Roadmap for the European Joint Program SOIL: Towards climate-smart sustainable management of agricultural soils

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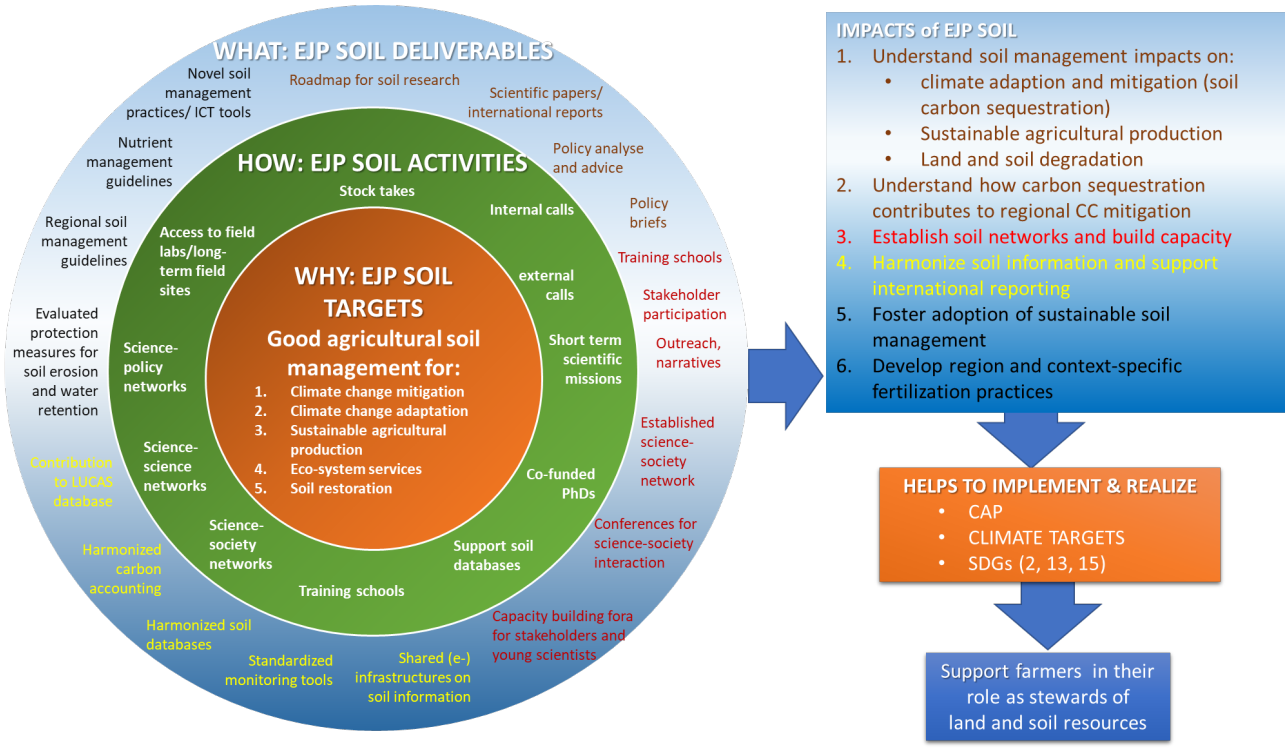
Graphical Abstract



Keywords: Soil, Agriculture, Management, Climate Change, Soil Quality, Data harmonization networks, climate-smart sustainable soil management knowledge, Sustainable development Goals, Soil information, science-policy interface

Reading guide for this roadmap

European Joint Programs (EJPs) are co-fund actions designed to support coordinated national research and innovation programs. EJPs aim at attracting and pooling a critical mass of national resources on objectives and challenges of Horizon 2020 and at achieving significant economies of scales by adding related Horizon 2020 resources to a joint effort.

The overall goal of the EJP SOIL is **to build a sustainable European integrated research system on agricultural soils** and **develop and deploy a reference framework on climate-smart sustainable agricultural soil management,** to create the enabling environment that will maximise 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. To structure the knowledge management needed to achieve this objective, EJP SOIL follows an adapted version of the knowledge framework of Dalkir (2005)[1] to structure the lines of thought and work that results from that.

After an introduction (Chapter 1) and explanation on the sources of the knowledge demands (Chapter 2), we explain the key issues that need to be addressed (Chapter 3). In this chapter all key research topics and activities have been organised following the four parts of the framework: Knowledge development, knowledge sharing & transfer, knowledge harmonisation, organisation &storage and lastly knowledge application.
This chapter is structured as follows:

1. key questions related to the knowledge compartment.
2. Actions and methodologies addressing the key questions in the EJP SOIL project.
3. *Impact pathways to describe the workflow:* an overview of proposed activities and expected outputs.

This provisional roadmap feed into the annual work plans of which the first is presented in Annex 7 of the overall proposal.

The current version of the roadmap is a provisional version, which was developed by the EJP core group during several workshops (in March, May, November 2018 and January 2019) in the preparation phase of the proposal. In Year 1 of the EJP SOIL project the knowledge demands across the knowledge framework from all Member states will be collected and an updated roadmap endorsed by all Program Managers will be delivered and form the base of the workplans for the remainder of the project.

[1] Dalkir, K., 2005. The knowledge management cycle. *Knowledge management in theory and practice. Oxford: Elsevier*, pp.25-46.

Contents

1 Introduction EJP-SOIL

The European Joint Programme (EJP) SOIL is a European network of research institutes in the field of soil science and agricultural soil management and policies. This EJP aims to boost research by finding synergies in research, avoid current fragmentation and make a leapfrog in research on good agricultural soil management in three main areas: climate change mitigation and adaptation, food security and ecosystem services delivery by joint programming, training and capacity building, whilst taking into account the need for effective policy solutions, as well as the socio-economic conditions of all stakeholders in the agricultural value chain. At the stage of proposal submission, the consortium consists of 26 partner institutes from 24 countries. EJP-SOIL is structured in nine Work Packages (Figure 1)

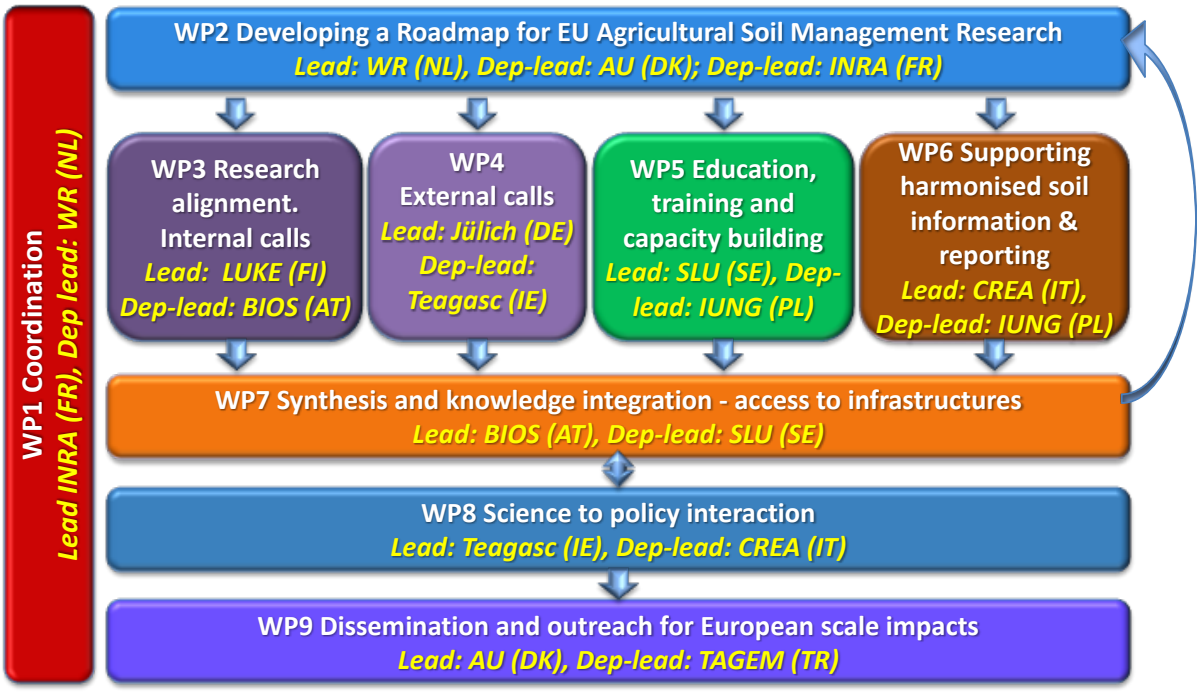


Figure 1: Structure of EJP SOIL

In the preparatory phase of the EJP SOIL, a provisional Strategic Research Agenda, or so-called provisional roadmap was developed using the input of the core group that was responsible for the development of the proposal which is described in this document. This provisional roadmap will be further developed & endorsed in the first year of the EJP SOIL, involving stakeholders and the scientific community, consequently the roadmap will be updated during the whole EJP project. The final endorsed roadmap will include: i) an overview on the current knowledge gaps for the expected impacts of EJP SOIL; ii) stakeholder needs related to knowledge, training, soil data and adoption of practices; iii) prioritization of the knowledge needs.

2 Knowledge demand: How is the EJP SOIL going to support solutions for the societal issues of our time: Climate change adaptation and mitigation, sustainable agricultural production, ecosystem services, soil restoration.

Our Planet suffers from human activities. Especially different forms of intensive agriculture with large inputs of fertilisers, pesticides and mechanical energy increasingly add to the human-pressure on the environment. As part of the environment soils are also under threat, while they are an essential part of this system as they need to provide safe food, feed, fibre and fuel for an increasing population, and it is the basis for bio-economy. In this field of play of economic constraints and environmental issues, farmers struggle to create a sustainable livelihood.
As scientists, we know more and more about our environment, about processes, rates of change, new threats and risks. However, the challenges seem to grow quicker than the solutions we can create. Our challenge as scientists is to focus on the scientific research towards finding solutions for the societal issues of our time. For this interdisciplinary collaboration and networking is needed. It is necessary to bring scientists and stakeholders that have the same goal, work on the same societal issue, but have different scientific backgrounds.

The EJP-SOIL links to key international policies and initiatives such as the Common Agricultural Policy (CAP), Climate Change related policy and relevant environmental policies, and the EU Soil Thematic Strategy. In the proposal Annex 1, an exhaustive list of initiatives, and projects (Table 1) and of agricultural soil related policies (Table 8), that share aims with EJP SOIL is presented: climate mitigation & adaptation, agricultural production, maintenance of ecosystem services, soil restoration.

Good agricultural management makes use of ecosystem services and can contribute to it.

The EU EJP SOIL has defined as its main challenge the creation of an integrated framework for soil research in Europe that supports harmonization of capacity, capability and knowledge such that all Member States find equal opportunity to contribute to targets set out in the various policy and societal challenges. This framework aims to overcome current fragmentation and aims to unleash and utilise the potential of agricultural soils to contribute to climate change adaptation and mitigation while preserving or even enhancing their performance in relation to other agricultural (plant productivity and health) and environmental functions (clean – drinking – water, air, biodiversity).

The road map functions as a strategic research agenda that allows for strategic decision making in science, policy and implementation issues. Therefore, EJP SOIL has three target groups: 1, science, 2 policy makers and 3. Implementers (farmers & advisors, land owners & managers, civil society and industry). The strategic agenda serves to create an implementation plan, engaging and committing member states and stakeholders across Europe in joining forces to collaborate on relevant research and complementary activities with respect to

Agricultural Soil Management. In addition to developing and synthesising new knowledge, knowledge on soils needs to be shared and transferred, needs to be harmonised, stored and organised and needs to be applied in practice.

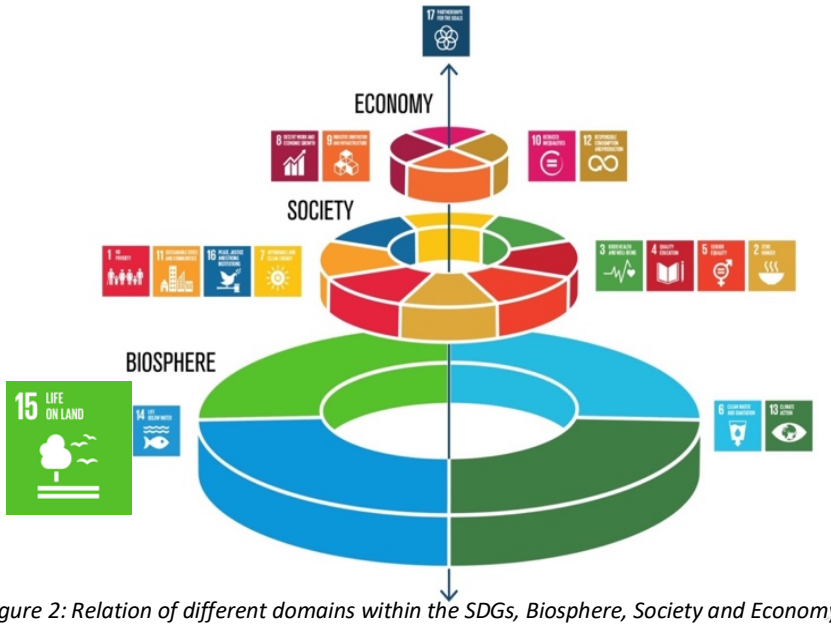


Figure 2: Relation of different domains within the SDGs, Biosphere, Society and Economy (adapted after the original figure of the Azote Images for Stockholm Resilience Centre).

