Contribution of the EJP SOIL programme to the Soil Health call for evidence

2022-03-15

Soils have a fundamental role in the functioning of terrestrial ecosystems and they provide invaluable ecosystem services and well-being to human societies. The European Joint Programme SOIL (EJP SOIL) is a research programme fostering knowledge development, knowledge sharing and transfer, knowledge organization and harmonization, and knowledge implementation towards climate-smart and sustainable management of agricultural soils in line with the Farm to Fork Strategy (www.ejpsoil.eu). As such, the EJP SOIL acknowledges and supports the vision of the new European Soil Strategy to have all soils in healthy conditions by 2050 and to make protection, sustainable use and restoration of soils the new normal. To reach healthy soils by 2050 it is crucial that the EU and Member States develop coherent legal frameworks to protect, restore and sustainably manage soils.

As a contribution to this call for evidence, the EJP SOIL Coordination and Executive Committee identified selected points on which the programme already provides evidence in relation to the objectives and policy options of a Soil Health Law perspective.

1) Soil health definition

Soil Health has been defined by the Mission "A soil deal for Europe" as the continued capacity of soils to support ecosystem services (Bonfante et al. 2020, Veerman et al. 2020). We do support this definition, where soil health refers to the actual capacity of soil to supply ecosystem services for human well-being and societies. This differentiates soil health from the widely used concept of soil quality that rather refers to the capability, i.e. the potential of soils to provide the desired ecosystem services. Both concepts are complementary.

The capacity of soils to deliver ecosystem services across an array of seven soil functions has been emphasized and these functions are critical. However, for a formal definition in legal terms (the Soil Health Law in preparation), we support this definition in an expanded manner, that 'soil health' would not be limited to these soil functions and associated ecosystem services, but we widened, e.g., including cultural ecosystem services. It is also important to consider potential trade-offs between ecosystem services (people, planet, profit). More research is required to disentangle which ecosystem services of soils are manageable and influenced by agricultural management and which ecosystem services are rather determined by soil and environmental factors that are independent of management. Soil health indicators should focus on the manageable and human affected part of soil ecosystem services.

See Annex 1. Executive summary of the SIREN project - Stocktaking for Agricultural Soil Quality and Ecosystem Services Indicators and their Reference Values

This project has received funding from the European Union's Horizon 2020 research and innovation

2) Indicators of soil health and their range of values

Defining indicators of soil health and their range of values is critical for monitoring soil health and to conceive and support a policy aiming at rendering health European soils. While a unique indicators framework is needed, the reference values of soil health indicators need to be context-specific (climate, soil type, land use). The EJP SOIL SIREN project provided a stocktake of soil quality indicators used to evaluate soil-based ecosystem services, together with their reference values in 20 European countries, focusing on agricultural soils. This analysis will be expanded in the on-going EJP SOIL project SERENA, aiming to model and map agricultural soil-based ecosystem services. Whenever new tools are being developed in the framework of the European Soil Strategy (e.g., soil health certificate for land transactions, EUSO soil dashboard), they should be consistent with the soil health indicators framework.

See Annex 1. Executive summary of the SIREN project- Stocktaking for Agricultural Soil Quality and Ecosystem Services Indicators and their Reference Values

3) Requirements for the sustainable use of soils

Assessing requirements for the sustainable use of soils must be accompanied with the definition of a set of sustainable soil management practices, i.e., that allow for the delivery of soil related ecosystem services without hampering the functions that enable those services nor biodiversity (FAO, 2017). Regarding agricultural soils, EJP SOIL considers that there is a whole portfolio of sustainable soil management options, that follow agroecological principles, i.e., preserving and relying on the ecological functioning of soils. The EJP SOIL surveyed soil stakeholders in 24 countries to identify sustainable agricultural soil management practices. These encompass, among others:

- Crop and cropping systems: diversified crop rotations, cover crops and catch crops, legumes within grasslands, temporary leys, perennial crops, agroforestry, returning crop residues.
- Soil tillage and cover: non-inversion/reduced tillage, no till, direct seeding.
- Nutrients management and crop protection: use of organic and mineral fertilizers appropriate for site and production system, efficient fertilization, use of soil amendments and biofertilizers.
- Water management: appropriate drainage systems, efficient irrigation, improved water storage capacity.

