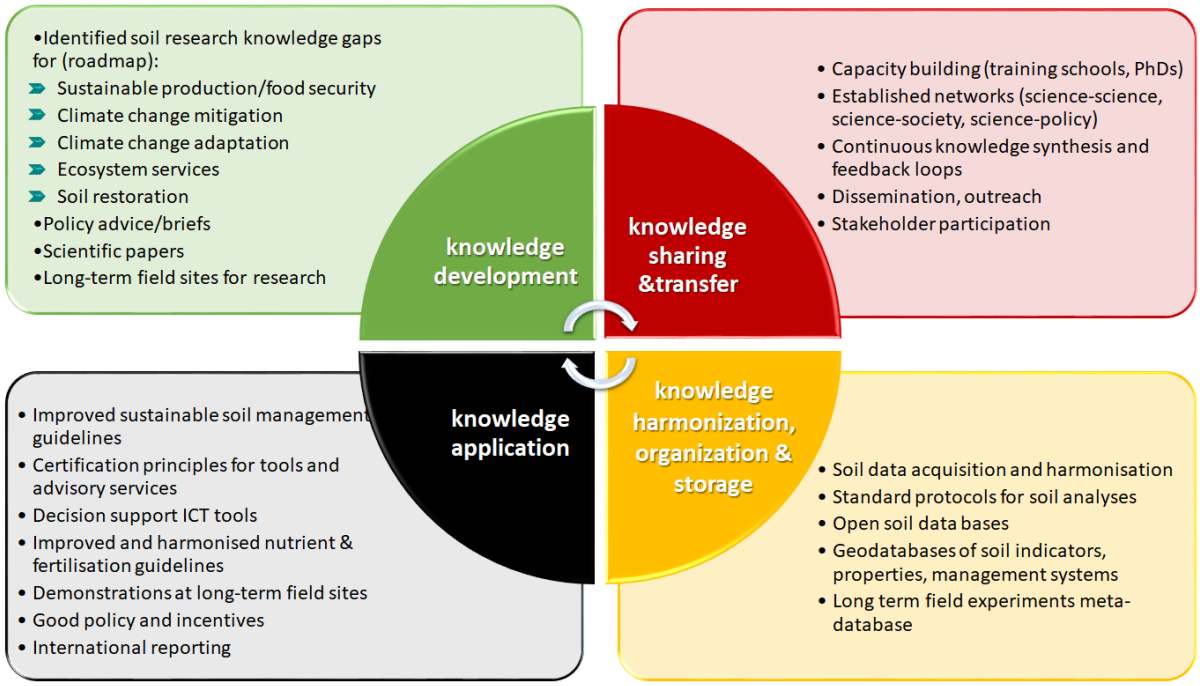

***Figure 1**: The EJP SOIL knowledge framework (adapted after Dalkir, 2005) comprising of four segments: Knowledge development, knowledge sharing & transfer, knowledge harmonization, organization & storage and knowledge application. The four segments are part of a cyclic process to enhance the development and use of knowledge on agricultural soils.*

In EJP-SOIL a soil concept framework was developed, linking management practices, soil challenges, soil functions with the EJP-SOIL research domains (Figure 2). In this framework the role of soil challenges in enhancing or reducing the soil functions is presented.

A total number of nine aspirations for soil challenges, i.e., the desirable evolution of the main properties characterizing the soil status for enhancing soil restoration and preserving its functions, have been identified. They can be split into two main groups: those that need to be improved and those that need to be avoided. In the first group, the soil characteristic to be improved/conserved includes soil organic matter and peat soil, water storage capacity, nutrient retention or use efficiency,

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soil biodiversity and disease suppression. In the group of the phenomena and characteristics to be avoided, we include GHG emissions, erosion (water/wind/tillage), salinization and acidification, soil sealing and soil compaction. In these latter categories, we can also include soil contamination.

In Task 2.3, aiming to overcome soil challenges and to contribute to the EJP-SOIL goals, barriers to and opportunities for the soil knowledge sector were assessed by national surveys and summarised at European level.

To this end, the national contacts were provided with a template to guide the preparation of the national questionnaires and to report the outcome of national surveys, designed within the WP2 and presented to all participants in a webinar held on June 8, 2020.

The survey was organized to let emerge firstly the priority soil challenges for each Country and EEZ (Figure 4) and then to investigate the perception of the partners on barriers to and opportunities for knowledge, linked to the possibility to overcome those main soil challenges, as indicated in Figure 2.

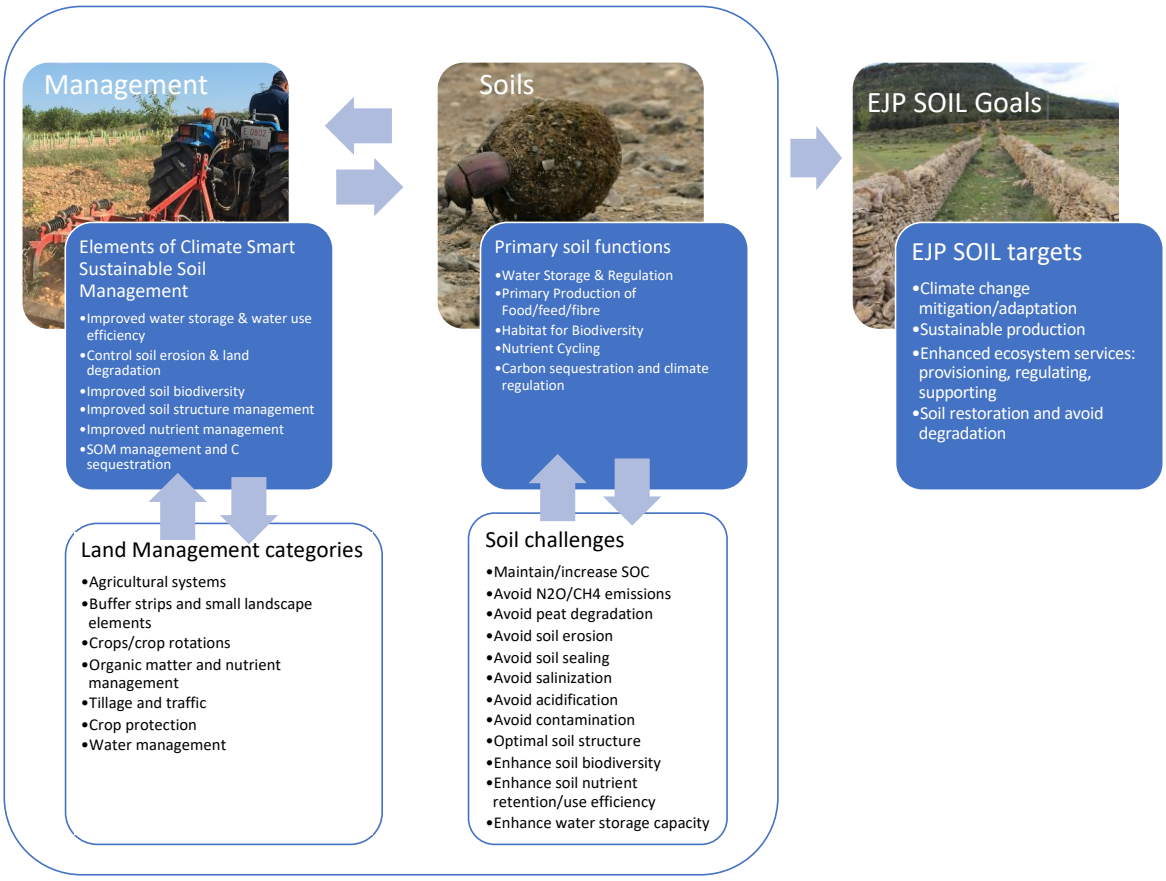

Figure 2: *EJP-SOIL: soil concept framework.*

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2. Materials and Methods

Data collection for the assessment of barriers to and opportunities for soil knowledge to overcome soil challenges and contribute to EJP-SOIL research domains was firstly conducted at national level. The process was organised in 5 steps:

1. preparation of guidelines for the participating countries and release of the template for reporting the results of the survey;
2. design of the national questionnaires, to collect all information required by the template for national reporting for task 2.3;
3. carry out the interviews of national stakeholders, collecting the soil challenges prioritisation, the relevance of EJP-SOIL goals and the relevant information on knowledge barriers and opportunities to overcome the soil challenges;
4. collation of data in the template, performed by each national contact person;
5. harmonization and analysis of national data and reporting at European level.

To acquire the necessary relevant information, predefined questionnaires with rigid fields and pre-set answers were not proposed from the Task leader's team. It was considered most appropriate to design the survey so that the stakeholders' ideas and opinions about the topics could emerge. Indeed, in each Country differences in sensitivities, cultures and social features are present, and national teams can exploit at best their knowledge on the stakeholder community without superimposed formats. Translating questionnaires in each native language often demonstrated to be a very critical and possibly biased process. Thus, each national contact person was asked to design his/her national interview coherently to the template, to collect the relevant information required from the protocol. General guidelines (Annex 1) and the template to be filled in by all participant Countries were provided. The template, available at https://www.dropbox.com/scl/fi/nosj88w5mcgl3hkuaca2h/Template_EJPS_T2_3_Member_Country_Report_Last-2.xlsx?dl=0&rlkey=3erzb6vug1hzohu17w29b44cr, released as a spreadsheet, was organised in several sections. The first section (A) was aimed at collecting general information about the Country, and the criteria adopted for stakeholder selection. The second section (B) was designed to collect stakeholders' personal information, such as gender, age, education, job. Moreover, each stakeholder was asked to identify which were the priority soil challenges for their Country/EEZ, by giving an order of importance from 1 to 6. In section C each stakeholder was required to identify the priority obstacles and opportunities that the research compartment must remove and enhance respectively, to reach the soil challenges aspirations. Eventually, in section D each stakeholder was

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firstly required to report the relevance of each soil challenge for his Country to contribute to the EJP-SOIL research domains - from highly relevant to not relevant. Subsequently, stakeholders were asked to define which are, in their opinion and separately for each soil challenge, the obstacles to be removed and the opportunities to be seized for the research sector. Dropdown menus with predefined answers were proposed (we called them *Tips*), but open answers were allowed. A schematic view of the workflow for Task 2.3 is reported in Figure 3.

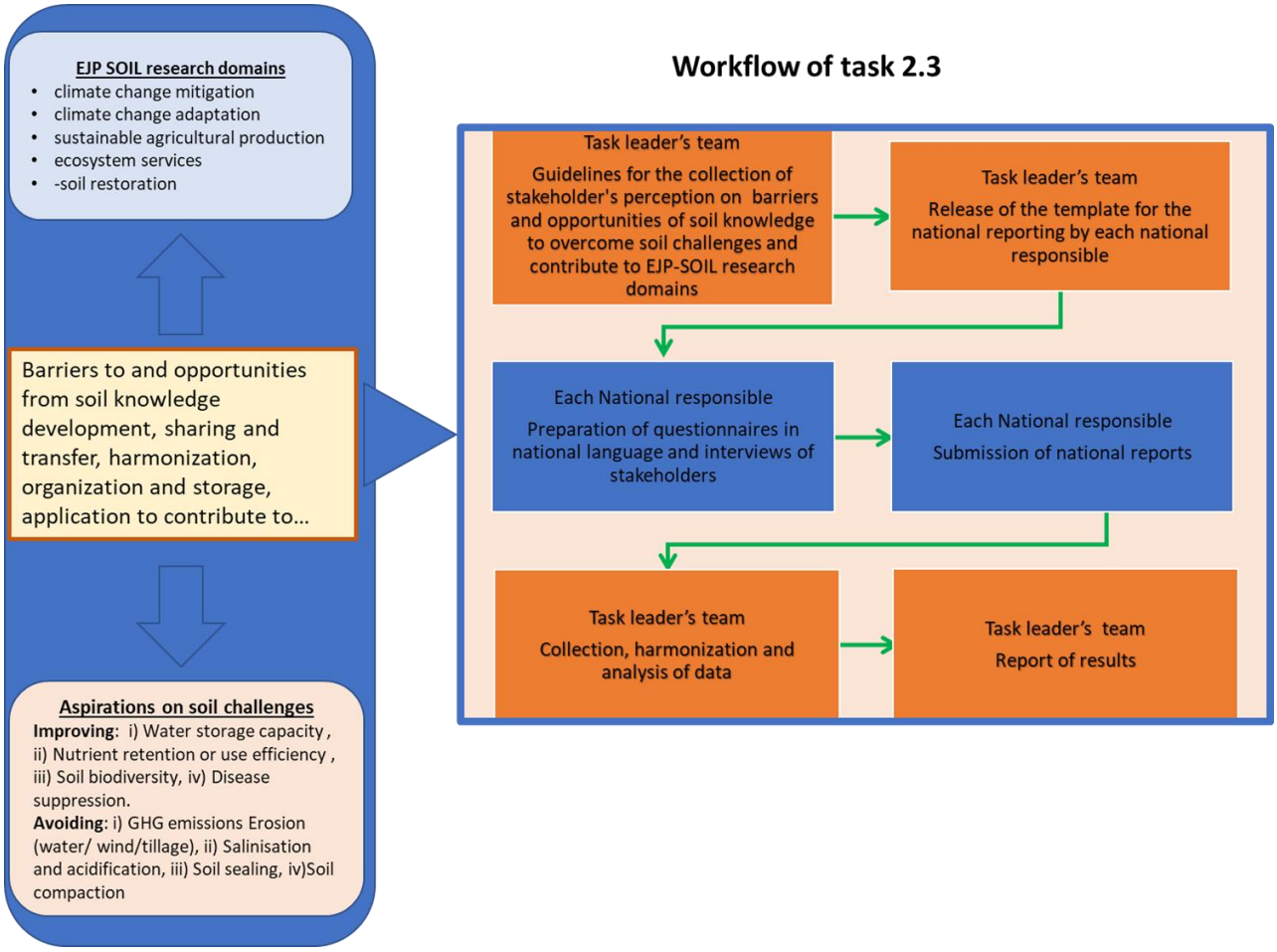

Figure 3: *Workflow of EJP-SOIL task 2.3.*

The data were collected by Country, but it was also required to indicate the EEZs (Metzger et al., 2012[4], Figure 4) to which the challenges and research barriers and opportunities referred to.

The data analysis was performed by clustering and aggregating the results by Country, GZ (Figure 5) and EEZ (Figure 4).

[4] Metzger, M.J., Shkaruba, A.D., Jongman, R.H.G., Bunce, R.G.H. (2012). Descriptions of the European Environmental Zones and Strata. Alterra Report 2281, Wageningen.

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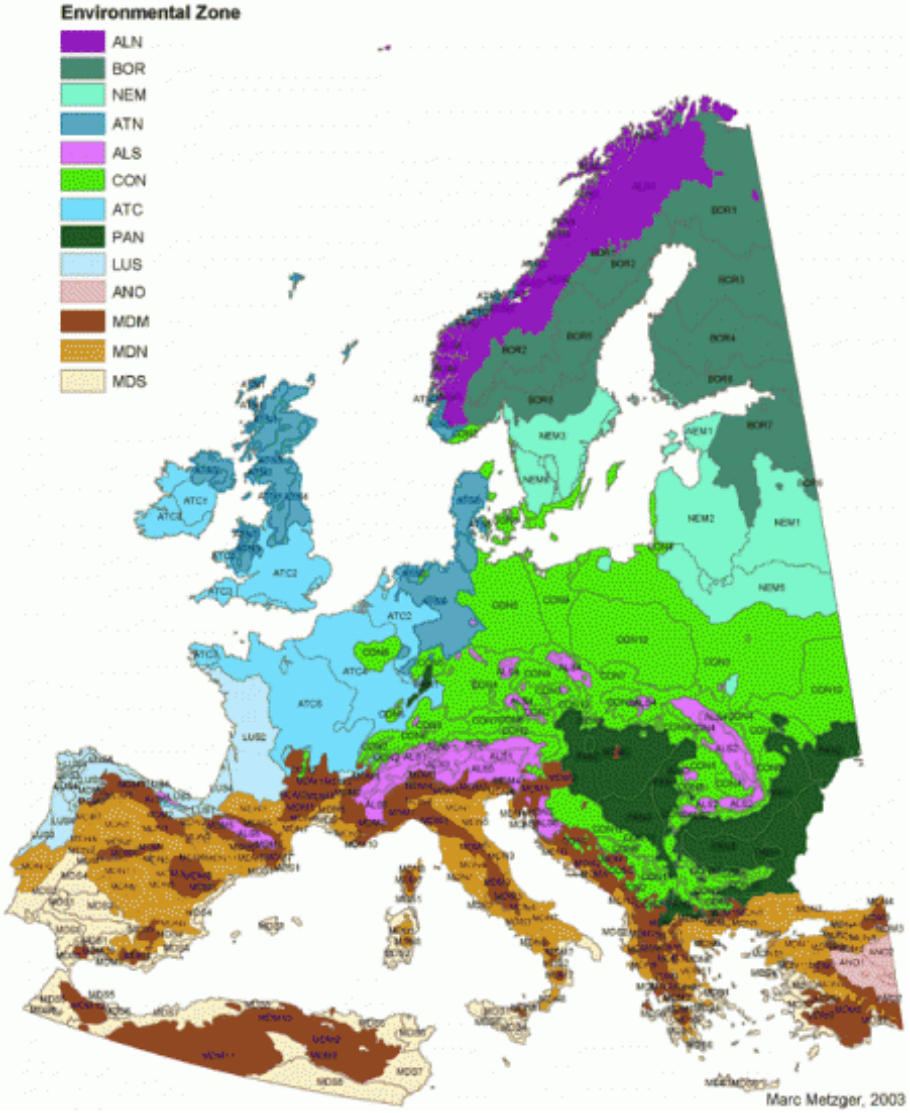

Figure 4: *Map of the main Environmental Zones of Europe-EEZ (based on Metzger et al., 2012).*

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Figure 5: *Map of the Geographical Zones considered in EJP-SOIL.*

Since the interviews and the reports were driven by the template structure (Annex 1), this allowed for a better data collection and analysis. Descriptive statistic was performed on the results, displayed using tables, graphs and maps.

Collected data were organized in two databases: one included the results of sections A and B of the template, and the other included other information from sections C-D.

The data were clustered by Country, GZ and EEZ.

3. Results and discussions

3.1. Countries, GZs, EEZs and stakeholders

Countries participant to the survey were 20 over 24: Austria, Belgium (Wallonia and Flanders), Denmark, France, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, The Netherlands, Turkey, United Kingdom - for a total of 324 stakeholders interviewed, whereas Estonia, Finland, Germany and Czech Republic did not participate. All the EEZs were represented, except for ALN (Alpine North), as reported in Table 1.

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Table 1: *Number of stakeholders for each participating country and related European Environmental Zones*

Country	Geographical Zone	European Environmental Zone	N. of stakeholders
Austria	Central Europe	Continental (CON)	9
Belgium Wallonia	Western Europe	Atlantic Central (ATC)	13
Belgium-Flanders	Western Europe	Atlantic Central (ATC)	13
Denmark	Northern Europe	Alpine South (ALS)	11
France	Western Europe	Atlantic Central (ATC)	5
		Lusitanian (LUS)	5
		Mediterranean North (MDN)	5
		Mediterranean Mountains (MDM)	5
Hungary	Central Europe	Pannonian (PAN)	15
Ireland	Western Europe	Atlantic Central (ATC)	5
Italy	Southern Europe	Mediterranean South (MDS)	2
		Mediterranean North (MDN)	14
		Mediterranean Mountains (MDM)	4
Latvia	Northern Europe	Nemoral (NEM)	56
Lithuania	Northern Europe	Nemoral (NEM)	10
Norway	Northern Europe	Boreal (BOR)	7
Poland	Central Europe	Continental (CON)	10
Portugal	Southern Europe	Mediterranean South (MDS)	10
		Lusitanian (LUS)	7
		Mediterranean North (MDN)	8
Slovakia	Central Europe	Continental (CON)	9
Slovenia	Central Europe	Alpine South (ALS)	26
Spain	Southern Europe	Mediterranean North (MDN)	20
Sweden	Northern Europe	Nemoral (NEM)	3
Switzerland	Central Europe	Continental (CON)	16
The Netherland	Western Europe	Atlantic North (ATN) and Atlantic Central (ATC)	12
Turkey	Southern Europe	Anatolian (ANA), Mediterranean South (MDS), Mediterranean North (MDN), Mediterranean Mountains (MDM)	4
United Kingdom	Western Europe	Atlantic North (ATN)	17
		Atlantic Central (ATC)	8
Total			**329**

Researchers, farmers, and farmer associations were the most represented groups within the stakeholders, with 95 and 81 respondents respectively, followed by 50 public administrators and 42 advisory/technicians. Other categories were less represented, i.e., middle and higher educational institutions (29), NGOs and agroindustry (only 3 respondent each). (Figure 6) In 44 interviews the stakeholder's group was reported either as "Other" (29 respondent) or not indicated, often because

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the results presented were the synthesis of a survey conducted at a more detailed level. (e.g., The Netherlands). Results are reported in Figure 6.

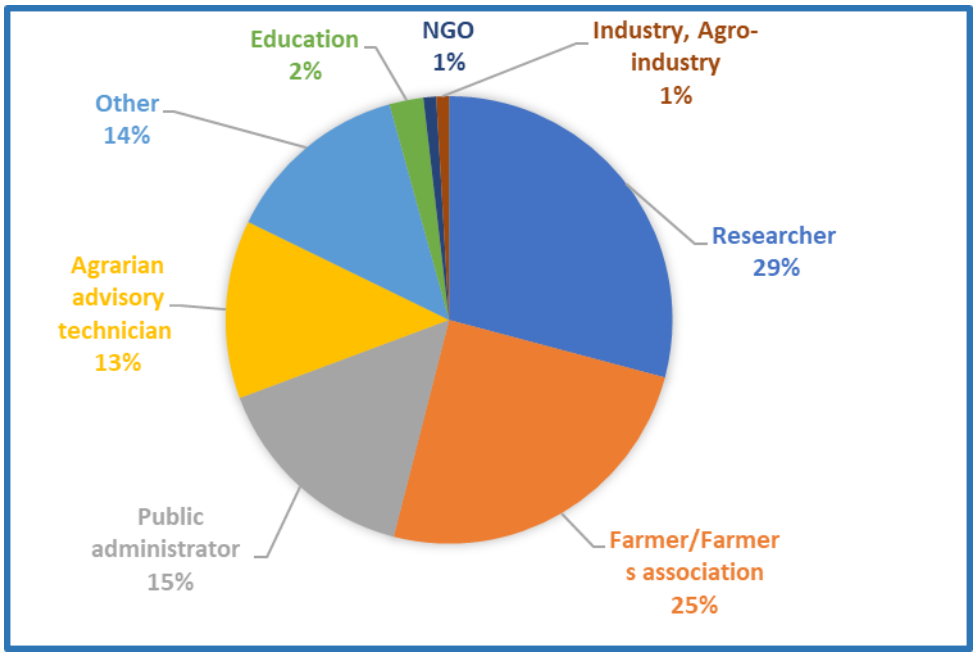

Figure 6: *Pie chart representing the rate of the different stakeholder groups across all partners.*

3.2. Priority soil challenges

The stakeholders were asked to score the soil challenges for their Country and EEZ giving a priority from 1 to 6. Results are reported in the following chapters. Different stakeholders valued the soil challenge priority differently.

Most of the stakeholders indicated the conservation of soil organic matter and peat soils as the first priority (34% of the interviewees), followed by the improvement of water storage capacity and water regulation (16%). The reduction of soil sealing, and the improvement of nutrient retention was a priority for 10% of the interviewed stakeholders. Reducing erosion and soil compaction, improving soil biodiversity, and reducing GHG emissions was a priority for 8, 7, and 6% of the respondents, respectively. Improving disease suppression and avoiding salinization, acidification and contamination were the most important soil challenges only for 1% of the stakeholders (Figure 7).

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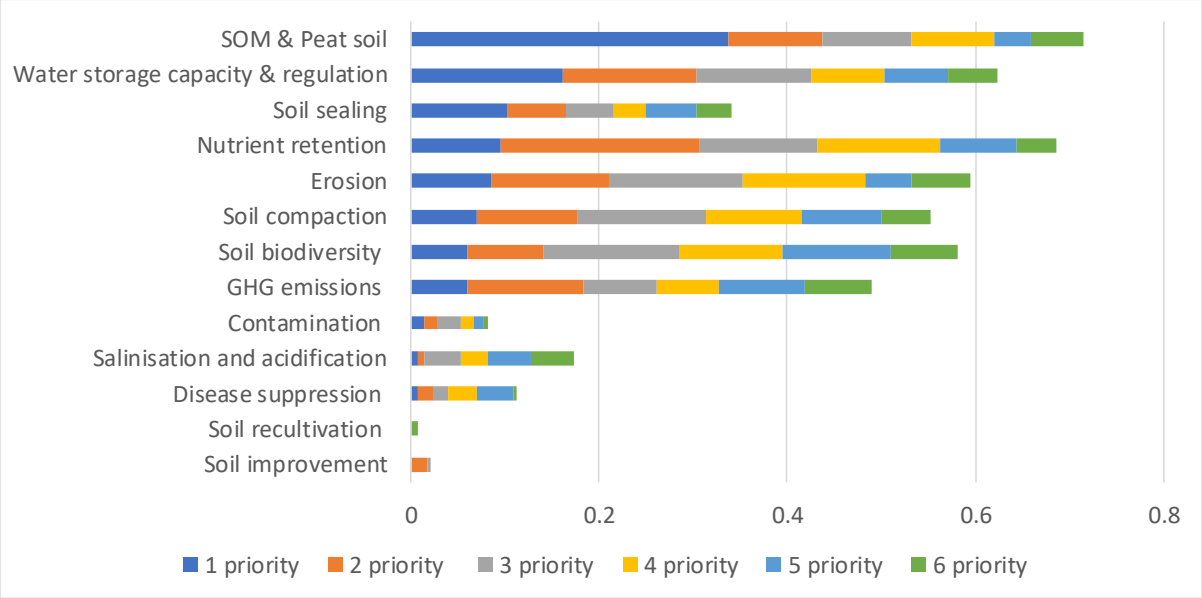
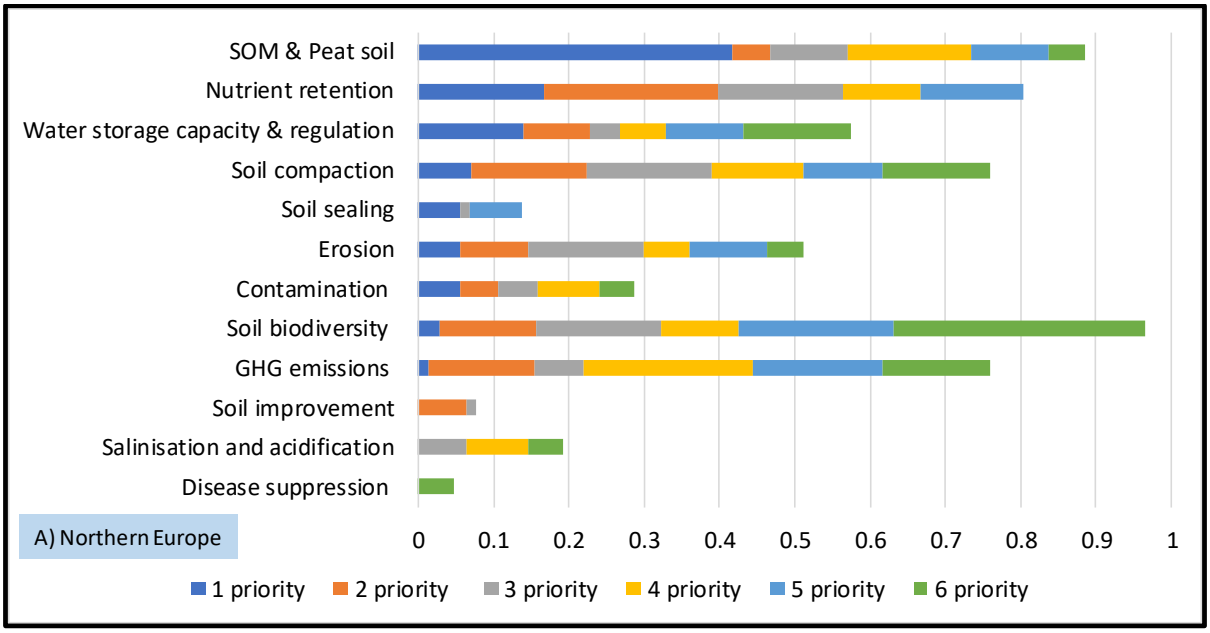


Figure 7: *Priorities in order of importance across Europe.*

Aggregating results for the 4 main GZs of Europe, i.e., Northern, Central, Western and Southern (Figure 8), showed that improving soil organic matter was the first soil priority for all zones except for Southern Europe, where instead improving water storage capacity was considered as the first priority.