This document provides a provisional roadmap for EJP SOIL and describes a targeted vision for sustainable agricultural soil management that contributes to food security, climate change mitigation and adaptation and ecosystem services, i.e. climate-smart sustainable soil management. The Climate-Smart Sustainable Soil Management concept addresses the diversity of agricultural models with an inclusive approach, i.e. all agricultures having an agroecological approach, such as organic agriculture, conservation agriculture, ecologically intensive agriculture, regenerative agriculture, etc., as well as more conventional forms of agriculture.

Leading up to a prioritization of research gaps to achieve these targets, we have used the spirit of the figure of the Stockholm resilience centre about the SDGs (Figure 2). This model shows that economies and societies are embedded parts of the biosphere. The current sectorial approach where social, economic, and ecological development are seen as separate parts has to transition into a paradigm in which Economy serves Society without damaging the Biosphere. Soils are part of the Biosphere, but people that live and work on the land are in the society and economy parts of this diagram. To be able to come to a sustainable situation in which all SDGs can be achieved the relationships between these rings are indispensable. Keesstra et al., (2016) described an inventory of the link between soil science, soil functions, ecosystem services and finally the SDGs. From this analysis it is clear that there are several SDGs where soils play a more important and prominent role than in others: SDG15 Life on Land, SDG13 Climate Action and SDG2 Zero Hunger rely heavily on soils as a natural resource. But also, in all other SDGs (except 17) soil plays a role in their achievement in one way or the other.

2.1 Key issues, lacking enabling conditions and knowledge gaps to be solved & closed for progress beyond the State-of-the-Art

In the long-term the EJP SOIL aims to help promoting farmers to be, and to be seen as the stewards of land and soil resources. For this, a shift in the perception of farmers among the general public, the majority of scientist and policy makers is needed; as well as a shift in the perception of farmers towards sustainability. Therefore, EJP SOIL prepares the step-wise approach to get a grip on the **key knowledge gaps and implementation barriers**

related to data harmonization, networks, capacity building and policy. In the soil thematic strategy[2] that was adopted in 2006 a list of targets was set towards halting soil degradation and restoring degraded land. However, soil degradation is still continuing, and it is still difficult to monitor and protect soils. Knowledge about the status and quality of soils remains fragmented and soil protection is not undertaken in an effective and coherent way in all Member States (EC, 2012 [3]).

Key issues that need to be addressed to tackle these issues according to the Soil Thematic Strategy[4] are:

- **Awareness raising** initiatives
- **Training** for young researchers
- **Research** projects focussing on different soil threaths, soil functions, nutrient cycles, carbon cycles, biodiversity and soil fertility.
- Support and expand the activities of the **European Soil Data Centre** which hosts soil data and information at European level.
- Consolidate harmonised soil **monitoring**
- **Integration** of soil protection in different policies.
- **Better integrated legislation**
- Collaborate and integrate with actions taken on **global level**
- Consolidate harmonisation of soil monitoring and of soil management and **fertilization guidance** and advisory services.

These goals have been set in 2006 and later evaluated in 2012. Even though progress has been made in some parts, some other goals are lagging behind compared to the ambitions. The core group of the EJP SOIL, identified several enabling conditions that are absent in the agricultural system and therefor prohibiting progress. The analysis below emerged from several internal workshops of the core EJP SOIL group, which was particularly involved in the preparation of the proposal, and from a review of main recent expert reports (e.g. EASAC 2018, EESC, 2017, Agri-GHG conference 2018, INSPIRATION SRA, 2017, FACCE-JPI SRA, 2016) and of scientific literature.

These missing enabling conditions can be grouped in four elements:

- Knowledge is missing:
  - Knowledge does not exist for some areas and pedoclimatic contexts of Europe (some contexts are heavily studied while others are understudied [5]).
  - Knowledge is not integrated enough, in particular knowledge specific to different spatial and temporal scales, to different components of an agricultural landscape, to different elements of the food chain or issued from different disciplines dealing with soils. The inherent complexity of soils – agroecosystems – food systems, requires assembling and integrating the available knowledge, in particular through interdisciplinary studies and using modelling.
  - Soils are part of a larger complex system: managing complex systems is inherently in-depth system knowledge intensive and need continuous innovation and adaptive management to remain on a resilient pathway to sustainability, productivity and climate regulating contribution.
  - Benefits of soil carbon and soil quality in general for both agricultural productivity and resource efficiency are not always quantified.
  - Uncertainty about the efficacy of measures and return on investment in soil management.
- Transfer of knowledge is blocked:

[3] REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS The implementation of the Soil Thematic Strategy and ongoing activities /* COM/2012/046 final */

[4] [4] Soil Thematic Strategy, COM(2006) 231: Policy Document. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - Thematic Strategy for Soil Protection [SEC(2006)620] [SEC(2006)1165]

5 2018. Summary Report: International Conference on Agricultural GHG Emissions and Food Security –Connecting research to policy and practice. 11-13th Sept 2018, Berlin.

- Knowledge is present, but in some situations, it is not available to the relevant stakeholders; Knowledge is present, but not yet translated into decision support tools (e.g. benefits of soil organic matter, benefits of vegetative or mulch cover in agricultural fields),
- Lack of compatibility between soil monitoring activities in different member states (MS);
- The management of agricultural soils in the EU is impacted by a diversity of agri-environmental policies rather than a single horizontal mechanism, making the knowledge transfer fragmentary and variable over Europe;
- Difficulty in converting research results into policy messages;
- Insufficient contact with farmers organizations in all MS's.

- Socio-economic aspects are under considered:
  - Economic incentives (either policy driven, or market driven) may be misguiding and/or contra-productive (e.g. Drip irrigation subsidies in previously dryland agricultural areas);
  - Social and cultural perception is often overlooked;
  - Conflicting interests of different stakeholders: need better understanding of socio-economic barriers.
- Paradigm shifts are needed:
  - In addition to the previous limits, a whole paradigm shift is required from land and soil managers, i.e. to go from protection to sustainable use, which is difficult to endorse, but EJP SOIL will improve the conditions to faciliate these shift.

2.2 How will EJP SOIL address research demand and barriers: A Knowledge framework to reach the impact goals

The main aim of the EJP is to construct a sustainable framework for an integrated community of research groups working on related aspects of agricultural soil management. Aspects of (knowledge on) agricultural soil management to be addressed in the EJP SOIL are:

1. To strengthen the European research community on agricultural soil management, through a concerted alignment of research, training and capacity building;
2. To co-construct with stakeholders a roadmap for agricultural soil research;
3. To fill the identified knowledge gaps by fostering research projects and synthesis through the organization of internal and external calls;
4. To develop harmonised soil information and foster its contribution to reporting, through a combination of methodological transnational activities and research projects using geodatabases and combining it with remote sensing and models.
5. To support European policies on agriculture and climate by providing scientific underpinning.

From these aims the following **six impacts** are expected (Table 1):

Table1: Six Expected impacts of EJP SOIL

1. Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment
2. Understanding how soil carbon sequestration can contribute to climate change mitigation at regional level including accounting for carbon;
3. Strengthening scientific capacities and cooperation across Europe including training of young soil scientists
4. Supporting harmonised European soil information, including for international reporting
5. Fostering the uptake of soil management practices which are conducive to climate change adaptation and mitigation
6. Develop region and context-specific fertilization practices (soil, water and pedo-climatic conditions)

To come to a structured roadmap to accomplish these goals EJP SOIL works with an adapted version of the knowledge management framework of Dalkir (2005; Figure 3). The EJP version comprises of four compartments: i) Knowledge development, ii) knowledge harmonisation, organisation & storage iii) knowledge sharing & transfer and iv) knowledge application. The four segments are part of a cyclic process to enhance the development and use of knowledge on agricultural soils. In the following sections the research needs within each section are elaborated.

This knowledge framework has a direct relation with the workflow in EJP SOIL. Impact 1 and 2 relate to **knowledge development:** what new knowledge do we need to develop to achieve these expected impacts. In a process of interaction between WP2, 3, 4 and 7 the knowledge gaps across Europe will be identified to work towards adoption of Climate-Smart Sustainable Agricultural Soil Management (CSSASM) on European scale. With impact 3 a wide range of stakeholders will be involved to make sure all regions in Europe will be involved and regional, national and Europe wide activities will need to be organised in a multi-actor approach. With **knowledge sharing & transfer** the capacity of scientists and non-academic stakeholders will be enhanced. WP5 and WP8 and 9 work towards network set ups and capacity building for different stakeholder groups. For Impact 4, a plan for **knowledge harmonisation, organization & storage** is made in WP6. The workflow ensures linkages with all stakeholders to ensure data harmonization and standardization. In the last two expected impact areas (5 and 6), the **application of knowledge** will be facilitated by creating better guidelines, awareness and capacity for CSSASM adoption.

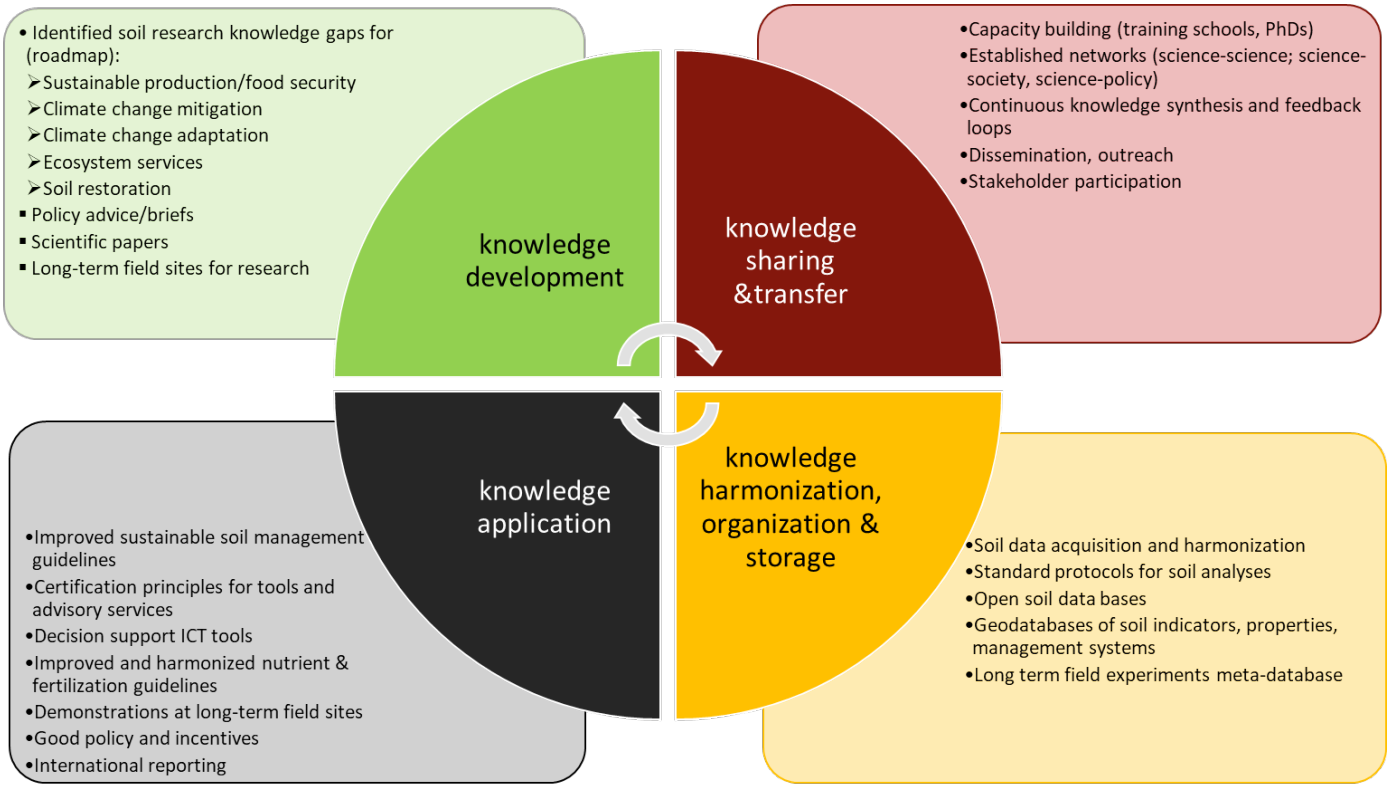


Figure 3: The EJP SOIL knowledge framework (adapted after Dalkir, 2005) comprising of four segments: Knowledge development, knowledge sharing & transfer, knowledge harmonization, organization & storage and knowledge application. The four segments are part of a cyclic process to enhance the development and use of knowledge on agricultural soils.