EJP SOIL inventoried and assembled in a database of 218 Long Term Experiment in Europe in which different management options for agricultural soils are being compared. Along with existing or to be created Living Labs, these Long-Term Experiments provide a unique platform to evaluate the ability of agricultural practices and systems to preserve and restore soil health. A selection of circa 40 of these Long-Term Experiments is currently being used in EJP SOIL research projects and will deliver information in this regard.

See Annex 2. Executive summary of the Deliverable D2.1- Synthesis of the impacts of sustainable soil management practices in Europe

See Annex 3: Executive summary of the Deliverable D7.3- Catalogue of experimental sites

This project has received funding from the European Union's Horizon 2020 research and innovation

4) Monitoring and reporting the condition of soils

While Europe is relatively soil data rich, there is an urgent need to develop standardized methods of soil analysis, to harmonize soil information, to increase soil data sharing and to align National Soil Monitoring systems, between themselves and with the LUCAS Soil monitoring system. EJP SOIL is tackling these issues for agricultural soils and is performing stocktakes on soil data management and sharing in Europe and on the existing National soil monitoring systems. These activities will contribute to the EUSO, which launch was very timely. Recommendations emerging from EJP SOIL activities are:

- promoting the designation of officially appointed soil officers, people and/or institutions, who should also be responsible for soil monitoring at the National scale;
- promoting a networking between the soil data owners/holders and the public institutions officially appointed for the INSPIRE implementation;
- developing and implementing specific national transpositional laws in relation to the sharing of soil information from National soil monitoring systems, given the relation between soils and private land property;
- developing capacity building on INSPIRE implementation and its technical aspects.

Combining data (measures on soil samples, remote sensing, activity data) will be needed to have an efficient soil monitoring system with sufficient spatial coverage. Several EJP SOIL projects focus on remote sensing and proximal sensing to monitor soil characteristics (projects STEROPES, ProbeField, Senres).

See Annex 4. Executive summary of the Deliverable D6.1- Report on harmonized procedures for the creation of databases and maps

See Annex 5. Executive summary of the Deliverable D6.2- Report on the national and EU regulations on agricultural soil data sharing and national monitoring activities

See Annex 6. Executive summary of the Deliverable D6.3 Proposal of methodological development for the LUCAS programme in accordance with national monitoring programmes

5) Measures that can contribute to reducing nutrient losses by 50% and fertilizer use by 20%

A number of management options can be implemented to reduce the use of fertilizers (legumes in the rotation, better dose adjustment, precision agricultural practices with digitalization, timing and placement of mineral and organic fertilizers…) and to reduce nutrient losses (cover crops and catch crops, agroforestry,…). Fertilizer guidelines are key. The large variability in fertilizer guidelines across European countries is a reflection of the diverse crop systems, climate, technology levels, historically developed soil analysis methods and pedoclimatic conditions. While homogenization was not recommended in the consultation performed by EJP SOIL across 24 European countries, there is room to greatly improve fertilizer strategies for efficiency and productivity, whilst reducing environmental

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(water quality, GHG emissions) impacts. The trade-offs between soil organic carbon sequestration and N and P losses by leaching, by ammonia volatilization or by N_2O emissions need to be better understood and mitigation measures proposed. This is being addressed by the EJP SOIL research projects Sommit and TraceSoils (mineral soils) and Insure (organic soils).