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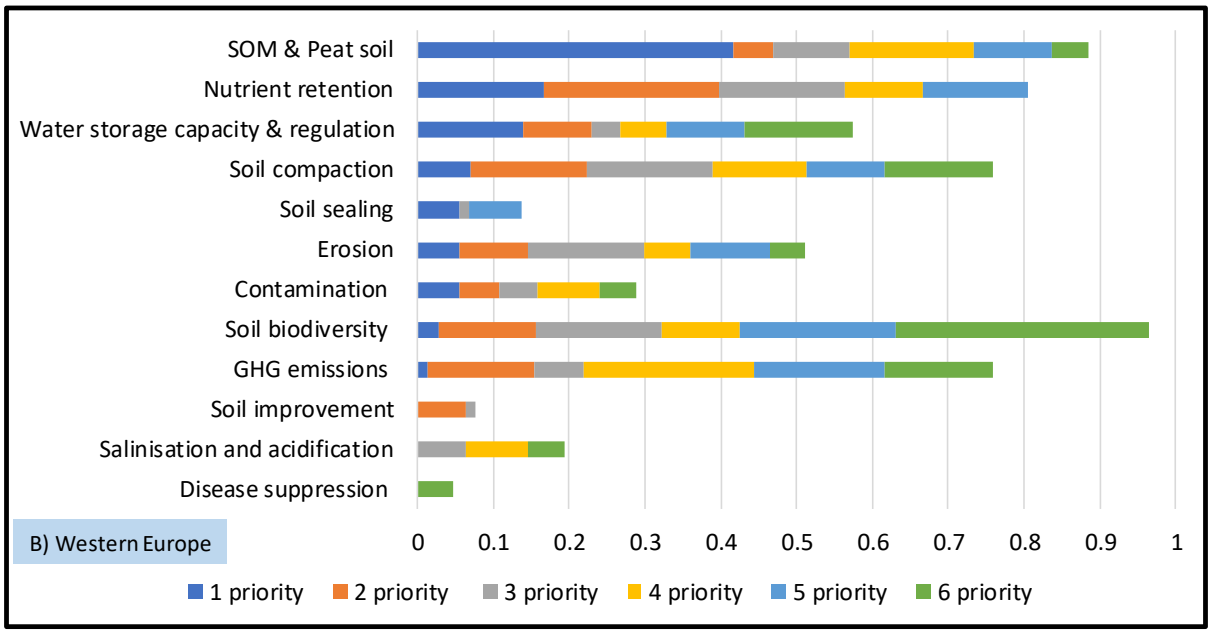

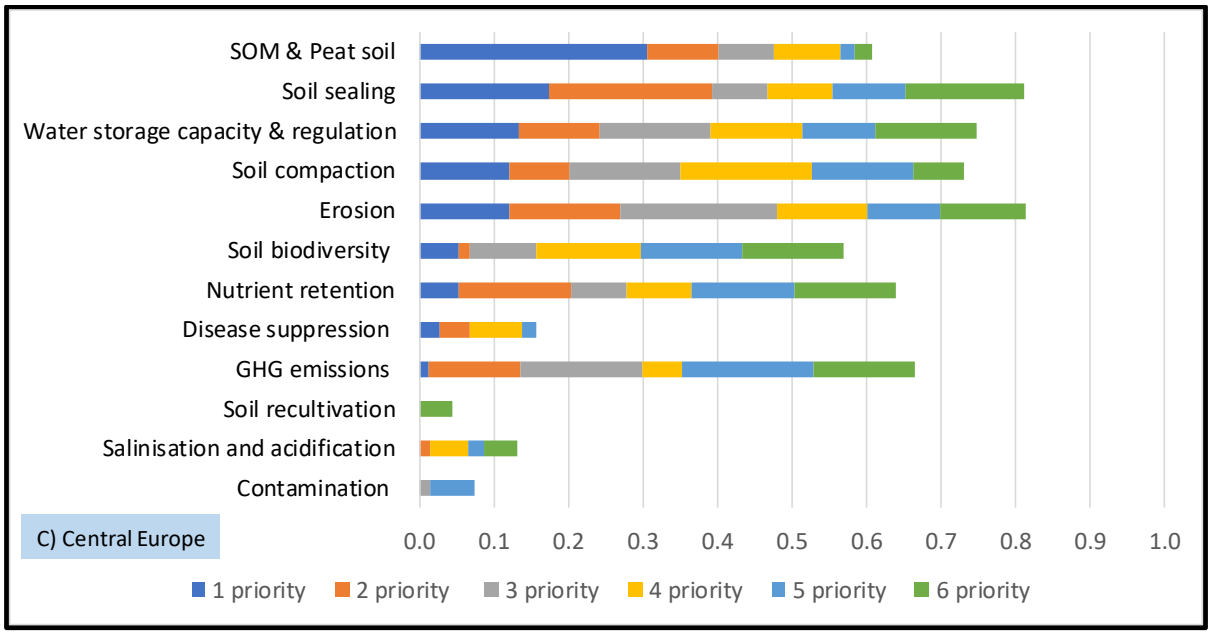

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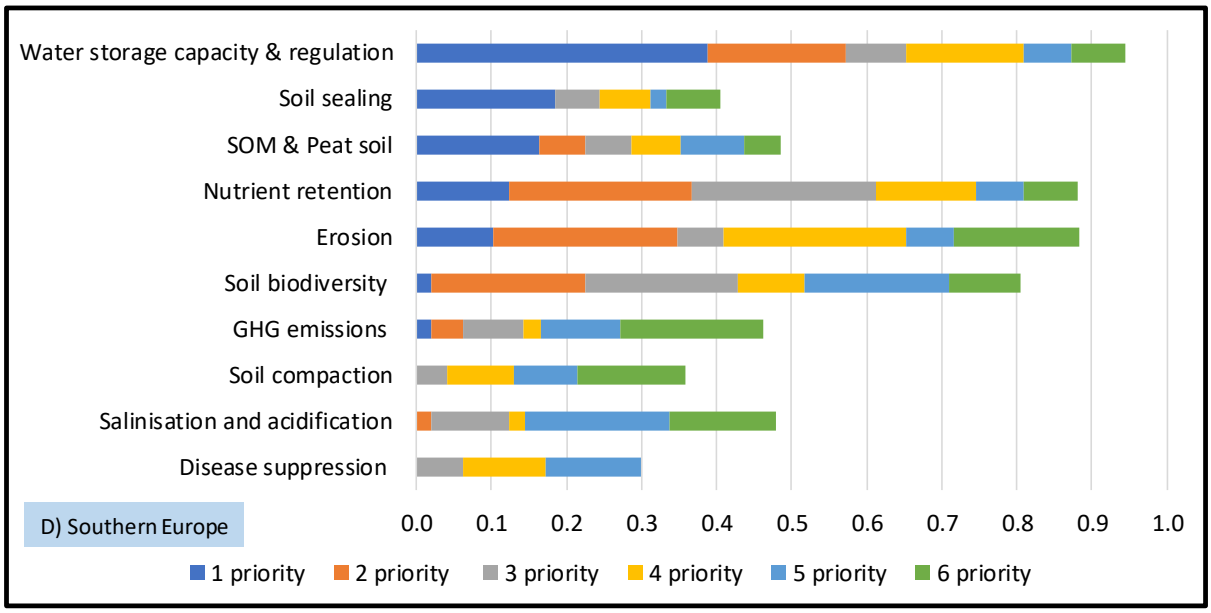

Figure 8: *Priorities for the main geographical zones of Europe: A) Northern Europe; B) Western Europe, C) Central Europe, D) Southern Europe.*

At EEZs level, the results of the interviews showed a very diversified perception of priority soil challenges, in which the soil challenges appear closely linked to the soil and climatic conditions (Atlantic). For example, for MDS, MDM, ANA and LUS the priority soil challenges were avoiding erosion and improving water storage capacity. MDN stakeholders put as the most important soil challenges soil sealing and soil compaction. Moving towards central and northern Europe (LUS, ATC, ATN, CON), other priorities arise, such as the conservation of soil organic matter and peat soils, soil compaction and nutrient use efficiency. In northern Europe avoiding soil sealing and preserving soil organic matter and peat soil prevailed among all the other soil challenges (**Figure 9**). Some soil challenges were specific for some EEZs, e.g., soil contamination was mentioned only in NEM, BOR and ATC. In some EEZs (PAN, MDS) stakeholders gave a relative importance also to the improvement of the disease suppression capacity of soils.

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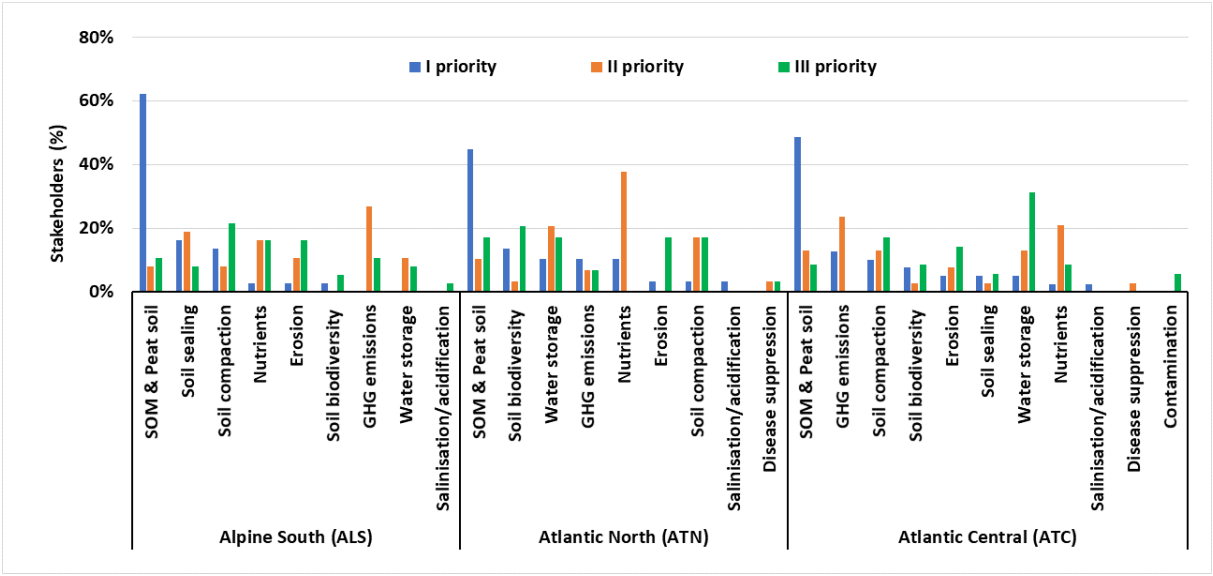

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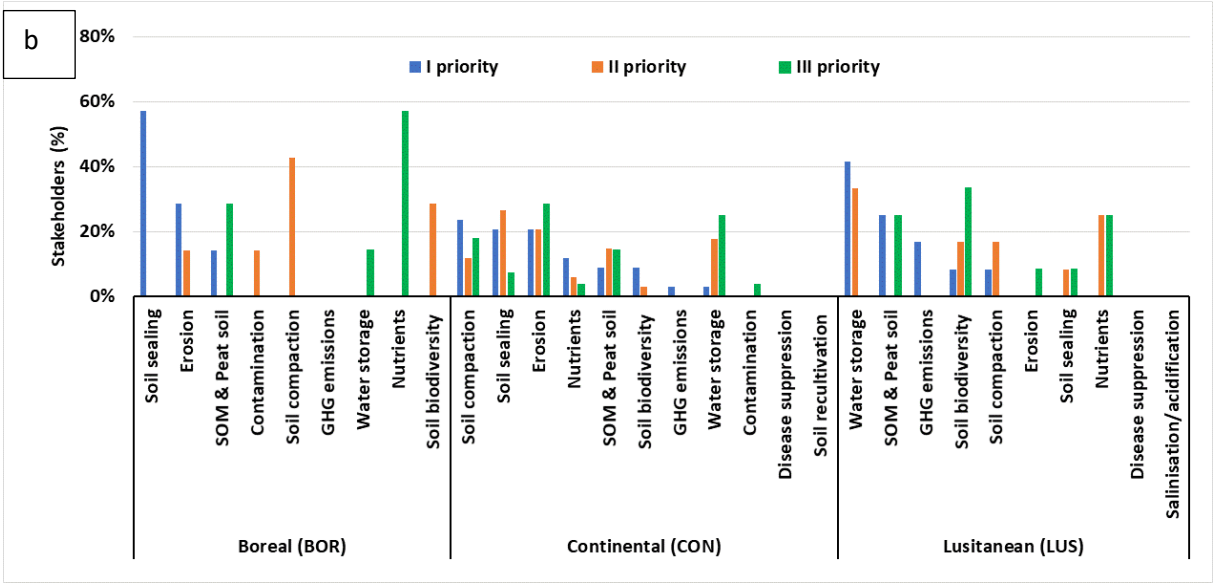

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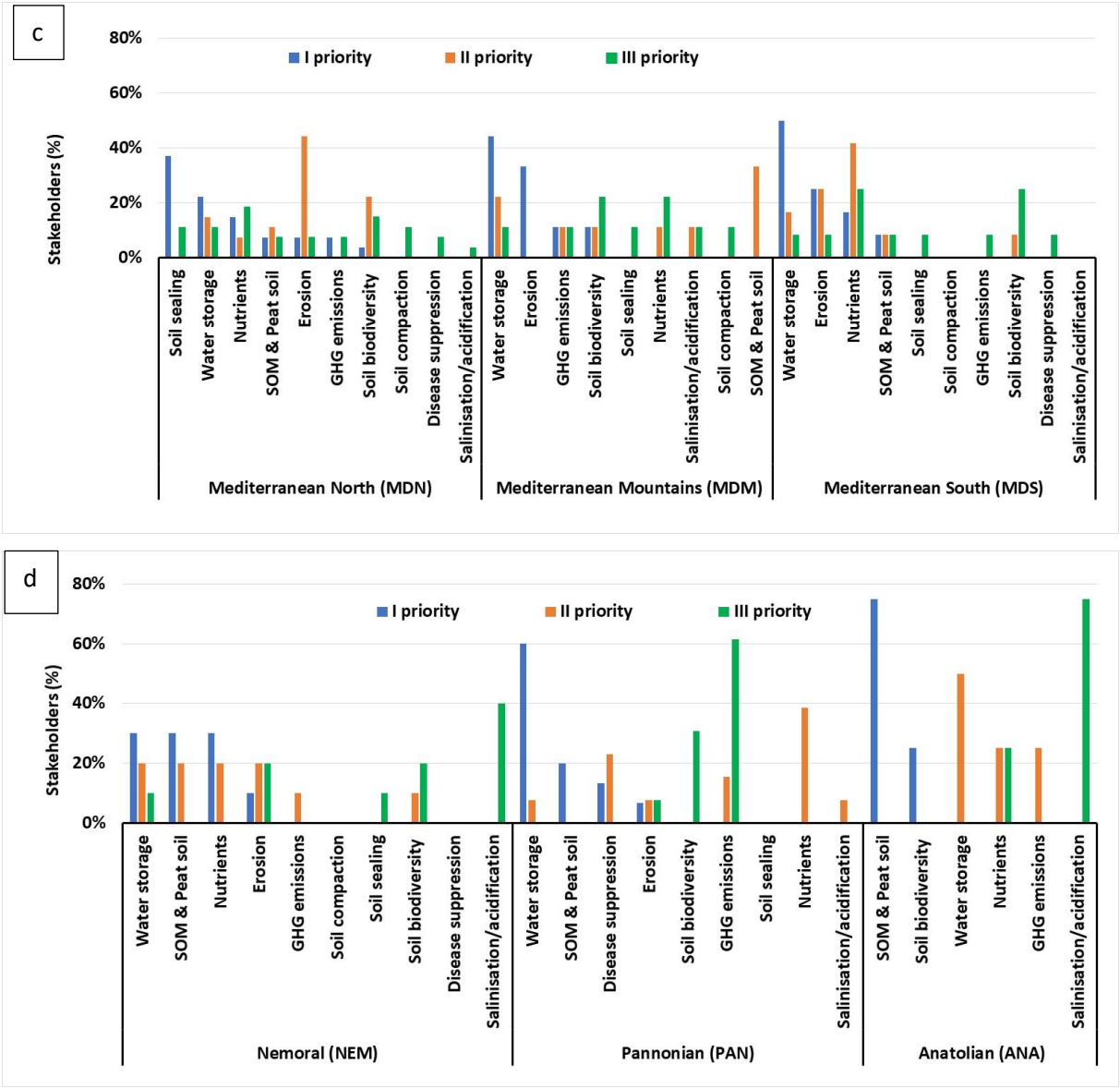

***Figure 9**: Soil challenges in order of importance (as % of answers) indicated by stakeholders for the EEZs: a) Alpine South (ALS), Anatolian (ANA), Atlantic Central (ATC); b) Atlantic North (ATN), Boreal (BOR), Continental (CON); c) Lusitanian (LUS), Mediterranean; d) Nemoral (NEM), Pannonian (PAN), Anatolian (ANA).*

As stakeholders were asked to indicate the soil challenges in order of priority, it was possible to evaluate the weighted importance of each of them. Figure 10*: Weighted importance of soil challenges across Europe* shows the result of the assessment, obtained putting together all information and weighting the position from 1 to 6 in order of importance given by the stakeholders. Position 1 was given a weight of 6, position 2 the weight of 5 and so on. The result confirms that improving soil organic matter is the most considered priority, followed by nutrient retention and improving water storage capacity. The weighted calculation highlights also that other priorities, such as soil biodiversity and

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erosion, even if not considered as first priority, are mentioned by many stakeholders as second, third or fourth priority (by 23, 41, 32 and 36, 40, 37 for biodiversity and erosion respectively) have an overall importance in the stakeholders' perception.

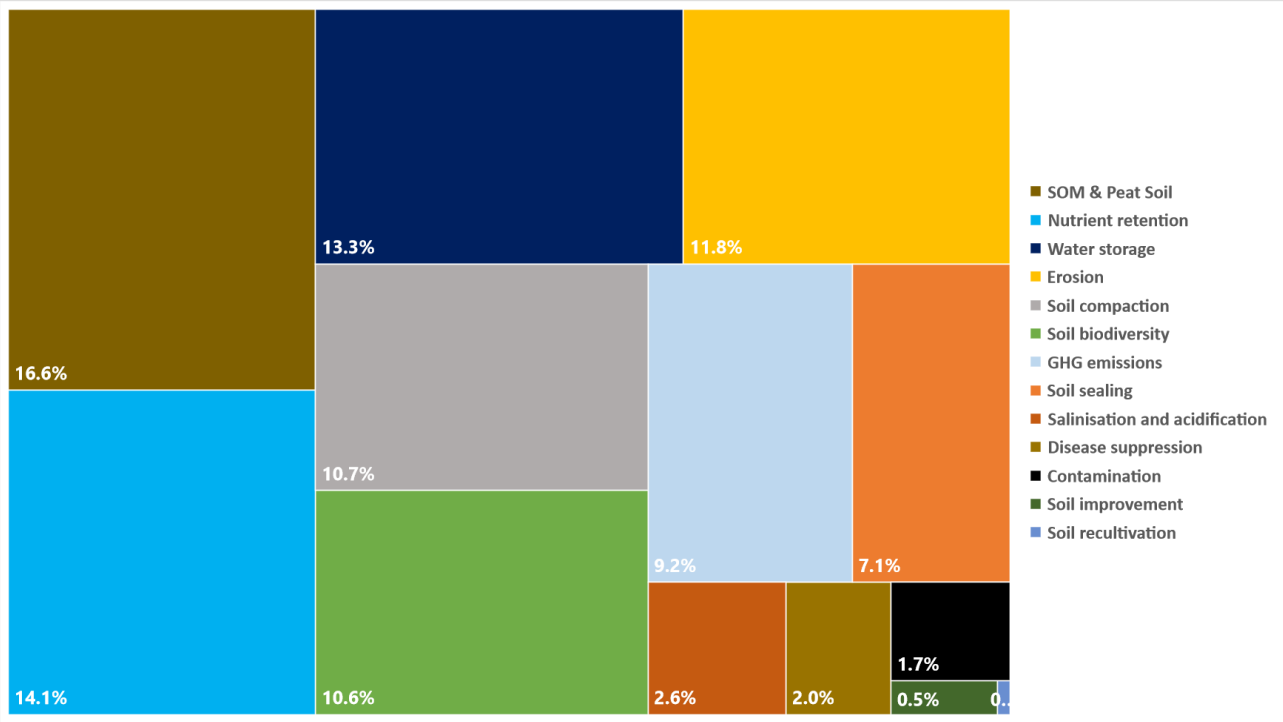

***Figure 10**: Weighted importance of soil challenges across Europe.*

3.3. Barriers and opportunities for knowledge

Twenty out of twenty-four Countries involved in the EJP-SOIL participated to the activity of WP2-T2.3, identifying the key elements of potential barriers and opportunities per each type of soil knowledge (i.e., development, sharing and transfer, harmonization and storage, and application). As reported in the Material and Methods (M&M) section, the participating countries were grouped by the four European GZs, i.e., Central (6), Northern (5), Southern (4), and Western Europe (6). Figure 11 shows the participation at Task 2.3 activities in percent, grouped by GZs. In details, all the participating countries included in the Western Europe and Southern Europe areas participated at the data collection (100%), followed by Central Europe (75%), and Northern Europe (71.4%).

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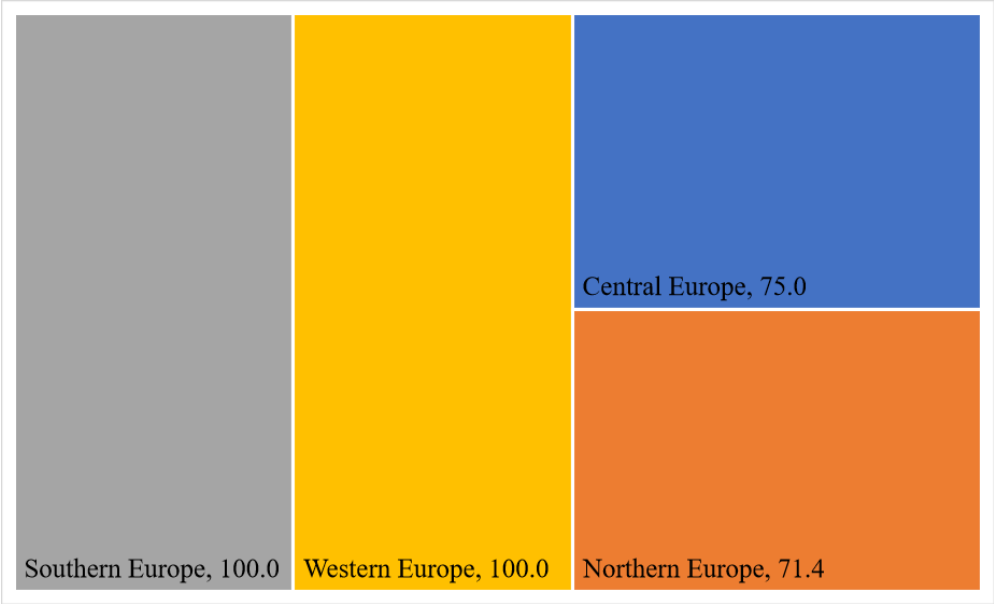

***Figure 11**: Participation of Countries at the Task 2.3 activities in percent, grouped by Geographical Zones.*

Barriers and opportunities, when possible and aiming to allow a qualitative and quantitative analysis, have been harmonized and then referred to a limited number of definitions. The answers not fitting in these definitions, were left in their original formulation and reported as such. In the following sections, the most relevant perceived barriers and opportunities per each type of soil knowledge are listed as summary matrices. Each summary matrix has two columns, one for the barriers and one for the opportunities.

Barriers and opportunities for knowledge development

For knowledge development, the summary matrix of the eleven most indicated elements by participating countries of EJP-SOIL as barriers and opportunities are reported in Table 2. In total, more than eleven barriers for knowledge development were indicated by the participating countries, as illustrated in Figure 12. The first five were indicated by 41.2% of the participating countries as illustrated in Figure 12. In details, 'Lack of relations among research, advisory services and farmers' and 'Financial resources allocated to soil research are not sufficient' were indicated by 9.9% of the participating countries, followed by 'Lack of public-private partnership on soil research' (7.4%), and 'Lack of training for advisors and farmers on soil-related issues' (7.4%).

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Table 2: *The first 11 barriers to and opportunities for knowledge development ordered by number of respondents.*

	Barrier	Opportunity
Knowledge development	1. financial resources allocated to soil research are not sufficient 2. lack of relations among research, advisory services and farmers 3. lack of public-private partnership on soil research 4. lack of training for advisors and farmers on soil-related issues 5. bottlenecks and lack of coordination among national/regional institutions within the research chain 6. institutions working on soil science are not enough 7. insufficient soil science education/research activities 8. selection processes and mechanisms for research projects are not appropriate 9. economic constraints 10. institutional/political bottlenecks and limitations 11. lack of funds for long-term trials/experiments	1. increasing funding for soil related research 2. supporting multi- and trans-disciplinary research 3. activate/valorise/fund long term experiments 4. increasing the number and improving curricula of soil science students 5. switch from top down to bottom-up research 6. supporting multi-actor research projects 7. increasing soil-specific training for farmers, advisors and other actors involved in soil issues 8. promoting start-ups 9. improving connection among researchers, farmers and advisors 10. enhance coordination among Ministries, Regions and National Agencies in the research chain 11. increasing training for farmers, advisors and other actors involved in soil issues

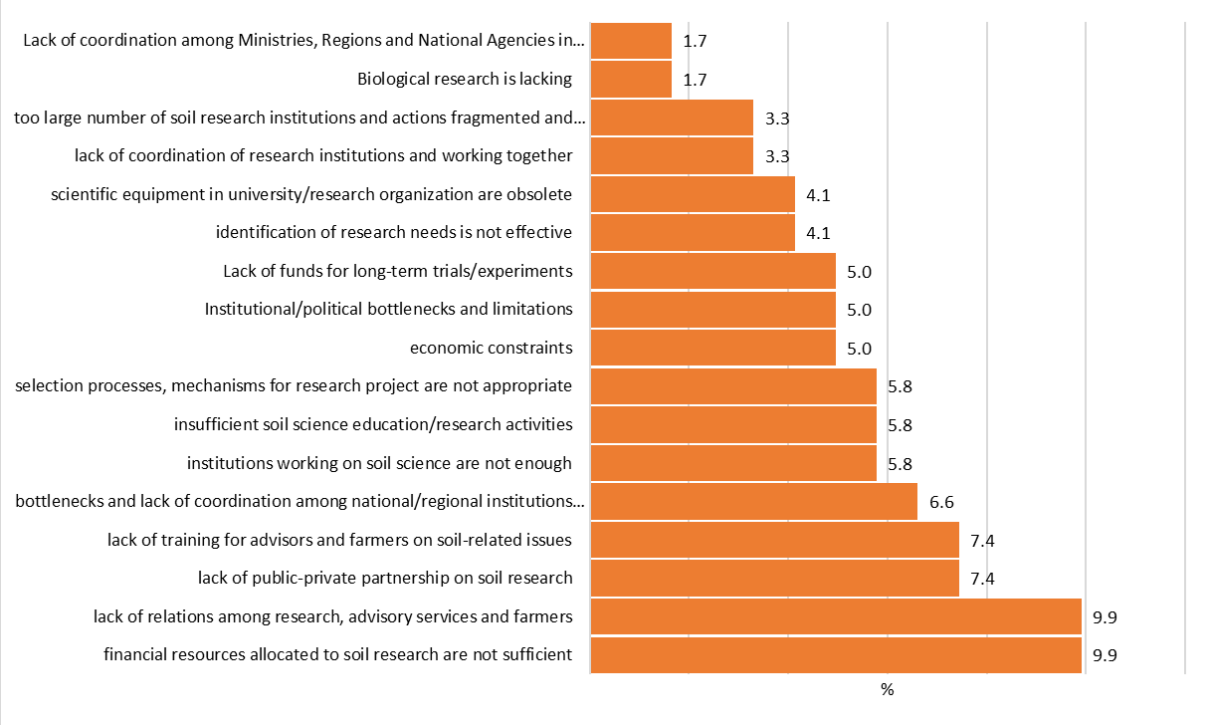

Figure 12*: Percentage of responses for the barriers to knowledge development indicated by the participant Countries.*

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Figure 13 shows the distribution of the ten most indicated barriers in the four GZs, as listed by participating countries. PCs within the Western Europe identified all of them, while in the other zones 8-9 barriers were identified (e.g. Southern, Central and Northern Europe). Three barriers were common for the PCs in all the GZs, although not homogeneously distributed among the zones. The two most indicated barriers (i.e., 'Lack of relations among research, advisory services and farmers', 'Financial resources allocated to soil research are not sufficient') were mainly identified in Western and Southern Europe, while some others in Central Europe (e.g., 'Institutional/political bottlenecks and limitations', and 'Identification of research needs is not effective').

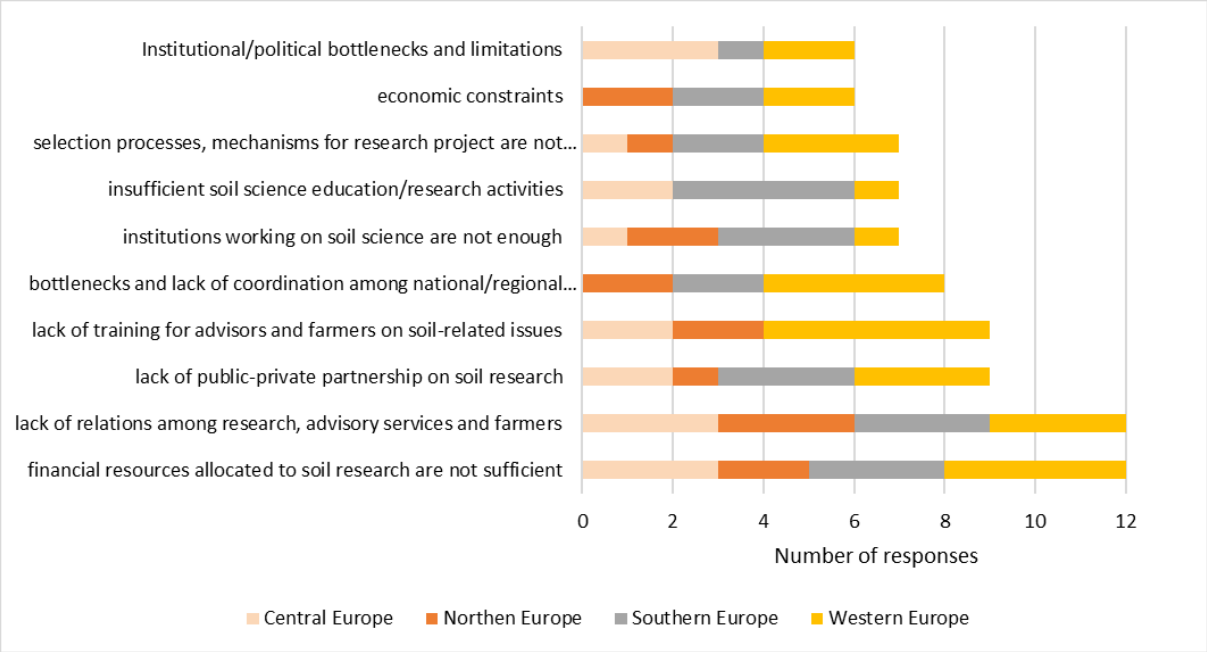

Figure 13: *Number of respondents for the most important barriers to knowledge development, grouped by Geographical Zones.*

Table 3 shows the twenty-seven barriers for knowledge development as listed by the participating countries of EJP-SOIL and grouped by GZs. PCs of Southern Europe identified most of the barriers (17 out of 25), followed by Central Europe and Northern Europe (15 each) and by Western Europe (14). As an example, in Southern Europe, one of the most indicated barrier was identified by all the PCs, while in Central Europe four of the most indicated barriers were identified by three out of five PCs. In detail, in all the GZs, the PCs identified 'Lack of relations among research, advisory services, and farmers' as an important barrier, although the weights of this barrier within the group of the GZs were different. This was identified by all PCs in Southern Europe, and by most of the PCs in the other zones, following this order: Western, Central, and Northern Europe.