To prioritise the research topics needed we started during the proposal phase to make an inventory of the research gaps and the knowledge that needs to be gathered, developed, shared, harmonised, stored and applied to reach the expected impacts (Figure 4 for year 1). In this document (chapter 3) this first prioritization is listed for these different impacts. From this inventory it became clear that for a range of topics there is a

need to create a Europe wide stocktake, or "base line", to be developed of what is the current State-of-the-Art is. Furthermore, for some topics a review and outlook need to be made to assess the research gaps in detail. In the first year of the EJP we aim to collect these base lines and reviews. This information will be used in WP2 to define the topics and precise description of the calls that will be launched at the start of Year 2. A similar process will be performed in year 3, and when needed and possible in the last year.

To identify the research needs (**Knowledge development, research)** WP2 developed a 5-step approach (WP2, 3, 4 and 7) to deliver the roadmap for the internal and external calls in year 2, 3 and 4.

1. **Identify soil service aspirations at regional, national and European level and provide storylines on futures in interaction with stakeholders**. This includes the identification of the future need for soil services and soil functions and the main drivers affecting soil functions and the prioritisation of soil services depending on relevant regional conditions and farming systems. For this process the National Hubs will be involved.
2. **Overview of the current situation.** This involves the stocktaking of current soil related research activities and soil-based policies and an assessment of the presence and use of the knowledge**.**
3. **Identification of barrier and opportunities by scenario development.** This includes the identification of barriers and opportunities for further harmonization and collaboration of research, data, training and education across partner organizations and member states. In a multi-actor approach. At the EU level this process will be organised by engaging stakeholders in the EJP scientific and Stakeholder Advisory Board in collaboration with the National Communication Representative (NCR) and National Hubs from each MS to identify the barriers and opportunities for soil services for all relevant scales. The scenario building will involve selected stakeholders who have regional, national and EU knowledge about soil resource use and governance conditions. The Advisory Group will be involved in identifying innovative topics (scientific side) likely resulting in knowledge transferable to policy within the lifespan of the project (stakeholder side).
4. **Building and regular updating of the roadmap (defined as a strategic research and innovation agenda with identified key priorities) in collaboration with WP7** for the project lifetime and beyond the project lifetime (10 y) for (innovation in) EU Agricultural Soil Management research. On the basis of the listed research and innovation needs the most important knowledge needs will be prioritised.
5. **Describe scopes for stocktaking and research projects,** starting from the research and innovation needs.

The implementation barriers for **data harmonization, networks, capacity building and policy** will be addressed in WP5, 6, 8 and 9.

Supporting harmonised soil information and reporting **(Knowledge** Data harmonization, organization and storage **(knowledge harmonization, organization and storage) (WP6)**

1. Develop a prototype of a distributed system to streamline the data flow from participating countries to ESDAC, dealing with the production of inventories, measurements, reporting and accounting of soil functional properties with an accompanying estimate of uncertainty to ensure harmonised procedures to produce soil data.
2. Build an enduring and easy-to-update soil information system, linking national data to ESDAC.
3. Defining a policy that respects the sovereign of data holders and, at the same time, supporting data sharing in Europe.
4. Define baselines and target sustainable values of SOC, soil erosion and fertility according to the different European pedoclimatic conditions and management systems.
5. Make an inventory of main soil management systems in different MSs and identify hotspots for soil threats and agricultural potential

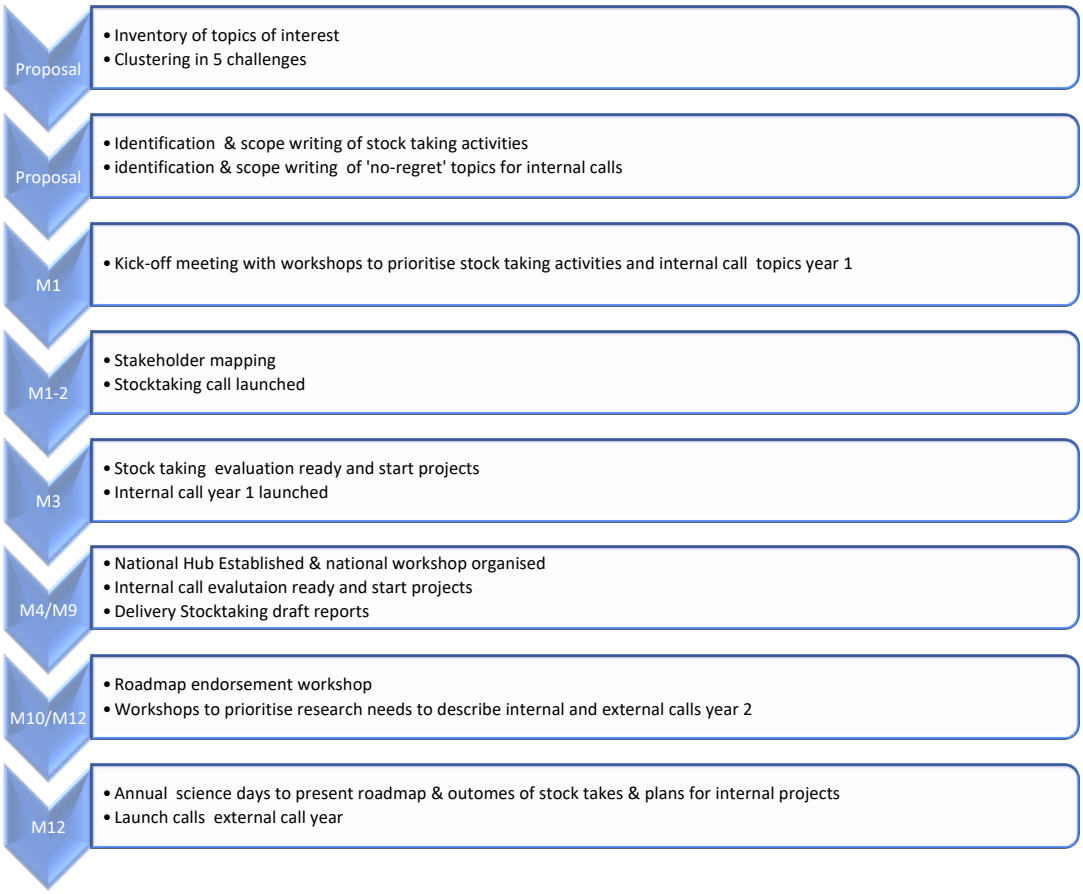


Figure 4: Research prioritization process towards large internal and external calls in start year 2.

Networks and capacity building (**knowledge sharing & transfer) (WP 5,8, 9)**

- Create scientific and societal environments and communication to enable the development new knowledge by:
    - National hubs
    - Targeted meetings to collect and disseminate knowledge transfer and demand
    - Established networks (science-science; science-society, science-policy)
    - Continuous knowledge synthesis and feedback loops
    - Dissemination, outreach
    - Stakeholder participation
- Strengthen capacity building/training for emerging and established soils scientists across Europe
- Provide early career paths for young soil scientists through co-funding of MSc, PhD and postdoc positions contributing to EJP SOIL
- Make knowledge IT available for sharing: e.g. Make high-resolution soil information accessible to all users, including policy makers and researchers.
- Build scientist research networks across EJP SOIL partners through staff exchange /visits

Dissemination of climate-smart sustainable soil management (**knowledge application) (WP9)**

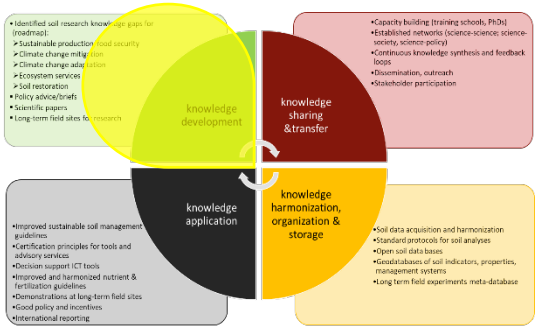
- Awareness raising through the establishment of an EJP SOIL communication structure in which dissemination, communication and knowledge exchanges activities facilitated and supported including a website, popular articles, social media, disseminate outcomes of EJP-funded projects to all stakeholders involved.
- Identify the most important European and national target groups, including soil and farmer organisations, industry, policy makers/institutions, other research groups and media and prepare an EJP SOIL Communication strategy and plans on how to reach the targeted groups

- Set up a network of National Communication Representatives (NCRs) to support EJP SOIL funded projects on national level. Furthermore, each project will appoint a Project Communication Representative (PRC), who will secure proper information exchange with the projects.
- The above described actions will facilitate to make soil management guidelines for large scale implementation in sequential years of SOIL EJP.
- A start will be made to create tools to raise awareness through the establishment of an EJP SOIL communication structure in which dissemination, communication and knowledge exchanges activities facilitated and supported including a website, popular articles, social media, disseminate outcomes of EJP-funded projects to all stakeholders involved.

Policy implementation (**knowledge application) (WP8)**

- Strengthen the science-policy interface in the area of agricultural soil management and climate change mitigation and adaptation.
- Providing support for the implementation of soil C accounting, the delivery of soil ecosystem services and enhanced soil quality and optimised soil management and fertilisation practices.
    - Establish open dialogue and active engagement with policymakers
    - Address current and future policy needs for new knowledge (e.g. CAP, Climate Policy, Land Degradation Neutrality)
    - Provide scientific support to policymakers to enable the design of effective policy measures, especially in relation to soil carbon accounting
    - Summarise key findings of the EJP for dissemination to policymakers
    - Capitalise on the lessons learned so far during implementation of initiatives/policies to enhance soil management and implement soil C accounting
    - Facilitate knowledge sharing and mutual learning among policymakers
    - Promote the work and outputs of the EJP to EU and international policymakers

3 The Roadmap of EJP SOIL: prioritised research gaps using a knowledge framework



3.1 Knowledge Development

In this knowledge framework compartment the focus lies on gathering the existing knowledge and identifying the knowledge gaps to provide new knowledge and innovation for the links between soils and the main societal challenges related to soils: Climate change mitigation/adaptation, food security and sustainable use of ecosystem services. These topics relate to expected impact 1 and 2. Impact goal 1 is described as: 'fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment. Impact goal 2 is described as: 'Understanding how soil carbon sequestration can contribute to climate change mitigation at regional level including accounting for carbon'. For both these expected impacts it is important to connect research fields: (i) climate change mitigation through soil carbon sequestration and reduction of other GHG emissions, (ii) climate change adaptation, (iii) sustainable agricultural production and food security, (iv) environmental health and ecosystem services and (v) land and soil degradation, soil fertility decline and soil erosion. All these societal issues can be impacted by soil management strategies; and it is important to study these interactions both from biophysical as well as from a socio-economic perspective.

The key questions (Figure 5) that lie at the base of this compartment of the framework are organised around the five key targets of EJP SOIL (see inner ring in overall figure on title page of this document):

- Soil and **climate change mitigation**
- Soil and **climate change adaptation**
- Soils, Sustainable agricultural production and **food security**
- Soils, environment and **ecosystems services**
- Land and **soil restoration**, soil fertility and soil erosion prevention

Soil and climate change mitigation

- What is the carbon sequestration potential of different soil types, and how to determine it? Is carbon sequestration capacity in soils really limited and will levels eventually move towards equilibrium? How can we enhance the equilibrium levels? And would deep soil carbon (eg by deep rooting, deep ploughing) enhance and enlarge the carbon sequestration potential? What is the trade-off with soil quality (productivity) of soils temporarily depreciated from high soil organic matter levels for carbon sequestration purposes only?
- What is the contribution of root systems to soil carbon and to its permanence?
- Where does the organic matter come from, how can it be transformed into sufficiently stable components and where should it be applied in the landscape?
- How can we enhance not just the quantity but also the *quality* of carbon in agricultural soils?
- How to process the biomass and when to return it to soil for soil carbon sequestration and climate change mitigation? What is the threshold between short-term nutrient release and long-term C sequestration?
- What standards are needed to reliably monitor, report and verify soil C sequestration in agricultural systems?
- What are the barriers and associated incentives for implementing measures to enhance soil C?
- How will enhanced carbon sequestration affect non-CO_2 greenhouse gases i.e. N_2O?
- How to make use of the microbial carbon pump for carbon sequestration?
- Do mineral soil amendments help stabilizing carbon in soils? Which are effective, and which are not?