See Annex 7. Executive summary of the Deliverable D2.13- Stocktake study and recommendations for harmonizing methodologies for fertilization guidelines

References:

Full texts of EJP SOIL public deliverables can be found at www.ejpsoil.eu

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Annex 1

Towards climate-smart sustainable management of agricultural soils

EJP SOIL Internal Project SIREN Deliverable 2

Stocktaking for Agricultural Soil Quality and Ecosystem Services Indicators and their Reference Values (SIREN)

Due date of deliverable: M24
Actual submission date: 28.02.2022

EXECUTIVE SUMMARY

Soils are rapidly becoming a focal point for integrated environmental policy. The European Commission's proposal for a renewed EU Soil Strategy is anchored in the EU's 2030 Biodiversity Strategy, in the Climate Adaptation Strategy and in the EU Action Plan, and envisages that by 2050 all soil ecosystems in the EU will be in a healthy state and be protected. It rests on three pillars of the Green Deal: climate, biodiversity and circular economy. The Commission has therefore launched the coordination of soil policy as the fourth pillar to achieve healthy terrestrial and aquatic ecosystems through better soil and water management, including across borders. Part of the soil policy involves the objective that 70% of agricultural soils are under sustainable management by 2030, which will need to be evaluated on the basis of nationally established monitoring systems for soil health. Because soils are now recognised as a crucial environmental compartment in the pursuit of a range of very ambitious policy objectives, the European understanding of concept of soil quality is currently evolving from the more traditional foci on soil fertility and soil contamination towards a broader inclusion of soil functions and ecosystem services, both in view of combating soil threats and in pushing forward sustainable land management. National soil monitoring schemes and evaluation criteria will need inclusive development along this course, not only to facilitate future policy evaluation, but also to support the development of innovative management practices and to inform governance regarding economic incentives for sustainable land use.

The SIREN project has been carried out as a priority in the EJP SOIL Roadmap to establish an inventory of evaluation frameworks for ecosystem services and soil quality in use in Europe and of the associated knowledge and development needs. The project also was aimed take stock of desirable values and associated target values of soil quality indicators and identification of the knowledge needs for pedoclimatic and agricultural system contexts.

Stocktaking of soil data use and evaluation in ES assessment

The SIREN consortium has taken stock amongst the associated EJP SOIL Partners of the use of soil data in the assessment of ecosystem services, and of the implementation of evaluation criteria for soil quality indicator data in monitoring schemes predominantly at the national scale. Where performed by Partners, ES assessment serves either of two purposes: to assess, at a national scale, the status and functioning of ecosystems under environmental change, or to inform decision-making in spatial planning or payments for services. For the majority of Partners, soils are theoretically taken into account in these ES assessments by characterising soil functions. Soil Quality data are poorly specified in National Ecosystem Assessment reports, however, and evaluated by unclearly documented modelling approaches or expert judgement.

The use of soil quality indicator (SQI) monitoring data to assess soil functions and ES is not widely distributed across the participating EJP SOIL MS. Those countries who do use Soil Quality indicator data generally use ES classification based on CICES, or a modification thereof. The largest commonality in SQIs implemented between MS is for parameters to quantify soil organic carbon (stocks and changes). A clear omission for almost all MS relates to soil biological parameters, addressing soil biodiversity either with respect to structural aspects (species richness, etc.), or functional aspects (associated with soil functions and provision of ES), or both. SQIs for water regulation and organic contaminants are also implemented by few MS.

The ES concept has been incorporated in policy by few MS only, and only for a limited number of ES - never for an integrated full range as e.g. classified by CICES. The challenges that hinder policy implementation are diverse and highly variable among MS. Top common priorities are the development and enforcement of national soil monitoring program in MS where such program does not exist or are deemed insufficient for ES assessment, the development of national ES assessment using SQI data, and the identification of references and target values to interpret ES assessments.

National evaluation criteria for soil quality indicators such as references and target values have been implemented scarcely, and primarily concern soil contaminants or nutrient contents in association to allowable fertilisation quota, rather than soil functions relating to ES provision. Particularly, no reference values exist for soil organic carbon stocks and sequestering (except for 'no decline').

A key knowledge gap shared by most Partners is the selection and development of indicators that are fit for purpose (translatable to targeted ES) and robust (sufficient background data, variability understood), and the quantification of the relationship between SQIs and associated ES. Also, the contextualisation of evaluation criteria by soil type, land use, climate zone, or management practices is a widely recognised research priority.
In terms of governance, a limited structuring and coordination of soil monitoring between government bodies and academia is hampering integrated and effective data acquisition and assessment. Capacity building and financial resourcing was also considered limited by many Partners.