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***Table 3**: Barriers to knowledge development identified by participating countries grouped by Geographical Zones. Per each barrier and Geographical Zone the value within the cell represents the number of countries that indicated the specific barrier, while the shades of orange show the relevance of the barrier (weight) inside the Geographical Zone: a light colour means that few countries indicated the barrier, a dark colour means that all countries of the Geographical Zone indicated the barrier.*

Barriers to knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Financial resources allocated to soil research are not sufficient	3	2	3	4
Lack of relations among research, advisory services and farmers	3	3	3	3
Lack of public-private partnership on soil research	2	1	3	3
Lack of training for advisors and farmers on soil-related issues	2	2		5
Bottlenecks and lack of coordination among national/regional institutions within the research chain		2	2	4
Institutions working on soil science are not enough	1	2	3	1
Insufficient soil science education/research activities	2		4	1
Selection processes, mechanisms for research projects are not appropriate	1	1	2	3
Economic constraints		2	2	2
Institutional/political bottlenecks and limitations	3		1	2
Lack of funds for long-term trials/experiments	3		3	
Identification of research needs is not effective	2	1	1	1
Scientific equipment in universities/research organizations are obsolete	1	1	2	1
Lack of coordination of research institutions and working together	3		1	
Too large number of soil research institutions and fragmented and not coordinated actions				4
Biological research is lacking	1	1		
Lack of coordination among Ministries, Regions and National Agencies in the research chain			2	
Barriers to orientation of agricultural policy	1			
Lack of a national soil database which is comprehensive, easily reachable for all user			1	
Lack of a sufficient number of researchers in universities/research institutions involved in the development of new knowledge			1	
Lack of young researchers and young farmers	1			
More international academic publications than national publications			1	
Site-specific interpretation required by farmers and growers				1
There is a lot of soil knowledge, but it is often not applicable, not known, or not considered as important		1		
Too much focus on nutrient management		1		
Lack of communication among research institutions and advisors (information and results are not well disseminated)		1		
Very large gap between research and real agriculture		1		

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More than sixteen opportunities for knowledge development were indicated by the PCs, as illustrated in Figure 14. The first four opportunities for knowledge development were indicated by the 47.9% of the PCs. In detail, 'Increasing funding for soil related research' was indicated by 14.2% of the PCs, followed by 'Supporting multi- and trans-disciplinary research' that cover 13.3% of the PCs. The 'Activate/valorise/fund long term experiments' opportunity was indicated by 12.4% of the PCs, while 'Increasing the number and improving curricula of the soil science students' was indicated by 8.0% of the PCs.

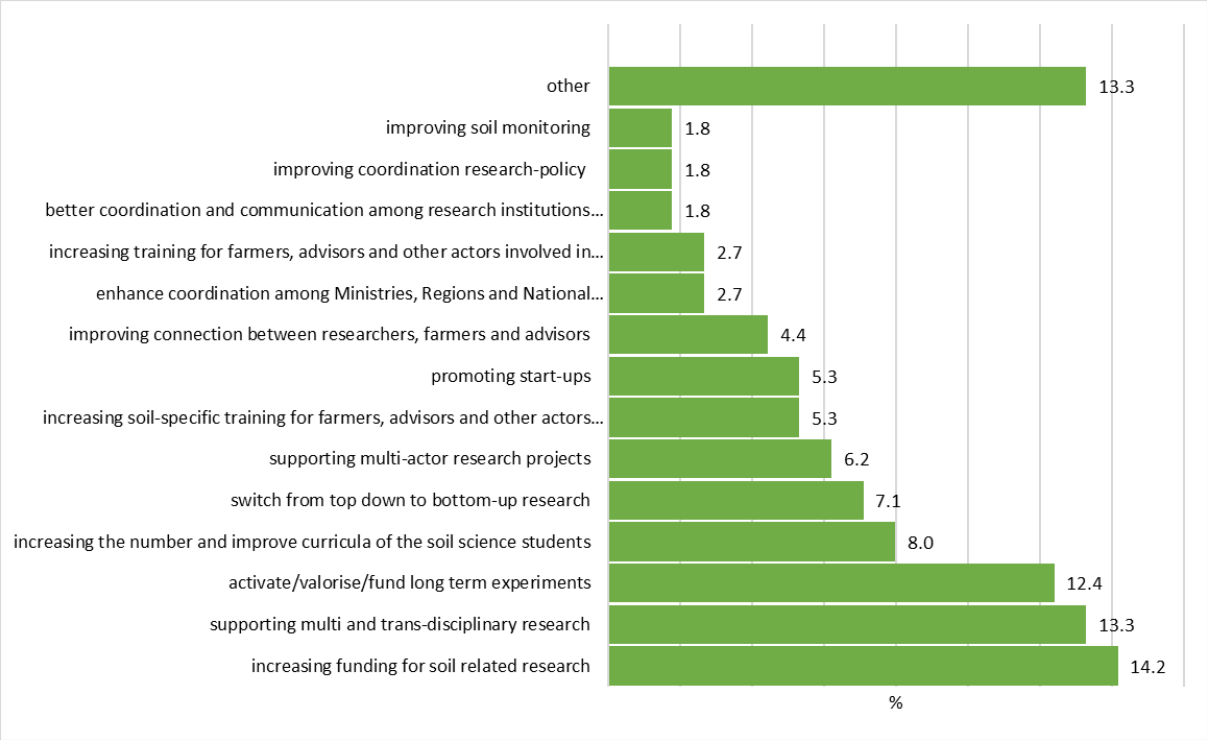

***Figure 14**: Percentage of responses for the opportunities for knowledge development indicated by the participating countries.*

Figure 15 shows the distribution of the eleven most indicated opportunities in the GZs, as listed by PCs. Among them, five opportunities for knowledge development were indicated by the PCs in all the GZs, although not homogeneously distributed among the zones. The most indicated opportunity (i.e., 'Increasing funding for soil related research') was mainly identified in Central Europe, while the second in Western Europe. PCs within the Central Europe identified all the eleven opportunities, while PCs of the other zones identified 7-8 of them (in Northern, Southern, and Western Europe).

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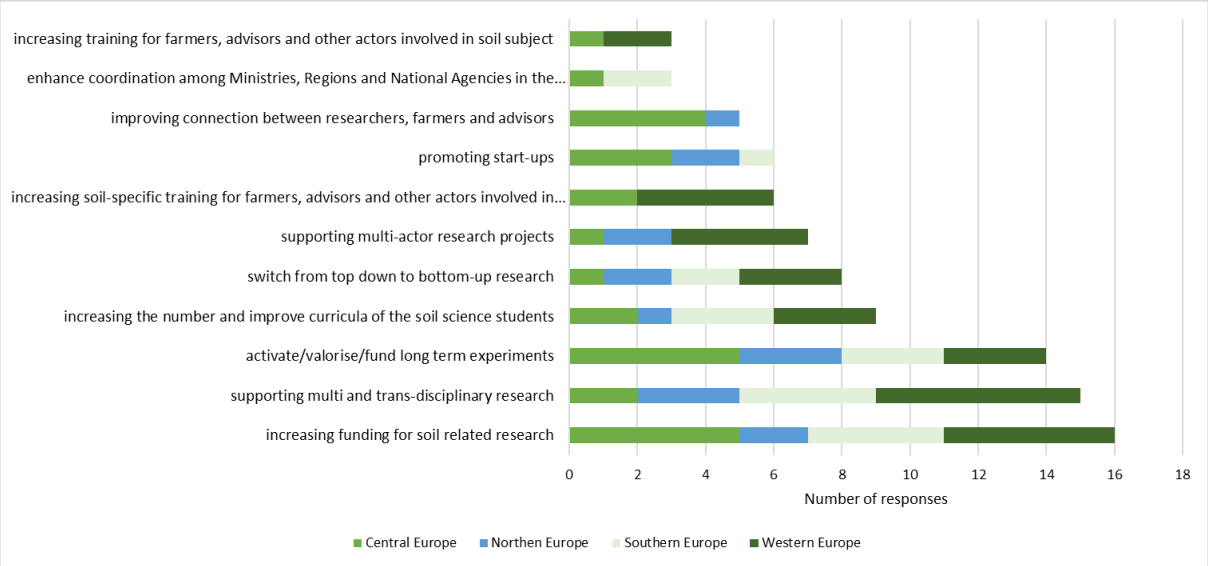

***Figure 15**: Percentage of respondents for the most important opportunities for knowledge development, grouped by Geographical Zones.*

Fig. 15 shows the twenty-nine opportunities for knowledge development as listed by the PCs of EJP-SOIL and grouped by GZs. PCs of Central Europe identified most of the opportunities (19 out of 29), followed by all the other areas (12 each). As an example, in Southern Europe two of the most indicated opportunities were identified by all the PCs (4), while in Western Europe, one of the most indicated opportunities was identified by all PCs (6). In detail, in all the GZs, PCs classified the first four opportunities as important and very important. In Southern Europe, the first two opportunities were identified by all PCs, while in the other zones they were indicated by most of the PCs, following this order: Western, Central, and Northern Europe.

***Table 4**: Opportunities for knowledge development identified by participant countries grouped by Geographical Zones. Per each opportunity and Geographical Zone, the value within the cell represents the number of countries that indicated the specific opportunity, while the shades of green show the relevance of the opportunity (weight) inside the Geographical Zone: a light colour means that few countries indicated the opportunity, a dark colour means that all participating countries of the Geographical Zone indicated the opportunity.*

Opportunities for knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Increasing funding for soil related research	5	2	4	5
Supporting multi- and trans-disciplinary research	2	3	4	6
Activate/valorise/fund long term experiments	5	3	3	3
Increasing the number and improve curricula of the soil science students	2	1	3	3
Switch from top down to bottom-up research	1	2	2	3
Supporting multi-actor research projects	1	2		4

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Increasing soil-specific training for farmers, advisors and other actors involved in soil issues	2			4
Promoting start-ups	3	2	1	
Improving connection among researchers, farmers and advisors	4	1		
Enhance coordination among Ministries, Regions and National Agencies in the research chain	1		2	
Increasing training for farmers, advisors and other actors involved in soil issues	1			2
Better coordination and communication among research institutions (cooperation instead of competition)	1		1	
Improving coordination research-policy	1	1		
Improving soil monitoring	1			1
Availability of databases			1	
Collaboration among research institutes and private/agro- industry	1			
Creating the conditions for modern interdisciplinary research requires the restructuring of the curriculum with a focus on addressing current and future challenges not only at the national but also at the global level	1			
Developing demonstrations farms across occupations (farmers, researchers…)		1		
Developing individual and institutional capacities of universities and research institutions			1	
Development of sustainable soil management options				1
Highly skilled and stable research system with respect to soils		1		
Improving the existing soil information systems of institutions			1	
Increase of critical mass in soil science domains			1	
Increase scientific research activities				1
Increase the number of trans-disciplinary researchers				1
Prices and respect for food and the farmer by the consumer	1			
The topics and curricula of pedology should regard the increased demands of knowledge transfer into practice	1			
Soil that is well-managed does not have a higher value - so the costs for increasing soil quality are too high in relation to the final value of the soil		1		
Supporting multi-actor projects	1			

Summarizing, across Europe the most perceived barriers to knowledge development are basically related to the 'Lack of relations among research, advisory services and farmers' and the 'Financial resources allocated to soil research are not sufficient'. To overcome such barriers, effective solutions were identified in 'Increasing funding for soil related research' and 'Supporting multi- and trans-disciplinary research'.

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Barriers and opportunities for knowledge sharing and transfer

The summary matrix of the eight most indicated elements listed by participating countries of EJP-SOIL as barriers to and opportunities for knowledge sharing and transfer, is reported in Table 5.

Table 5: *First 8 most important barriers to and opportunities for knowledge sharing and transfer identified by the stakeholders of participating countries.*

	Barrier	Opportunity
Knowledge sharing and transfer	1. networks science-science, science-farmers, science-advisors, science-society, science-policy are not established 2. communication among researchers and farmers is not effective 3. dissemination is missing, insufficient or does not convey useful information 4. lack of training for farmers and advisors for soil-specific topics 5. communication is not clear for all stakeholder categories 6. lack of training for researchers on how better communicate with practitioners 7. difficult access to proper advice for farmers 8. knowledge from research (university/institute) to other stakeholders is not good	1. establishment of permanent national networks science-science, science-farmers, science advisors, science-society, science-policy 2. improvement of targeted and effective dissemination 3. making dissemination mandatory in all funded projects 4. better/effective communication to increase awareness on the importance of soil in society 5. improving peer-to-peer training programmes for farmers and advisors 6. supporting multi-actor approach, in particular among researchers and farmers/advisors 7. valorisation of knowledge from universities, education systems and research, involving stakeholders 8. supporting the setting-up of demonstration activities

More than fifteen barriers for knowledge sharing and transfer were indicated by the stakeholders of PCs, as illustrated in Figure 16. The first five were indicated by 55.9% of the PCs as illustrated in Figure 16. In detail, 'Networks science-science, science-farmers, science-advisors, science-society, science-policy are not established' was indicated by 16.1% of the PCs, followed by 'Communication among researchers and farmers is not effective' (14%), 'Dissemination is missing, insufficient or does not convey useful information' (9.7%), 'Lack of training for farmers and advisors for soil-specific topics' (8.6%), and 'Communication is not clear for all stakeholder categories' (7.5%). Figure 17 shows the distribution of the fourteen most indicated barriers in the four GZs, as listed by PCs. PCs within the Southern Europe identified most of them (11 out of 14), while PCs in Central and Northern Europe identified nine barriers. Two barriers were indicated by the PCs in all the GZs, although not homogeneously distributed among the zones. The two most indicated barriers (i.e., 'Networks science-science, science-farmers, science-advisors, science-society, science-policy are not established', and

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'Communication among researchers and farmers is not effective') were mainly identified in Western and Central Europe, while others were identified in Southern Europe (e.g., 'Dissemination is missing, insufficient or does not convey useful information', and 'Few communication and little awareness of the importance of soil in society').

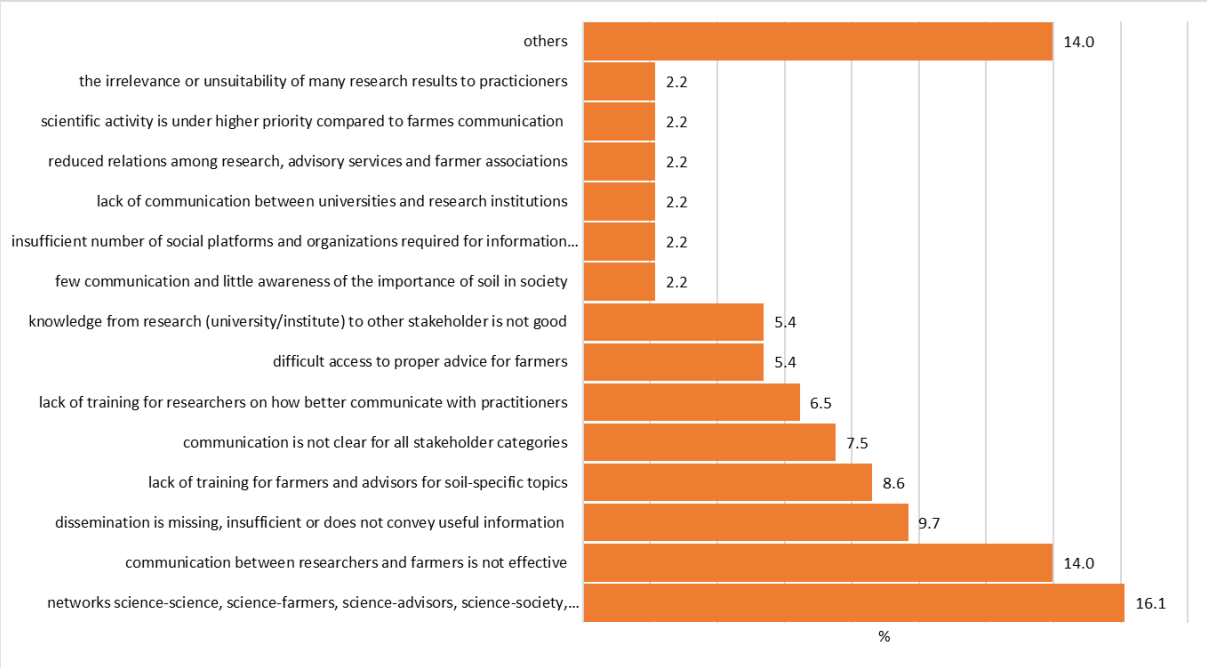

***Figure 16**: Percentage of responses for the barriers to knowledge sharing and transfer indicated by the participating countries.*

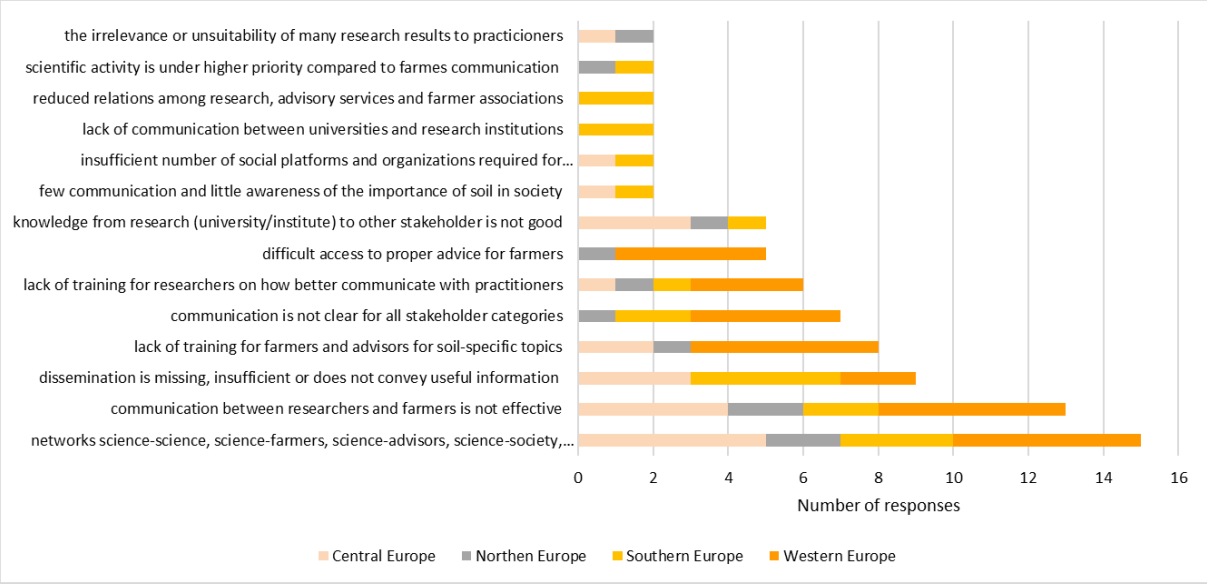

***Figure 17**: Percentage of respondents for the most important barriers to knowledge sharing and transfer, grouped by Geographical Zones.*

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Table 3 shows the twenty-seven barriers for knowledge sharing and transfer as listed by the PCs of EJP-SOIL and grouped by GZs. PCs of Southern Europe identified most of the barriers (15 out of 27), followed by Northern (14), Central (11), and Western Europe (9). In detail, in all the GZs, PCs identified 'Networks science-science, science-farmers, science-advisors, science-society, science-policy are not established', and 'Communication among researchers and farmers is not effective' as the two most important barriers.

Table 6: *Barriers to knowledge sharing and transfer identified by participting countries grouped by Geographical Zones. Per each barrier and Geographical Zone the value within the cell represents the number of countries that indicated the specific barrier, while the shades of orange show the relevance of the barrier (weight) inside the Geographical Zone: a light colour means that few countries indicated the barrier, a dark colour means that all participating countries of the Geographical Zone indicated the barrier).*

Barriers to knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Networks science-science, science-farmers, science-advisors, science-society, science-policy are not established	5	2	3	5
Communication among researchers and farmers is not effective	4	2	2	5
Dissemination is missing, insufficient or does not convey useful information	3		4	2
Lack of training for farmers and advisors for soil-specific topics	2	1		5
Communication is not clear for all stakeholder categories		1	2	4
Lack of training for researchers on how better communicate with practitioners	1	1	1	3
Difficult access to proper advice for farmers		1		4
Knowledge from research (university/institute) to stakeholders is not good	3	1	1	
Few communication and little awareness of the importance of soil in society	1		1	
Insufficient number of social platforms and organizations required for information sharing and transfer	1		1	
Lack of communication among universities and research institutions			2	
Reduced relations among research, advisory services and farmer associations			2	
Scientific activity is under higher priority compared to farmer communication		1	1	
The irrelevance or unsuitability of many research results to practitioners	1	1		
Focus on regulation is time consuming		1		
ICT equipment in universities is obsolete or inadequate			1	
Lack of dissemination of knowledge among research institutes and policy makers				1
Lack of economic resources	1			
Lack of public-private partnership			1	
Political influence on research objectives		1		

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Reduced public-private interrelations			1	
Research projects results are difficult to implement in agricultural practice.		1		
Science policy is more tied to university issues than to applied institutes, which have been deliberately excluded from several projects (e.g. when solving the RISS project, it was very difficult to get agriculture and ecology into the research topics)	1			
Strong need for more "on-farm" measurements and not only "artificial" parcel experiments		1		
The cost:benefit (Return on Investment, ROI) is often not clear for soil management options				1
Time constraints. Researchers are too busy writing proposals disseminating. Farmers are too busy to educate themselves		1		
Universities are not efficient enough in agricultural extension			1	

More than nine opportunities for knowledge sharing and transfer were indicated by the PCs, as illustrated in Figure 18. The first four opportunities for knowledge sharing and transfer were indicated by 35.9% of the PCs. In detail, 'Making dissemination mandatory in all funded projects' was indicated by 10.9% of the PCs, followed by 'Better/effective communication to increase awareness on the importance of soil in society' (9.8%).

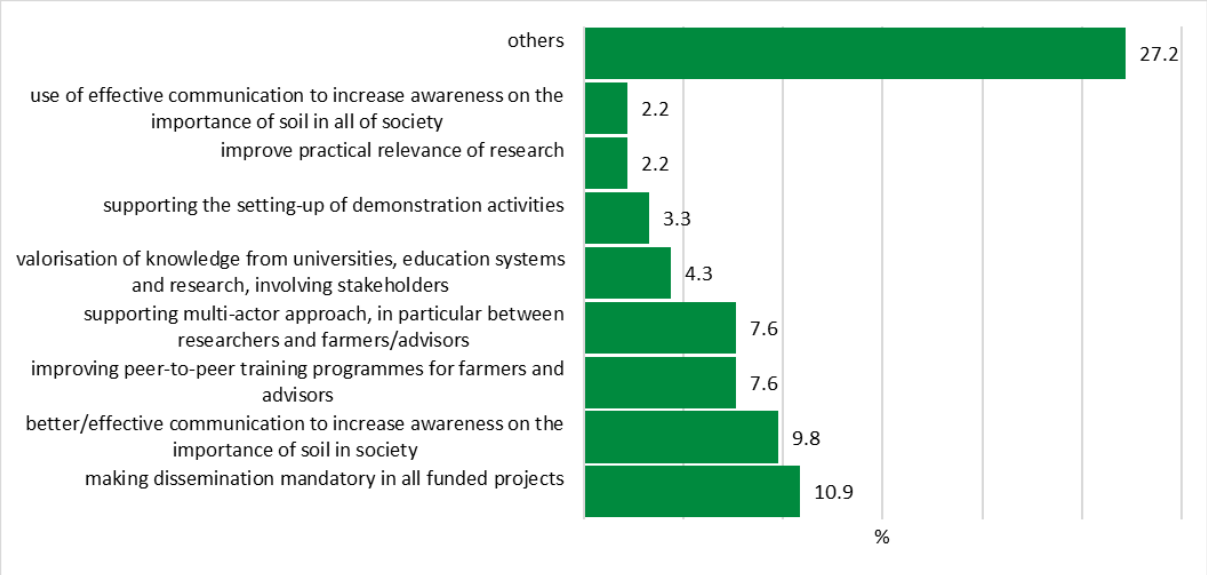

***Figure 18**: Percentage of responses for the opportunities for knowledge sharing and transfer indicated by the Countries.*

Figure 19 shows the distribution of the ten most indicated opportunities in the GZs, as listed by PCs. Among them, six opportunities for knowledge sharing and transfer were indicated by the PCs in all the GZs, although not homogeneously distributed among the zones. The first four most indicated

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opportunities were mainly identified in Western and Southern Europe. PCs within the Central Europe identified nine opportunities, while PCs of the other zones identified 7-8 of them (in Western, Northern, and Southern Europe).

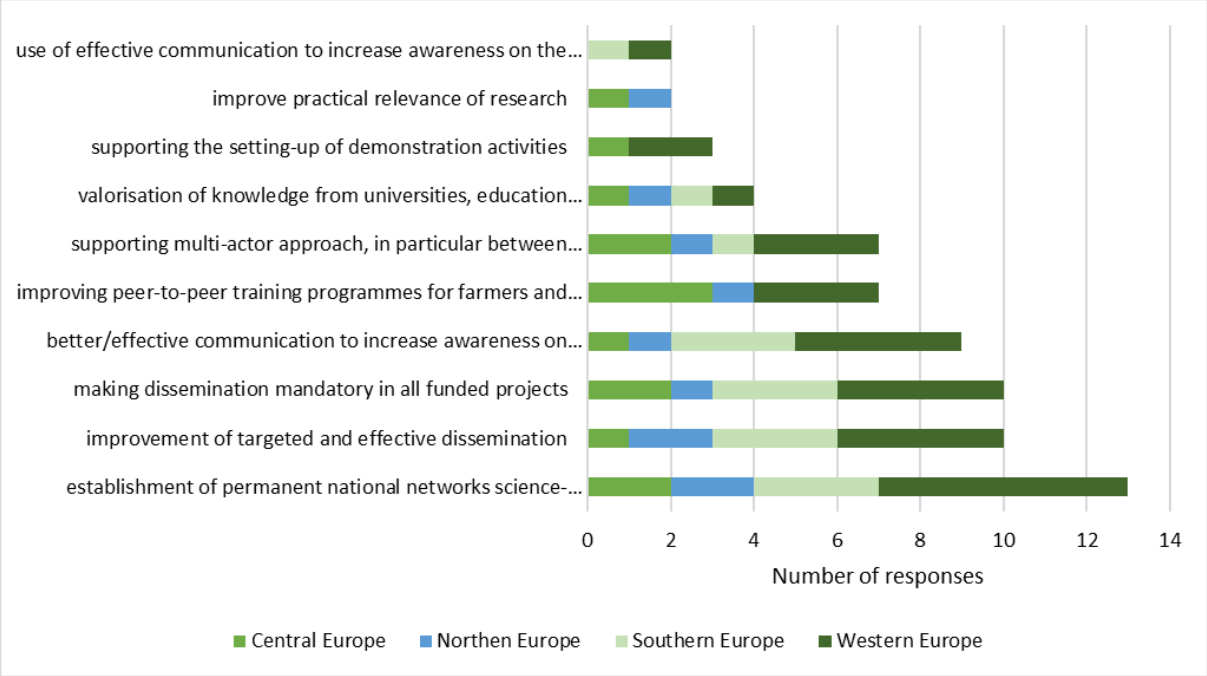

***Figure 19**: Percentage of respondents for the most important opportunities for knowledge sharing and transfer, grouped by Geographical Zones.*

Table 7 shows the thirty-five opportunities for knowledge sharing and transfer, as listed by the PCs of EJP-SOIL and grouped by GZs. PCs of Central Europe identified most of the opportunities (23 out of 35), followed by Western (15), Northern (11), and Southern Europe (9). In detail, in all the GZs, PCs identified the first four opportunities as important and very important. For Southern Europe, they were identified by all the PCs, while for the other zones by most of the PCs, following this order: Western, Northern, and Central Europe. As an example, in Southern Europe, the three most important opportunities were identified by all the PCs (3), while in Western Europe only the first one was identified by all of them (6).

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Table 7: *Opportunities for knowledge sharing and transfer identified by participating countries grouped by Geographical Zones. Per each opportunity and Geographical Zone the value within the cell represents the number of countries that indicated the specific opportunity, while the shades of green show the relevance of the opportunity (weight) inside the Geographical Zone: a light colour means that few countries indicated the opportunity, a dark colour means that all participating countries of the Geographical Zone indicated the opportunity.*

Opportunities for knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Establishment of permanent national networks science-science, science-farmers, science advisors, science-society, science-policy	2	2	3	6
Improvement of targeted and effective dissemination	1	2	3	4
Making dissemination mandatory in all funded projects	2	1	3	4
Better/effective communication to increase awareness on the importance of soil in society	1	1	3	4
Improving peer-to-peer training programmes for farmers and advisors	3	1		3
Supporting multi-actor approach, in particular among researchers and farmers/advisors	2	1	1	3
Valorisation of knowledge from universities, education systems and research, involving stakeholders	1	1	1	1
Supporting the setting-up of demonstration activities	1			2
Improve practical relevance of research	1	1		
Use of effective communication to increase awareness on the importance of soil in society			1	1
Improving knowledge from universities, education and research systems by involving stakeholders			1	
A convenant developed by the government, farm visitants and farmers				1
Activities in schools and kindergartens to build relationship and awareness among children	1			
Allowing for targeted and effective dissemination				1
Barriers to data sharing	1			
Civic associations and non-governmental organizations are important communication tools	1			
Creating a network of independent advisors, who are annually retrained with the newest insights from research projects				1
Data dispersed and often not available to the public (sometimes in paper reports or thesis)	1			
Enhance the involvement of education in research activities				1
Establishment of permanent national networks science-science, science-farmers, science-advisors, science-society, science-policy			1	
In agriculture, it is necessary to establish contacts with renaissance and progressive farmers, including young people, and work on mutual communication	1			
Increase social awareness by activities with an observable publicity effect	1			

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Involving various stakeholders in research projects/transdisciplinary projects offer the possibility to create better understandable results	1			
More research (projects) in the crop production regions		1		
Motivations and incentives	1			
Organization of several events where scientists had the opportunity to present the results to stakeholders	1			
Raising people's awareness of healthy food production	1			
Raising public awareness through mobile applications	1			
Rather than creating networks, collaborations should have a clear topic and aim				1
Regional demonstration farms that actively share knowledge				1
Setting up special campaigns (field days, practical training, workshops for advisers and farmers)	1			
Sharing experiences and successful practices of farmers	1			
The agricultural service's role to function as a link among farmers and researchers should strengthen		1		
Transfer scientific knowledge into the practical sphere, for practical use	1			
Well adapted advisory service		1		

In summary, what is mainly perceived as a barrier to knowledge sharing and transfer across Europe is basically a lack of communication among the different actors dealing with soil. Being it a lack of clarity and effectiveness, a lack of proper specific training about soil or a lack of networking, anyway soil knowledge is perceived as being held within academic and research segments, with little or no exchanges and little or no transfer of information. To overcome such barrier, an effective solution was identified in the improvement of communication, also for enhancing a greater awareness of the importance of soil and of soil functions. This could be reached through both permanent national networks to be established and a targeted dissemination. Inserting dissemination of the findings and of the knowledge achieved in research projects as mandatory was also proposed by several stakeholders.

Barriers and opportunities for knowledge harmonization, organization, and storage

For knowledge harmonization, organization, and storage the summary matrix of the six most indicated important barriers and opportunities, as listed by PCs of EJP-SOIL are reported in **Table 8**.