Soil and **climate change adaptation**	• What are the benefits from soil carbon for adaptation to climate change? What are the effects of soil organic matter on soil structure and water related properties that bring better resistance and resilience to modified climated ? • How do plant rooting patterns affect soil water properties? Are plant roots a tool to climate change adaptation? • How to make soils more resistant and resilient against extreme events (e.g. drought, floods) and ready for the circular economy ? • What are the main the enabling conditions for sustainable soil management under changing climatic conditions, including sequences of incentives? • What knowledge delivers enhanced implementation of climate resilient sustainable soil management?
Soils, Sustainable agricultural production and **food security**	• What are the regional specific fertilisation guidelines and how scientifically supported are these guidelines by knowledge on soils ? How would harmonisation of such guidelines benefit sustainable European agriculture production and enhance and its environmental performance? • Do innovative agricultural practices (e.g. mixed annual perennial crops, associated crops, crops with deep rooting systems, rewetting of organic soils…) succeed in achieving multiple goals? (soil quality, biodiversity, production, environmental effects, climate change adaptation and mitigation) • Which farming system specific soil management strategies can contribute to reaching economic and environmental goals? • Which practices are feasible at a national/regional level taking socio-economic considerations into account? • Biochar vs. conventional soil amendment – what is the impact on SOC, GHG emissions (incl. formation of biochar and composting) and soil fertility (e.g. WHC, nutrients, pot. CEC) • How much land is needed to secure food supply in Europe? Which areas/soils have to be protected because of their top-ranking soil fertility? • What ICT Tools can be used to stimulate for sustainable climate smart soil management? • How can the effectiveness of the implementation of different agricultural soil management strategies be evaluated (from the field to regional scale), in a time and cost-efficient way? • What is the agricultural potential in different present and future climate conditions and what are actually sustainable SOC storage and soil fertility rates, in Europe?
Soils, environment and ecosystems services	• What are the main paradigm shifts in the way landscape management is approached and what scientific solutions can we find forflooding and erosion protection; changed water and sediment dynamics acros scales after new implantation, removal of terraces, introduction of no-tillage, introduction of the use of herbicides for weed control? • What are the thresholds and tipping points in current and future agricultural systems? • What robust indicators allow verifiable soil quality information to be associated with farming practices? • Can we reveal relationships between soil-species richness, soil-ecosystem composition and C cycling under different agricultural soil management? • What is the effect of increased carbon and soil fertility on symbiotic and oligotrophic taxa of the soil microbial community? • How can we address the Red List of threatened soil types in Europe in a sustainable manner? • What are Agricultural Soil Management practices for a healthy soil microbiome and healthy food? • How can we improve existing biogeochemical SOM models by incorporating soil organisms as a significant regulation factor?
Land and **soil restoration**, soil fertility and soil erosion prevention	• Landscape implications: What are offsite effects of non-sustainable soil management & off-site benefits of climate-smart sustainable soil management? • Erosion impact: loss of soil and SOM due to water and wind erosion in agricultural fields: where does it occur, what is the impact and how can it be prevented? • Where are the hot spots of soil degradation? Will they change in a changing climate and under evolving agricultural practices? • How can socio-economic drivers of soil degradation (farm-lease, legislation, economic incentives) be changed in order to make land use more sustainable? • What is the soil degradation status based on key soil functional properties relating to soil fertility, salinization, acidification, aridification and compaction? Where does it occur and how severe is the status? How accurate is the spatial explicit information on soil functional properties and is it detailed and accurate enough for decision makers?

Figure 5: Knowledge gaps for the main societal challenges related to soils: Climate change mitigation/adaptation, food security and sustainable use of ecosystem services.

3.1.1 Proposed actions for IMPACT 1 and 2: Methodology for implementation of the knowledge development

To achieve the outcomes to realise the impacts, a set of methodologies have been developed that aim to collect existing knowledge across Europe and develop new knowledge for impact. The methods aim to bring synergy between different scientific fields in the spirit of the figure of the Stockholm resilience centre about the SDGs (Figure 2). For sustainable solutions we need a multi-actor approach that builds towards impacts and not just syntheses existing knowledge or provide single discipline innovations. Stocktakes and individual projects will collect individual data, by consequent sharing this new knowledge with other related projects synergy will be created.

3.1.1.1 Stock take, baseline development

For many information sources needed to facilitate climate-smart sustainable soil management there is possibly no need to develop new knowledge. However, the available information is scattered and fragmented in a European context. Therefore, in the roadmap (WP2, WP5, WP6, WP8) we have identified topics where the available knowledge needs to be harvested from many different parts of Europe. These WPs will prepare scopes for expressions of interest, which will be launched by WP3. Topics are listed in the consequent sections.

3.1.1.2 Targeted research in competitive calls: internal and external calls

According to the identified knowledge gaps, calls for research will be set out. The EJP consortium partners have agreed to develop scopes for internal research projects prior to the approval of the EJP project based upon the identified knowledge gaps, which will feed into toe prioritization workshop in M1 of EJP SOIL. The workshop will deliver a list of call topics for the first internal call.
EJP SOIL will work with both internal calls and external calls:

Internal calls will be on topics that can be covered by the current group of EJP participants.
Internal calls will include the following types of projects

- Project for stocktaking, review and base-level development on a specific topic based on literature and/or pilot projects (WP2, 5, 6, 7 and 8)
- Projects on prioritised research topics as listed above in this section of which there is sufficient expertise in the consortium (WP3).
- MSc and PhD co-funding (WP 5)
- Training schools (WP 5)
- Short term scientific missions and visits to long term research sites (WP 5 and 7)

External calls (WP 4) will be on topics that need the expertise of participants that are (partially) not among the EJP participants or that bring a unique opportunity to assemble a wider scientific community in a concerted research effort. The external funding body will be consulted in the exact identification of the research topic which will be closely linked to the prioritised topics as listed above in this section.

The workflow to come to a project (either internal or external) starts with detailed annual plan that is made based on the roadmap. The projects that will be called for are asked to be organised in a way that the projects will facilitate the alignment and integration (see Figure 6 for a graphical representation of the integration flows).:

- **Integration on the European scale:** Each project should have partners from at least 4 different countries with a good geographical balance and, when relevant, projects associating the consortium will be promoted. When appropriate co-funded PhD students become part of the project and supervision is shared by partners to exchange experiences, knowledge and create long term collaborations and networks.
- **Integration in knowledge**: In different areas of Europe similar studies can be executed and it can be assessed how similar issues may need a different approach in terms of coming to a solution. Also having multiple projects working on the effects of CSSASM for the EJP SOIL targets (Climate Change

Mitigation/Adaptation, Food security, ecosystem services) in one overarching project will facilitate integration and alignment.

- **Integration in data collection:** in each project data collection and storage should be standardised and harmonised. Use of long-term experiments and soil research infrastructures of the partner institutes and countries will be promoted.
- **Integration of knowledge transfer**: project results are used in PhD training schools according to their suitability to progress the capacity of the students. When appropriate, projects are based on a participatory approach with stakeholders.
- **Integration with societal challenges of the private sector**: Through a valorisation approach projects may be linked to companies, making the research directly relevant for society.

The projects calls will be evaluated on the basis of multiple criteria such as:

- Number of countries involved
- Geographical spread in Europe to overcome barriers (inclusiveness of countries)
- Embedding of several parts of the knowledge framework including:
    - Innovative research
    - Outreach and capacity building for PhDs
    - Data management
    - Use of research facilities such as long-term field sites, laboratories etc.
    - Development of usable tools for society

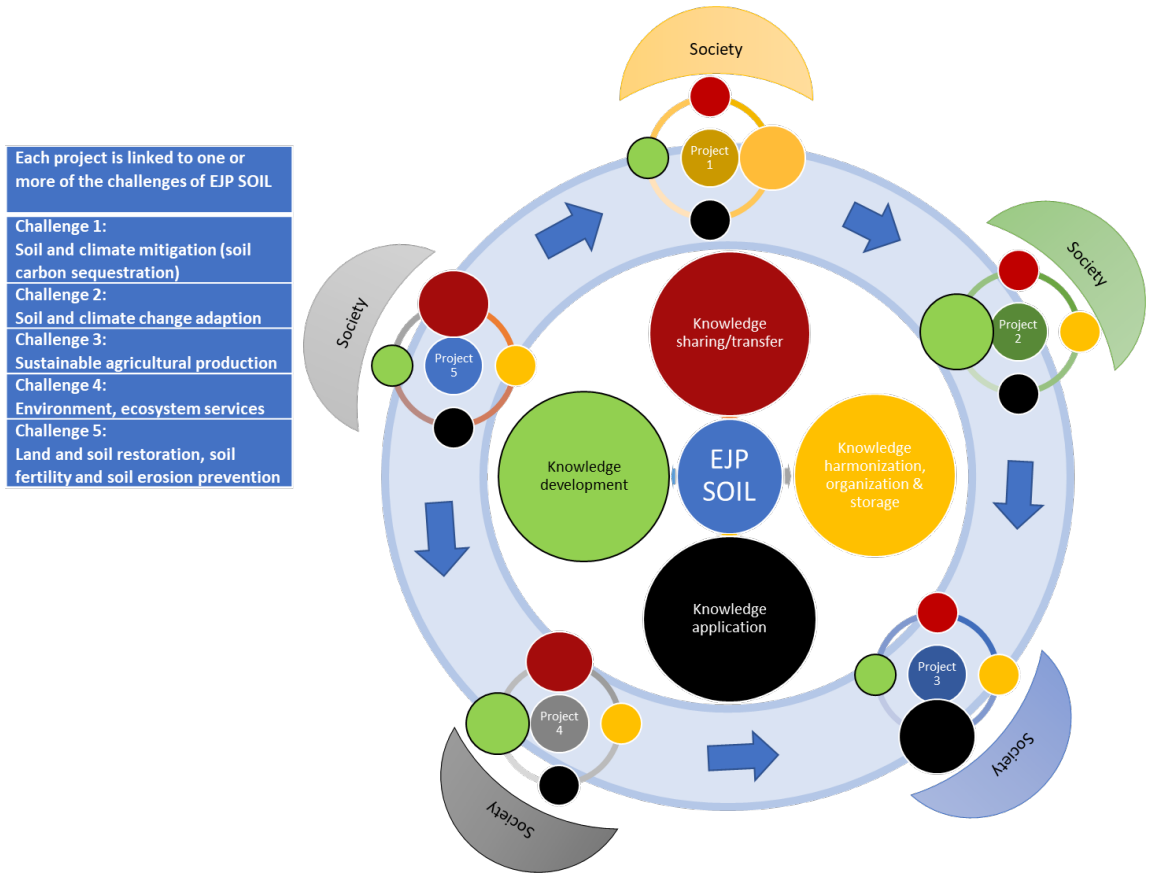


Figure 6: Alignment of Knowledge management in EJP SOIL projects: Each project is: (i) linked to one or more EJP SOIL challenges; (ii) has each part of the knowledge framework as part of their workplan, even though each project may have its main focus in one of the knowledge framework compartments, the other three must be addressed also; (iii) has a link to society and (iv) will interact with other EJP SOIL projects. This workflow will be ensured through a set of project requirements that will be asked for in the internal and external calls.

Alignment of research

Our EJP SOIL approach will provide added value from its activities over existing initiatives, programmes and projects at EU level and National levels. The consortium of 24 countries with its programme owners and programme managers will allow to source directly into national initiatives, programmes and projects via its national hubs. At the EU level many initiatives and programmes have been or are continuously supported and funded:

- **H2020 (and FP7)**: among the EJP Soil programme managers we have all coordinators for the relevant soil related past and ongoing R&D projects and these include a.o. SmartSoil, Catch-C, Recare, SoilCare, Landmark, CIRCASA, Nutri2Cycle. These projects have partnerships that do include many regions and MS's across Europe yet rarely cover all. EJP SOIL offers a unique opportunity to source the information and knowledge developed in these programmes directly and liaise with the coordinators through targeted meetings and teleconferences in order to identify knowledge gaps. In doing EJP SOIL aims that all European regions' needs will be taken into account and translated into relevant knowledge and implementation.
- **EU COST actions**: relevant COST Actions will be liaised with to cross-fertilize the two programmes.
- EJP SOIL does include partners that engage in **service contracts to DG Agri, DG ENV and DG CLIMA** in many occasions and will organise teleconferences and video interactions with coordinators from recent services to EU DG's on the relevant topics of Soil, Agriculture and CAP and Climate Change and identify with these operators what the main findings from their assessment studies and evaluations and outlook studies relevant for the CAP and the EU soil strategy, and formulate the related knowledge gaps. Also EU wide initiatives like MAES will be linked too.

As a result of the above, EU and DG Agri should benefit from wide and full use of the existing knowledge, data, assessments and future outlooks more than from individual project or programme-based activities. This benefit is an exclusive added value from our EJP SOIL approach.

3.1.2 Impact pathways to describe the workflow

The research underpinning Expected Impact 1 'fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment' focuses on how (changes in) soil management affect soil quality as well as carbon and nutrient flows that in multiple (direct and indirect) ways influence sustainability aspects of the agricultural production systems. The specific key outcomes aimed at this expected impact are:

1. Knowledge on the effects of current and new management practices is used to select sustainable management options in different production, climate and soil contexts.
2. Knowledge is incorporated in co-design of mineral and organic soil management options with farmers and supports implementation. Tools for practice are used by farmers.