Framework linking Soil Quality and Ecosystem Services

Terminology and definitions are different, and misunderstanding, miscommunication and segregation by schools of thought have slowed down cooperative development between the science realms of 'soil quality' (originally natural sciences) and that of 'ecosystem services' (originally socio- and environmental economics). Based on review of scientific literature and feedback from consortium Partners' on an earlier draft, SIREN has collated a conceptual framework linking soil quality to ecosystem services, featuring a consistent glossary of key terminology from environmental and socio-economic sciences.

As defined by the Soil Mission reports (Veerman et al. 2020, Giuffré et al. 2021), the European understanding of 'soil quality' appears to be developing towards a broader inclusion of soil functioning, and a wide array of ES provision with no increases in trade-offs, in the interest of an inclusive society. Observing that a range of definitions exists in the literature and amongst the MS, we consider that the concepts of soil quality and soil health need to be defined with a wide scope, integrating across land uses and soil functions, before being narrowed down for application in particular situations, for specific stakeholders and objectives (which in itself may justify specifically focused selections of fit-for-purpose indicators).

A general need for development towards policy implementation of the soil health and ecosystem approaches will require further integration of environmental policies, with consolidation of common concepts and frameworks, and harmonisation and synchronisation of monitoring in time and space, and between governance levels.
To use soil data in a harmonised assessment of ES at European level, the relationships between soil functions and ES need to be quantified under a harmonised conceptual framework and standardised terminology, and using a common classification of ES. The CICES classification system seems most appealing, but has been elaborated to specific requirements by many MS, and should be elaborated to become more inclusive for soils.

Towards harmonised pan-European SQ monitoring

First of all, it showed from the inventory amongst EJP SOIL MS that there is substantial support for harmonisation of SQ monitoring in Europe. This is expected to help "levelling the playing field" by stimulating the scientific exchange and capacity building across MS, as well as some standardisation in indicator selection. However, where some partners plead for simple, low-cost and replicable soil indicators, others support the use of complex and integrated indicators. Simplicity and pragmatism seem key to success, however, for short-term harmonisation of a first generation of SQIs for national and pan-European monitoring of SQ. Moreover, a fifth of the MS phrased conditions to a harmonised approach. Flexibility in the choice of methods and protocols for harmonised SQIs (i.e. limited standardisation) was motivated by the desire to be able to continue long-term measurement series. A possibility for differentiation of evaluation criteria by regional context was also a strongly expressed condition, reflecting that soils, climate and agricultural systems can differ significantly between countries and SQ assessment would therefore require references and target values for SQIs tailored at a national or EU region level. Instead of homology, an approach by *analogy* is recommended for harmonisation, where the programming of monitoring and basic indicators are agreed upon but the actual implementation of specific methods and their protocols to assess indicators is left open to MS with regard to specific needs and historical usage. A tiered approach may alleviate the problem of countries moving at different speeds, and with different levels of detail.

Indicator selection should be a top-down process where policy-relevant SQIs are selected to inform on predefined policy objectives, rather than a bottom-up process where SQIs are preselected on the basis of localised experience from historical use, cheap costs rather than cost-effectiveness, or -worst of all- scientific lobbyism. It can be concluded that process guidance on the optimalisation of SQI selection is needed, especially regarding national and pan-European applications.

Based on a compilation from literature review, application in EU projects, stakeholder needs, and inclusion in national regulations and soil monitoring schemes (EJP SOIL stocktakes), SIREN has evaluated a longlist of most policy-relevant SQ indicators for application in pan-European soil monitoring. The result is a shortlist of commonly applied parameters that can be considered a ”minimum dataset” for a first tier of harmonised SQ monitoring. This set, however, still lacks some essential indicators for soil biodiversity, water regulation, and organic contaminants; these could not be selected from the longlist in an objective way, mostly for lack of wide application in national soil monitoring schemes.

Need for stakeholder participation in the development of national monitoring schemes.