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Table 8: *First six most important barriers and opportunities for knowledge harmonization, organization and storage identified by the stakeholders of participating countries.*

	Barrier	Opportunity
Harmonization, organization and storage of information	1. different methodologies used for soil sampling, analysis and mapping or storage 2. outdated information 3. data fragmentation 4. lack of common data policy 5. storage data dispersed and often not available to the public 6. lacking common "decision support" ICT tools able to secure soil data storage	1. creation of national infrastructures and interactive web-based communication of soil data 2. promotion of harmonization and standardization methodologies 3. validation and integration of large data sets by using new ICT tools 4. data storage with international standards 5. contributing to reporting on the international commitments (Kyoto protocol, UNFCCC, CAP) 6. data and information available to stakeholder (from research to farmer)

More than fifteen barriers for knowledge harmonization, organization, and storage were indicated by the PCs, as illustrated in Figure 20. The first five were indicated by the 61.5% of the PCs. In detail, 'Different methodologies used for soil sampling, analysis and mapping or storage' was indicated by 14.8% of the PCs, followed by 'Outdated information' (12.5%), 'Data fragmentation', 'Lack of common data policy', and 'Dispersed storage of data, often not available to the public', which together cover 34.2% of the responses because they were indicated by 11.4% of the PCs each.

Figure 21 shows the distribution of the ten most indicated barriers in the four GZs, as listed by PCs. PCs within the Southern Europe identified all of them, followed by Central (9), Western (7), and Northern (5). Five barriers were indicated by the PCs in all the GZs, although not homogeneously distributed among the zones. They were mainly identified in Western Europe, while some others in Southern Europe (e.g., 'Lacking common infrastructure/database and interactive communication on soil data').

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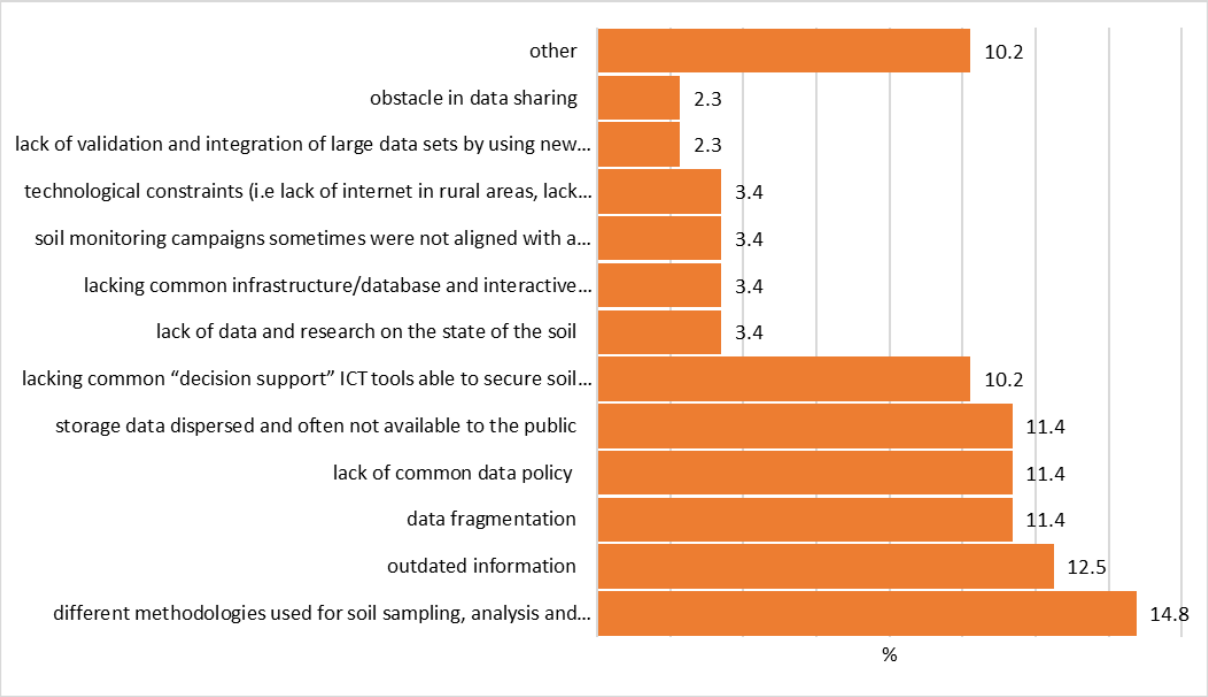

***Figure 20**: Percentage of responses for the barriers to knowledge harmonization, organization, and storage indicated by the participating countries.*

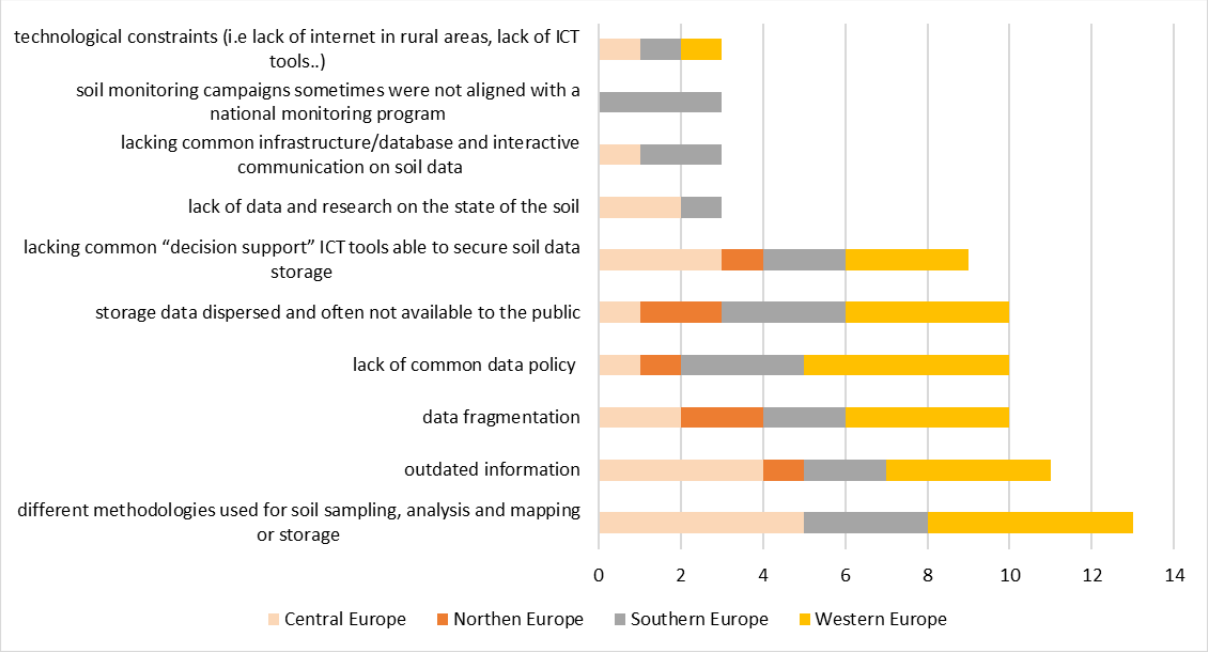

***Figure 21**: Percentage of respondents for the most important barriers to knowledge harmonization, organization, and storage, grouped by Geographical Zones.*

Table 9 shows the twenty-one barriers to knowledge harmonization, organization and storage as listed by the PCs of EJP-SOIL and grouped by GZs. PCs of Southern Europe identified most of the barriers (13

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out of 21), followed by Western (10) and Northern (10), and Central (9). In detail, in all the GZs, most of the PCs identified from the second to the sixth barriers as important.

***Table 9**: Barriers to knowledge harmonization, organization and storage identified by participating countries grouped by Geographical Zones. Per each barrier and Geographical Zone the value within the cell represents the number of countries that indicated the specific barrier, while the shades of orange show the relevance of the barrier (weight) inside the Geographical Zone: a light colour means that few countries indicated the barrier, a dark colour means that all participating countries of the Geographical Zone indicated the barrier.*

Barriers to knowledge harmonization, organization, and storage	Central Europe	Northern Europe	Southern Europe	Western Europe
Different methodologies used for soil sampling, analysis and mapping or storage	5		3	5
Outdated information	4	1	2	4
Data fragmentation	2	2	2	4
Lack of common data policy	1	1	3	5
Storage data dispersed and often not available to the public	1	2	3	4
Lacking common “decision support” ICT tools able to secure soil data storage	3	1	2	3
Lack of data and research on the state of the soil	2		1	
Lacking common infrastructure/database and interactive communication on soil data	1		2	
Soil monitoring campaigns sometimes were not aligned with a national monitoring program			3	
Technological constraints (i.e. lack of internet in rural areas, lack of ICT tools, etc.)	1		1	1
Lack of validation and integration of large data sets by using new developments in information technology (geographic information systems, statistics and modelling)			2	
Obstacle in data sharing			2	
Data/information is too general, difficult to translate into local/farm/field specific circumstances				1
Good data, but poor site specificity		1		
Insufficient training programs in the university (agricultural faculties) to carry out the work of harmonizing knowledge			1	
Integration is lacking				1
Lack of standardization of methodologies used for soil sampling, analysis and mapping or storage		1		
Overemphasis on nutrient management (particularly N)		1		
The costs (for example for journals and printed media)				1
Comprehensive soil data (such as soil maps) is necessary to tackle the different soil challenges		1		
Legitimacy of models		1		

More than eight opportunities for knowledge harmonization, organization and storage were indicated by the PCs, as illustrated in Figure 22. The first four were indicated by 76.3% of the PCs. In detail, the first three opportunities (i.e., ‘Creation of national infrastructures and interactive, web-based

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communication of soil data', 'Promotion of harmonized and standardized methodologies', and 'Validation and integration of large data sets by using new ICT tools') cover together 60.5% of the PCs. They were followed by 'Data storage with international standards', which represents 15.8% of the responses.

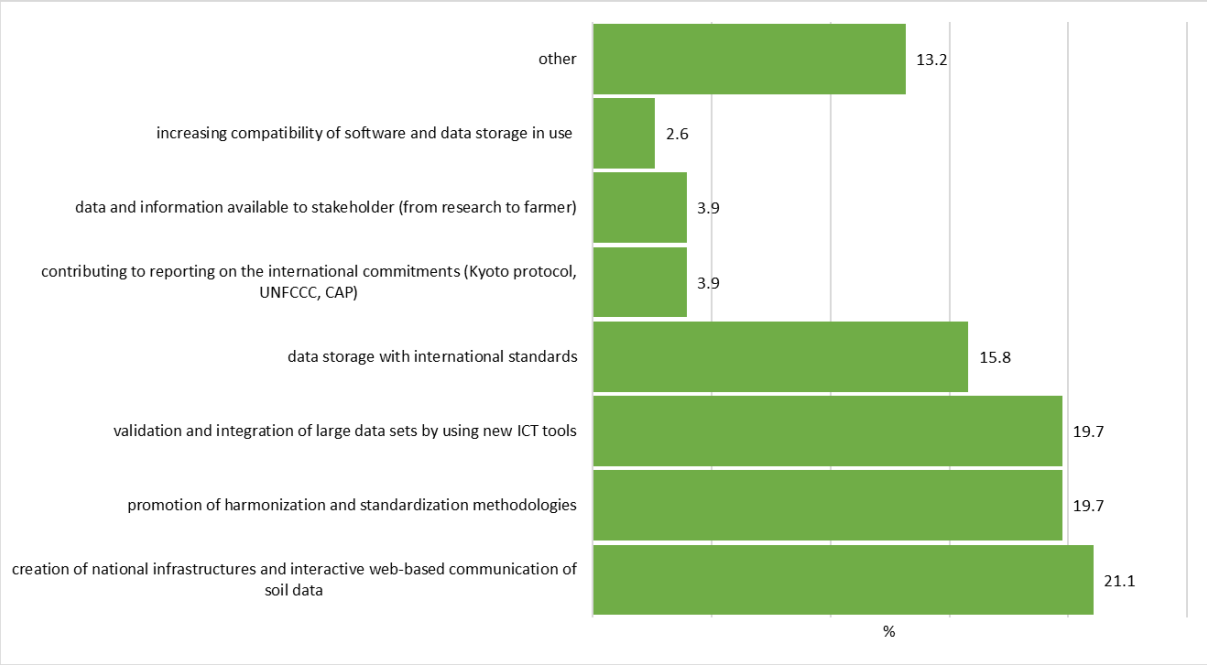

***Figure 22**: Percentage of responses for the opportunities for knowledge harmonization, organization, and storage indicated by the participating countries.*

Figure 23 shows the distribution of the seven most indicated opportunities for knowledge harmonization, organization, and storage in the GZs, as listed by PCs. Four of them were indicated by the PCs in all the GZs, although not homogeneously distributed among the zones. They were mainly identified in Western and Central Europe, which identified most of the opportunities (6 out of 9), followed by Northern (5), and Southern Europe (4).

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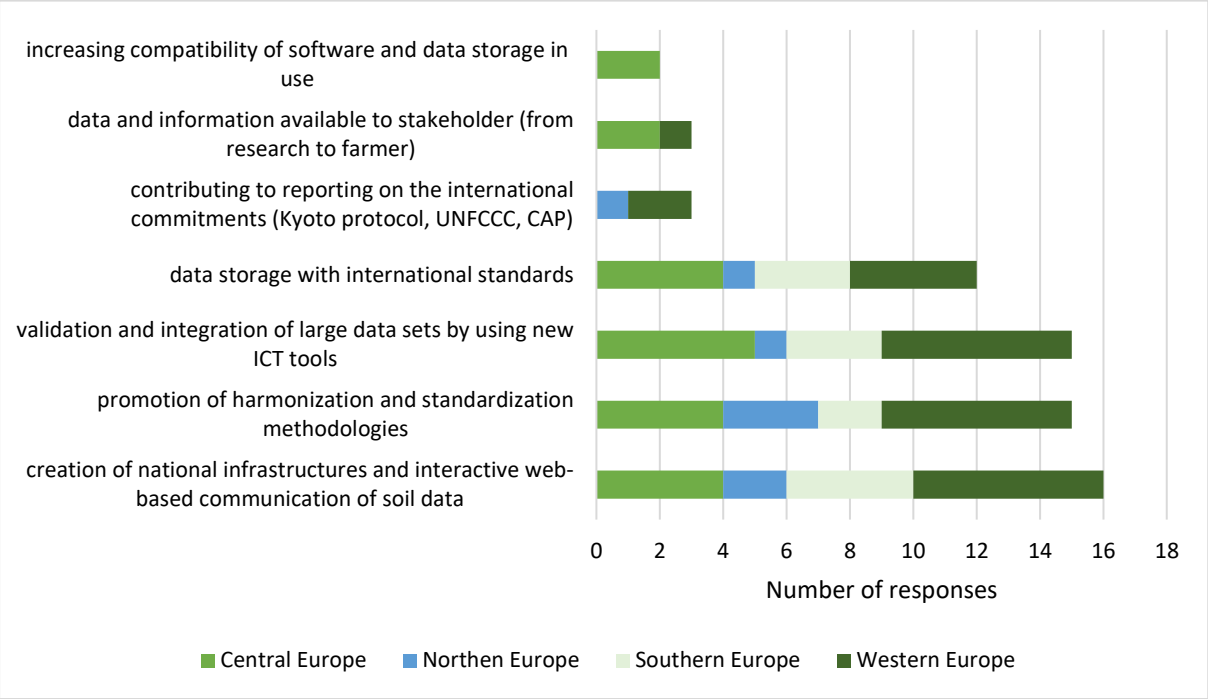

***Figure 23**: Percentage of respondents for the most important opportunities for knowledge harmonization, organization, and storage, grouped by EEZ.*

Table 10 shows the sixteen opportunities for knowledge harmonization, organization, and storage as listed by the PCs of EJP-SOIL and grouped by GZs. PCs of Central Europe identified most of the opportunities (12 out of 16), followed by Northern (7), Western (6), and Southern Europe (5). In detail, in all the GZs, the PCs identified the first four opportunities as important and very important. For Western Europe, the first three opportunities were identified by all PCs (6), while for the other zones they were identified by most of the PCs, following this order: Southern, Central, and Northern Europe.

***Table 10**: Opportunities for knowledge harmonization, organization and storage identified by participating countries grouped by Geographical Zones. Per each opportunity and Geographical Zone the value within the cell represents the number of countries that indicated the specific opportunity, while the shades of green show the relevance of the opportunity (weight) inside the Geographical Zone: a light colour means that few countries indicated the opportunity, a dark colour means that all participating countries of the Geographical Zone indicated the opportunity.*

Opportunities for knowledge harmonization, organization, and storage	Central Europe	Northern Europe	Southern Europe	Western Europe
Creation of national infrastructures and interactive web-based communication of soil data	4	2	4	6
Promotion of harmonization and standardization methodologies	4	3	2	6
Validation and integration of large data sets by using new ICT tools	5	1	3	6
Data storage with international standards	4	1	3	4

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Contributing to reporting on the international commitments (Kyoto protocol, UNFCCC, CAP)		1		2
Data and information available to stakeholder (from research to farmer)	2			1
Increasing compatibility of software and data storage in use	2			
Extensive database of fertilization and crop rotations		1		
IT training for farmers	1			
Mobile application for standardized soil sampling	1			
More research on soil (organic matter, biodiversity, optimal tillage)	1			
Opening new undergraduate and graduate education programs related to these fields			1	
Transition towards targeted regulation		1		
Applied academic research papers and final theses at schools for agricultural profession	1			
Combine, use, and release the total available soil information as they were created for different purposes/questions	1			
Interactive soil specific websites: promote and integrate all soil specific website into one platform/website containing all soil relevant information	1			

Summing up the results, two major categories of obstacles, issues and constraints can be identified. First, a lack of uniformity in the process going from soil samples collection to the creation of datasets and maps, is perceived. This also includes the unavailability of common data policy and tools to secure data storage. On the other hand, even the quality of the already available data was questioned, since they are often outdated, fragmented, stored in a myriad of different sites and often unavailable. The perception of obstacles is unevenly distributed across Countries and GZs. Issues related with the different methodologies used to process soil samples, are perceived mostly by Central, Southern and Western Europe. The fragmentation of information on soil and the scarce availability of soil data is an obstacle recognised, even if with different shades, across all PCs.

The creation of national infrastructures, based on internationally standardized methodologies (from sampling to data storage), exploiting all the new opportunities offered by ICT tools, is perceived as an opportunity to remove the aforementioned barriers. Among the promising tools interactive web-based solutions are indicated, which allow to make data accessible to a large audience.

Barriers and opportunities for knowledge application

For knowledge application, the summary matrix of the seven most important elements listed by PCs of EJP-SOIL as barriers and opportunities are reported in **Table 11**.

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***Table 11**: The first most important barriers and opportunities for knowledge application, identified by the participating countries of EJP-SOIL.*

	Barrier	Opportunity
Knowledge application	1. yields and profits may not respond as farmer expect 2. lack of good policies and incentives 3. technological constraints (lack of internet access in rural areas, lack of common "decision support" ICT tools, lack of applied agricultural technology) 4. communities' pressure (traditional practices and gender norms) 5. institutional and legal barriers can affect implementation of sustainable soil management practices 6. lack of exchange/communication among researchers and farmers/advisors 7. lack of appropriate incentives	1. development of region-specific soil management strategies 2. good policies and incentives with effective policy measures 3. farmers have adequate ICT tools and use them 4. existence of specific mechanisms to support farmers in applying soil knowledge 5. soils are better integrated in the circular economy and bioeconomy 6. incrementation of farms profits; 7. policy making or legislation to support the implementation of sustainable soil management practices

More than sixteen barriers for knowledge application were indicated by the PCs as illustrated in **Figure 24**. The first three were indicated by 34.6% of the PCs, as illustrated in Figure 24. In detail, 'Yields and profits may not respond as farmer expect' was indicated by 14.4% of the PCs, followed by 'Lack of good policies and incentives', 'Technological constraints' and 'Outdated information', which cover 10.6% and 9.6% of the responses of the PCs, respectively.

Figure 25 shows the distribution of the ten most indicated barriers in the four GZs, as listed by PCs. PCs within the Southern, Central, and Western Europe identified all of them, followed by Northern Europe (6). Five barriers were indicated by the PCs in all the GZs, although not homogeneously distributed among the zones. They were mainly identified in Western and Central Europe, while others in Southern Europe (e.g., 'Lack of scientific support to policy makers and-or vice versa', 'Lack of tools that facilitate positive exchanges among farmers and researches', and 'Lack of communication structure in which dissemination, communication and knowledge exchange activities are facilitated').

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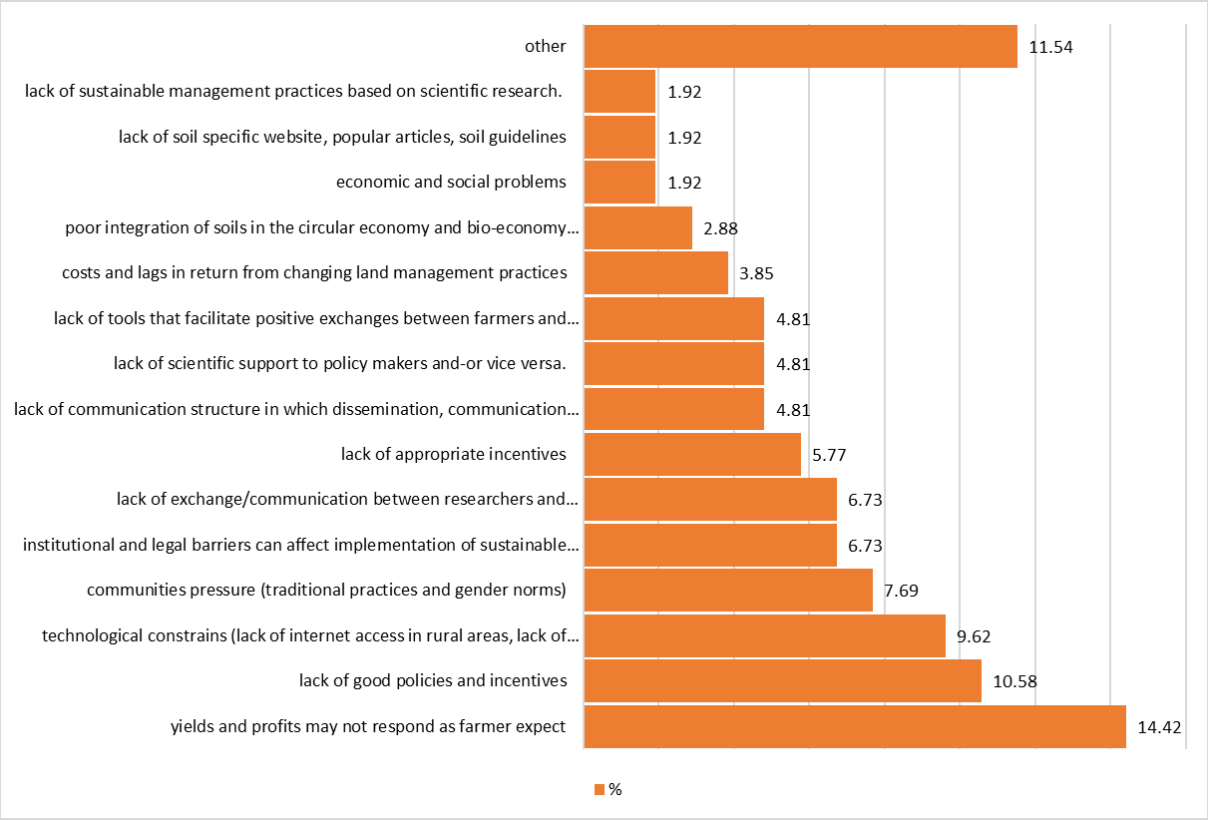

***Figure 24**: Percentage of responses for the barriers to knowledge application indicated by the participating countries.*

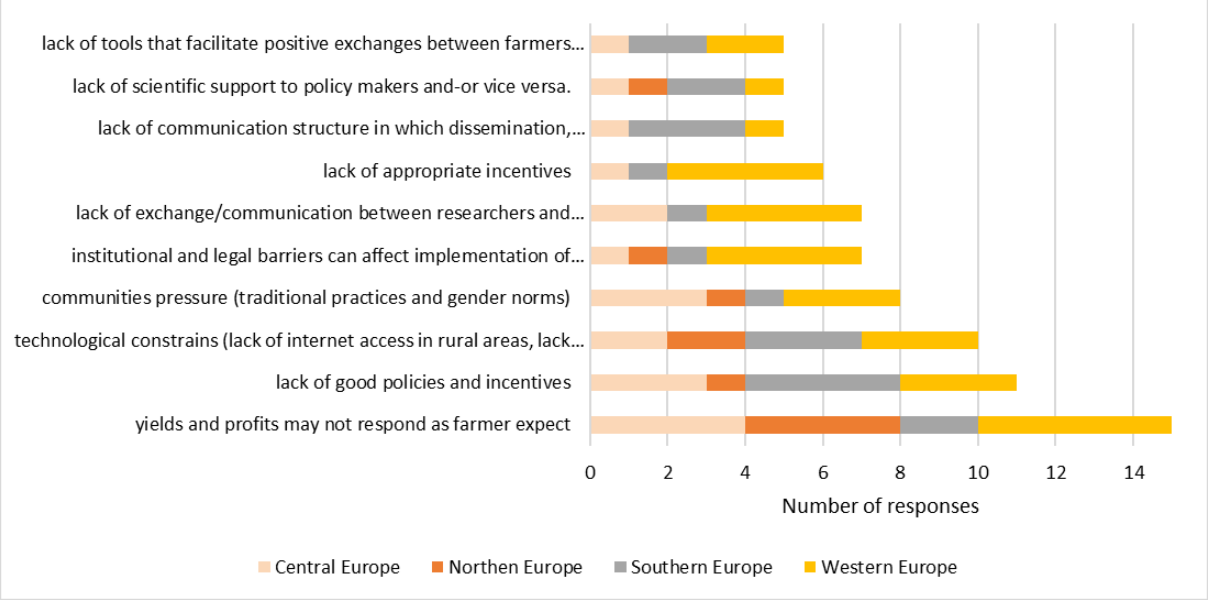

***Figure 25:** Percentage of the respondents for the most important barriers to knowledge application, grouped by Geographical Zones.*

Table 12 shows the twenty-seven barriers to knowledge application as listed by the PCs of EJP-SOIL and grouped by GZs. PCs of Southern Europe identified most of the barriers (20 out of 27), followed

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by Central (15), Western (13), and Northern Europe (11). In detail, in all the GZs, most of the PCs identified the first four barriers as important.

Table 12: *Barriers to knowledge application identified by participating countries grouped by Geographical Zones. Per each barrier and Geographical Zone the value within the cell represents the number of countries that indicated the specific barrier, while the shades of orange show the relevance of the barrier (weight) inside the Geographical Zone: a light colour means that few countries indicated the barrier, a dark colour means that all participating countries of the Geographical Zone indicated the barrier.*

Barriers to knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Yields and profits may not respond as farmer expect	4	4	2	5
Lack of good policies and incentives	3	1	4	3
Technological constraints (lack of internet access in rural areas, lack of common “decision support” ICT tools, lack of applied agricultural technology)	2	2	3	3
Communities pressure (traditional practices and gender norms)	3	1	1	3
Institutional and legal barriers can affect implementation of sustainable soil management practices	1	1	1	4
Lack of exchange/communication among researchers and farmers/advisors	2		1	4
Lack of appropriate incentives	1		1	4
Lack of communication structure in which dissemination, communication and knowledge exchange activities are facilitated (i.e. Lack of soil specific website, popular articles, soil guidelines)	1		3	1
Lack of scientific support to policy makers and-or vice versa	1	1	2	1
Lack of tools that facilitate positive exchanges among farmers and researchers	1		2	2
Costs and lags in return from changing land management practices	2		1	1
Poor integration of soils in the circular economy and bioeconomy (consequence in farms profits)	1		2	
Economic and social problems	1		1	
Lack of soil specific website, popular articles, soil guidelines			1	1
Lack of sustainable management practices based on scientific research			1	1
External contractors carry out field work		1		
European political measures have to be adapted to Member State cropping management		1		
Insufficiency of information sources from which they can obtain information on the subject as well as obstacles in his access to existing information sources			1	
Lack of exchange among researchers and farmers/advisors	1			

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Lack of interest and information of stakeholders			1	
Lack of knowledge about SSM			1	
Lack of soil communication/dissemination			1	
Lacking “decision support” ICT tools	1			
Political measures are not related to the farmer´s needs and, consequently, seldomly used		1		
Poor integration of soils in the circular bioeconomy and bioeconomy			1	
Theoretical nature of the knowledge produced at universities		1		
Time is limited		1		

More than 12 opportunities for knowledge application were indicated by the PCs, as illustrated in Figure 26. The first three were indicated by the 59.6% of the PCs. In detail, the first opportunity (i.e. ‘Development of region-specific soil management strategies’) represents the 17.5% of the responses, followed by ‘Good policies and incentives with effective policy measures’ (14.4%), ‘Farmers have adequate ICT tools and use them’ (11.3%), while ‘Existence of specific mechanisms to support farmers in applying soil knowledge’, and ‘Soils are better integrated in the circular economy and bioeconomy’ together cover 16.4% of the responses, being indicated by 8.2% of the PCs each.

Figure 27 shows the distribution of the nine most important opportunities in the GZs, as listed by PCs. Among them, a total of four opportunities for knowledge application were indicated by the PCs in all the GZs, although not homogeneously distributed among the zones. They were mainly identified in Western and Central Europe. PCs within the Central Europe identified most of the opportunities (8 out of 9), while PCs of the other zones identified 7-8 of them (in Western, Central, and Southern Europe).