This can only be achieved when there is knowledge on the influence of soil management on the above cited items. These insights will be generated through a set of actions, consisting of stocktakings and internal and external calls:

- Synthesis on the impacts of climate-smart sustainable soil management practices, including soil tillage practices on carbon and nutrient cycles in soil, soil quality and biodiversity, climate change adaptation and mitigation in mono and mixed based cropping systems and on their uptake by practitioners and other stakeholders,
- Synthesis on the development of soil quality indicators and associated decision support tools, including ICT tools (information and communication technology) from recent and on-going H2020 projects and on their use in member states,
- Synthesis on sustainable values of SOC, soil fertility and degradation risk and associated target values of indicators,
- Assessment of suitability of key soil management technologies for European farming systems given specific climatic and soil constraints and associated barriers and incentives for their implementation,

- Assessment of innovative practices (e.g. mixed annual perennial crops, associated crops, crops with deep rooting systems…) : how do they succeed in achieving multiple goals ? (soil quality, biodiversity, production, environmental effects, climate change adaptation and mitigation),
- Quantification of below ground residues inputs and turnover. Assessment on the role of crops and cropping patterns with different diversity and below ground residue input on soil quality, biodiversity, production, climate change adaptation and mitigation,
- Evaluation of technologies for processing crop residues (e.g. composting, anaerobic digestion, biochar or – innovation – combinations of these): how to process the biomass and when return it to soil for soil quality and biodiversity, climate change adaptation and mitigation? What is the optimum – if it exists – between short term nutrient release and long-term C sequestration?
- Linking soil management to soil water (infiltration, retention, evaporation) and soil structure. How do plant rooting patterns affect soil water properties. Are plant roots a tool to climate change adaptation?
- Climate-smart sustainable soil management guidelines for practitioners. These are based on information on soils, indicators of soil quality, target and threshold values of soil characteristics and context specific knowledge on the effects of agricultural management.
- Economic assessment of the benefits and costs of soil management options, in particular of those leading to increased SOM contents and stocks and increased biodiversity.
- Geodatabase of agricultural soil threat hotspots.
- Synthesis of soil management technologies for mineral soils and their effect on agricultural production, environment, climate mitigation and adaptation.
- Synthesis of soil management technologies for organic soils and their effect on agricultural production, environment and to climate mitigation and adaptation.
- Soil futures: Improved models and scenarios of the impacts of climate change, land use changes (incl urbanization) and soil management on soils and their ecosystem services, including agricultural production

Expected Impact 2: “Understanding how soil carbon sequestration can contribute to climate change mitigation at regional level including accounting for carbon’.
The research underpinning this impact focuses on how soil carbon sequestration can be achieved using narratives and adequative incentives for farmers to implement soil management strategies that will contribute to carbon sequestration. Options should be found that will facilitate the adoption of climate mitigating soil management practices. For this it is necessary that soil organic carbon changes will be better accounted for by nations in their UNFCCC declarations, and Farm-scale soil carbon credit mechanisms are developed. The specific key outputs aimed at this expected impact are:

- Efficient narratives and adequate incentives are developed to enable the implementation of soil C sequestering and GHG mitigating soil management options by farmers.
- Implementation of soil management options by farmers accounts for the potential effects on soil organic carbon stocks and GHG emissions.
- Soil organic carbon changes with management are better accounted for by nations in their UNFCCC declarations
- Farm-scale soil carbon credit mechanisms are developed.

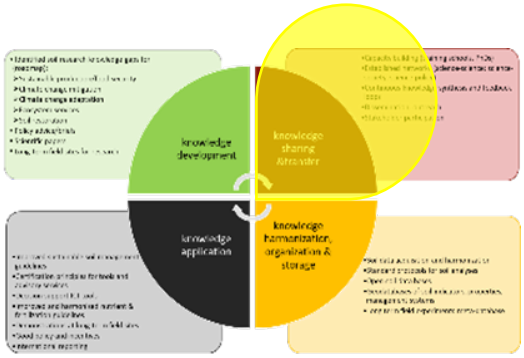
To reach this outcome two sets of actions leading to two outputs have been identified to be retrieved from stocktake and internal or external projects:

1. Better knowledge of potential soil carbon sequestration under different soil types/pedo-climatic conditions across European regions for both mineral and organic soils considering their current status and potential for change. Actions leading to output
   1.1. Synthesis of available knowledge on achievable soil carbon sequestration on agricultural land across Europe under different farming systems, soil types and pedo-climatic factors
   1.2. Research for an improved quantification of soil carbon sequestration rates and potentials in European mineral soils at regional scale under different cropping and soil management systems, in different pedoclimatic conditions

1.3. Research for an improved understanding and assessment of the permanence of soil organic carbon stocks, under climate-smart soil management, under changing climate and changing management
1.4. Analysis of trade-offs and synergies of soil carbon sequestration with other greenhouse gases (methane and nitrous oxide)
1.5. Analysis of barriers and associated incentives for implementation of management options and changes in land use of agricultural soils that enhance soil carbon

2. Developed methods for accounting for soil carbon changes at field and farm level based on economically and practically feasible indicators/indexes, integrating remote sensing and modelling for different European pedo-climatic conditions. The set of actions needed to reach this output have been identified as:
2.1. Inventory of the use of models for accounting and policy support (soil quality and soil carbon) in partner countries
2.2. Development of novel methods, including high throughput and low-cost technologies, for measuring soil carbon of mineral and organic soil considering typical depth profiles of carbon and relations to soil mineralogy
2.3. Development of robust indicators linking farming practices to soil carbon changes rates under a standardised set of soils/pedo-climatic conditions for European regions (new emission factors for a Tier 2 approach)
2.4. Development of robust indicators to predict trade-offs and synergies of soil carbon sequestration with other greenhouse gases (methane and nitrous oxide)
2.5. Development of a proposal for farm level soil carbon credit mechanisms linking verifiable farming practices or soil measurements to climate change mitigation

3.2 Knowledge sharing and transfer



The third expected impact of this EJP SOIL is defined as 'Strengthening scientific capacities and cooperation across Europe including training of young scientists'. The knowledge sharing and transfer section of our knowledge framework addresses this impact. We have translated this into two related activities (i) to establish soil networks for scientists, science-policy and science-society and (ii) capacity building for young soil scientists and societal stakeholders: farmers & advisors, policy makers, land owners & managers, civil society and industry.

This part of the knowledge management framework comprises of tools that will be developed and used to disseminate the knowledge acquired in the knowledge development cohort to scientists and society. The purpose is to create connected Networks including the governance and operationalisation and beyond EJP project life expectancy. The networks will be established during the EJP and it is our ambition that the networks will continue to meet at regularly organised conferences also after the funded project lifetime.

The key questions that are embedded in this part of the framework are:

- What do we need to work together with regional stakeholders/policy makers (science-based policies, knowledge based, national mirror groups, identify specific people, identify policy issues in terms of science?
- What knowledge is available and what present knowledge needs to be shared in which areas?

- How to exchange ideas and progress on best practices between the Member States on the implementation of the Common Agricultural Policy (CAP) and land and soil-related SDGs?
- How to promote interaction with the private sector?
- Which narratives are needed for awareness raising and adoption of climate-smart sustainable soil management?
- What do want to leave after the EJP SOIL as a legacy in terms of networks?

This Impact goal aims to work on creating (i) three types of soil networks: (a)scientist-scientist, (b) Science-society and (c) science –policy interactions; and (ii) Capacity building for young soil scientists and capacity building for agricultural soils related stakeholders: farmers & advisors, policy makers, land owners & managers, civil society and industry.

3.2.1 Networks

One of the main goals of the EJP is building an inclusive network of stakeholders in Europe that have an interest in or influence on agricultural soil. These stakeholders consist of course of scientists working with soils, but also policymakers, stakeholders from civil society, practitioners and people from the private sector. We have identified several interaction foci.

- Science-science: soil scientists interacting within their discipline as well as with other disciplines.
- Science-society: which can be further broken into science-practitioners and science-business.
- Science-policy: which is aimed to be on different levels in the policy chain.

The EJP SOIL activities and governance structure have been carefully planned to incorporate these interactions. Five broad stakeholder target groups have been identified, each with specific interests and influence on agricultural soil management in Europe (see Section 3.3.2 of the EJP proposal). Their perspectives and needs will be addressed both in the initial analysis and planning stage of the EJP, and in the project execution phase. The level of stakeholder engagement will depend on the aim of the specific activity, ranging from communication processes (information sharing, awareness-raising) to full representation (engagement of stakeholders through the governance structure of the EJP) (see Figure 7).

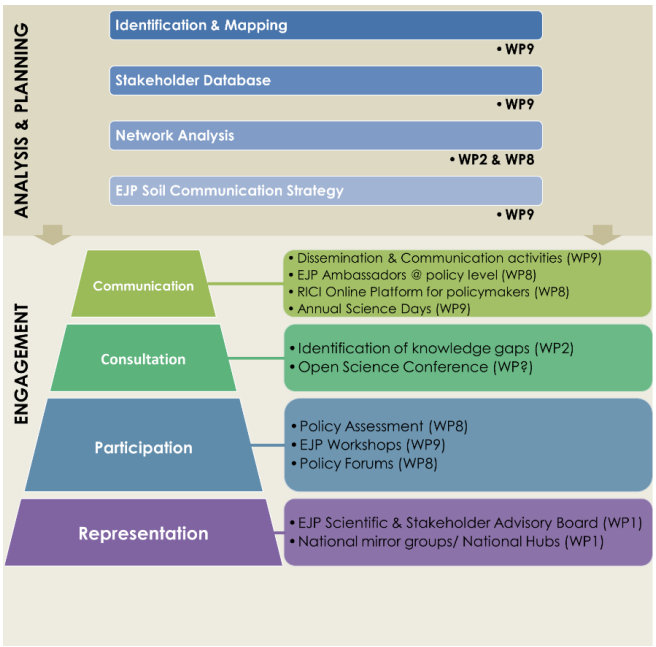


Figure 7: EJP SOIL stakeholder engagement activities and responsibilities through the initial analysis/planning and project execution phases: ***Communication:*** *sharing information and data, increasing awareness, promoting the EJP****; Consultation:*** *collecting views, experiences, perceptions from stakeholders,* ***Participation:*** *creating opportunities for stakeholders to participate in EJP processes and* ***Representation:*** *engaging through the governance/structure of the EJP to jointly develop ideas, actions.*

3.2.1.1 Science-science networks

Even though there are many conferences where scientists meet and exchange knowledge, there still seem to be many boundaries between disciplines, while solutions for the societal issues of our time lie in the synergy of different disciplines. Synergy across disciplines facilitates cross-fertilization, which will streamline and harmonise current concepts and research methodologies so that studies and applications of climate-smart sustainable soil management across Europe can be compared and contrasted. The possibility to discuss and cooperate among researchers from Europe and around the world will serve as a basis for new research, through the cross-fertilisation of ideas and approaches from various disciplines (specifically soil science, agronomy, hydrology, geomorphology, ecology, sociology, economics, political science). This will harness the experience and expertise in the field of climate-smart sustainable soil management within Europe (and the diversity of European environments) to come to more generic, theory-guided, comparable research that will enhance the potential of climate-smart sustainable soil management as an option for land managers from both a biophysical as well as a socio-economic point of view.

Bringing together researchers and research projects from across Europe (and around the world), by means of activities organised within the framework of this EJP SOIL will thus avoid duplication of work and improve the efficiency of funding.

Annual General Assembly and open science conferences

Annually a General Assembly will be held at one of the institutes of the partners. Connected to the GA a two-day meeting will be held to report and interact on the progress of all WPs and projects (Annual Science Days). In the start, mid-term and final meeting an additional two-day meeting will be held which will be open to all interested stakeholders (scientists, public relations, media, policy makers, land managers, etc.). The event will address all 6 EJP SOIL impact areas, and representatives of the projects (knowledge development) will be invited to update the group on their progress and at the open science conferences will be invited to organise a session on their topic. EJP SOIL internal conferences and workshops will be open to everyone without registration fee. The annual EJP SOIL GA and Annual Science Days will be held in different parts of Europe during the time frame of the EJP.

Long-term network building

The EJP SOIL project aims to establish promote a long-term network of all agricultural soils stakeholders in Europe. Through project meetings and conferences and workshops organised in the framework of the EJP SOIL a network will be established. To ensure the continuation of this network after EJP SOIL, these activities will be developed in collaboration with existing conferences. In the long term, a bi-annual meeting is aimed to be established as a side event of an existing conference (EUROSOIL, Wageningen Soil Conference, TERRAenVISION, AQUACONSOIL etc.).

3.2.1.2 Science-society networks: A multi-actor approach

Several constraints have been identified (section 2.1) that restrict the transfer of knowledge between science and society. EJP SOIL aims foster better synergies between scientists and key stakeholders. The Science-society networks aim to have multi-way, multi-actor conversations to ensure relevant contributions in new knowledge from non-academic stakeholders. This will encourage and facilitate multi-sectoral collaboration, allowing practitioners and policy makers to benefit too. It will also allow for greater cross-fertilisation of ideas and procedures and the development of new ideas (methods and techniques) for effective implementation of soil management strategies and EU policy measures.

The focus will be on knowledge sharing rather than knowledge transfer. Farmers know their land like no one else, and also have specific ideas about how the land should be managed. Good willing scientists sometimes bring solutions that are unacceptable for farmers to implement due to cultural values or economic constraints. Therefore, stakeholder engagement is essential for designing solutions that are sustainable from a biophysical

point of view (the view of the scientist) and also sustainable and acceptable for farmers from a technical and socio-economic point of view.

Science-society interaction is also about facilitating knowledge application and supporting innovation. The involvement of the private sector is therefore important. Apart from connecting with existing businesses, start-ups as spin-offs from research institutes can be a way to shape business innovation. Newly developed knowledge can be implemented in these spinoffs. When a private sector sees value in a new innovation, they can be engaged in further research also. A good example of this is precision farming. Advanced farmers have taken up this innovative way to enhance their crop yields and reduce irrigation and fertilization input. By implementing practices in the field, they have come back with new research questions for science: e.g the use of drones, new sensors, new algorithms to monitor the soil and vegetation characteristics in real time.