Given the large heterogeneity in specific land use and management next to climatic and edaphic conditions, as well as substantial differences in political and social conditions among European countries, there is need to include local and regional stakeholders in the development of national monitoring schemes, as they can help identifying the issues they face in their home regions (representativeness) and can contribute in a multi-actor approach to the implementation of sustainable land management practices by participatory planning and decision-making at the national level and lower scales of governance. There is need for dialogue and co-construction between research and practice, and some countries have already recognised so and engaged accordingly.

Annex 2

Towards climate-smart sustainable management of agricultural soils

Deliverable 2.1
Synthesis of the impacts of sustainable soil management practices in Europe

Due date of deliverable: M12 (January 2021)
Actual submission date: 27.01.2021
Date of resubmission: 29.10.2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

1. Executive summary

This report provides a synthesis of the impacts of sustainable soil management practices (SSP), assessed by the research teams of the EJP SOIL participating countries, as a result of task 2.4.1. The information was provided by twenty three countries, by completing a questionnaire concerning the knowledge availability about SSP, their biophysical and socioeconomic impacts, and the related EJP SOIL challenges. The synthesis provides an analysis of the level of reported SSP, impacts, and challenges, for the overall contributing countries, for Environmental Zones and for European Regions. The high or low level of reporting of the SSP and their associated impacts and challenges can be related to varying levels of knowledge or awareness about these relations.

The knowledge over all the SSP and their impacts is very broad and difficult to tackle within this task alone. As a result, the following represent only some of the key findings of the synthesis:

- There was a low level of reported knowledge about the reduction of N_2O and CH_4 emissions from agricultural soils, considering the overall relevance of this challenge in the context of climate change mitigation. On the other hand, SSP contributing to maintaining and increasing SOC had a high level of reported knowledge. This can be due to the fact that emissions reduction has not been a central question for farmers, agronomists and researchers, and indicates a need for more research and/or dissemination of practices addressing this challenge.
- The effect of SSP on "C storage in the soil" is mainly reported for the top soil layers. In deeper soil layers, few inputs are reporting that no significant differences or even decreases with depth. Information provided by participating countries indicates that further knowledge is needed on what extent do sustainable soil management practices impact "C storage in the soil".
- Reports on the impact "Farmers' profitability" indicate the need for more quantitative evidence on the adoption of SSP and, eventually, additional incentives at the national/regional/EU level would help farmers to adopt these practices.
- The SSP related to "Water management" is the most important group in Southern Europe, but knowledge about irrigation and water use efficiency is reported in every European Region, with several countries in Western Europe identifying interest in this SSP related to adaptation to climate change.
- Even though several countries have large parts of their territories susceptible or at risk of desertification (mainly in Southern Europe), desertification was the less reported impact, with marginal reported knowledge, even in the referred region. This result indicates the lack of studies considering the integration of the different processes leading to desertification and the SSP to counter it.

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Towards climate-smart sustainable management of agricultural soils

Deliverable 7.3

Catalogue of experimental sites

Due date of deliverable: M24

Actual submission date: 31.01.2022

ABSTRACT

Long-term field experiments (LTE) are a key source of information to design future climate-smart agriculture. In D7.3, a database containing metadata from 218 LTEs across Europe was built. Metadata collected included precise description of the treatments (combination of factors) investigated related to tillage, crops, amendments, grazing and pest/weed management as well as measurements collected and pedo-climatic information. Using several maps and figures, an overview of those LTE is presented and basis statistics such as research theme, duration and pedo-climatic zone are depicted. The analysis enables us to identify knowledge gaps in terms of practices (e.g. grazing, pest/weed management) but also pedo-climatic context (e.g. Western Europe, coarse texture soil) rarely investigated within LTE. An interactive web portal developed in collaboration with Bonares enables users to explore the database and find relevant LTEs for specific combinations of practices (e.g. all LTE that investigate cover crops on a Cambisol in no-tillage system).