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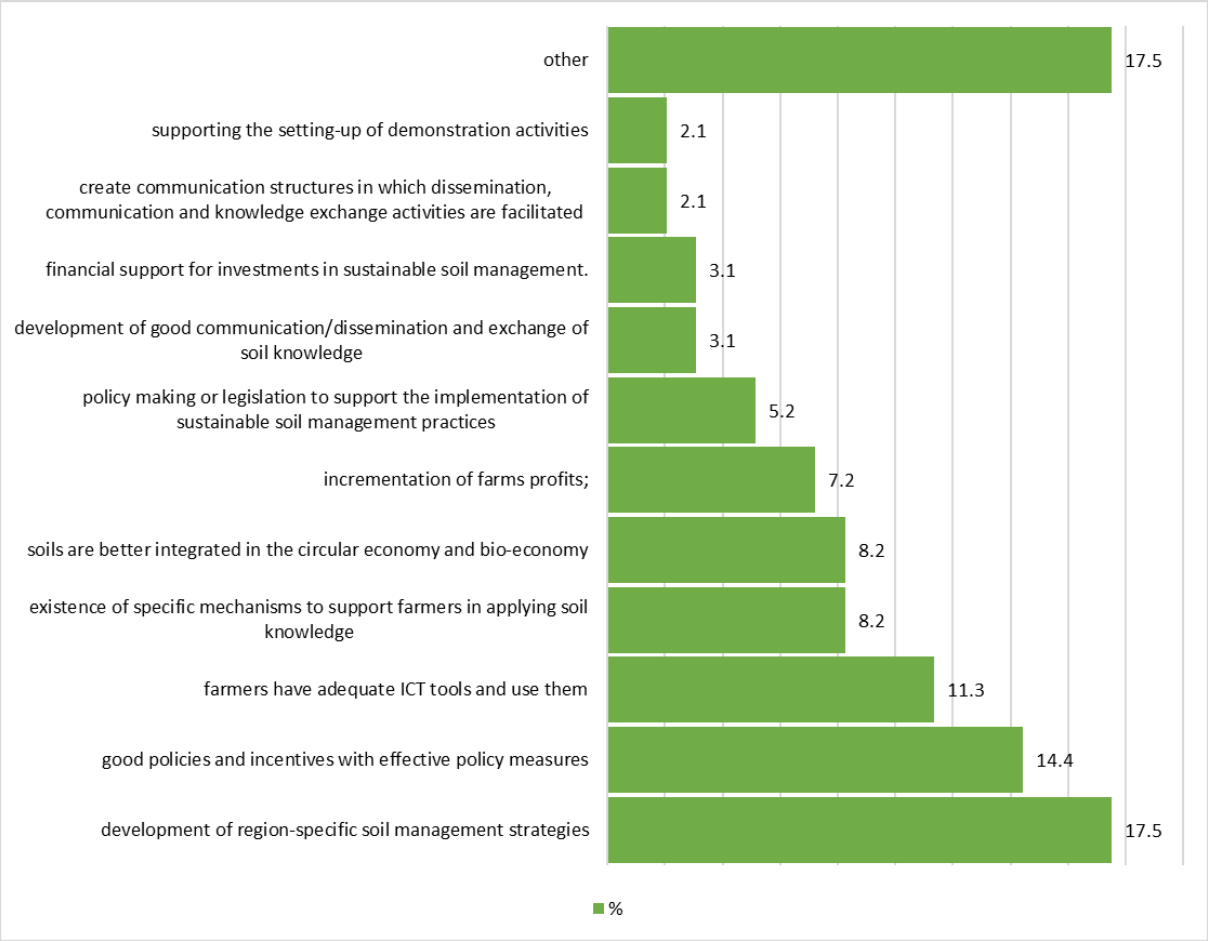

Figure 26: *Percentage of responses for the opportunities for knowledge application indicated by the participating countries.*

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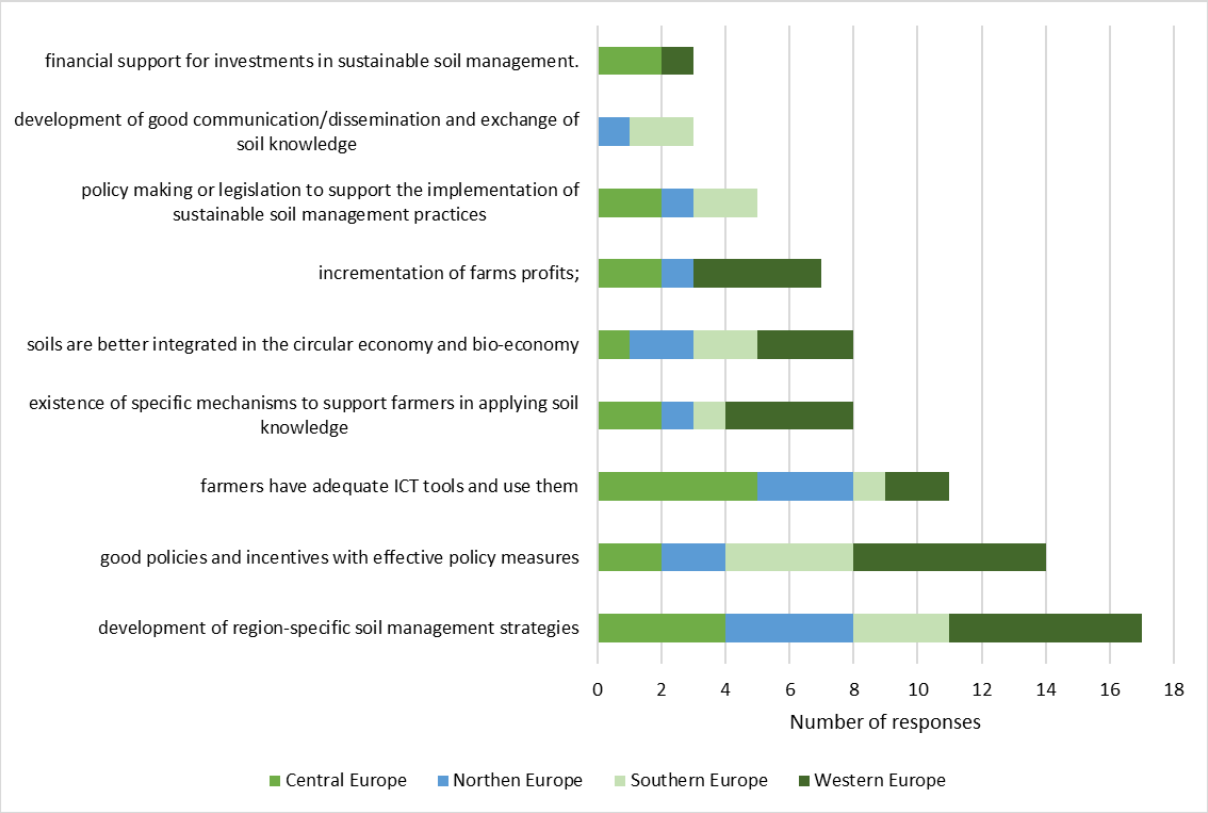

Figure 27: *Percentage of the respondents for the most important opportunities for knowledge application, grouped by Geographical Zones.*

Table 13 shows the twenty-eight opportunities for knowledge application as listed by the PCs of EJP-SOIL and grouped by GZs. PCs of Central Europe identified most of the opportunities (15 out of 28), followed by Northern (14), Western (11), and Southern Europe (10). In detail, in all the GZs, PCs identified the first four opportunities as important and very important. For Western Europe, the first two of them were identified by all PCs (6), while for the other zones by most of the PCs, following this order: Southern, Northern, and Central Europe.

Table 13: *Opportunities for knowledge application identified by participating countries grouped by Geographical Zones. Per each opportunity and Geographical Zone the value within the cell represents the number of countries that indicated the specific opportunity, while the shades of green show the relevance of the opportunity (weight) inside the Geographical Zone: a light colour means that few countries indicated the opportunity, a dark colour means that all participating countries of the Geographical Zone indicated the opportunity.*

Opportunities for knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Development of region-specific soil management strategies	4	4	3	6
Good policies and incentives with effective policy measures	2	2	4	6

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Farmers have adequate ICT tools and use them	5	3	1	2
Existence of specific mechanisms to support farmers in applying soil knowledge	2	1	1	4
Soils are better integrated in the circular economy and bioeconomy	1	2	2	3
Incrementation of farms profits	2	1		4
Policy making or legislation to support the implementation of sustainable soil management practices	2	1	2	
Development of good communication/dissemination and exchange of soil knowledge		1	2	
Financial support for investments in sustainable soil management	2			1
Create communication structures in which dissemination, communication and knowledge exchange activities are facilitated			2	
Supporting the setting-up of demonstration activities	1	1		
Close community societies and peer pressure also bear an opportunity to have innovative farmers acting as multiplicators when trying new and successful land management strategies	1			
As multidisciplinary projects, soil physics and soil chemistry experts should be included in the project teams			1	
Creation of new websites for professionals and the general public	1			
Dialogue		1		
Denmark need to be a frontrunner		1		
Entrepreneurial freedom for farmers to set their own sustainable goals and focus areas, in consultation with regional and local governments				1
Good practice demonstrations on farms	1			
Improved exchange among farmers	1			
Joint programme, synthesising all research on reaching main EJP goals	1			
Plug-and-play technology is available that fits the needs of sustainable management				1
Providing opportunities for farmers		1		
Sustainable soil management is associated with increased yields				1
The emergence of new values such as ecosystem services, land degradation neutrality, land use or soil ethics. If these values are effectively introduced to society, the viewpoint of the soil may change			1	
The idea and benefits of conservation agriculture should be taught much more, in order to make young people and future farmers sensitive to it		1		
There is a lack of good policies and incentives with effective policy measures at national level. A long-term soil policy strategy needs to be developed to ensure the proper management of soil resources	1			
Unambiguous and non-contradicting advice from science and farm visitants, aligned with policies and regulations				1
Use economic instruments under the RDP		1		

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Summarizing, for knowledge application the main barriers are strictly linked with societal aspects and in particular with the farm's management. In all Europe, the main barrier is that "yields and profits may not respond as farmer expect" and this issue is connected with "technological constraints" as the lack of internet in rural areas and/or the difficulties of farmers to apply agricultural technologies, etc. These aspects are due also to the community's pressure: in many areas, in particular Central and Western Europe, the traditional practices and gender norms have a strong influence on agricultural soil management practices. All these barriers are strictly connected with the policy: the "lack of good policies and incentives" linked with "institution and legal barriers" that do not help stakeholders, in particular farmers, in the implementation of sustainable soil management practices. To overcome such barriers, a "development of region-specific soil management strategies" and "good policies and incentives with effective policy measures" are recommended to provide support to stakeholder, in particular farmers, to applying soil knowledge, new technologies in agriculture and consequently to improve farmers' profit.

3.4. Barriers and opportunities by each soil challenge

In this chapter, barriers and opportunities are presented for those soil challenges indicated by PCs as "High relevant" in terms of contribution to overall EJP-SOIL goals. Highly relevant soil challenges were the following:

- Soil organic matter & peat soil conservation (improving)
- Water storage capacity (improving)
- Nutrient retention or use efficiency (improving)
- Erosion - water/ wind/tillage (avoiding)
- Soil biodiversity (increasing)
- Soil compaction (avoiding)
- Soil sealing (avoiding).

Soil organic matter & peat soil conservation (improving)

The soil challenge "Soil organic matter & peat soil conservation (improving)" is considered highly relevant in all the GZs.

Tables 14-21 show all barriers to and opportunities for knowledge development, sharing and transfer, organization and storage of information, application as defined by the PCs for the "Soil organic matter & peat soil conservation" challenge.

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The 'Lack of long-term experimental field sites, coordination of the scheme and development of specific advice' and the 'Lack of understanding the links among soil management, farming systems and soil quality' were considered the most important barriers to the knowledge development. In detail, the 'Lack of long-term experimental field sites' is considered the most important barrier by two PCs in Western Europe and one MS in Southern Europe, while the 'Lack of understanding the links' is considered the most important barrier by one MS in three GZs (i.e., Central, Southern, and Western Europe). The 'Gap of research knowledge' was indicated by one MS in Central and Western Europe, while the 'Gaps in local specific knowledge' by one MS in both Southern and Western Europe (Table 14).

Table 14: *Barriers to knowledge development identified by the* participating c*ountries for the improvement of soil organic matter and peat soil conservation. Per each barrier and Geographical Zone, the value within the cell represents the number of* participating c*ountries that indicated the specific barrier.*

Barriers to knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Gap of research knowledge (quantified data, reference value, data for model, micro-nutrients, emission factors, etc.)	1			1
Lack of long-term experimental field sites, coordination of the scheme and development of specific advice			1	2
Lack of understanding the links among soil management, farming systems and soil quality	1		1	1
Gaps in local specific knowledge (soil, crop, residues management on the soil challenge)			1	1
Lack of national soil database	1		1	
Agricultural production is a stressful activity and farmers have economic concerns			1	
Financial resources allocated to soil research are not sufficient	1			
In the case of soil carbon loss both practitioners and advisors are asking for better field tests systems			1	
Institutions working on soil science are not enough				1
Integrating climate change into studies				1
Lack of applicable and accurate decision support tools	1			
Lack of a mechanism to examine soil problems in large scales periodically			1	
Lack of relations among research, advisory services and farmers	1			
Lack of training for advisors and farmers on soil-related issues	1			

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Lack of understanding by advisors and farmers of the importance of soil organic carbon for multiple ecosystem services delivery				1
Management of soils to avoid SOM decrease	1			
Mineralization of organic fertilizers (when combined with artificial fertilizer) is not yet sufficiently quantified, and the role of soil biodiversity in the degradation is not sufficiently clear				1
Policy mechanisms for planning and implementing new research projects are not appropriate				1
The potential to increase SOM on different soil types, a set of reference values is missing				1
The SSM philosophy is not popular enough in the community consciousness due to these concerns			1	
Trend analyses and site-specific solutions are missing	1			
Limited funds and calls for soil research	1			
Young researchers not attracted by a job	1			
Limited exchange between industry and research	1			
Lack of recent data on peatland status	1			
There is no compensation given to the farmers (money from the government) for applying measures that can be expected to increase SOC		1		
For some measures, there are still technical issues and new equipment has to be purchased (or developed) to efficiently apply specific measures without investing too much time/energy without ensured success		1		
Political measures/compensations are not necessarily related to the farmers needs and don´t consider the farmer´s gain/yield		1		
Information is still lacking in how far that might increase SOC stocks (not enough research + probably bad communication/outreach from the research institutes)		1		

The most important opportunities for knowledge development were individuated in the 'Supporting and funding multi-actor research project design' and in the 'Activate/valorise/fund long term experiment and develop specific advice' by three GZs, while the following two opportunities (i.e., 'Better dissemination of information' and 'Improving networking among researchers, farmers and advisors') were indicated by two GZs. The other opportunities by only one MS and GZs (**Table 15**).

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Table 15: *Opportunities for knowledge development identified by the participating countries for the improvement of soil organic matter and peat soil conservation. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Supporting and funding multi-actor research project design (more synergies among multiple stakeholders)		2	1	2
Activate/valorise/fund long term experiment and develop specific advice	2		1	2
Better dissemination of information		1		1
Improving networking among researchers, farmers and advisers	1	1		
Create a national database on soils			1	
Development and application of soil sustainable management indicators				1
Effectiveness of agri-environmental measures and incentives at national and regional level				1
Evaluation of the connection between land use and the soil challenge				1
Increasing funding for soil related research	1			
Increasing the number and improve curricula of the soil science students	1			
Individual and institutional capacities should be improved			1	
Nutrient management plans should be developed and improved on farm level				1
Practical and quantified knowledge is required				1
Promotion of the carbon indicator in CAP and other strategies (IPCC)	1			
Several models on soil carbon sequestration developing a calibration	1			
Conducting leading projects with university-public cooperation with the purpose of developing knowledge, transformation and developing SSM concept in society in important agricultural regions			1	
Trainings should be organized on SSM for all stakeholders			1	
Supporting multi-stakeholder research initiatives and projects involving researchers, farmers and advisors				1
Delineation of areas under risk	1			
Evaluating potential to ensure food security	1			
Evaluating consequences of policy instruments	1			
Building awareness	1			
Designing best management options for given conditions	1			

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Helping to reach reduction in pesticides and synthetic fertilisers	1			
Enhance the importance of measuring at local level and predicting/extrapolate at watershed, landscape, and regional scale			1	
Better integration of knowledge by policymakers (financial compensation as an incentive for the farmers for applying measures that favour SOC sequestration)		1		

For knowledge sharing and transfer, a total of twenty-two barriers were identified: most GZs have defined three main barriers: the 'Lack of communication/knowledge among all interested actors', the 'Lack of training for farmers and advisors' and 'More inter-disciplinary collaboration among scientists and among researcher and all communities' (Table 16).

Table 16: *Barriers for knowledge sharing and transfer identified by the participating countries for the improvement of soil organic matter and peat soil conservation. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Lack of communication/knowledge among all interested actors			2	2
Lack of training for farmers and advisors	1			2
More inter-disciplinary collaboration: among scientists and among researcher and all communities (farmers, advisors, policymakers)	1	1		1
Knowledge is not available for all actors involved in soil	2		1	
Dissemination is lacking, insufficient or does not convey useful information			1	1
Research data on specific soil topic are not available or missing		2		
Cost/benefit balance is often not clear for soil management options. Uncertainty about profit if new management practices are put in place				1
Create/improve networks science-science, science-farmers, science-advisors, science-society	1			
Diversity of approaches to characterise organic matter (what should be measured?)				1
Effects of measures are invisible in the short term and are therefore not considered effective	1			
High scepticism when it comes to alternative measures (no-one wants to make bad investments)		1		
Insufficient demonstration	1			
Insufficient dissemination of research/results from research institutes		1		
Lack of available IT tools	1			

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Lack of awareness of the problem	1			
Lack of connection advisory - farmers	1			
Lack of sufficient platforms to share and transfer knowledge on soil challenges among stakeholders			1	
Low effectiveness of agri-environmental measures and subsidies at regional and national level				1
More precision in site-specific knowledge on soil carbon can clear the way for both precision-farming and more targeted regulation		1		
Research questions that do not reflect the actual agriculture and farmers work		1		
The privatization of farm advice and the presence of commercial advisors is often mentioned as a bottleneck				1
Topic not sufficiently represented in education	1			

A total of nineteen representative opportunities for the knowledge sharing and transfer were identified for improving soil organic matter and peat soil conservation. Among them, the main opportunities individuated by almost all the GZs were the possibility of 'Increasing the availability of knowledge to stakeholders', the 'Capacity building from universities and schools', the 'Creation/improving networks science-science, science-farmers, science-advisors, science-society', and the 'Improve dissemination of soil knowledge/activities' (Table 17).

Table 17: *Opportunities for knowledge sharing and transfer identified by the participating countries for the improvement of soil organic matter and peat soil conservation Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Increase the availability of knowledge for interested parties/stakeholders		1	3	2
Capacity building from universities/schools and for young researchers	2		3	1
Create/improve networks science-science, science-farmers, science-advisors, science-society	1	1	2	
Increasing awareness on the importance of soil function	2	1		1
Improve dissemination of soil knowledge/activities	1		1	1
Supporting multi-actor approach, in particular among researchers and farmers/advisors	2			1
Active/Improve stakeholder participation			1	1
Many tools and data available for soil models				2
Application of new sustainable soil and crop management/technologies		1		
Climate policies, bioeconomy, circular economy that emphasise the C in soils				1

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Improving training programmes for farmers	1			
Increasing number of advisers supporting farmers				1
Interdisciplinary project application	1			
New laboratory approaches (more accessible measurements)				1
Perception of multifunctional benefits (e.g. Erosion, nutrient cycling, biodiversity...)				1
Setting up operational groups	1			
Setting up soil research and sharing centre	1			
Stronger introduction of the idea and benefit of SOC favouring measures to the young people (future farmers), e.g. at the university		1		
Support and funds to research start-ups			1	

Regarding knowledge harmonization, organization, and storage, all the GZs indicated the 'Lack of common/standard methodologies used for soil sampling, analysis, and mapping' as the main barrier (Table 18). In two out of four GZs the following three other barriers were identified: 'Insufficient long-term experiment and lack of data sharing', 'Lacking common decision support ICT tools able to secure soil data storage, available for all actors', and 'Lack of harmonization and standardization in data collected over time'.

Table 18: *Barriers to knowledge harmonization, organization and storage identified by the participating countries for the improvement of soil organic matter and peat soil conservation. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge harmonization, organization and storage	Central Europe	Northern Europe	Southern Europe	Western Europe
Lack of common/standard methodologies used for soil sampling, analysis and mapping	2	1	1	2
Insufficient long-term experiment and lack of data sharing		1	2	
Lack of harmonization and standardization in data collected over time			2	1
Lacking common "decision support" ICT tools able to secure soil data storage, available for all actors	2			1
Missing a national database on soils			1	1
Data fragmentation				1
Insufficient dissemination		1		
Insufficient integration of data from different domains	1			
Lack of access to data on soil properties at farm level				1
Lack of data and research on specific topics	1			
No full coverage with recent data (peat)	1			

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Outdated information. Updates should be available more frequently				1
Soil data acquisition, organization in open soil data base, georeferencing of soil properties, standard protocols for soil analyses			1	

Regarding opportunities for knowledge harmonization, organization, and storage, all GZs identified 'Good soil harmonized database and ICT tools', while three out of four indicated 'Standardization of methodologies/data with international standards and accepted procedures' and 'Enhance an interactive web-based communication of soil data' as opportunities (

Table **19**).

Table 19: *Opportunities for knowledge harmonization, organization and storage identified by the participating countries for the improvement of soil organic matter and peat soil conservation. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge harmonization, organization and storage	**Central Europe**	**Northern Europe**	**Southern Europe**	**Western Europe**
Standardization of methodologies/data with international standards and accepted procedures	2		2	1
Good soil harmonized database and ICT tools	1	1	1	1
Enhance an interactive web-based communication of soil data	1		1	1
Better networking possibilities and availability of new ICT tools for the validation and integration of large data sets				2
Improving/Ensure long-term experiments databases, that can be made public		1	1	
Application of specific knowledge management, common tools, organizational learning				1
Currently, a National project selected several indicators to determine SOM and aims to develop a set of reference values				1
Effectiveness of specific regulations, agri-environmental measures and incentives at national and regional level			1	
Generalisation of interpretation tools				1
Harmonisation of data on management effects for soil quality and function	1			
Harmonized and standardized methodologies and specific regulations, agri-environmental measures and national or regional incentives				1
Interactive communication on soil data via internet				1

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International scientific cooperation	1			
More research on soil (organic matter, biodiversity, optimal tillage)	1			
Possibility to contribute to reporting on the international commitments (Kyoto protocol, UNFCCC, CAP)				1
Publishing results/state of the art/current research projects in a farmer´s journal		1		

For knowledge application for this soil challenge, a total amount of twenty-three barriers were identified, among them the 'Reluctance of farmers to apply new soil management practices and technologies' and the 'Lack of soil specific information, guideline and updated advice' were indicated by five and three PCs, respectively (**Table 20**).

Table 20: *Barriers for knowledge application identified by the participating countries for the improvement of soil organic matter and peat soil conservation. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Reluctance of farmers to apply new soil management practices and technologies	2		1	2
Lack of soil specific information, guideline and updated advice (water, nutrient, fertilizer)			1	2
Contradictions in policies and regulations, especially the mineral policy is seen as a barrier				2
Farmer loss yield and profit			1	1
Lack of good policies and appropriate incentives	1			1
Lack of long-term time series experiments to observe effect of sustainable soil management		1		1
Yields and profits goals remain disconnected from sustainable soil management goals	1			1
Insufficient demonstration	1			
Insufficient support mechanism			1	
Lack of exchange among researchers and farmers/advisors	1			
Lack of ICT tools and DSS (Decision Support Systems)	1			
Lack of insights in the financial consequences				1
Lack of knowledge-sharing structure to facilitate knowledge exchange (i.e., no soil-specific web site, popular articles, soil guidelines)				1
Lack of practical tools for humus balance monitoring	1			
Lack of specific regulations and EU Policies			1	
Lack of unambiguous advice				1

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Lack of updated guidelines and advise tables (water, nutrient and fertilizer)			1	
Limited capacity to implement new practices	1			
Possible problems in soil-specific information application			1	
Since the production of information about these problems (field sampling-analysis-data generation) is not compatible with the scientific policies of some institutions which fund to research projects, data collection projects are generally rejected			1	
Soil data bases and digital maps must be not only established, but information renewed		1		
The effects of soil carbon loss and soil compaction are not immediately visible to the practitioners. This creates a gap between theoretical knowledge and practical management. Furthermore, it prevents contractors who are eager to offer solutions - cultivate a market for such solutions		1		
Underestimation of this issue	1			
Willingness of farmer to apply new soil management practices			1	

Eighteen opportunities for knowledge application were individuated; among them the majority of the GZs put the attention on 'Farmers have more access to adequate ICT tools/technologies and use them' and 'Facilitate knowledge sharing and mutual learning among science-society-policy' as shown in Table 21. Moreover, in Central and Western Europe, the 'Good interfacing between science and policy', the 'Good specific policy and incentives', and the 'Improve the ICT decision support system' were identified as two important opportunities.

***Table 21**: Opportunities for knowledge application identified by the participating countries for the improvement of soil organic matter and peat soil conservation. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Farmers have more access to adequate ICT tools/technologies and use them (well aware about sustainable soil management)	1	1		3
Facilitate knowledge sharing and mutual learning among science-society-policy	1	2		1
Good specific policies and incentives	1		1	1
Good interfacing among all actors	2			1
Improve the ICT decision support system	1			1

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Increasing number of mechanisms/incentives to support farmers in applying soil knowledge				2
Better addressing soil challenges by policy	1			
Creating funds for large-scale data acquisition and private sector collaborations			1	
Creating opportunities for small farms	1			
Financial incentives and support for farmers to take risks (change of practice)				1
Generalisation of interpretation tools (e.g. SIMEOS AMG)				1
Improvement of access to sites with long-term trials and development of specific consultancy				1
Improving thematic guidelines (water, nutrient and fertilizer)			1	
More research and the development of guidelines		1		
Opportunity for intermediate and/or cover crops				1
Soils should be better integrated in the circular economy and bioeconomy				1
Upgraded study programs		1		
Using on-line training and mobile applications	1			

Water storage capacity (improving)

The soil challenge 'Water storage capacity (improving)' was considered highly relevant in all the GZs. The barriers and opportunities of this soil challenge were mainly identified by the PCs of Central and Southern Europe.

Tables 22-29 show all the barriers to and opportunities for knowledge development, sharing and transfer, organization and storage of information, application as defined by the PCs for the 'Water storage capacity' soil challenge.

The three most important barriers to knowledge development indicated by the stakeholders were the 'Gaps in local specific knowledge', the 'Lack of prediction/extrapolation from local measurements to landscape and regional scale', and the 'Lack of long-term experimental field sites, coordination of the scheme and development of specific advice' (Table 22).

***Table 22**: Barriers to knowledge development identified by the participating countries for the improvement of water storage capacity. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Gaps in local specific knowledge (soil, crop, residues management on the soil challenge)	2		3	
Lack of prediction/extrapolation from local measurements to landscape and regional scale	1		3	

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Lack of long-term experimental field sites, coordination of the scheme and development of specific advice	1		2	
Lack of training for young soil scientists and researchers			3	
Lack of understanding the links among soil management, farming systems and soil quality	1		2	
Lack of national soil database			2	
Lack of spatially explicit soil data			2	
Lack of understanding of the basic processes and dynamics of water, nutrients and organic matter in soils			2	
Barriers to orientation of agricultural policy	1			
Droughts are becoming more frequent. From the perspective of waterboards, it is interesting to know what the options are to store water in agricultural soils. Even so important, what's in it for the farmers?				1
Due to climate change the water may become in shortage or in surplus state in Lithuania. The means for both scenarios have to be developed. Modern soil drainage "two-way" system is of great interest		1		
Lack of coordination among research institutions and working together	1			
Lack of recent data on peatland status	1			
Lack of relations among research, advisory services and farmers	1			
Limited exchange between industry and research	1			
Limited funds and calls for soil research	1			
New research topics	1			
Scaling issues for the soil challenge			1	
The (quantified) impact of soil preparation techniques on the soil structure and water storage capacity is insufficient				1
The effect of the water table on peatland degradation and CO2 emissions is not sufficiently clear				1
The variations in rooting depth and associated resilience to droughts in grasslands is not sufficiently clear				1
Ways to reduce nutrient and pesticide leaching are not sufficiently clear				1
Young researchers not attracted by a job	1			

The main identified opportunities for knowledge development for the improvement of water storage capacity is 'Activate/valorise/fund long term experiment and develop specific advice' as show in Table 23.

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Table 23: *Opportunities for knowledge development identified by the participating countries for the improvement of water storage capacity. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for soil knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Activate/valorise/fund long term experiment and develop specific advice	2		2	1
Development and application of soil sustainable management indicators	1		2	
Development and application of specific knowledge and evaluation of the connection between the land use and the soil challenge	1		2	
Create a national database on soils	1		1	
Development and validation of relevant bio-physical models for predicting the long-term soil dynamics	1		1	
Effectiveness of agri-environmental measures and incentives at national and regional level			2	
Enhancing the importance of measurement at local level and forecast/update at basin, landscape and regional scale			2	
Improving networking among researchers, farmers and advisers	2			
Strengthen soil science development by identifying new research needs (topics)			2	
Building awareness	1			
Delineation of areas under risk	1			
Designing best management options for given conditions	1			
Evaluating consequences of policy instruments	1			
Improving the water storage in the soil with new crop species, growing and tillage technologies		1		
Increasing funding for water capacity research	1			
Increasing training for farmers, advisors and other actors involved in soil subject	1			
Practical and quantified knowledge is required				1
Promotion of knowledge and the importance of water capacity in policy sectors	1			

The most identified barrier to knowledge sharing and transfer for the improvement of water storage capacity is that 'Communication is not clear/effective for all stakeholder categories' (Table 24) and the most individuated opportunity is 'Create/improve networks science-science, science-farmers, science-advisors, science-society' (Table 25).

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Table 24: *Barriers to knowledge sharing and transfer identified by the participating countries for the improvement of water storage capacity. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Communication is not clear/effective for all stakeholder categories	2		2	
Dissemination is lacking, insufficient or does not convey useful information	1		2	
Lack of communication/knowledge among all interested actors	1		2	
Lack of development and application of soil sustainable management indicators	1		2	
Low effectiveness of agri-environmental measures and subsidies at regional and national level	1		2	
Knowledge is not available for all actors involved in soil	2			
Insufficient demonstration	1			
Lack of available IT tools	1			
Lack of connection advisory - farmers	1			
More research is needed concerning water storage increase on different soil types and texture composition		1		
The privatization of farm advice and the presence of commercial advisors is often mentioned as a bottleneck				1

Table 25: *Opportunities for knowledge sharing and transfer identified by the Countries for the improvement of water storage capacity. Per each opportunity and Geographical Zone, the value within the cell represents the number of Countries that indicated the specific opportunity.*

Opportunities for knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Create/improve networks science-science, science-farmers, science-advisors, science-society	3		2	
Increase the availability of knowledge for interested parties/stakeholders	2		2	
Improve dissemination of soil knowledge/activities	1		2	
Activation/Improve stakeholder participation			2	
Increase capacity building of young soil scientists and societal stakeholders, as farmers/advisory/policy makers			2	
Strengthen scientific capacities and cooperation improvement through establishing soil networks for scientists			2	
Application of new sustainable soil and crop management/technologies		1		
Better continuing education possibilities for agricultural consultation experts	1			
Improve continuous soil knowledge synthesis and feedback loop			1	
Several projects have been launched				1

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'Lack of harmonization and standardization in data collected over time' was the most important barrier to knowledge harmonization, organization and storage individuated by three PCs in Central and Southern Europe (Table 26).

Table 26: Barriers to knowledge harmonization, organization and storage identified by the participating countries for the improvement of water storage capacity. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.

Barriers to knowledge harmonization, organization, and storage	Central Europe	Northern Europe	Southern Europe	Western Europe
Lack of harmonization and standardization in data collected over time	1		2	
Data fragmentation			2	
Lack of common/standard methodologies used for soil sampling, analysis and mapping			2	
Lacking common "decision support" ICT tools able to secure soil data storage, available for all actors	2			
Missing a national database on soils			2	
Integration of data from different domains	1			
Lack of evaluation of water resources	1			
Lack of water programs	1			
Methodologies to assess soil compaction are limited				1
Old drainage system prevailing on agricultural land. Water permeability throughout soil profile is low		1		
Scaling issues for the soil challenge			1	

The most indicated opportunity is strictly connected with the barrier: 'Standardization of methodologies/data with international standards and accepted procedure' (

Table 27).