For science-society interaction, the formats need to be very different taking into account the restrictions and wishes of the societal stakeholders. In the EJP SOIL, science-society networks will be realised through two main mechanisms.

Firstly, **National Hubs** will bring together, at a national level, researchers, practitioners and other interested stakeholders to share information and define a common national position towards agricultural soil management. They will also help to ensure that national activities are coordinated and serve to inform the direction and activities of the EJP.

Secondly, dedicated **workshops** are proposed as a tool for internal projects will on specific topics to collect information and knowledge demands from stakeholders around Europe (e.g. on fertiliser management in European countries). With this tool each member state can send one representative to a Europe-wide workshop after they have collected the relevant information in their country.

The National Hubs and workshops will address key questions as they arise over the lifetime of the EJP, focussing in particular on knowledge and data gaps, differences between Member States or barriers to adoption of sustainable practices.

Other important topics include:

- Economic barriers to shift to climate-smart sustainable soil management
- Social and cultural barriers to shift to climate-smart sustainable soil management
- Development of evidence-based narratives
- Science-society market: general public: raising awareness of and promoting the sustainability of soil resources
- Science-business market: business opportunities built on sustainability, discussions on labelling and incentives for implementation of more sustainable practices.

3.2.1.3 Science-policy

The management of agricultural soils in the EU is impacted by a diversity of agri-environmental policies rather than a single horizontal mechanism. These instruments take effect at different spatial and temporal scales, may be binding or non-binding and generally address soil protection as a secondary rather than a central objective. Various regulations encompassing aspects of soil protection are often not consistently implemented or equally effective across Member States. New knowledge is urgently needed to effectively address the targets set by the CAP and other policies such as SDGs and Climate Policy at the Member State level. In particular, baseline data, performance indicators and benchmarking are needed to build the evidence base for effective policy implementation, especially in relation to the proposed future CAP. This new knowledge will also create a bridge among climate, agriculture and environmental policies having soil targets. By (a) evaluating the impacts/coherence/complementarity of existing policy, (b) analysing and orienting EJP results with policy relevance and (c) bringing together the perspectives of policymakers and other stakeholders, EJP SOIL will provide evidence-based recommendations to EU and national/regional policymakers on optimal soil management.

One of the key objectives of the EJP is to strengthen the science-policy interface in the area of agricultural soil management and climate change mitigation and adaptation. The focus will be on establishing and maintaining two-way open dialogue with policymakers and relevant stakeholders to ensure that the EJP's activities address current and future needs for knowledge and effective policy solutions. Four Policy Workshops will be held over the lifetime of the EJP to bring together nominated national representatives having responsibility for agri-environmental policy and soil management, EU and international policymakers. These workshops will adopt a collaborative and participative approach to identify key challenges, barriers to adoption and solutions to enhance agricultural soil management in Europe, in particular in support of the CAP. Transitioning from a focus on stock-taking activities and ex-ante assessment of current policy measures at the start of the EJP to future-oriented methodologies and policy recommendations as the EJP progresses, these workshops will facilitate a number of important outcomes:

- Identification of policymaker needs for new knowledge, data and capabilities (to feed into the Roadmap and Annual Work Plan)
- Informing policymakers of the latest scientific findings
- Mutual learning among policymakers and knowledge sharing with National Mirror Groups
- Europe-wide and multi-stakeholder assessment of current and proposed policy interventions
- Shared learning through a critical analysis of existing schemes/initiatives to enhance soil management and/or implement soil C accounting
- Inventory of the strengths and weaknesses of European research infrastructures.

3.2.2 Outreach and dissemination

For the purpose of reaching out to all stakeholders (inside and outside the EJP SOIL consortium) and disseminating the findings of EJP SOIL several tools are planned for.

A website will be developed and will act as the gathering point, securing linkage to:

- submission tools (WP3 and WP4),
- e-learning tools and material (WP5),
- open databases (WP6)
- meta-database of the long-term experiments and facilities (WP7)
- technical summaries for practitioners (WP7)
- RICI-platform (WP8)

The web site will perform three functions. First it will enable dissemination/exploitation of the EJP results and data, including via the use of social media as well as by more traditional reports. Secondly, there will be an area to post e-learning modules that will be the result of scientific collaborations and on-site trainings for young scientists. Thirdly, the website will be used as a platform for web-conferencing of all small workshops and conferences organised by EJP SOIL to provide maximum connection of researchers and minimise our carbon footprint.

Furthermore, popular articles will be published together with a newsletter (at least twice per year). Based the outcomes of the projects popular articles, technical summaries for practitioners and policy briefs will be written to secure dissemination and exploitation beyond the scientific community. The EJP SOIL newsletter aims to exchange information about new material online (popular articles, policy briefs, new e-learning tools), events and calls with a broad audience within the area of climate-smart sustainable soil management on the European level, especially research communities, EU policy makers, industry and innovators.

New information from EJP SOIL projects will be disseminated to all MS though their national hubs, and national communication coordinator who will be asked to share the relevant information though national distribution channels.

3.2.3 Capacity building

3.2.3.1 Capacity building for young soil scientists

PhD co-funding and PhD training

The EJP SOIL partnership recognise the need to strengthen emerging and future human capacity across multiple fields of soil science in order to meet the vision mechanism of sustainable, productive and climate smart agricultural soils in Europe. To meet the call objective (impact 3) to *…strengthening scientific capacities and cooperation across Europe including training of young soil scientists'; the EJP SOIL partnership supports four principal mechanisms:

1. Support to PhD grants that co-funds PhD and MSc researchers undertaking research and thesis work integrated into EJP research activities and projects (WP5). to further enhance integration and strengthen network, we envisage a grant being sought by more than one EJP partner, and/or co-supervision by EJP partners beyond hosting institutions.
2. Develop a joint PhD school across multiple EJP partners, open for EJP-supported PhDs and early career researchers as primary target, but also, in view of resources, provide opportunity beyond core partners of EJP. The curriculum and associated courses will be available in open source.
3. Support funding for research exchange/visiting researchers (Wp5), incl. lecturers, to enhance network capacity across joint activities and EJP partners engaged in EJP SOIL. The mechanism is intended for middle- senior researches of EJP partnership but could also include other staff categories e.g. technical, laboratory staff that would benefit from better exchange across European soils related institutes. In this category we include the possibility to visit long-term research sites and soil laboratories (Wp7).
4. A specific effort related to enhancing the use of ICT tools, specifically for European soil data management and knowledge products (in close collaboration with WP6) will be undertaken to strengthen and align competencies on soil data base management, quality assurance and protocol consistencies.

All above mechanisms contribute to EJP capacity development and network strengthening within the partnership and beyond, linked to the specific research and policy agenda of EJP SOIL (cf. section NNN.NNN).

3.2.4 Impact pathways to describe the workflow

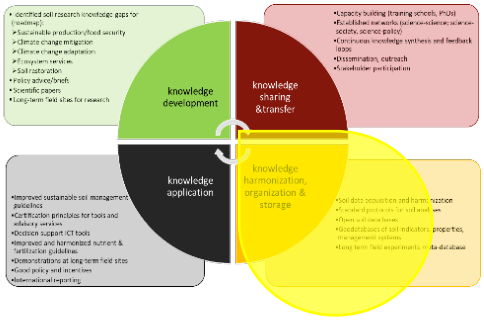
Impact 3: strengthening scientific capacities and cooperation across Europe including training of young soil scientists;

To be able to reach this impact at the end of EJP SOIL several outcomes have been identified with their associated actions:

- A stocktaking study on existing soil science higher education in Europe in combination with a commissioned foresight study on soil science professional needs will be made to **plan better informed actions for medium term capacity building** needs in Europe.
- Early career soil scientists engaged in EU networks will be trained through co-funded, jointly supervised **MSc and PhD grants**. These young scientists will have and established network at EJP where they will be in contact with all relevant consortium partner institutions through involvement in EJP SOIL related funded activities. Furthermore, the PhDs will be trained in **jointly organised courses** which will organised using a **new curriculum for SOIL PhD school**, covering EPJ relevant subjects which will be developed through an internal call project.
- Collaboration between consortium partners will be facilitated through **staff exchange grants** for early to mid-senior scientist. These visits will expose individual researchers to new research methods & data in formalised collaboration.
- The increased use of open geodatabases and new tools for agricultural soil management will be promoted through courses that will be organised by a consortium partners.

- Lastly, **improved access to experimental facilities** to support research on agricultural soils and to help inventories, measurements and reporting is needed. For this a monitoring network of research infrastructures for studying agricultural soil management and its effects on soil carbon and soil quality will be set up. For this several actions need to be done: a) a meta-database on long term experiments research infrastructures on agricultural soils in Europe, with a focus on long-term field experiments will be obtained through a stock taking together with a commissioned construction of a meta-database of all experimental facilities. b) a handbook of rules of access and use of the infrastructures, linked to the meta-database through an inventory- Agreement between parties. Subsequently a website meta database on long term experiments infrastructures on agricultural soils in Europe will be created. From the acquired meta data analysis the strengths and weaknesses of the present Europe agricultural soil research long term experiments will be reported on through a commissioned research project. c) A network of soil analysis laboratories in relation to Glosolan will be established. d) an access plan for experimental sites and soil lab facilities will be made. This will be initiated and promoted by collaborative research call for projects and short-term missions.

3.3 Knowledge harmonization, organization and storage of soil information



The fourth expected impact of this EJP SOIL is defined as 'Supporting harmonised European soil information, for advancing agricultural research and international reporting'. We have translated this into three related aims (i) Improved harmonisation of data standardisation of methods for soil sampling, analysis and mapping; to support (transboundary) research on agricultural soils, monitor soil fertility and quality, and to improve inventories, measurements, reporting and accounting activities at different scales, (ii) Improved EU contributions to global soil mapping activities, and (iii) Facilitated sampling and further development of LUCAS.

The key questions that are embedded in this part of the framework are:

- **Knowledge harmonization**: how can methods currently used across EU and it's MS's for assessing soil fertility, soil quality, soil pollution and fertiliser recommendations be harmonised?
- **Knowledge organization**: How to secure that soil data compilation and availability for all Member States, will feed into European databases (LUCAS)?
- How can European databases feed global soil data initiatives?
- How can better understanding of soil features help to prioritise actions for better policy development and implementation?
- **Knowledge storage**: Which ICT tools are needed to secure such soil data storage facilities?
- What will live beyond the life time of the EJP Soil as a legacy in terms of soil databases and how will this be (financially and institutionally) be secured.

Due to regional, national and EU initiatives, Europe is relatively rich on soil data, though information is aged, collected with diverse methodologies, dispersed in the countries, and often not available to the public. Serious knowledge gaps exist, e.g. on the characteristics of soils in various regions of Europe, their fertility including the capacity to store carbon and degradation status. Moreover, transboundary research is often hampered due to the lack of standardization. In order to overcome the current fragmentation, bridge the knowledge gaps, and allow for a more precise planning and assessment of agricultural policies, there is the need for 1) an integrated framework for data exchange and harmonization in Europe and 2) up-to-date and transboundary

soil information that allows for strategic decision making and support science, policy and implementation issues, at multiple scales.

3.3.1 Data compilation and sharing (Soil Databases and data sharing)

Europe passed the INSPIRE directive, where standards for sharing soil information exist, however, a main impediment to data sharing is still the concern of data holders to maintain the ownership of the data, which must be resolved through a common data policy. The European Soil Data Centre (ESDAC), placed in the Joint Research Centre, is the EU reference for data collection and distribution. EJP SOIL will develop the prototype of a distribution system to streamline the data flow from participating countries to ESDAC, dealing with the production of inventories, measurements, reporting and accounting of soil functional properties with an accompanying estimate of uncertainty. Key soil functional properties are those relating to soil water retention, organic carbon, salinization, erosion risk, and nutrients balance. The perspective is to build an enduring and easy-to-update soil information system, linking national data to ESDAC. A prototype will be delivered to ESDAC in a common format. Data sharing will respect the sovereignty of data holders. For this, an inventory of national regulations on soil data sharing and reuse is realised and a policy of data sharing between national soil data holders and ESDAC is accepted. The policy will also consider the collection of data for the LUCAS geodatabase and a way to create synergies with national monitoring programmes.

The proposed actions for this topic are mainly aimed at developing a i) data sharing policies and ii) a distributed system among European member states and ESDAC to streamline the soil data flow. Interoperability among distributed resources will be possible without the need of changing or updating national databases, by the adoption of harmonizing and standardizing tools. Such tools allow the development of easy-to-use soil information systems to share national soil data, making European soil data accessible through the ESDAC portal.

The proposed actions to overcome these obstacles are:

- Defining a policy that respects the sovereign of data holders and, at the same time, supporting data sharing in Europe.
- Harmonizing and standardizing soil data, fostering the modelling effort already defined by the INSPIRE thematic SOIL working group
- Developing an easy-to-update soil information system, linking the shareable national data of EU members to ESDAC.
- Collecting and sharing national soil profiles and related information.