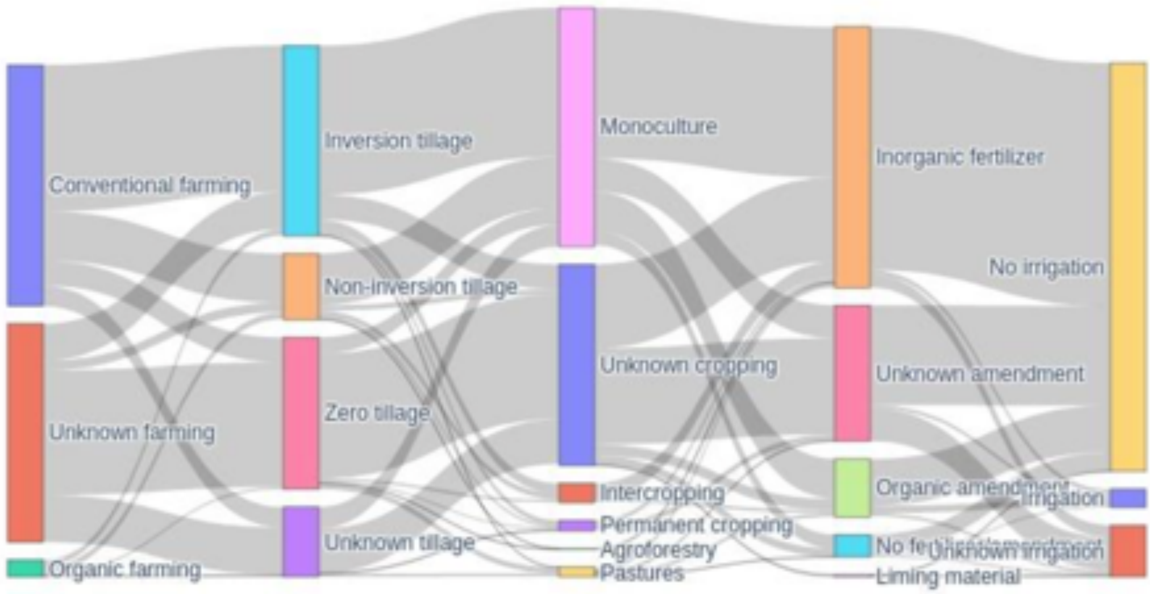

Figure: Sankey graph of the major combination of practices in the LTE database per treatments. Where the information was missing, 'Unknown X' was used

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Annex 4

Towards climate-smart sustainable management of agricultural soils

Deliverable 6.1

Report on harmonized procedures for creation of databases and maps

Due date of deliverable: M14

Actual submission date: 31.03.2021

Resubmission date: 29.10.2021

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Executive Summary

Many research and policy advice depends on the presence and quality of adequate information. For soil related research and policies, this is existing or newly collected data about soil, soil properties, use, functions, quality and threats. Often the quality and the possible extent of the research and policy advice strongly depends on the available data. The proper *collection, organisation, management and analysis of soil data* towards useful soil information is therefore crucial in any project. This includes performing an inventory of existing data and knowledge, organising and annotating this data such that it is findable, accessible, reusable and if possible interoperable for various projects and purposes, choosing the best strategy for new data collection through sampling or other techniques and then analysing the data towards adequate and understandable spatial soil information products such as maps.

There are however many ways to approach each step of this soil data workflow, it requires a range of different expertise and the best options to choose depend on the aim and scale of the project. This report aims to provide a common basis, a synthesis and a reference for available knowledge on the best practices in this soil data workflow at EJP SOIL partners, aimed at soil institutes.

Data sources

Various recent and ongoing EU and global projects and initiatives have addressed one or more of the topics in the soil data workflow and are therefore presented and discussed in the first chapter and for each topic separately. To understand which soil and soil related data is available in Europe a stocktake on soil data sources was performed. The main conclusions of this stocktake are:

1. Basic soil property (such as soil organic carbon, pH, particle size) databases are available in each country, but some use different measurement methods. If not harmonised before mapping soil properties across Europe, this will result in sudden value changes at national or survey borders of (transboundary issues). A third of the EJP SOIL partners also collect spectral data collection on soil properties.
2. In less than half of the countries data on soil threats are available for soil pollution, compaction, water erosion, and organic matter decline.
3. Many data on soil properties are freely available, but their spatio-temporal resolution varies a lot and often uncertainty quantification is missing. The launch of the European Soil Observatory in 2020 can accelerate a comparison between national databases and LUCAS.
4. There are only a few databases available on measures to control soil erosion. Most partners reported limited access to national soil management databases. This is regulated by the national ministries of agriculture.