Table 27: *Opportunities for knowledge harmonization, organization and storage identified by the participating countries for the improvement of water storage capacity Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge harmonization, organization, and storage	Central Europe	Northern Europe	Southern Europe	Western Europe
Standardization of methodologies/data with international standards and accepted procedures	1		2	
Application of specific knowledge management, common tools, organizational learning			2	
Effectiveness of specific regulations, agri-environmental measures and incentives at national and regional level			2	

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Enhance an interactive web-based communication of soil data	1		1	
Improving collaboration/networking among researchers and stakeholders	1			1
Integrated framework and ICT tools to secure soil data storage facilities at different levels			1	
New drainage systems investigation		1		
Building water smart villages	1			

Three barriers to knowledge application were indicated by the same number of PCs and in the same GZs: 'Lack of ready-to-use technologies, ICT tools and DSS', 'Lack of soil specific information, guideline and updated advice', and 'Reluctance of farmers to apply new soil management practices and technologies' (

Table 28).

Table 28: *Barriers to knowledge application identified by the* participating c*ountries for the improvement of water storage capacity. Per each barrier and Geographical Zone, the value within the cell represents the number of* participating c*ountries that indicated the specific barrier.*

Barriers to knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Lack of ready-to-use technologies, ICT tools and DSS (Decision Support Systems)	1		2	
Lack of soil specific information, guideline and updated advice (water, nutrient, fertilizer)	1		2	
Reluctance of farmers to apply new soil management practices and technologies	1		2	
Farmer loss yield and profit			2	
Lack of knowledge sharing structure to facilitate knowledge exchange (i.e. Lack of soil specific website, popular articles, soil guidelines)			2	
Lack of specific regulations and EU Policies			2	
Lack of exchange among researchers and farmers/advisors	1			
Lack of good policies and appropriate incentives	1			
Management options to improve the water availability in the soil is not sufficiently clear				1
No clear opinion/way about if greening measures are good	1			
Possibility of reduced crop yield hinders farmers to change land management practices	1			
Too many regulations and policies/programs that may contain different clauses	1			
Water permeability throughout soil profile is low. Soil compaction is drastically increasing		1		
Lack of ICT tools and DSS (Decision Support Systems)	1			
Limited capacity to implement new practices	1			

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Insufficient demonstration	1			

The most indicated opportunities for knowledge application were 'Improvement of thematic guidelines', followed by 'Good interfacing between science and policy'. They were identified by four and two PCs, over two GZs (i.e., Central and Southern Europe) (Table 29).

Table 29: *Opportunities for knowledge application identified by the participating countries for the improvement of water storage capacity Per each opportunity and Geographical Zone the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Improvement of thematic guidelines (water, nutrients and fertilizers)	2		2	
Good interfacing between science and policy	1		1	
Improving knowledge sharing among research-policy-stakeholder			2	
More participants in incentive measures	2			
Improvement of the application of ready-to-use technologies, ICT and decision support system	1		1	
Address future policy needs for new knowledge			1	
Better addressing soil challenges by policy	1			
Creating opportunities for small farms	1			
Efforts are made on the development of financial rewarding on the basis of KPI's, which include water storage and quality				1
Good interfacing among all actors	1			
Good practice demonstrations on farms	1			
Good specific policies and incentives			1	
Improvement of access to sites with long-term trials and development of specific consultancy			1	
Joint programme, synthesising all research on water storage capacity	1			
Overview of the costs and benefits related to soil measures would be very useful				1
Surface soil water permeability increase, OM increase, soil drainage improvement		1		

Nutrient retention or use efficiency (improving)

The soil challenge "Nutrient retention or use efficiency (improving)" is considered highly relevant in all the GZs.

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Tables 30-37 show all the barriers to, and opportunities for, knowledge development, sharing and transfer, organization and storage of information, application as defined by the PCs for the "nutrient retention or use efficiency" challenge. A total of eighteen barriers were indicated by the PCs. The most indicated barriers to knowledge development were 'Gaps in local specific knowledge', 'Institutions working on soil science are not enough/lack of coordination among research institutes', 'Lack of long-term experimental field sites', 'Lack of prediction/extrapolation from local measurements to landscape and regional scale' and 'Lack of relations/knowledge/communication among research, advisory services and farmers', that were indicated by the 50% of the GZs (Table **30**).

Table 30: *Barriers to knowledge development identified by the participating countries for the improvement of nutrient retention or use efficiency. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Gaps in local specific knowledge (soil, crop, residues management on the soil challenge)	1		2	
Institutions working on soil science are not enough/Lack of coordination among research institutes	1			1
Lack of long-term experimental field sites, coordination of the scheme and development of specific advice	1		1	
Lack of prediction/extrapolation from local measurements to landscape and regional scale	1		1	
Lack of relations/knowledge/communication among research, advisory services and farmers	1			1
Deficiency of nutrients	1			
Lack of national soil database	1			
Lack of spatially explicit soil data	1			
Lack of understanding the links among soil management, farming systems and soil quality			1	
Lack of understanding the basic processes of water, nutrients and organic matter dynamic in soils			1	
Need to focus on opportunities for recapturing phosphorous from wastewater		1		
New research topics	1			
Phosphorous loss is underprioritized		1		
Policy mechanisms for planning and implementing new research projects are not appropriate				1
Research projects are conducted on small plots and under ideal conditions		1		
Question of organic matter and organic farming and its influence on GHG	1			
Scaling problems for the soil challenge			1	

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Soils of morainic origin are poor in nutrients. Plant nutrition improvement (macro and micronutrients) is of great interest		1		

The most indicated opportunity 'Better dissemination of information on nutrient management and application' was defined by PCs of Northern and Western Europe (Table 31).

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Table 31: *Opportunities for knowledge development identified by the participating countries for the improvement of nutrient retention or use efficiency. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for soil knowledge development	Central Europe	Northern Europe	Southern Europe	Western Europe
Better dissemination of information on nutrient management and application		2		1
Effectiveness of agri-environmental measures and incentives at national and regional level	1		2	
Activate/valorise/fund long term experiment and develop specific advice	1		1	
Development and application of soil sustainable management indicators	1		1	
Development and application of specific knowledge and evaluation of the connection between the land use and the soil challenge	1		1	
Strengthen soil science development by identifying new research needs (topics)			2	
Create a national database on soils	1			
Develop and support synergies among multiple stakeholders				1
Development and validation of relevant bio-physical models for predicting the long-term soil dynamics	1			
Enhance the importance of measurement at local level and forecast/update at basin, landscape and regional scale			1	
Evaluation of the connection between land use and the soil challenge				1
Improving networking among researchers, farmers and advisors	1			
increasing training for farmers, advisors and other actors involved in soil subject	1			
Supporting and funding multi-actor research project design (more synergies among multiple stakeholders)				1

'Communication is not clear/effective for all stakeholder categories' and 'Dissemination is lacking, insufficient or does not convey useful information' are the two barriers to knowledge sharing and transfer identified by the major number of PCs inside the 50% of GZs (Table 32) for the improvement of nutrient retention or use efficiency.

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Table 32: *Barriers to knowledge sharing and transfer identified by the participating countries for the improvement of nutrient retention or use efficiency. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Communication is not clear/effective for all stakeholder categories	2		1	
Dissemination is lacking, insufficient or does not convey useful information	1		1	1
Cost/benefit balance, large amount of nutrients is applied to maintain yields				1
Insufficient dissemination of research/results from research institutes		1		
Knowledge is not available for all actors involved in soil			1	
Lack of development and application of sustainable soil management indicators			1	
Lack of economic resources	1			
Lack of training for farmers and advisors				1
Missing link between research projects and actual information		1		
More inter-disciplinary collaboration: among scientists and among researcher and all communities (farmers, advisors, policymakers)		1		
Narrow list of crop species in a crop rotation is not favourable for nutrient balance in the soil		1		
Research data on specific soil topic are not available or missing	1			
Research questions that do not reflect the actual agriculture and farmers work		1		

Three out of four GZs groups had individuated the main opportunities 'Improve dissemination of soil knowledge/activities' and 'Increase the availability of knowledge for interested parties/stakeholders' for knowledge sharing and transfer (Table 33).

Table 33: *Opportunities for knowledge sharing and transfer identified by the participating countries for the improvement of nutrient retention or use efficiency. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge sharing and transfer	Central Europe	Northern Europe	Southern Europe	Western Europe
Increase the availability of knowledge for interested parties/stakeholders	1	1	2	
Improve dissemination of soil knowledge/activities	1		1	1

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Create/improve networks science-science, science-farmers, science-advisors, science-society	1		1	
Increasing awareness on the importance of soil function	1			1
Supporting multi-actor approach, in particular among researchers and farmers/advisors	1			1
Activation of operational groups			1	
Better integration of results into policies and, consequently, adaptation of "compensations" and fees		1		
Capacity building from universities/ schools and for young researchers			1	
Improve soil knowledge dissemination			1	
Interface of soil-policy platform on permanent base for dissemination of knowledge	1			
Joint scientific-production projects as model´s solutions	1			
Motivations and incentives	1			
New crop species, growing and tillage technologies are the opportunities to improve soil nutrient status		1		

The main barrier to knowledge harmonization, organization and storage 'Lack of harmonization and standardization in data collected over time' was identified by almost all the GZs, followed by 'Data fragmentation' and 'Lacking common decision support ICT tools able to secure soil data storage, available for all actors' (Table 34).

Table 34: *Barriers to knowledge harmonization, organization and storage identified by the participating countries for the improvement of nutrient retention or use efficiency. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge harmonization, organization, and storage	Central Europe	Northern Europe	Southern Europe	Western Europe
Lack of harmonization and standardization in data collected over time	1		2	1
Data fragmentation			2	
Lacking common "decision support" ICT tools able to secure soil data storage, available for all actors	1			1
Data harmonization and organization is not established mainly relating to soil management	1			
Insufficient dissemination of results by research institutes		1		
Lack of common/standard methodologies used for soil sampling, analysis and mapping			1	
Lack of research funding		1		
Lack of trust to new methods, a need for demonstration farms		1		
Missing a national database on soils			1	

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Outdated information. Updates should be available more frequently				1

The opportunity 'Enhance an interactive web-based communication of soil data' was identified by the major number of PCs, followed by 'Effectiveness of specific regulations, agri-environmental measures and incentives at national and regional level' (Table 35).

Table 35: *Opportunities for knowledge harmonization, organization and storage identified by the participating countries for the improvement of nutrient retention or use efficiency. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge harmonization, organization and storage	Central Europe	Northern Europe	Southern Europe	Western Europe
Enhance an interactive web-based communication of soil data	3		1	
Effectiveness of specific regulations, agri-environmental measures and incentives at national and regional level			2	1
Good soil harmonized database and ICT tools	1			1
Standardization of methodologies/data with international standards and accepted procedures			1	1
Application of specific knowledge management, common tools, organizational learning			1	
Integrated framework and ICT tools to secure soil data storage facilities at different levels			1	
Periodic revision of soil chemical status on a digital map would be important		1		
Possibility to contribute to reporting on the international commitments (Kyoto protocol, UNFCCC, CAP)				1

The most indicated barrier to knowledge application for the improvement of nutrient retention is the 'Reluctance of farmers to apply new soil management practices and technologies', defined in three GZs Table **36**). The same number of PCs indicated the main opportunities for knowledge application that are 'Create ready-to-use technologies, openness and contact between the soil science community and society' and 'Farmers have more access to adequate ICT tools/technologies and use them' (Table 37).

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Table 36: *Barriers to knowledge application identified by the participating countries for the improvement of nutrient retention or use efficiency. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Reluctance of farmers to apply new soil management practices and technologies	1		1	1
Farmer yields and profits goals remain disconnected from the sustainable soil management			1	1
Lack of appropriate incentives/good policies to reduce nutrient loads	1			1
Lack of soil specific information, guideline and updated advice (water, nutrient, fertilizer)			1	1
Farmer loss yield and profit			1	
Lack in knowledge regarding the geographical distribution of the environmental impact of farming, which is needed to increasingly target regulation		1		
Lack of a dialogue with stakeholders facilitated by someone they trust, otherwise it is difficult for farmers to see the purpose of adopting solutions		1		
Lack of communication	1			
Lack of knowledge sharing structure to facilitate knowledge exchange	1			
Lack of knowledge sharing structure to facilitate knowledge exchange (i.e. Lack of soil specific website, popular articles, soil guidelines)			1	
Lack of ready-to-use technologies, ICT tools and DSS (Decision Support Systems)			1	
Lack of specific regulations and EU Policies			1	
Lack of updated guidelines and advise tables (water, nutrient and fertilizer)			1	
Soil data bases and digital maps must be not only established, but information renewed		1		

Table 37: *Opportunities for knowledge application identified by the participating countries for the improvement of nutrient retention or use efficiency Per each opportunity and Geographical Zone the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge application	Central Europe	Northern Europe	Southern Europe	Western Europe
Create ready-to-use technologies, openness and contact between the soil science community and society	1		2	
Farmers have more access to adequate ICT tools/technologies and use them (well aware about sustainable soil management)	1	1		1
Good interface between science and policy			1	1
Good specific policies and incentives			2	

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Improvement of access to sites with long-term trials and development of specific consultancy			2	
Better opportunity for approaching information through consultations		1		
Good interfacing between science and policy			1	
Improving thematic guidelines (water, nutrient and fertilizer)			1	
Increasing number of mechanisms/incentives to support farmers in applying soil knowledge				1
Respond to future policy demands for new knowledge			1	
Soils should be better integrated in the circular economy and bioeconomy				1
Using on-line training and mobile applications	1			

Erosion (water/wind/tillage) (avoiding)

The soil challenge "Erosion (avoiding)" is considered highly relevant in almost all the GZs, except for Northern Europe.

Tables 38-45 show all the barriers to, and opportunities for, knowledge development, sharing and transfer, organization and storage of information, application as defined by the PCs for the "erosion" challenge.

Three barriers - 'Gap of local specific research knowledge', 'Lack of long-term experimental field sites, coordination of the scheme and development of specific advice', and 'Lack of national soil database' are considered the most important ones to the knowledge development for Central and Southern Europe (Northern Europe Countries did not answer) (Table 38). PCs in Western Europe identified only three barriers, namely 'Gaps in research and data measured anti-erosion', 'Integrating climate change into studies', and 'Multi-scale and multi-actor approaches to be developed'.

Table 38: *Barriers to knowledge development identified by the participating countries for avoiding erosion. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge development	Central Europe	Southern Europe	Western Europe
Gaps in local specific knowledge (soil, crop, residues management on the soil challenge)	1	3	
Lack of long-term experimental field sites, coordination of the scheme and development of specific advice	1	3	
Lack of national soil database	1	3	
Gaps in research and data measured anti-erosion	2		1
Lack of prediction/extrapolation from local measurements to landscape and regional scale	1	2	
Lack of spatially explicit soil data	1	2	
Lack of training for young soil scientists and researchers		2	

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Lack of understanding of the basic processes and dynamics of water, nutrients and organic matter in soils		2	
Lack of understanding the links among soil management, farming systems and soil quality		2	
Basic knowledge exists, transfer to practice is missing	1		
Integrating climate change into studies			1
Lack of multidisciplinary research directions that also include social aspects	1		
Multi-scale and multi-actor approaches to be developed			1
Need of new limits for soil matter run-off	1		
New research topics	1		
Scaling issues for the soil challenge		1	
Underestimation of this issue	1		

The most indicated opportunity for knowledge development was 'Activate/valorise/fund long term experiment and develop specific advice'. In Western Europe only two barriers, 'Opportunities for funding and study areas in the most impacted areas' and 'Strong link with soil C' were identified (Table 39).

Table 39: *Opportunities for knowledge development identified by the participating countries for avoiding erosion. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for soil knowledge development	Central Europe	Southern Europe	Western Europe
Activate/valorise/fund long term experiment and develop specific advice	2	3	
Create a national database on soils	1	2	
Development and application of soil sustainable management indicators	1	2	
Development and application of specific knowledge and evaluation of the connection between the land use and the soil challenge	1	2	
Development and validation of relevant bio-physical models for predicting the long-term soil dynamics	1	2	
Effectiveness of agri-environmental measures and incentives at national and regional level	1	2	
Efficacy of agro-environmental measures at national and regional level, country or regional incentives		1	
Strengthen soil science development by identifying new research needs (topics)	2	1	
Enhance the importance of measurement at local level and forecast/update at basin, landscape and regional scale		2	
Application of minimizing soil erosion knowledge on the field	1		
Good ITC tools for soil erosion maps	1		

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Opportunities for funding and study areas in the most impacted areas			1
Strong link with soil C			1

A total of ten barriers to knowledge sharing and transfer were individuated by PCs for avoiding erosion. Among them, the two most indicated by Central and Southern European countries were 'Lack of communication/knowledge among all interested actors', and 'Low effectiveness of agri-environmental measures and subsidies at regional and national level' (Table 40).

Table 40: *Barriers to knowledge sharing and transfer identified by the participating countries for avoiding erosion. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge sharing and transfer	Central Europe	Southern Europe	Western Europe
Lack of communication/knowledge among all interested actors	1	3	
Low effectiveness of agri-environmental measures and subsidies at regional and national level	1	3	
Dissemination is lacking, insufficient or does not convey useful information	1	2	
Lack of development and application of soil sustainable management indicators	1	2	
Communication is not clear for all stakeholder categories		2	
Lack of awareness of the problem	2		
Existing knowledge must be imparted more strongly in education in order to strengthen this awareness	1		
Few structured exchanges, lack of facilitation structures			1
Knowledge is not available for all actors involved in soil		1	
There is a lot of experience on the subject, but there is a lack of systematic exchange and coordinated dissemination	1		

Among the thirteen opportunities indicated by PCs, two were mainly identified by Central and Southern European PCs: 'Create/improve networks science-science, science-farmers, science-advisors, science-society', and 'Increase the availability of knowledge for interested parties/stakeholders' (Table 41).

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Table 41: Opportunities for knowledge sharing and transfer identified by the participating countries for avoiding erosion. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.

Opportunities for knowledge sharing and transfer	Central Europe	Southern Europe	Western Europe
Create/improve networks science-science, science-farmers, science-advisors, science-society	1	3	
Increase the availability of knowledge for interested parties/stakeholders	1	3	
Improve dissemination of soil knowledge/activities	1	2	
Activation/Improve stakeholder participation		2	
Increase capacity building for young scientists and societal stakeholders		2	
Strengthen scientific capacities and cooperation improvement through establishing soil networks for scientists		2	
Improve awareness to the risk to avoid soil erosion	1		1
Improve continuous soil knowledge synthesis and feedback loop		1	
Improve stakeholder participation		1	
Improve soil knowledge dissemination		1	
Better cooperation and communication among different research institutions	1		
Efforts to implements soil erosion action in CAP and other legislation	1		
National soil information database	1		

A total of seven barriers to knowledge harmonization, organization and storage were indicated by PCs. Among them, only 'Difficult access/gaps to very precise and detailed spatialized information on erosive risks and hazard' was individuated by PCs of Southern and Western Europe area (Table 42). The barriers 'Data fragmentation' and 'Missing a national database on soils' were indicated only by PCs in Southern Europe.

***Table 42:** Barriers to knowledge harmonization, organization and storage identified by the participating countries for avoiding erosion. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge harmonization, organization, and storage	Central Europe	Southern Europe	Western Europe
Difficult access/gaps to very precise and detailed spatialized information on erosive risks and hazard		2	1
Data fragmentation		3	
Missing a national database on soils		3	

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Lack of harmonization and standardization in data collected over time		2	
Conflict of objectives between plant protection and soil protection	1		
Lack of economic incentives	1		
Lack of problem awareness	1		

Among the nine opportunities defined by PCs, 'Effectiveness of specific regulations, agri-environmental measures and incentives at national and regional level' was the most indicated one, but only by Southern European PCs (Table 43).

Table 43: *Opportunities for knowledge harmonization, organization and storage identified by the participating countries for avoiding erosion. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge harmonization, organization, and storage	Central Europe	Southern Europe	Western Europe
Effectiveness of specific regulations, agri-environmental measures and incentives at national and regional level		3	
Application of specific knowledge management, common tools, organizational learning		2	
Enhance an interactive web-based communication of soil data		2	
Integrated framework and ICT tools to secure soil data storage facilities at different levels	1	1	
Standardization of methodologies/data with international standards and accepted procedures		2	
International scientific co-operation	1		
New erosion models, detailed maps being applied on the farm level	1		
Raising awareness for the problem	1		
Support for geographical data infrastructures (especially regional ones) for dissemination			1

Thirteen barriers to knowledge application were indicated by PCs for avoiding erosion. Among them, 'Reluctance of farmers to apply new soil management practices and technologies' was the most indicated, followed by 'Farmer loss yield and profit' (Table 44).

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Table 44: *Barriers to knowledge application identified by the participating countries for avoiding erosion. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge application	Central Europe	Southern Europe	Western Europe
Reluctance of farmers to apply new soil management practices and technologies	3	2	
Farmer loss yield and profit	1	3	
Lack of specific regulations and EU Policies		3	
Lack of incentives (support) for change of practice or change of use	1		1
Lack of knowledge sharing structure to facilitate knowledge exchange		2	
Lack of soil specific information, guideline and updated advice (water, nutrient, fertilizer)		2	
Effects of climate change on the solutions currently being developed			1
Farmers are often not aware of the effects of soil erosion in ecological and economical terms	1		
Lack of knowledge sharing structure to facilitate knowledge exchange (i.e. lack of soil specific website, popular articles, soil guidelines)		1	
Lack of ready-to-use technologies, ICT tools and DSS (Decision Support Systems)		1	
Lack of user-friendly fact sheets that provide support and draw attention to the consequences	1		
Peer pressure is seen as an obstacle for better application of soil erosion protection measures - nice looking agricultural field with evenly growing plants is regarded as good	1		
Willingness of farmer to apply new soil management practices		1	

Among the 18 opportunities individuated, two were indicated by three PCs in two GZs: 'Good specific policies and incentives' and 'Improve the ICT decision support system' (Table 45).

Table 45: *Opportunities for knowledge application identified by the participating countries for avoiding erosion. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge application	Central Europe	Southern Europe	Western Europe
Good specific policies and incentives	1	3	
Improve the ICT decision support system	1	2	
Awareness rising on the erosion issue in all stakeholder, in particular for farmers	2		

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Creation of ready-to-use technologies, openness and contact between the soil scientific community and society		2	
Facilitate knowledge sharing and mutual learning among science-society-policy		2	
Good interfacing between science and policy		2	
Improvement of thematic guidelines (water, nutrients and fertilizers)		2	
Improvement of access to sites with long-term trials and development of specific consultancy		2	
Cooperative measures and projects with municipalities are seen as chances to find out critical areas and think about collaborative measures (including farmers) against soil erosion and pluvial floods	1		
Development of knowledge exchange platforms			1
Demonstrations of good practices on farms	1		
Harmonize recommendations for soil and plant protection	1		
Improve active and attractive dissemination	1		
Improve applicability of fact sheets	1		
Improve availability of assessment of the current situation	1		
Improving principles for tools and advisory services		1	
Link between carbon policies and erosion/water protection/biodiversity			1
Strong local needs that will drive the application of solutions			1

Soil Biodiversity (increasing)

The soil challenge "Biodiversity (increasing)" is considered highly relevant in three GZs: Northern, Southern and Western Europe.

Tables 46-53 show all the barriers and opportunities about different aspects of knowledge as defined by the PCs for the "soil biodiversity" challenge.

A total of thirteen barriers to the knowledge development were identified for increasing biodiversity. Only in Southern and Western Europe there was a fragmentation of responses about barriers and no one of them was indicated in both areas (Table 46); the same occurred for opportunities (Table 47).

Table 46: *Barriers to knowledge development identified by the participating countries for increasing biodiversity. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge development	Southern Europe	Western Europe
Gaps in local specific knowledge (soil, crop, residues management on the soil challenge)	2	
Lack of long-term experimental field sites, coordination of the scheme and development of specific advice	2	

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Institutions working on soil science are not enough		1
Lack of national soil database	1	
Lack of prediction/extrapolation from local measurements to landscape and regional scale	1	
Lack of spatially explicit soil data	1	
Lack of training for young soil scientists and researchers	1	
Lack of understanding by advisors and farmers of the importance of soil biodiversity in relation to soil ecosystem functioning		1
Lack of understanding of the basic processes and dynamics of water, nutrients and organic matter in soils	1	
Lack of understanding the links among soil management, farming systems and soil quality	1	
New research topics	1	
Policy mechanisms for planning and implementing new research projects are not appropriate		1
Scaling issues for the soil challenge	1	

Table 47: *Opportunities for knowledge development identified by the participating countries for increasing biodiversity. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge development	Northern Europe	Southern Europe	Western Europe
Activate/valorise/fund long term experiment and develop specific advice		2	
Effectiveness of agri-environmental measures and incentives at national and regional level		2	
Enhance the importance of measurement at local level and forecast/update at basin, landscape, and regional scale		2	
Better dissemination of information on soil biodiversity and its links with soil functions			1
Create a national database on soils		1	
Develop and support synergies among multiple stakeholders			1
Development and application of soil sustainable management indicators		1	
Development and application of specific knowledge and evaluation of the connection between the land use and the soil challenge		1	
Development and validation of biophysical models relevant for the prediction of long-term soil dynamics		1	
Evaluation of the connection between land use and the soil challenge			1
Raise awareness for the soil function importance in connection with soil biodiversity	1		
Strengthen soil science development by identifying new research needs (topics)		1	

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Supporting and funding multi-actor research project design (more synergies among multiple stakeholders)			1

'Lack of communication/knowledge among all interested actors' is the barrier to knowledge sharing and transfer identified for increasing biodiversity by PCs in Southern and Western Europe (Table 48); the same PCs indicated 'Improve dissemination of soil knowledge/activities' as the main opportunity for the same knowledge (Table 49).

Table 48: *Barriers to knowledge sharing and transfer identified by the participating countries for increasing biodiversity. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge sharing and transfer	Northern Europe	Southern Europe	Western Europe
Communication is not clear for all stakeholder categories		2	
Dissemination is lacking, insufficient or does not convey useful information		2	
Lack of communication/knowledge among all interested actors		1	1
Lack of development and application of sustainable soil management indicators		2	
Low effectiveness of agri-environmental measures and subsidies at regional and national level		2	
Cost/benefit balance is often not clear for soil management options. Uncertainty about profit if new management practices are put in place			1
Dissemination content does not convey useful information			1
Lack of clear information on how soil biodiversity is associated with yields, carbon and nutrient cycling and storage			1
Lack of trust in new system, they are too used to old methods	1		
Lack of will to get the knowledge	1		

Table 49: *Opportunities for knowledge sharing and transfer identified by the participating countries for increasing biodiversity. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge sharing and transfer	Southern Europe	Western Europe
Improve dissemination of soil knowledge/activities	2	1
Create/improve networks science-science, science-farmers, science-advisors, science-society	2	

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Increase capacity building for young soil scientists and societal stakeholders i.e. Farmers and advisors, policy makers, landowners and managers, civil society and industry	2	
Increase the availability of knowledge for interested parties/stakeholders	2	
Strengthen scientific capacities and improve cooperation through networking for soil scientists	2	
Activation/Improve stakeholder participation	1	
Improve continuous soil knowledge synthesis and feedback loop	1	
Increasing awareness on the importance of soil function		1
Supporting multi-actor approach, particularly among researchers and farmers/advisors		1

'Lack of harmonization and standardization in data collected over time' is the main identified barrier to knowledge harmonization, organization and storage (Table 50); while 'Standardization of methodologies/data with international standards and accepted procedures' is the most indicated opportunities for increasing biodiversity (Table 51).

Table 50: *Barriers to knowledge harmonization, organization and storage identified by the participating countries for increasing biodiversity Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge harmonization, organization, and storage	Northern Europe	Southern Europe	Western Europe
Lack of harmonization and standardization in data collected over time		2	1
Data fragmentation		2	
Lack of common/standard methodologies used for soil sampling, analysis, and mapping		2	
Improve demonstration farms, that would scientifically prove that they need to be aware of the problem	1		
Lacking common "decision support" ICT tools able to secure soil data storage, available for all actors			1
Missing a national database on soils		1	
Outdated information. Updates should be available more frequently			1
Scaling issues for the soil challenge		1	

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Table 51: *Opportunities for knowledge harmonization, organization and storage identified by the participating countries for increasing biodiversity. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge harmonization, organization, and storage	Southern Europe	Western Europe
Standardization of methodologies/data with international standards and accepted procedures	1	2
Effectiveness of specific regulations, agri-environmental measures and incentives at national and regional level	2	
Application of specific knowledge management, common tools, organizational learning	1	
Better networking possibilities and availability of new ICT tools for the validation and integration of large data sets		1
Enhance an interactive web-based communication of soil data	1	
Integrated framework and ICT tools to secure soil data storage facilities at different levels	1	
Methodologies standardization according to international standards and procedures	1	
Possibility to contribute to reporting on the international commitments (Kyoto protocol, UNFCCC, CAP)		1

PCs in Southern and Western Europe identified 'Lack of soil specific information guideline and updated advice' and 'Reluctance of farmers to apply new soil management practices and technologies' as barrier to knowledge application for increasing biodiversity (Table **52**). The most indicated opportunity by PCs was 'Good interfacing between science and policy' as shown in **Table 53**.

Table 52: *Barriers to knowledge application identified by the participating countries for increasing biodiversity. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge application	Southern Europe	Western Europe
Lack of soil specific information, guideline, and updated advice (water, nutrient, fertilizer)	2	1
Lack of knowledge sharing structure to facilitate knowledge exchange (i.e. lack of soil specific website, popular articles, soil guidelines)	2	
Lack of specific regulations and EU Policies	2	
Reluctance of farmers to apply new soil management practices and technologies	1	1

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Farmer loss yield and profit	1	
Lack of appropriate incentives to promote management that could have positive effects on soil biodiversity		1
Lack of ready-to-use technologies, ICT tools and DSS (decision support systems)	1	
Lack of technologies, ICT tools and DSS (decision support systems) ready to be applied	1	
Yields and profits goals remain disconnected from sustainable soil management goals		1

Table 53: *Opportunities for knowledge application identified by the participating countries for increasing biodiversity. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge application	Southern Europe	Western Europe
Good interfacing between science and policy	1	1
Good specific policies and incentives	2	
Improvement of thematic guidelines (water, nutrients and fertilizers)	2	
Creation of ready-to-use technologies, openness and contact between the soil scientific community and society	1	
Facilitate knowledge sharing and mutual learning among science-society-policy	1	
Farmers have more access to adequate ICT tools/technologies and use them (well aware about sustainable soil management)		1
Address future policy needs for new knowledge	1	
Create ready-to-use technologies, openness and contact between the soil science community and society	1	
Improve exchange among research and advisors/farmers	1	
Improve the ICT decision support system	1	
Improvement of access to sites with long-term trials and development of specific consultancy	1	
Improving principles for tools and advisory services	1	
Increasing number of mechanisms/incentives to support farmers in applying soil knowledge		1
Soils should be better integrated in the circular economy and bioeconomy		1

Soil compaction (avoiding)

The soil challenge “Soil compaction (avoiding)” was considered highly relevant in Western, Northern, and Central Europe GZs. PCs of Southern Europe did not considered this soil challenge.