3.3.2 Harmonization and standardization of soil information (Thematic databases and maps)

The development of a successful data sharing policy is key for advancing the quality of soil information in Europe. With that policy it will become possible to compile data from participating countries and develop harmonised procedures to standardise and produce thematic data and maps. Previously, this was hampering research across Europe. For example, in the framework of the Global Soil Partnership (GSP), many EU countries have contributed to the production of the Global Soil Organic Carbon (GSOC) map, published by FAO. The map however highlights many inconsistencies between countries, due to different methodological approaches or sampling density. This demonstrates that indeed transboundary research is often hampered due to the lack of harmonization and standardization. Therefore, activities are aimed to organise, harmonise and share soil data from country and regional levels to the European level are needed to provide suitable data for European and international policies on soil.

Harmonization and standardization should follow existing international standards and accepted procedures. For EJP SOIL the INSPIRE directive and the GSP guidelines for collecting and mapping soil information are

pivotal. Europe has worked out the INSPIRE directive, where standards for sharing soil information are reported. Hence, most of EU Member States are officially part of the Global Soil Partnership (GSP), promoted by FAO which aims at enhancing the quantity, quality and availability of soil data and information for international accounting (e.g. production of the GSOC map and SoilSTAT) through Pillar4. GSP Pillar 4 provides guidelines for soil harmonization, data collection, analysis and mapping of various thematic soil data properties. Moreover, they are developing guidelines for data compilation and sharing (GloSIS), accounting (SoilSTAT) and laboratory measurement (Global Soil Laboratory Network). After the success of the Global SOC map, the GSP has already drafted guidelines and planned to ask the forthcoming GSP Data Products: i) Global SOC Sequestration Potential Map, ii) Global Soil Erosion Map, iii) Global Soil Salinity Map, iv) Global Soil Pollution Assessment. The EJP will significantly contribute to the fulfilment of the GSP requests, in particular, the Global SOC Sequestration Potential Map, and the Global Soil Erosion Map. The proposed actions are:

- Developing harmonised procedures to produce thematic data
- Delivering thematic soil geodatabase and maps at 1km and 100m resolution of soil functional properties, including carbon, soil degradation rate and ferity

3.3.3 Knowledge Storage & Development (Facilitated sampling and further development of LUCAS)

Fulfilling goal 4 'Supporting harmonised European soil information, for advancing agricultural research and international reporting' implies that all stakeholder will have access to useful, reliable and up-to-date soil information. The previous sections described how EJPSOIL will provide an integrated framework for data exchange and harmonization in Europe. However, in order to advance agriculture research and international reporting, up-to-date and transboundary soil information is required that allows for strategic decision making and support science, policy and implementation issues, at multiple scales.

Section 3.2 pinpointed several needs for thematic soil information, especially the need for new thematic data (e.g. soil fertility) at high resolution and monitoring of changes in soil cover over time. Partly, this data is already available at the country level, such as the soil managements systems, but other data still has to be developed before it can be shared with all users. This means that on the one hand, data on various themes will need to be collated and harmonised while on the other hand innovative techniques are needed to generate up-to-date, reliable and usable soil information to stakeholders.
In order to address the knowledge gaps identified under Section 3.2, there is a need for high-resolution baseline information which should be accessible to all users, including policy makers and researchers. The baseline information will hold the minimum set of information required for advancing agricultural research and international reporting, including:

- Thematic soil data on key functional properties
- Soil management system
- Status of soil degradation
- Current status of soil fertility, carbon and soil degradation

Providing access to this data is crucial for achieving Goal 1: 'fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment. In order to support data access to Goal 2: "Understanding how soil carbon sequestration can contribute to climate change mitigation at regional level, including accounting for carbon'. The following data is foreseen:

- Inventory of available EU databases and maps on SOC and indicators of soil fertility and degradation in various pedoclimatic conditions
- Mapping hotspots of soil degradation based on target sustainability values
- Maps of agricultural potential in different present and future climate conditions and of SOC storage potential and GHG emission in SOC in agricultural soils
- Accounting, monitoring and mapping soil carbon, fertility and degradation changes

- Harmonised procedures for monitoring, mapping and accounting based on innovative cost-effective solutions (e.g. sensor-based data acquisition) from field to regional scale.
- Maps of changes in soil carbon, degradation and fertility

3.3.4 Facilitated sampling and further development of LUCAS

ESDAC is running a soil and land use monitoring programme (LUCAS). For a more precise planning and assessment of agricultural policies, there is the need to complement LUCAS with additional sampling locations, new properties, information on management systems, and to synergise with national soil data inventories and monitoring activities.

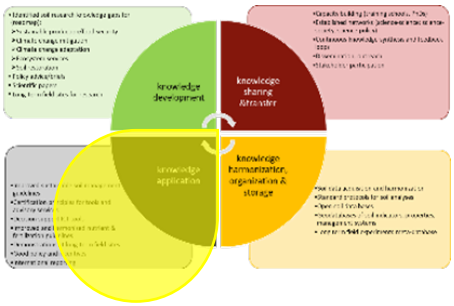
3.3.5 Impact pathways to describe the workflow

For the expected impact '**Supporting harmonised European soil information, including for international reporting: "** the following outcomes and actions have been identified:

For the expected impact 'Supporting harmonised European soil information, including for international reporting: " the following outcomes have been identified:

1. Harmonized and standardized methods are used to monitor soil fertility and quality, and to improve inventories, measurements, reporting and accounting activities at different scales. This outcome will be obtained through improved harmonisation, standardisation of methods used for sampling soils, measuring their characteristics and mapping them. The prototype of a distributed system among European countries and ESDAC will be developed to streamline the soil data flow, and will be obtained through (i) policy of data sharing that respects the sovereign of data holders; (ii) templates for soil data sharing of distributed soil information and a framework for a soil information system; (iii) common soil geodatabase able to store shared data from EU countries; (iv) geodatabases filled with national observed or derived soil profiles & polygon maps.
2. Facilitated sampling and further development of LUCAS that will be obtained through improved methodology for and development of LUCAS. For these new protocols for additional soil properties and further georeferenced soil information available for the LUCAS database are needed. A geodatabase of the European agricultural soil management systems will be developed that could be coupled with LUCAS.
3. European countries contribution is incorporated in global soil mapping activities. This will be obtained through the development of thematic country scale geodatabases and maps of soil properties and ecosystem services (to be transferred to ESDAC and GSP). These databases will be generated using a set of harmonized procedures (methods, measurements, indicators) to produce the thematic data.
4. Better understanding of soil futures. Regional prioritization of action, development of adequate policies which will be obtained through scenarios of European soil futures under climate and management changes. Scenario analysis is a fruitful approach to explore impacts of global changes and possible options for adaptation. Scenarios are also necessary to explore possible transformation pathways to reach long term desirable objectives, linking short term action with long term consequences. These scenarios will be generated making use of: (i) available databases and maps on SOC and indicators of soil fertility and degradation; (ii) set of country maps of agricultural potential and (iii) set of country maps of European agricultural soils ecosystem services (SOC sequestration, GHG emission) and soil degradation.

3.4 Knowledge application: Activities that lead to impact: Implementation climate-smart Sustainable soil management practice



The last compartment of the knowledge framework comprises of knowledge application. The impact goals that are linked part of the frameworks are impact 5 'Foster adoption of climate-smart sustainable soil management which are conductive to Climate change mitigation and adaptation' and impact Goal 6 'Develop region and context-specific fertilization practices (soil, water and pedo-climatic conditions'.
In the framework this compartment links back to other compartments of the knowledge framework, back to the knowledge development, as implementation will reveal new problems and new routes for innovative research and solutions. It links to the knowledge sharing & transfer as the application of climate-smart sustainable soil management will involve stakeholder capacity building and informing policy makers and setting new policy tools for climate-smart sustainable agricultural practices. Finally, it also links to the knowledge harmonisation, organisation & storage as the field is where the data is, and the information that will be in the databases will be essential to for the implementation into useful tools for climate-smart sustainable soil management.

In addition to impact goals 5 and 6 the knowledge application compartment addresses the goal of improved access to long-term field sites to this part of the framework. Actually, long-term field sites are a connecting element in the knowledge framework, as long-term field sites are used to develop new knowledge and central to demonstration activities. The field sites also facilitate hands on transfer of knowledge from science to students and stakeholders and the facilities are important for, researching and developing future scenario's. The long-term-field sites are important for testing application of new knowledge, and development of implementation advice.

The key questions to be addressed in this part of the knowledge framework:

- Are current farming practices regionally and climate appropriate? And how to demonstrate the need to consider and change in time to respond to climate change? How do we combine the aims for reaching climate smart sustainable agricultural production and food security? Can we ensure food security (zero hunger, SDG2) while producing sustainably? Where are the optima between one and the other?
- What are the barriers to adoption and enabling conditions for implementation?
- Could we develop a knowledge framework and associated tools so that farmers can make better informed decisions on soil management practices, based on soil information, soil quality indicators and region-specific knowledge on the impact of practices on production, soil quality, climate change adaptation and mitigation and environmental impacts?
- How to better integrate soils in the circular and bio-economy? What are the right metrics and calculations to better account for soils in regular life cycle analyses? Would soil health related labels be relevant?
- Improving enabling conditions:
    - How can we support policymakers in their efforts to develop effective policy solutions that protect our soils while contributing to a vibrant and sustainable agricultural sector?

    - What databases, tools, guidelines, maps and methodologies are required to support national/regional governments to implement current and proposed EU legislation?
    - Can we maximise long term capacity use: Training and capacity building/farmers networks
- What lessons can be learned from existing schemes/initiatives implementing soil management interventions at a national/regional level?
- Development of value chains/labels and certification where appropriate
- How to incentivise best practices for soils? What about putting an € values to soils or soil organic matter (e.g. by having society pay for carbon sequestration based on carbon pricing and value)?
- How can we take into account the impact of climate change over time?
- What assessment and accounting tools for monitoring progress towards targets and to meet given benchmarks should be developed?

These Impact goal aims to work on several overarching topics related to soil knowledge application (i) Current practices with their restrictions for applications across Europe including socio-economic barriers (ii) circular economy including business investments, (iii) adequate tools for farmers (ICT), (iv) effective policy measures, (v) better fertilization management and (vi) access to and use of long-term field sites.

3.4.1 Current practices with their restrictions for applications: what are the enabling conditions needed (bio-physical, socio-economic and capacity conditions)

Economic, socio-cultural, institutional, and technological barriers exist that limit the implementation of climate-smart sustainable soil management practices. These barriers operate from the scale of individuals/communities through to the global scale. Developing solutions to these barriers is vital for increasing sustainability.

For climate-smart sustainable soil management these three conditions are intertwined. EU projects like DESIRE, SMARTSOIL, RECARE, LANDMARK, ECOFINDER and DIVERFARMING, CIRCASA, CATCH-C and INSPIRATION have addressed the question which practices and applications are the best at which location? They have addressed the restrictions for implementation of sustainable practices in different regions. In the planned EJP SOIL stock take and review activities the information from all relevant projects (EU and otherwise funded) will be collected to compile the current state of knowledge on this topic. Based on this, further actions will be set out through internal and external calls (WP2,3,4).

In addition to the past and running projects the EU policies such as the future CAP will be linked to EJP SOIL. The CAP contributes significantly to develop a resilient, sustainable and competitive agricultural sector in Europe. It combines also the three types of enabling conditions (biophysical, socio-economic and capacity conditions). In addition, agriculture is also a major driver of failure of good chemical status to EU groundwater and surface waters, mainly due to diffuse pollution by nutrients (nitrogen and phosphorus) and pesticides. Water abstraction for agriculture is a significant pressure, among others, causing failure of good quantitative status of groundwater bodies. In order to deal with this pollution, the EU has developed an extensive set of directives, guidelines and policies over the last decades. However, regulations arising from these directives are not achieving a consistent level of implementation and effectiveness across all MS. To improve this situation, the European Commission is looking the potential for: i) increasing synergies between environment planning tools (WFD, PD) and CAP Strategic Plans; and ii) designing relevant measures under the Common Agricultural Policy, including innovative solutions for tackling diffuse water pollution in the EU. Therefore, the future CAP will put more focus to bolster environmental care and climate action and to contribute to the environmental and climate related objectives of the Union. In this EJP SOIL may play an important role to facilitate the role of farmers and other implementers of land management strategies. Farmers already play a key role in tackling climate change, protecting the environment and preserving landscapes and biodiversity. To increase the level of environmental and climate ambition, the new CAP will set the ambitions even higher. Specific objectives of the CAP include to contribute to climate change mitigation and adaptation, as well as sustainable energy, foster sustainable development and efficient management of natural resources such as water, soil and air and contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and

landscapes. Current instruments – cross-compliance, green direct payments and voluntary agri-environmental and climate measures – could be replaced with a more targeted, more ambitious yet flexible approach. In addition to ambitious mandatory requirements, farmers will have the possibility to contribute further and receive additional support through various voluntary schemes.