In addition to the stocktake on data sources the GSP CountrySIS survey was updated for EJP SOIL partner countries. The main conclusions are:

1. Basic soil data are stored in databases of very different formats, with very different data standards. Their accessibility is variable among countries, among different data owners inside the countries, and for different types of soil data. General soil properties and plant nutrients are always recorded. This is not the case for data on soil salinity, pollution, and contamination.

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2. Not all countries that have soil databases, also have a soil information system (SIS) and/or a soil monitoring system. The maintenance of a SIS needs skilled staff, which is not always available. Some countries reported to have a SIS in 2018, which is no more accessible in 2020. There is a general complaint about the lack of skilled staff, lack of financial resources, lack of time.
3. Other complaints are on the lack of communication/coordination between organizations, which makes it difficult to organize and maintain a national soil database, a connected SIS and a soil monitoring system. Another complaint is on the lack of common standards needed to integrate different soil data sources.
4. Some countries reported the lack of specific legislation for the legal implementation of soil surveys and a soil information system, specifically for soil data protection and data ownership.

Data organisation

In response to the results of the GSP CountrySIS survey, a chapter is dedicated to the ongoing initiatives, background, basic principles and choices for setting up a soil information system while using available standards for data storage, exchange and harmonisation of soil data. Following these structures, it will be easier to organise, store, use and exchange soil data for research, policy and other applications. When setting up a SIS, there is not one single best way to do it because every situation has its own requirements and therefore appropriate choices in architecture, data standards etc. Best practices that apply in all cases include a good documentation of metadata, adherence to existing standards such as INSPIRE, OGC, ISO, Dublin Core etc., and making data findable, accessible, interoperable and reusable (FAIR).

Within the EJP SOIL programme, we aim to set up a distributed soil information system that adheres to and uses the INSPIRE Directive specifications for metadata and soil (Annex III). This means that we choose that data remain at and is curated and updated by its owner (institute) and can be exchanged in a common infrastructure using the INSPIRE soil domain model and appropriate technology. This can be independent from the way partners choose to organise their data. The examples and the overview of harmonisation possibilities show that there is still quite some work to be done before harmonised soil data can be exchanged effortlessly by partners and or member states and the EC/ESDAC/EU Soil Observatory following the INSPIRE model. Currently ongoing activities are aimed at resolving as much as possible the present impediments for full and easy implementation of INSPIRE Soil by partner institutions and member states. This is geared towards at some point in time arriving at a full-fledged standardised decentralised soil information system for Europe that allows harmonisation of soil data for many different applications.

Sampling

Often the existing soil data is not sufficient to answer new questions and new soil data needs to be collected. As becomes clear in the chapter on statistical sampling methods, there is not one sampling method that fits all possible aims and campaigns. Depending on the purpose(s) of the sampling campaign (estimating a mean, mapping, monitoring, gap filling/additional sampling into an existing scheme) a choice needs to be made on the most appropriate design. In general, we can conclude that to estimate global quantities, such as means and totals, probability sampling approaches with design-based inference are more suitable than model-based methods. For sampling for mapping, model based

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designs are considered more appropriate. In the designs for monitoring, not only spatial variation is a factor, but temporal variation must be taken into account as well.

When choosing a design, a general rule of thumb is to keep a sampling design as simple as possible. The primary concern when designing a monitoring scheme should be to develop an adequate design that makes good use of the available resources and not to construct the perfect, optimal design. Practical convenience and simplicity cannot be sacrificed to achieve optimal statistical efficiency. On the other hand, practical convenience and simplicity should not be the reasons for cumbersome and complicated statistical inferences.

When the aim is to combine data from two designs by far the most important aspect is to know which designs have been used including the details of the construction of the design, such as which strata were used for instance. When the design and, for probability sampling, the inclusion probabilities of the sampling units are known, this can be used to obtain an estimate of a mean or total for the area of interest. How to combine national and European monitoring schemes and other aspects of sampling such as metadata storage and sampling protocol will be elaborated more in deliverable D6.3. An overview of soil monitoring networks in Europe has been published along with suggested options for harmonizing these networks.