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Tables 54-61 show the summary matrices of the most important barriers and opportunities for knowledge development, sharing and transfer, organization and storage of information, application as defined by the PCs for the "soil compaction" challenge.

A total of four representative barriers for the knowledge development were identified for avoiding soil compaction. Among them, two were identified by one MS of Southern Europe (1-2) and two by one MS of Central Europe (3-4). The most important barrier for Southern Europe was the 'Institutions working on soil science are not enough', while for Central Europe it was the 'Lack of understanding by advisors and farmers of the importance of soil compaction for soil functioning' (Table 54).

Table 54: *Barriers to knowledge development identified by the participating countries for avoiding soil compaction. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge development	Northern Europe	Western Europe
Institutions working on soil science are not enough		1
Lack of understanding by advisors and farmers of the importance of soil compaction for soil functioning		1
Morainic soils are sensitive to soil compaction. Especially subsoil layer. At present, some farmers implementing reduced or no-till management on tilled land has compaction problems	1	
Policy mechanisms for planning and implementing new research projects are not appropriate		1

A total of six representative opportunities for knowledge development were identified for avoiding soil compaction. Among them, one was identified by one MS of Northern Europe (2), two were identified by one MS of Central Europe (1, 5), and three by one MS of Western Europe (3, 4, 6). The most important opportunity for Central Europe was the 'Activate/valorise/fund long term experiment and develop specific advice', for Northern Europe the 'Application of sustainable soil management system at farm level', and for Western Europe the 'Better dissemination of information on soil compaction and its effects on nutrient, carbon, water retention and cycling' (Table 55).

Table 55: *Opportunities for knowledge development identified by the participating countries for avoiding soil compaction. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for soil knowledge development	Central Europe	Northern Europe	Western Europe
Activate/valorise/fund long term experiment and develop specific advice	1		

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Application of sustainable soil management system at farm level		1	
Better dissemination of information on soil compaction and its effects on nutrient, carbon, water retention and cycling			1
Develop and support synergies among multiple stakeholders			1
Improve models	1		
Supporting and funding multi-actor research project design (more synergies among multiple stakeholders)			1

A total of three representative barriers for knowledge sharing and transfer were identified for avoiding soil compaction by one MS of Western Europe. The most important barrier was the 'Cost/benefit balance is often not clear for soil management options' (Table 56).

Table 56: *Barriers to knowledge sharing and transfer identified by the participating countries for avoiding soil compaction Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge sharing and transfer	**Western Europe**
Cost/benefit balance is often not clear for soil management options	1
Dissemination content does not convey useful information	1
Lack of training for farmers and advisors	1

A total of five representative opportunities for the knowledge sharing and transfer were identified for avoiding soil compaction. Among them, one was identified by one MS of Northern and Central Europe (3 and 4, respectively), and three were identified by one MS of Western Europe (1, 2, 5). The most important opportunity for Central Europe was the 'Networking and cooperation between practice and theory to find answers to practical questions', for Northern Europe the 'Long-term field experiment results are of great interest for practitioners', and for Western Europe the 'Improve dissemination of soil knowledge/activities' (Table 57).

Table 57: *Opportunities for knowledge sharing and transfer identified by the participating countries for avoiding soil compaction. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge sharing and transfer	**Central Europe**	**Northern Europe**	**Western Europe**
Improve dissemination of soil knowledge/activities			1
Increasing awareness on the importance of soil function			1
Long-term field experiment results are of great interest for practitioners		1	

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Networking and cooperation between practice and theory to find answers to practical questions	1		
Supporting multi-actor approach, in particular among researchers and farmers/advisors			1

A total of three barriers to knowledge harmonization, organization and storage were indicate by PCs in two GZs for avoiding soil compaction; 'Lacking common "decision support" ICT tools able to secure soil data storage, available for all actors' was most identified by two PCs in Western Europe (Table 58).

Table 58: *Barriers to knowledge harmonization, organization and storage identified by the participating countries for avoiding soil compaction. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge harmonization, organization, and storage	Northern Europe	Western Europe
Lacking common "decision support" ICT tools able to secure soil data storage, available for all actors		2
Outdated information. Updates should be available more frequently		1
Soil physical properties monitoring. Maps for soil physical properties and soil areas sensitive to compaction	1	

All the four opportunities were indicated by only one MS in the Northern and Western Europe (Table 59).

Table 59: *Opportunities for knowledge harmonization, organization and storage identified by the participating countries for avoiding soil compaction. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge harmonization, organization, and storage	Northern Europe	Western Europe
Better networking possibilities and availability of new ICT tools for the validation and integration of large data sets		1
Good soil harmonized database and ICT tools	1	
Possibility to contribute to reporting on the international commitments (Kyoto protocol, UNFCCC, CAP)		1
Standardization of methodologies/data with international standards and accepted procedures		1

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The five identified barriers to knowledge application were defined by single PCs in three European zones (*Table 60*); as for the four opportunities identified by PCs in Northern and Western Europe (*Table 61*).

Table 60: *Barriers to knowledge application identified by the participating countries for avoiding soil compaction. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge application	Central Europe	Northern Europe	Western Europe
Industry and technological progress in terms of machinery production is heading in a direction where bigger and heavier is the focus	1		
Lack of appropriate incentives to avoid soil compaction			1
Lack of soil specific information, guideline and updated advice (water, nutrient, fertilizer)			1
Soil physical properties database is of interest		1	
Yields and profits goals remain disconnected from sustainable soil management goals			1

Table 61: *Opportunities for knowledge application identified by the participating countries for avoiding soil compaction. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge application	Northern Europe	Western Europe
Farmers have more access to adequate ICT tools/technologies and use them (aware about sustainable soil management)		1
Increasing number of mechanisms/incentives to support farmers in applying soil knowledge		1
Soils should be better integrated in the circular economy and bioeconomy		1
Surface soil water permeability increase, OM increase, soil drainage improvement	1	

Soil sealing (avoiding)

The soil challenge “Soil sealing (avoiding)” was considered highly relevant only for the Central and Southern Europe GZs.

Tables 62-69 show the summary matrices of the most important barriers and opportunities for knowledge development, sharing and transfer, organization and storage of information, application as defined by the PCs for the “soil sealing” challenge.

‘Gap in local specific knowledge’ and the ‘Lack of specific policies/policy restriction land-use transformation’ were considered the most important barrier to knowledge development for both GZs,

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followed by the 'Lack of prediction/extrapolation from local measurements to landscape and regional scale', the 'Lack of spatially explicit soil data', and the 'Lack of training for young soil scientists and researchers', which were indicated only for Southern Europe GZs by one MS (Table 62).

Table 62: *Barriers to knowledge development identified by the participating countries for avoiding soil sealing. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge development	Central Europe	Southern Europe
Gaps in local specific knowledge (soil, crop, residues management on the soil challenge)	2	1
Lack of specific policies/policy restriction regarding land-use transformations	1	1
Lack of prediction/extrapolation from local measurements to landscape and regional scale		1
Lack of spatially explicit soil data		1
Lack of training for young soil scientists and researchers		1

A total of seven opportunities for knowledge development were identified for avoiding soil sealing. Among them, four were identified by one MS of Southern Europe (1-4) and three by one MS of Central Europe (5-7). The most important opportunity for Southern Europe was the 'Development and application of soil sustainable management indicators', while for Central Europe the 'Giving economic value to soil multifunction' (Table 63).

Table 63: *Opportunities for knowledge development identified by the participating countries for avoiding soil sealing. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for soil knowledge development	Central Europe	Southern Europe
Development and application of soil sustainable management indicators		1
Development and application of specific knowledge and evaluation of the connection between the land use and the soil challenge		1
Effectiveness of agri-environmental measures and incentives at national and regional level		1
Enhance the importance of measurement at local level and forecast/update at basin, landscape and regional scale		1
Giving economic value to soil multifunction	1	
Promotion of knowledge and the importance of avoiding soil sealing	1	
Strengthening of leadership	1	

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A total of three barriers for knowledge sharing and transfer were identified for avoiding soil sealing. Among them, the first barrier was identified by one MS of Central and Southern Europe, while the second and third were identified by one MS of Southern and Central Europe, respectively. 'Lack of communication/knowledge among all interested actors' was considered the most important barrier to the knowledge development for both GZs (Table 64).

Table 64: *Barriers to knowledge sharing and transfer identified by the participating countries for avoiding soil sealing. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge sharing and transfer	Central Europe	Southern Europe
Lack of communication/knowledge among all interested actors	1	1
Lack of development and application of sustainable soil management indicators		1
Raise awareness for the importance of soil functions, when talking about soil sealing	1	

A total of six opportunities for the knowledge sharing and transfer were identified for avoiding soil sealing. Among them, the first was identified by one MS of Central and Southern Europe, while the others were identified by one MS of Southern (2-5) and Central Europe (6-7), respectively. 'Improve dissemination of soil knowledge/activities' was considered the most important opportunity to the knowledge sharing and transfer for both GZs (Table 65).

Table 65: *Opportunities for knowledge sharing and transfer identified by the participating countries for avoiding soil sealing. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge sharing and transfer	Central Europe	Southern Europe
Improve dissemination of soil knowledge/activities	1	1
Create/improve networks science-science, science-farmers, science-advisors, science-society		1
Increase capacity building of young soil scientists and societal stakeholders, as farmers/advisory		1
Increase the availability of knowledge for interested parties/stakeholders		1
Increasing awareness on the importance of soil function	1	
Setting up special campaigns	1	

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A total of four barriers for knowledge harmonization, organization and storage were identified for avoiding soil sealing. Among them, three were identified by one MS of Southern Europe (1, 3, 4) and one by one MS of Central Europe (2). The most important barrier for Southern Europe was the 'Data fragmentation', while for Central Europe the 'Lack of data and research on specific topic giving economic value to soil multifunction' (Table 66).

Table 66: *Barriers to knowledge harmonization, organization and storage identified by the participating countries for avoiding soil sealing. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge harmonization, organization, and storage	Central Europe	Southern Europe
Data fragmentation		1
Lack of data and research on specific topic	1	
Lack of harmonization and standardization in data collected over time		1
Missing a national database on soils		1

A total of four opportunities for the knowledge harmonization, organization and storage were identified for avoiding soil sealing. Among them, three were identified by one MS of Southern Europe (1-3) and one by one MS of Central Europe (4). The most important opportunity for Southern Europe was the 'Application of specific knowledge management, common tools, organizational learning', while for Central Europe the 'Promoting specific data on soil sealing in all of society' (Table 67).

Table 67: *Opportunities for knowledge harmonization, organization and storage identified by the participating countries for avoiding soil sealing. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge harmonization, organization, and storage	Central Europe	Southern Europe
Application of specific knowledge management, common tools, organizational learning		1
Effectiveness of specific regulations, agri-environmental measures, and incentives at national and regional level		1
Enhance an interactive web-based communication of soil data		1
Promoting specific data on soil sealing in all of society	1	

A total of seven barriers for knowledge application were identified for avoiding soil sealing. Among them, four were identified by one MS of Southern Europe (1, 3, 5, 6) and four by one or two PCs of Central Europe (1, 2, 4, 7). The most important opportunity for Southern and Central Europe was the 'Lack of good and specific policies (EU and national) and appropriate incentives' (

Table 68).

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Table 68: *Barriers to knowledge application identified by the participating countries for avoiding soil sealing. Per each barrier and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific barrier.*

Barriers to knowledge application	Central Europe	Southern Europe
Lack of good and specific policies (EU and national) and appropriate incentives	1	1
Political/legislative and economic/financial issue	2	
Farmer loss yield and profit		1
Lack of good policies and appropriate incentives	1	
Lack of knowledge sharing structure to facilitate knowledge exchange		1
Lack of ready-to-use technologies, ICT tools and DSS		1
Regional land use planning (country and municipality level) and zoning of areas (municipality level) issue	1	

A total of seven opportunities for knowledge application were identified for avoiding soil sealing. Among them, three were identified by one MS of Southern Europe (1, 4, 5) and five by one MS of Central Europe (1, 2, 3, 6, 7). The most important opportunity recognised for both GZs was the 'Good interface between science and politics' (Table 69).

Table 69: *Opportunities for knowledge application identified by the participating countries for avoiding soil sealing. Per each opportunity and Geographical Zone, the value within the cell represents the number of participating countries that indicated the specific opportunity.*

Opportunities for knowledge application	Central Europe	Southern Europe
Good interface between science and politics	1	1
Adaptations on legislative and regulations/land use planning and zoning	1	
Changes in tax and financial system of local/regional level	1	
Creation of ready-to-use technologies, openness and contact between the soil scientific community and society		1
Good specific policies and incentives		1
Increasing social awareness for real value of unsealed and healthy soil	1	
Joint programme, synthesising all research on avoiding soil sealing	1	

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4. Conclusions

The task 2.3 aimed at quantifying the current opportunities and limitations for soil knowledge to overcome the soil challenges in Europe, in the opinion of the stakeholders.

The most relevant soil challenge for the four main GZs of Europe (i.e., Northern, Central, Western and Southern Europe) was “Improving soil organic matter”, which was considered the first soil priority for all GZs except for Southern Europe, where “Improving water storage capacity” was considered as the first priority.

The main barriers and opportunities were identified for each knowledge compartment: development, sharing and transfer, harmonization and storage, and application.

Overall, our results showed that there are many areas of improvement of soil research needed to respond adequately to the soil challenges. Barriers are identified in cultural, organizational, legal/institutional, economic, and political obstacles, not allowing a proper development of new knowledge and exploitation of the efforts put in research. The main issues point to inadequate communication and exchange of information among actors, also linked to harmonization of terminology, methodology, data handling and sharing. The flux of knowledge along the 4 segments of the knowledge framework (i.e., development, transfer and sharing, harmonization, organization and storage, and application, Fig. 1) is slowed by several bottlenecks, whose removal appear as the main strategy to increase and realize the identified opportunities.

The increase of funding for research, long-term experiments, and education, together with the creation of knowledge networks and national infrastructure linked to those operating at European level, and the development of regional tailored soil management strategies can be promising opportunities to successfully overcoming soil challenges.

Some of the barriers/opportunities highlighted by the respondent are already encompassed in the different activities of EJP SOIL (long term experiment, creation of networks including science, policy and society, creation of harmonized databases on soil properties across Europe), Regarding the need to develop regional tailored soil management strategies, EJP SOIL makes use of the diversity of its partners within internal research projects, which specifically address organic vs mineral soils or consider the diversity of pedoclimatic conditions.

Several of the opportunities go beyond EJP SOIL scope (e.g. the creation of national soil infrastructures, improving communication between researchers and farmers) but the Program will offer an initial common platform, and put the basis for informed future European and national programs and projects.

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ANNEX 1

Guidelines for work package 2 task 2.3 Identification of barriers and opportunities by scenario development

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Task 2.3 Identification of barriers and opportunities by scenario development

1. OBJECTIVE

The European Joint Program SOIL aims to create an integrated framework for soil research in Europe, to support harmonization of capacity, capability and knowledge for all Countries (MS), in order to enable all countries to use the knowledge on soil to face the global challenges. The program objective is to reduce the fragmentation of research to enhance agricultural soils potential to contribute to climate change adaptation and mitigation, while preserving productivity and environmental functions. The soil knowledge has to be developed, shared and transferred, stored and organised, and applied, and task 2.3 activity aims to identify barriers to and opportunities for the enhancement of knowledge – development, sharing and transfer, organization and storage, application - on agricultural soils (Fig. 1).

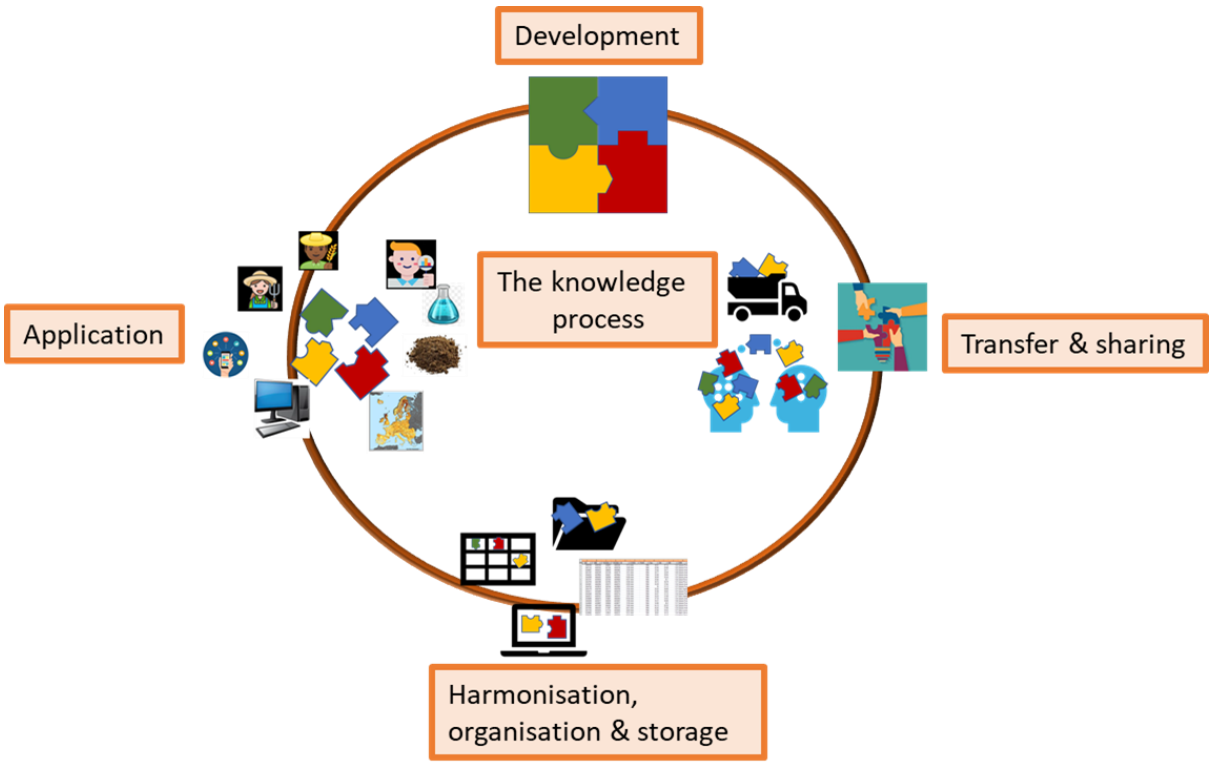

Fig. 1. The knowledge cycle

Output of task 2.3 will contribute to the definition of the roadmap, a key tool to support strategic decision making for science, policy and implementation issues.

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2. GUIDELINES FOR THE IDENTIFICATION OF BARRIERS AND OPPORTUNITIES FOR SOIL KNOWLEDGE - TASK 2.3

2.1 METHODS

Data collection for the assessment of barriers to, and opportunities for soil knowledge will be organised at national level. To acquire the relevant necessary information, it has been considered appropriate not to propose from our side predefined questionnaires, with rigid fields and predetermined answers, but to design the survey in order to let the ideas and opinions of stakeholders on the topics emerge. In fact, for each country there are differences in sensitivities, cultures and social features, and national teams can exploit at best their knowledge on the stakeholder community. Furthermore, translating questionnaires in each native language often demonstrated to be a very sensitive process. Therefore, we recommend that each national team defines the most appropriate way to collect the data. At the end of the process, based on the survey, the national teams will report back the results on the tool provided, created and managed by CREA, that will guide the survey. Tips are added to helps stakeholders during the interview, but they should be considered only as suggestions. The limitations imposed by the Corona virus could slow the collection of information, hence we suggest using all available means as questionnaires, phone interviews, Skype or similar tools, web meetings, email, and to start as soon as possible. Using videos, tutorials and webinars to illustrate the program and to help retrieve the information might be considered. A schematic view of Task 2.3 is reported in Fig. 2.

We suggest conducting the survey to at least 15-20 individuals. It could be useful to divide stakeholders in 3-4 categories such as: managing authorities, scientists, evaluators/technicians, farmers (farmers associations). Other categories might be included depending on the country.

The deadline for the compilation of the online tool is the 31st of July.

How to get the best results from your survey

In order to get the right information and to be able to convey your Country's information by using the tool provided, we suggest following the steps indicated below:

PRELIMINARY ACTION

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The procedures proposed in the following guidelines must be validated by the key-contact person of each PCs by the 10th of May. Comments and proposal modification should be sent to roberta.farina@crea.gov.it.

STEP 1: PREPARATION OF THE QUESTIONNAIRES/INTERVIEWS/WEB MEETINGS

Who: each MS team.

Timing: by the 30th of May.

Objective: to define the format and content of the questionnaires/interviews/web meetings.

Description: this activity includes the preparation of the questionnaire/interviews/web meetings. The submission of questionnaires to stakeholders might be accompanied by leaflets or information sheets with the objectives and the main information on EJP-Soil.

Output: a consolidated version of the most important questions for the stakeholders.

STEP 2: PREPARATION OF THE SURVEY

Who: each MS team.

Timing: by the 30th of May.

Objective: this activity aims to set up all tools for the interviews/questionnaires.

Description: this activity includes the logistic set up of the survey. As already indicated, face-to-face workshops are probably not feasible in most countries. The following options should be used: 1) phone/web interviews, 2) online consultation; 3) workshops in web-conferences. The operational tool to be used should be tailored to the type of stakeholders involved.

Output: tools ready to start the collection of data.

STEP 3: SELECTION OF THE STAKEHOLDERS TO THE SURVEY

Who: Each MS teams in collaboration with WP9.

Timing: By the 30th of May.

Objective: To prepare the list of stakeholders.

Description: The selection of participants to the survey is essential for its success. We suggest following the multi-actor approach by engaging relevant and influencing actors. Identifying stakeholders, differentiating and categorising them is important to represent as much as possible the multifaceted world of soil knowledge. This selection will be made according to WP9. We suggest ensuring representativeness of all categories; and considering the technical/scientific capability to tailor the interviews.

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Output: List of stakeholders per MS (defined by category such as: evaluators, Managing Authorities, technician, scientist, etc…).

STEP 4 CARRY ON THE SURVEY

Who: Each MS team for task 2.3.

Timing: By the 10th of July.

Objective: To acquire information.

Description: See the template.

Output: Internal report with all information acquired.

STEP 5. REPORTING RESULTS OF SURVEY

Who: Each MS team for task 2.3.

Timing: By the 31st of July.

Objective: To organize and report the results of the survey.

Description: An online tool (template) will be prepared by CREA (in English) for the upload of information by the national representatives.

Output: Template filled in with all information required

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Fig. 2 Schematic view of the Task 2.3 Identification of barriers and opportunities by scenario development

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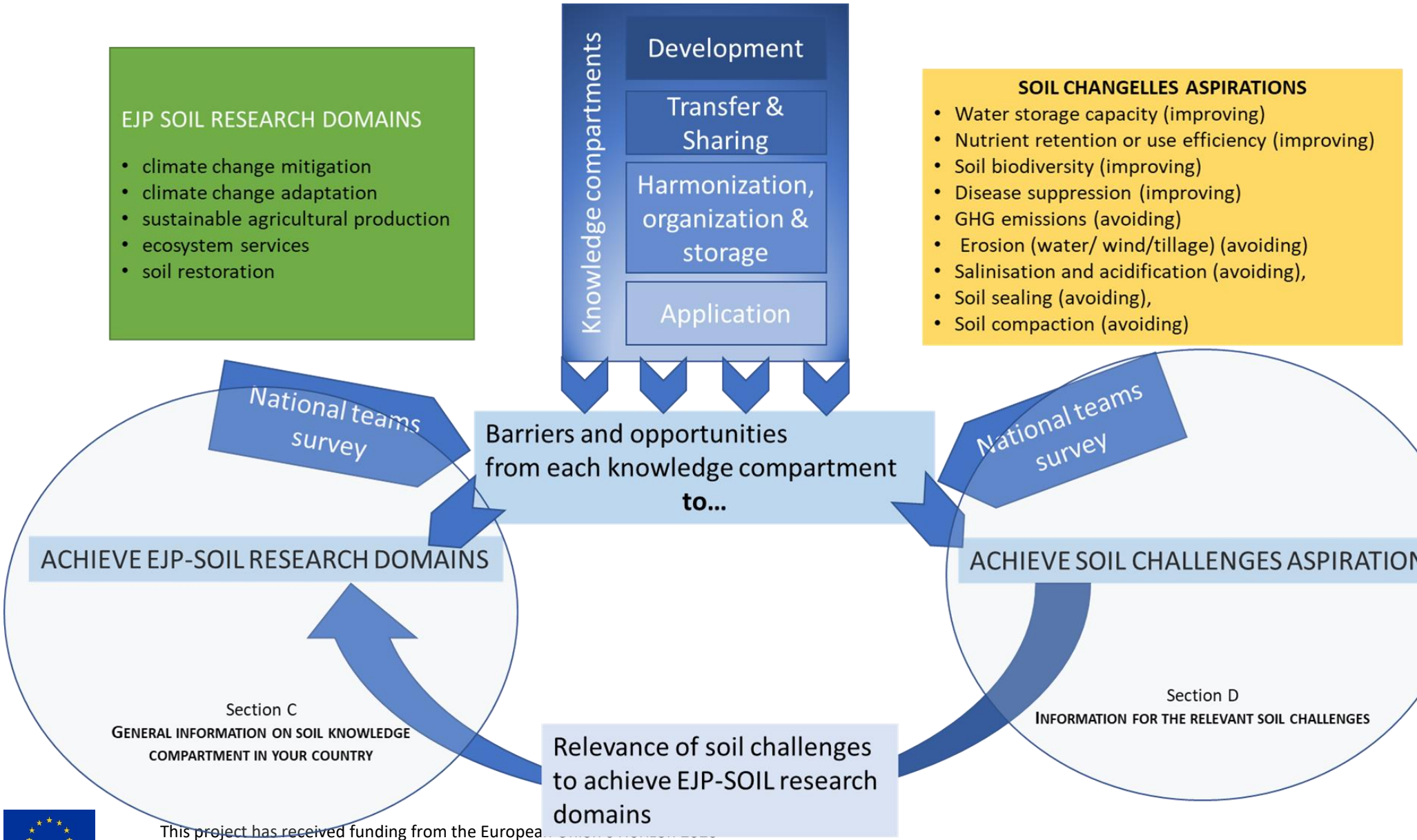

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1. TEMPLATE FOR REPORTING ON BARRIERS AND OPPORTUNITIES FOR SOIL KNOWLEDGE DEVELOPMENT AND USE

Fig. 3 Template for Member State (MS) data upload

EJP SOIL Task 2.3 - Identification of barriers and opportunities by scenario development

REPORT of SINGLE MEMBER STATE

Instruction

1) The aim of this document is to collect data derived from Member State survey to create a Task2.3 database as homogeneous as possible.

2) How to fill this file: Per each Environamental zone you have information, you are required to compile one Excel file. So, if you have information of 2 zones, you have to send us two separate files. Please rename the file as follow: Country name_environmental code.xls (e.g. Italy_MS.xls)

3) This file is divided in several spreadsheets named with the same letters used in the description section of the Guidelines (i.e., A, B, etc.). This is to maintain the correspondence with the information requested in the document.

4) In section A, please insert the general information about your Country.

5) In section B, please insert all the data about the interviewed stakeholders. In each cell, select directly from a list.

6) In section C, please include the barriers and opportunities related to the knowledge compartment. In the cells, you have two options: select directly from a list or insert manually your data.

7) The section D is divided in several sub-sections (i.e., D, D1, D2, etc.): "D" corresponds to the question 19 of the section D of the guideline, while "D1, D2, etc.," correspond to the other questions replicated for the different soil challenges. For the most relevant soil challenges, please compile sheet D1, D2, etc. You (as country conctact) are allowed to insert other spreadsheets if the most relevant soil challenges are more than 5.

8) In the cells of each section, you have two options: select directly from a list or insert manually your data. In sections "C" and "D", you can write directly your answer or select from a list, where some "tips" are listed.

For information you can contact silvia.vanino@crea.gov.it

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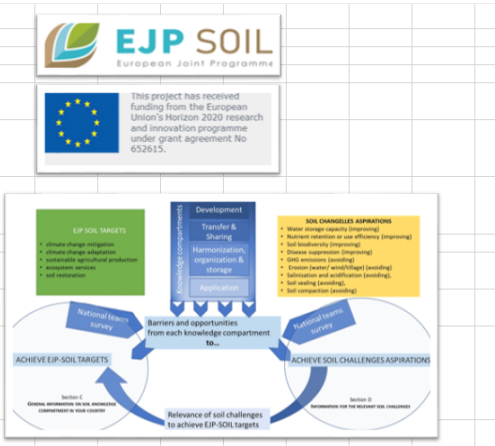

A) GENERAL INFORMATION

1 Name of the Member State (select from dropdown list)

2 Which environmental zones are relevant to consider in your country (select, from the dropdown list, the relevant zones for the country). Please prepare a file for each zone.