Member states can tailor the CAP interventions to their needs, taken into account regional circumstances and effectives of measures to meet environmental objectives. New obligations include - preserving carbon-rich soils through protection of wetlands and peatlands and crop rotation instead of crop diversification. The impact indicators of the current CAP (2014-2020) comprise two specific soil indicators 1.12 'Soil organic matter in arable land, and 1.13 'Soil erosion by water', both serving the objective of 'Sustainable management of natural resources and climate action'. Although the 2017 EC updates on these indicators are based on data from 2012[6] and do not allow to assess trends, the tendencies in these indicators as presented in scientific reports signal negative trends in many regions[7]. Several other indicators have indirect relations with soil quality, soil management or fertiliser recommendations and in many cases relate to surface and ground water quality to serve the Water Framework Directive and Nitrate Directive targets.

In the new CAP (2021-2027) DGAGRI foresees that soil quality will require to be enhanced, contributing substantially to the objective 'Preserving landscapes and biodiversity' and to deliver to climate change mitigation (LULUCF and soil carbon sequestration)[8]. In its proposal, the European Commission sets high ambitions on environmental change. Mandatory requirements include preserving carbon-rich soils through protection of wetlands and peatlands, obligatory nutrient management tools to improve water quality, reduce ammonia and nitrous oxide levels, and crop rotation instead of crop diversification. In addition to these ambitious mandatory requirements, farmers will have the possibility to contribute further and receive additional support through various voluntary schemes. Member states can tailor the CAP interventions to their needs, taking into account regional circumstances and effectiveness of measures to meet environmental objectives. These extensions and innovations will require re-assessing the indicators to design, monitor and evaluate the new CAP beyond 2020 effectiveness. EJP Soil will engage in interactions with EU wide stakeholders, with European regions and identify their regional differences and specific conditions and engage in developing harmonised indicator sets that are attractive and acceptable to all.

Socio-cultural practices have a strong influence on agricultural soil management practices. In some communities, changing soil management can be hindered by traditional practices and gender norms; and the willingness of farmers and other implementers is heavily impacted by the social acceptance of a specific measure. For example, residue and pruning burning on agricultural land may undermine soil organic carbon efforts. Community pressure also influences adoption, if land management practices require vegetation on the fields instead of clean soil, which is in many areas the tradition, these farmers have the risk to lose their reputation as good farmer in their community. The key issue lies in how the communities can communicated, educated and make them participate to adopt new more sustainable practices? Some studies have been performed on this topic, and this shows that region-specific capacity building is needed to tackle this constraint. This capacity building needs to be not only for the actual implementers such as the farmers, but also the rest of the community needs to be involved in raising awareness for the broader usefulness of climate-smart sustainable soil management. Agriculture plays a definitive role in for sustainable development in all regions. The SDGs are interlinked and cannot be achieved independently of each other. There is a huge diversity within the EU in farming systems, climate, geomorphology, hydrology, soils, education level of farmers, quality of extension services, hydrological conditions and vulnerability of important water resources.

Economic factors that prevent the adoption of sustainable soil management can be the set up costs and lags in return from changing land management practices, yields and profits may not respond as land managers/implementers expect. Costs associated with soil restoration are often poorly understood. Since many

[6] EC (2017) CAP CONTEXT INDICATORS 2014-2020 41. SOIL ORGANIC MATTER IN ARABLE LAND 2017 update
[7] Stolte et al. (2016). Soil threats in Europe – Status, methods, drivers and effects on ecosystem services. JRC Technical reports, EUR 27607 EN.
[8] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en

claims on land and soils are made at the same time, it is necessary to have more insights in these claims, potential synergies and trade-offs. However, in many governance and regulatory documents the necessity to conserve this integrated picture of a healthy, properly functioning soil is not reflected, and therefore not addressed in a sufficient way. Therefore, an analysis of the progress of the implementation of land and soil-related SDG targets in the EU is timely, taking due consideration of the 2030 Agenda commitments which date, in terms of the natural system, is fast approaching.

Institutional and legal barriers can limit implementation. Legal barriers can affect implementation of sustainable soil management practices. For example, land tenure and access issues which are anchored in law. Institutional support such as agricultural extension can provide land users with useful information on the benefits of improving soil quality and practices that enhance organic carbon stocks. Institutional initiatives (e.g. the Common Agricultural Policy) can be used to encourage sustainable soil management.

Technological readiness: Access to agricultural technology varies over Europe. This may limit agricultural communities' ability to monitor soil parameters and implement optimal land management practices.

3.4.2 Capacity building for societal stakeholders: farmers, policy makers, land owners, land managers of all sort.

In order to bring the new knowledge base that is developed in the first compartment of our knowledge framework (knowledge development) to the relevant stakeholders, a specific capacity building program will be set up. This will be targeted to each specific group of soil stakeholders so as to secure impact for all. There are three target groups: scientists, policy makers and implementers. In this capacity building plan, we aim for the last group.
In the EJP SOIL we do not aim to actually implement the capacity building schemes, but the goal is to identify the needs of the implementers, and what is the best way to promote large-scale implementation of climate-smart soil management (WP7).

Three main issues need to be addressed for this:

1. **Make existing knowledge on climate-smart agricultural soil management available:**

The EJP project coordinators, all national partners as well as coordinators of flagship EU-projects and outstanding international experts will be approached and asked to contribute knowledge on key topics of agricultural soil management under climate change. This knowledge will be compiled with the aim of launching an online knowledge platform (eg soil knowledge.net) in WP 9 with the EJP website. The knowledge compiled will be continuously updated during the life time of EJP SOIL and will stay available in the years after. The online resources will include ICT support tools.

2. **Design capacity building for farmers and contractors and for advisory and extension service experts to upscale implementation of climate-smart sustainable soil management.**

The developed knowledge and information compiled in planned stock-takes on barriers for the implementation of sustainable soil management practices (WP3) will feed into the development of new capacity building tools. The design of these capacity building tools will be called for in an internal call (WP3). The way the project should be approached is an integrative project in which the farming sector will be involved in identifying and proposing the capacity building tools needed. Integrated ICT tools will be analysed for their usefulness and the appropriate way to be used by stakeholders as well as how to transmit the knowledge to local stakeholders. Among others this will include to improved climate smart sustainable soil management and harmonised nutrient & fertiliser application guidelines.

3. **Designing upscaling of climate-smart sustainable soil management implementation**

To promote the upscaling process a cascade of actions is proposed. The first step is to identify proven climate-smart sustainable soil management practices and strategies, either by new knowledge developed in projects of EJP SOIL, or from proven concepts from other projects. These practices and strategies will be implemented in an experimental setting to verify and demonstrate their usefulness with the climate-smart sustainability target in mind. If found useful, in the next level of upscaling multiple demonstration trials will be set up in different MS. After this, an advice can be given how to proceed after EJP SOIL: how to set up the next step: larger pilots, how to set up policy driven implementation, how to promote decentralised organic upscaling, and finally how to draft recommendation manuals for practitioners, which should lead to large scale implementation.

3.4.2.1 Business development: Circular economy including business investments

Fertilization recommendations

One of the outcomes of EJP SOIL is better performing fertilization guidance combined with more harmonised and effective fertiliser recommendations and fertiliser management as a result of advisory service/extension service with farmer and contractor work at farm levels.

The main issues that need to be addressed for this:

- **Harmonizing and proposing certification principles** for tools should be available and applied in education and training and instructions to advisory and extension services that result in enhanced on farm performance by farmers, products and contractors.

- **Soils are better integrated as a significant component of the circular economy and bio-economy**. Agricultural businesses and farms are better equipped to evaluate the importance of soils for their activities directed to targeted investments in securing and improving soil quality. Improvements and extension of environmental tools such as Life Cycle Assessment (LCA) and performance labelling or quality labelling are helpful to inform consumers and industry. This needs formulation of principles and parameterizing of relations and interactions including soils in addition to e.g. energy and products.
- Allow **soil quality and resources** to be included **in environmental performance tools** such as LCA and develop the metrics for assessing soil as a resource used in such calculations and evaluations.
- Knowledge application is putting science to work in **indicator values** that are useful for industry and financial and advisory services to assess the value of proposition and to identify risk.

3.4.2.2 Access to and use of long-term field sites.

The long-term field sites have multiple functions in EJP SOIL. These infrastructures are essential to support research and obtain high quality data on the interactions between soil properties and agricultural management (*impact 1 and 2*) that can be conveyed to European databases (impact 4) and help develop region specific fertilization practices (*impact 6*). At present, some of these long-term field experiments, but also laboratories, are not used to their full potential for research. Facilitating the access to research infrastructures with transparent and agreed pathways will also strengthen scientific capacities and cooperation across Europe (contribution to *impact 3*).

Facilitating the access and the improved use to these research infrastructures requires:

(i) Available information on the existence and characteristics, i.e. access to meta-data, of these infrastructures;

(ii) Explicit and fair rules of access and use (e.g. access to unpublished data or archive samples in the framework of collaborations; access to analytical platform)

(iii) An analysis of the performance and weakness of present infrastructures to support agricultural soil management research and soil reporting. Identifying gaps (e.g. for LTE: gaps in the set of LTE (combinations of cropping practices- soil type-climate; occurrence of emerging agro-ecological cropping practices); gaps in measurements).

(iv) Collaborative experiments using these infrastructures that will be used for:

   a. Development of region-specific soil management strategies (including fertilization practices)

b. Development of novel soil management practices
c. Evaluate protection measures for soil erosion and water retention

In the whole of Europe currently 251 European long-term experimental sites have been identified. They do experiments on alternative management practices such as crop rotation, catch crops, cover crops/green manure, no-tillage, non-inversion tillage and organic fertilization. The data sets need to be better available for all researchers and implementers in all of Europe. The meta-database of these long-term experiments need to be made available, which can be linked to the planned work in e.g. the CIRCASA H2020 project. This will show the strengths and weaknesses of each of these long-term experiments to address research questions on agricultural soil management. The meta-data is needed to establish better cooperation and knowledge sharing with a range of other initiatives: (LTER Europe (Long-Term Ecosystem Research in Europe (http://www.lter-europe.net/elter/ta)) and ANAEE Europe (https://www.anaee.com). Similarly a European Soil Laboratory Network will be established and implemented in cooperation with the FAO-(GLOSOLAN http://www.fao.org/global-soil-partnership/pillars-action/5-harmonization/glosolan/en) and the SOPHIE-network (https://www.wur.nl/en/article/Soil-Program-on-Hydro-Physics-via-International-Engagement-SOPHIE.htm).

3.4.3 Impact pathways to describe the workflow

For the workflow to achieve these impact pathways EJP SOIL will use again the methodologies as described in the previous sections: stocktaking/baseline development, targeted research in competitive calls: internal and external calls, networks, courses, grants, and development of dissemination materials like knowledge platforms and ICT tools.

3.4.3.1 Impact 5: Fostering the uptake of soil management practices which are conducive to climate change adaptation and mitigation

For this impact four outcomes have been defined:

1. Actions are implemented **to overcome the identified barriers**. For this a stocktake of existing knowledge of the barriers for implementation needs to be done together with new knowledge development in combination with stakeholder workshops. From these information sources these barriers will be identified and analysed (biophysical, agronomical, technical, economic, social, insufficient knowledge and training) for the implementation of novel technologies for soil management and carbon sequestration and of the ways to overcome them.
2. **Soils are better integrated as a major component of the circular economy and bio-economy**. Businesses better evaluate the importance of soils for their activities and invest in soils. For this analysis are needed on how to better integrate soils in the European circular economy and bio-economy (soils in value chains, labels, LCA analyses)
3. Farmers have **adequate ICT tools and use them**. For this new information and communication technology (ICT) tools and improved existing tools are needed (up-to-date with scientific understanding and science based) that will help farmers to protect and manage soils and based on farmer's needs. Information needed for this will be acquired through stocktaking of available ICT tools to help farmers to protect and manage soils and organise farmer for a to ask for their current practices, wishes and needs. This information will be synthesised in an internal call.
4. **Effective policy measures** specifically targeted at protecting soil ecosystem services and enhancing climate change mitigation/adaptation are conceived. Evidence-based recommendations for EU policies (Common Agricultural Policy, Climate Change related policy and relevant environmental policies, EU Soil Thematic Strategy). To reach this output a set of inputs are needed. First of all, a RICI (Resources, Infrastructure and Capabilities Inventory) online platform for policymakers needs to be created. From these fora research need to be identified and reported. Through an internal call a set or recommendations on policy options will be made comprising of an analysis of the impact of existing policies on soil management and of the potential of further supportive instruments. The results of this will be communicated to policymakers to report on synergies found between different policies.

3.4.3.2 Impact 6: Developing region-specific fertilisation practices considering the local soil, water and pedo-climatic condition

For this impact one outcome has been defined: **Fertilization is better managed in Europe**, leading to less losses of fertilisers in water and to less mineral fertilisers consumption. This outcome will be tackled by creating improved fertilization guidelines when necessary (accounting for soil characteristics & local conditions, including reference values, for mineral and organic fertilization). In order to be able to generate these guidelines a stock take study of how are soil properties accounted for in fertilization guidelines across regions is needed. Next to this stocktake a collaborative work between partners to better account for soil characteristics in fertilization guidelines where missing will be undertaken. This process will lead to region-specific guidelines that consider local conditions such as soil, water and pedo-climatic conditions.