3 How many stakeholders did you interview for this exercise (indicate the number)

4 Please illustrate the criteria of stakeholders selection (max 500 words)

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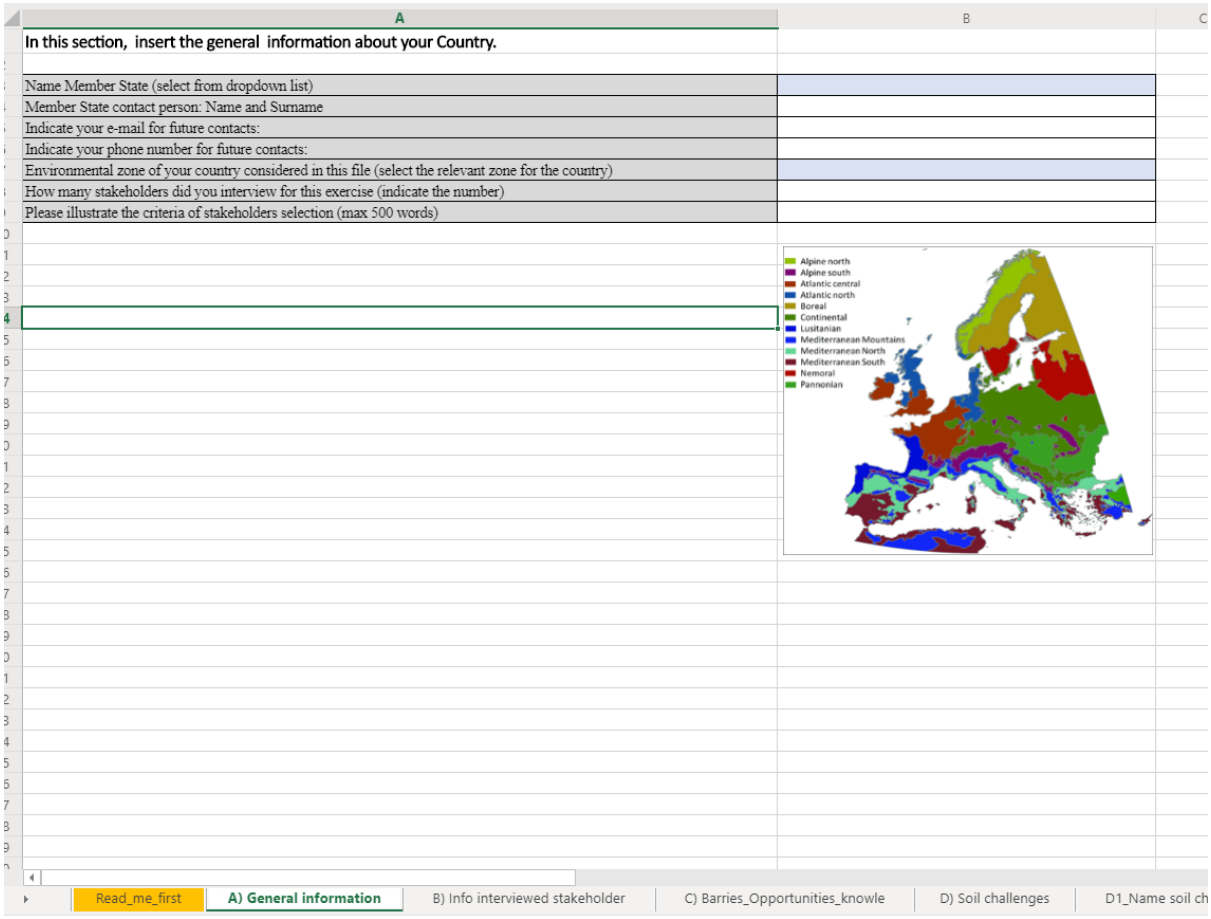
Fig. 4 Template section A) General Information



B) INFORMATION FOR EACH INTERVIEWED STAKEHOLDER

5 Gender (Select)

6 Age (Select from the dropdown list)

7 Level of education (select from the dropdown list)

8 Stakeholder group (Select from the dropdown list)

9 Interview type (select from the dropdown list among: phone, face-to-face, focus group/workshop, email)

10 According to each stakeholder, what are the most relevant soil challenges for their country (dropdown list)

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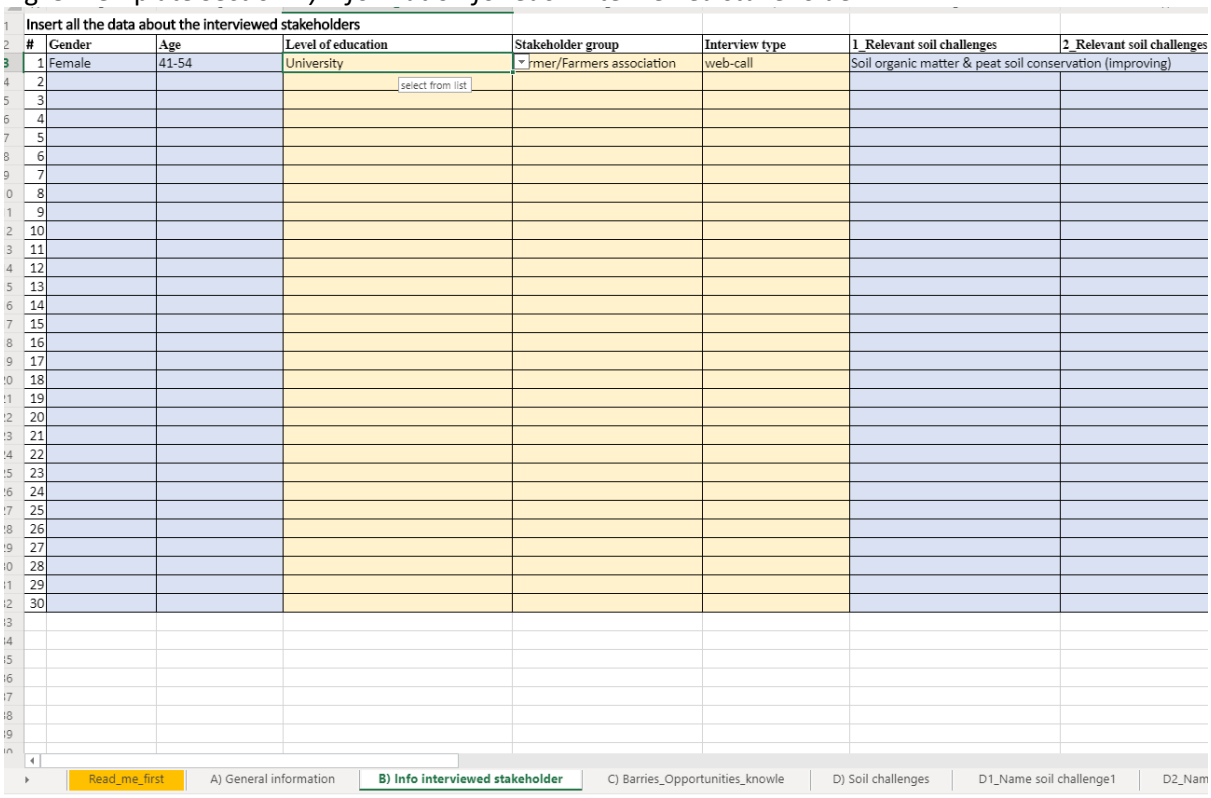
Fig. 5. Template *Section B) Information for each interviewed stakeholder*



Insert all the data about the interviewed stakeholders

#	Gender	Age	Level of education	Stakeholder group	Interview type	1_Relevant soil challenges	2_Relevant soil challenges
1	Female	41-54	University	rmer/Farmers association	web-call	Soil organic matter & peat soil conservation (improving)	
2			select from list				
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Read_me_first | A) General information | B) Info interviewed stakeholder | C) Barries_Opportunities_knowle | D) Soil challenges | D1_Name soil challenge1 | D2_Nam

C) GENERAL INFORMATION ON SOIL KNOWLEDGE COMPARTMENT IN YOUR COUNTRY

To inquire separately for each compartment of knowledge (template questions from 11 to 18) might require an excessive time for some or most of the stakeholders. You can group knowledge segments in only one question. However, keep in mind that to allow for a complete exploration of the barriers/opportunities, you must report results separately for each compartment.

11 According to stakeholders, which are the most important general barriers, at national level, to knowledge development, perceived as obstacles to reach the main EJP goals? (List and prioritisation of barriers; relevant observations and comments, max 500 words)

Tips: *For this compartment, you can refer to critical aspects related to the main actors/processes of knowledge development, namely universities & education systems, research organizations, but also advisory services, farmers, consumers. Critical aspects might be: the identification of research needs is not effective, as a result research is not focusing on the most important topics; too large number of soil research institutions whose actions are fragmented and not coordinated; institutions working on soil science are not enough; scientific equipment in university/research organizations are obsolete; financial resources allocated to soil research are not sufficient; selection processes mechanisms for*

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research project are not appropriate, bottlenecks and lack of coordination among national/regional institutions (ministries, regions and national agencies) within the research chain; lack of public-private partnership on soil research; lack of relations among research, advisory services and farmers (including their associations); lack of training for advisors and farmers on soil-related issues. In the survey also other drivers out of the knowledge compartment, such as economic constraints, institutional/regulatory political bottlenecks and limitations, social, cultural, gender and gaps, might be mentioned.

12 According to stakeholders, which opportunities are offered by soil knowledge development to reach the main EJP goals at country level? (List and prioritisation of general opportunities in knowledge development, relevant observations and comments, max 500 words)

Tips: *As seen for knowledge development barriers, you can list and describe the opportunities offered by the development of new knowledge at national level. In this case opportunities can come from elements such as: promoting start-ups; increasing funding for soil related research; increasing the number and improving curricula of the soil science students; increasing training for farmers, advisors and other actors potentially involved in developing soil-related knowledge; promoting women participation to soil research; supporting multi- and trans-disciplinary research; supporting multi-actor projects (better involvement of farmers/advisors in the early stages of projects definition might boost more appropriate definition of research needs), activate/valorise/fund long term experiments; switch from top-down to bottom-up research, etc.*

13 According to stakeholders, which are the general barriers/gaps to knowledge sharing and transfer perceived as obstacles to reach the main EJP goals? (List and prioritisation of issues in knowledge sharing and transfer, relevant observations, and comments, max 500 words)

Tips: *Barriers in this compartment at general level typically refer to critical aspects related to the sharing and transfer of knowledge by the main actors/processes, namely universities & education systems, involved in the development of new knowledge, to the stakeholders in the broadest sense. Processes of knowledge transfer and sharing that might happen among farmers, advisors, practitioners should also be considered (operational groups implemented within the EIP AGRI, as well as multi-actor projects funded under H2020 could be examples). Furthermore, when considering knowledge sharing it could be worth to distinguish between sharing with farmers/practitioners/advisors from the dissemination of knowledge to the civil society. Barriers identified in this step could be: networks science-science, science-farmers, science-advisors, science-society, science-policy are not established;*

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communication between researchers and farmers is not effective and this hampers the transfer of useful knowledge; lack of training for farmers and advisors; lack of training for researchers on how better communicate with practitioners; difficult access to proper advice for farmers; dissemination is missing, dissemination content does not convey useful information, communication is not clear for all stakeholder categories, etc.

14 According to stakeholders, which opportunities at general level are offered by knowledge sharing and transfer? (List and prioritisation of opportunities; relevant observations and comments, max 500 words)

Tips: *Opportunities in knowledge sharing and transfer at country level typically refer to the valorisation of knowledge from universities & education systems, involving stakeholders. Sharing and transfer of knowledge between farmers and advisors should also be considered. Opportunities might be: establishment of permanent national networks science-science, science-farmers, science advisors, science-society, science-policy; improving training programmes for farmers and advisors; supporting peer-to-peer training between farmers/advisors; supporting the setting-up of demonstration activities (e.g. experimental and demonstration farms); supporting multi-actor approach, particularly the exchange between researchers and farmers/advisors; improving dissemination activity; making dissemination mandatory in all funded projects; allowing for targeted and effective dissemination; using effective communication to increase awareness on the importance of soil in all of society, etc.*

15 According to stakeholders, which are the most important general barriers to harmonization, organization and storage of information about soil-related knowledge, perceived as obstacles to reach the main EJP goals? (List and prioritisation of barriers; relevant observations and comments, max 500 words)

Tips: *For this topic, you can refer to the main general barriers affecting knowledge harmonization, organization, and storage of soil information. In this case barriers might deploy their negative effects at different levels. (i) Barriers on soil data might be: outdated information, different methodologies used for soil sampling, analysis and mapping, and/or storage data dispersed and often not available to the public; (ii) barriers on data sharing might be lack of common data policy and data fragmentation; (iii) technological barriers might be lack of internet access in rural areas, lacking common "decision support" ICT tools able to secure soil data storage facilities at EU level.*

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16 According to stakeholders, which are the opportunities offered by harmonization, organization and storage of information about soil-related knowledge, to reach the main EJP goals?

Tips: *You can list and describe the opportunities offered by the harmonization, organization and storage of information about soil-related knowledge (both already existing and new) at national level. Opportunities to overcome current soil data fragmentation might be promotion of harmonization and standardization methodologies; creation of national infrastructures and interactive web-based communication of soil data; data storage with international standards, etc. Another opportunity can be the validation and integration of large data sets by using new developments in information technology such as geographic information systems, statistics and modelling, contributing to reporting on the international commitments (Kyoto protocol, UNFCCC, CAP).*

17 According to stakeholders, which are the most important general barriers to knowledge application perceived as obstacles to reach the main EJP goals? (List and prioritisation of barriers; relevant observations and comments, max 500 words)

Tips: *In knowledge application you can refer to four main general barriers: economic, socio-cultural, institutional and technological. These barriers operate from the scale of individuals/communities through to the global scale. Economic barriers can be costs and lags in return from changing land management practices, yields and profits may not respond as farmer/land managers expect; lack of appropriate incentives. Social barriers can be lack of communication structure in which dissemination, communication and knowledge exchange activities are facilitated (i.e. lack of soil specific website, popular articles, soil guidelines...) or/and communities pressure/traditional practices and gender norms that can hinder change of soil management practices. Institutional and legal barriers can affect implementation of sustainable soil management practices as well as land tenure and access; lack of good policies and incentives; lack of scientific support to policy makers and/or vice versa. Technological barriers can be lack of internet access in rural areas, lacking "decision support" ICT tools, lack of applied agricultural technology. In addition to these four main categories of barriers, it should also be considered the lack of exchange, often reported, between researchers and farmers/advisors. Correct application of knowledge and research results require specific capacities that often farmers or advisors do not possess. The lack of tools that facilitate positive exchanges among farmers and researchers, or among farmers (peer-to peer) might represent an important barrier to applying knowledge already developed and tested.*

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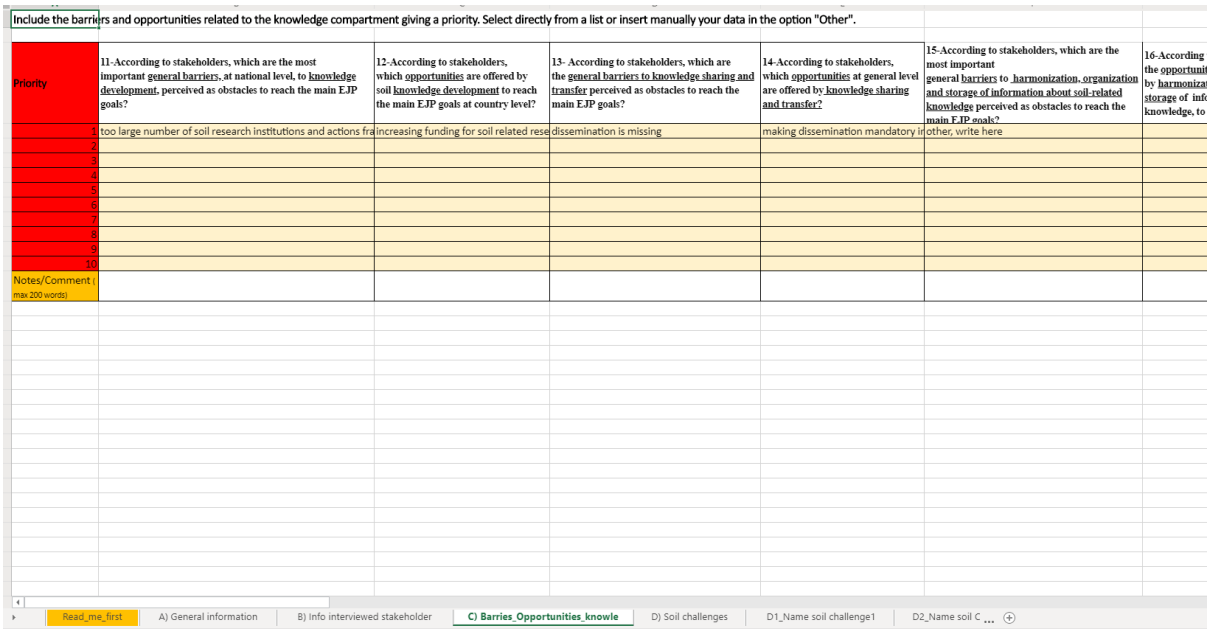
18 According to stakeholders, which are the opportunities offered by soil knowledge application to reach the main EJP goals?

Tips: *As seen before, you can list and describe the opportunities offered by the application of new knowledge at national level: soils are better integrated in the circular economy and bio-economy with a good consequence in farms profits; good policies and incentives with effective policy measures; development of region-specific soil management strategies; farmers have adequate ICT tools and use them; the existence of specific mechanisms to support farmers in applying this knowledge (access to training and advice, demonstration activities, field visits, etc.).*

Fig. 6. Template Section C) General information on soil knowledge segments in your country



Include the barriers and opportunities related to the knowledge compartment giving a priority. Select directly from a list or insert manually your data in the option "Other".

Priority	11-According to stakeholders, which are the most important general barriers, at national level, to knowledge development, perceived as obstacles to reach the main EJP goals?	12-According to stakeholders, which opportunities are offered by soil knowledge development to reach the main EJP goals at country level?	13- According to stakeholders, which are the general barriers to knowledge sharing and transfer perceived as obstacles to reach the main EJP goals?	14-According to stakeholders, which opportunities at general level are offered by knowledge sharing and transfer?	15-According to stakeholders, which are the most important general barriers to harmonization, organization and storage of information about soil-related knowledge perceived as obstacles to reach the main EJP goals?	16-According the opportuni by harmoniza storage of info knowledge, to
1	too large number of soil research institutions and actions fra	increasing funding for soil related rese	dissemination is missing	making dissemination mandatory in	other, write here	
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10						
Notes/Comment (max 200 words)						

Read_me_first | A) General information | B) Info interviewed stakeholder | C) Barries_Opportunities_knowle | D) Soil challenges | D1_Name soil challenge1 | D2_Name soil C ...

D) INFORMATION FOR THE RELEVANT SOIL CHALLENGES ASPIRATION (*LIMIT THIS PART OF SURVEY TO THE MOST RELEVANT CHALLENGES*). FOR EACH RELEVANT CHALLENGE:

As for session C), to inquire separately for each compartment of knowledge (template questions from 20 to 27), might require an excessive time for some or most of the stakeholders. You can group all the knowledge segments in only one question for each relevant soil challenge aspiration. However, in order to allow for a complete exploration of the barriers/opportunities, you might report results separately for each compartment.

19 According to stakeholders, what is the relevance of each soil challenge for the achievement of the main EJP-SOIL goals (from dropdown list: None, Low relevant, Medium relevant, High relevant)

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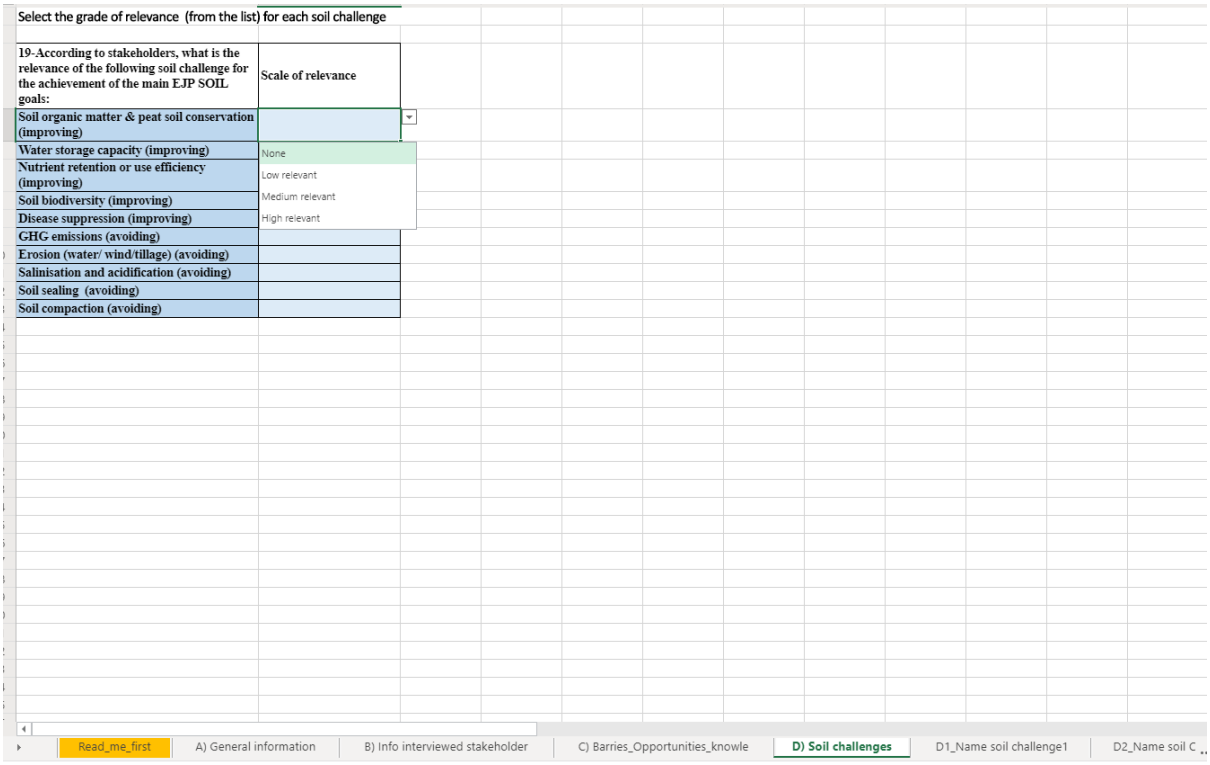
Fig. 7. Template section D), question 19- Relevance of each soil challenge for the achievement of the main EJP-SOIL goals



20 According to stakeholders, which are the most important general barriers and gaps, at national level, in the actual knowledge development, which are perceived as obstacles to overcome the challenge [name of the challenge]? (List and prioritisation of barriers; relevant observations and comments, max 500 words)

Tips: *In the template you can describe the barriers with a specific focus on gaps in soil knowledge which hinders the overcoming of [name of the challenge]. Elements of knowledge gaps specific for soil and the soil challenge are of the type: lack of understanding of basic processes of water; nutrients and organic matter in soils in this pedoclimatic area; new research topics; missing a national database on soils; lack of spatially explicit soil data; gaps in local specific knowledge (effect of soil, crop, residues management on the soil challenge); scaling issues for the soil challenge; links between soil management; farming systems and soil quality; training for young researchers; etc.*

21 According to stakeholders, which are the opportunities offered by soil knowledge development for the challenge [name of the challenge]? (List of opportunities; relevant observations and comments, max 500 words)

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Tips: *Opportunities focusing on soil science development could be represented by the identification of research needs (topics) in the soil challenge or be of the type: evaluation of the connection between the land use and the [name of the challenge]; development and application of soil sustainable management indicators; development and validation of relevant bio-physical models for predicting the long term dynamics of soil phenomena; measuring at local level and predicting/extrapolate at landscape and regional scale, and can be also more detailed for local knowledge needs. Other opportunities can descend from specific regulations, agro-environmental measures at national and regional level, country or regional incentives.*

22 According to stakeholders, which are the most important barriers/gaps to sharing and transfer knowledge perceived as obstacles to overcome [name of the challenge] in this country? (List and prioritisation of barriers in knowledge sharing and transfer, relevant observations and comments, max 500 words)

Tips: *In the template you can describe the barriers to knowledge sharing and transfer with a specific focus to soil knowledge which hinders the overcoming of [name of the challenge]. Possible issues in knowledge sharing and transfer specific to the soil can be of the type: there is knowledge on the issue, but it is not disseminated, the knowledge is not available for all actors involved in soil; there is no communication among all stakeholders; there are not appropriate methods to support an effective sharing among researchers and farmers; etc.*

23 According to stakeholders, which are the opportunities offered by knowledge sharing and transfer for the soil challenge [name of the challenge]? (List of opportunities; relevant observations and comments, max 500 words)

Tips: *Opportunities to overcome the soil challenge might be: availability of knowledge for stakeholders; capacity building from universities and schools; technical networks science-farmers; establishing soil networks for scientists, science-policy and science-society; improving dissemination; continuous knowledge synthesis and feedback loop; stakeholder participation; setting-up operational groups and taking stock from those already working on soil-related themes; strengthening scientific capacities and cooperation; setting-up capacity building programmes for young soil scientists and societal stakeholders i.e. farmers and advisors, policy makers, landowners and managers, civil society and industry.*

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24 According to stakeholders, which are the most important barriers/gaps to knowledge harmonization, organization and storage (i.e. soil data acquisition, organization in open soil data base, georeferencing of soil properties, standard protocols for soil analyses, sharing long term experiment data) perceived as obstacles to overcome the challenge [name of the challenge]? (List and prioritisation of barriers; relevant observations and comments, max 500 words)

Tips: *In the template you can describe the barriers to data harmonization, organization and storage with a specific focus on [name of the challenge]. Possible issues specific to the soil are: lack of harmonization and standardization in data collected over time; common methodologies used for soil sampling; analysis and mapping; data fragmentation; integrated framework and ICT tools to secure soil data storage facilities at different levels. Application of specific knowledge management, common tools, organizational learning can overcome the current fragmentation.*

25 According to stakeholders, which are the opportunities offered by knowledge harmonization, organization and storage for soil challenge [name of the challenge]? (List of opportunities; relevant observations and comments, max 500 words)

Tips: *For [name of the challenge], opportunities focusing on data harmonization, organization and data storage can be related to the standardization of methodologies with international standards and accepted procedures, the interactive web-based communication of soil data. Other opportunities can descend from specific regulations, agro-environmental measures at national and regional level, country or regional incentives.*

26 According to stakeholders, which are the most important barriers/gaps, at national level, to knowledge application perceived as obstacles to overcome the challenge [name of the challenge]? (List and prioritisation of barriers; relevant observations and comments, max 500 words)

Tips: *In the template you can describe the barriers to knowledge application with a specific focus to [name of the challenge]. Possible issues in knowledge application specific for the soil are: lack of technologies, ICT tools and DSS (Decision Support Systems); willingness of farmer to apply new soil management practices; farmer loss yield and profit; lack of specific regulations and EU Policies; barriers to adoption and enabling conditions to implement soil challenge; etc.*

27 According to stakeholders, which are the opportunities offered by knowledge application for soil challenge [name of the challenge]? (List of opportunities; relevant observations and comments, max 500 words)

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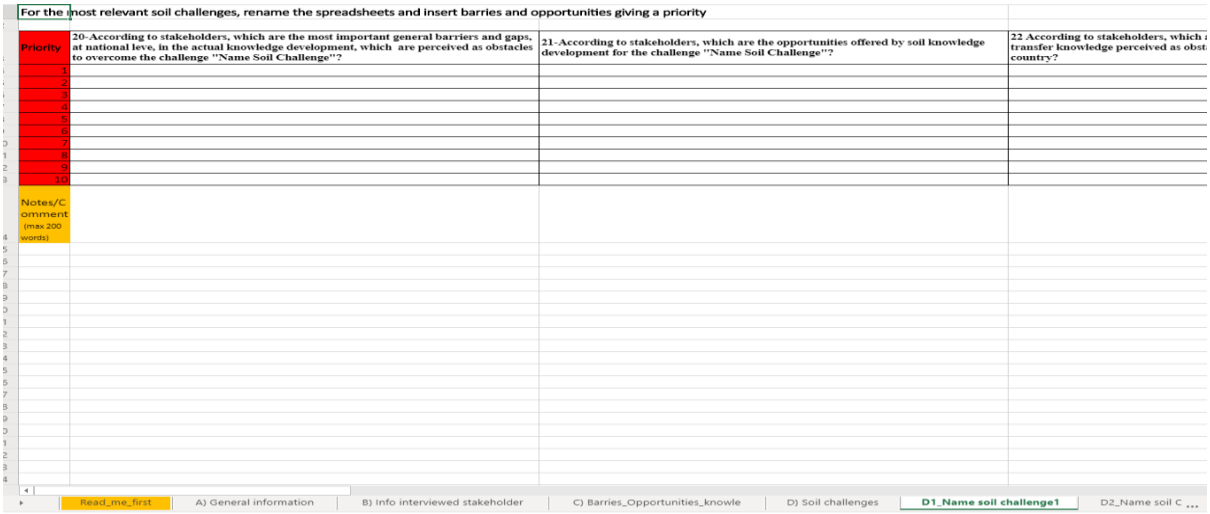
Tips: *Opportunities of the application of knowledge can be: improving thematic guidelines (water, nutrient and fertilizer…); certification principles for tools and advisory services; ready-to-use technologies, openness and contact between the soil science community and society; good interfacing between science and policy; improving access to long-term field sites and development of specific advice; ICT decision support system; good specific policies and incentives, address future policy needs for new knowledge; facilitate knowledge sharing and mutual learning science-society-policy.*

Fig. 8. Template section D) Information for each relevant soil challenge


For the most relevant soil challenges, rename the spreadsheets and insert barries and opportunities giving a priority

Priority	20-According to stakeholders, which are the most important general barriers and gaps, at national leve, in the actual knowledge development, which are perceived as obstacles to overcome the challenge "Name Soil Challenge"?	21-According to stakeholders, which are the opportunities offered by soil knowledge development for the challenge "Name Soil Challenge"?	22 According to stakeholders, which transfer knowledge perceived as obst country?
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Notes/Comment (max 200 words)			

Read_me_first | A) General information | B) Info interviewed stakeholder | C) Barries_Opportunities_knowle | D) Soil challenges | D1_Name soil challenge1 | D2_Name soil C ...

E) FINAL CONSIDERATIONS

28 According to stakeholders, which are the other drivers/constraint/opportunities (economic, social, policy, others) influencing the achievement of the soil challenge? (max 500 words)

29 Could you briefly report about the different perceptions of stakeholders' groups on the different topics? (max 500 words)

30 And in your opinion, what is the reason for the different perceptions - age, level of education, profession, field of activity, other? (max 500 words)

Fig. 9. Template for section E) Final considerations

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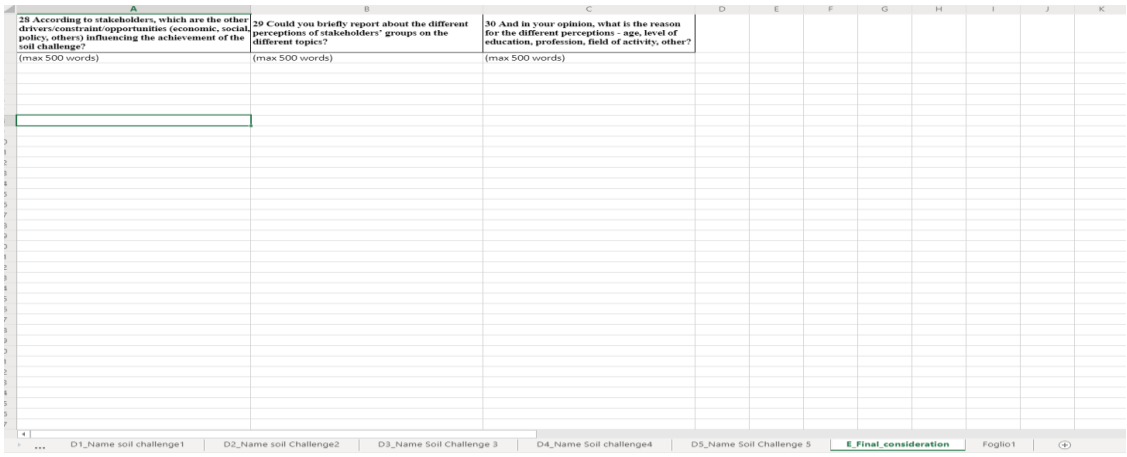

28 According to stakeholders, which are the other drivers/constraint/opportunities (economic, social, policy, others) influencing the achievement of the soil challenge?	29 Could you briefly report about the different perceptions of stakeholders' groups on the different topics?	30 And in your opinion, what is the reason for the different perceptions - age, level of education, profession, field of activity, other?
(max 500 words)	(max 500 words)	(max 500 words)

D1_Name soil challenge1 | D2_Name soil Challenge2 | D3_Name Soil Challenge 3 | D4_Name Soil challenge4 | D5_Name Soil Challenge 5 | E_Final_consideration | Foglio1

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