Mapping

When the research or policy question requires a map of a soil property, function or threat and the input data is collected it is important to choose the most suitable mapping method. Different intended uses for a map and the availability of existing (in situ point or covariate) data will result in different preferred approaches, there is not one best method. At the same time there are a few general best practices that we advise to adhere to and a stepwise procedure is proposed to select a suitable method. This starts with defining the purpose of the map and inventorying the existing data. Thereby using knowledge of soil forming factors and the SCORPAN model to make effective choices and verifying the quality of the input data and eliminating possible errors, i.e. ‘garbage in is garbage out’. During the entire data collection and mapping process a good documentation of methods, metadata, sampling design strategy and protocol, used data, chosen method, resulting uncertainty metrics and maps, validation of the result and a continuous effort to decrease possible sources of uncertainty are very important and result in a better quality map that can be validated using described methods and a repeatable mapping process. Within EJP SOIL we will adhere to the INSPIRE grid specifications for European and national maps and will aim to reduce transboundary inconsistencies and/ or propose possibilities to address these such as (lab) method harmonisation, combining different sample designs and protocols, using GPS etc.

A good soil data workflow is centred around the defined aims and (research or policy) questions. It uses existing knowledge, experience (from projects, initiatives, literature), and data, a good data organisation, a well-chosen sampling strategy, and the most suitable mapping method followed by validation of the result. This allows to adequately address research and policy questions based on relevant and sufficient quality data, thereby enabling reliable information-based decision making.

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Annex 5

Towards climate-smart sustainable management of agricultural soils

Deliverable 6.2

Report on the national and EU regulations on agricultural soil data sharing and national monitoring activities

Due date of deliverable: M18

Actual submission date: 29.07.2021

Executive summary

Following the Aarhus Convention of 1998, several European Directives have been approved with the aim to promote the release of the spatial data held by public authorities and improve evidence-based environmental policymaking. Among these, the most relevant EU-Directives were the European Directive 2003/04/EC 'on public access to environmental information', the Directive 2007/2/EC 'on establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)', and the Directive 1024/2019/EC on open data and re-use of public sector information, known as the Open Data Directive. The aim of the present deliverable was to analyse the state of implementation of the above mentioned EU-Directives and the implications linked to their transposition in relation to soil information. Agricultural soils are usually under private property in Europe, therefore the public right to have access to environmental information, must be balanced with the right of landowners in relation to their properties. Member States are allowed to a certain flexibility in the transposition of EU-Directives, given their national legislations, therefore the national transposition may be changed substantially.

After an overview of the regulatory framework at supranational level, and a review of literature and previous projects on the topic, the main activity carried out for this deliverable preparation was the development, distribution, and analysis of an *ad hoc* questionnaire sent to EJP SOIL partners. The final aim was to draft a general agreement for soil data sharing among EJP SOIL partners, between EJP SOIL partners and other institutions at national level owning/holding soil data, and in relation to external EU public institutions, such as EU DGs, EEA-EIONET, and JRC-ESDAC.

Analyzing the questionnaire answers, complemented with information retrieved from EU official web-sites, we found that the EU Directives 2003/04/EC and 2007/2/EC have been transposed in all the EJP SOIL Member State countries (with the exception of the 2003/4/EC for Sweden), in UK (MS up to the 31/01/2020), and even in Norway (EFTA member). Switzerland (EFTA member) has not transposed these two Directives, but has adopted the Aarhus convention, and has adopted a special law on geoinformation analogous to the INSPIRE Directive. With the questionnaire we investigated on the existence of specific national transpositions of the Directive 2003/4/EC in relation to soil, to understand how the conflict between public and private interests had been eventually settled. As the result, we evidenced the lack of specific national transpositions of the Directive 2003/4/EC in relation to soil. The tackling of this conflict of interest was, therefore, to be analysed inside the generic national legislations, and by analysing the concrete implementations of the EU directives given by the EJP SOIL countries in relation to soil information. The analysis of the concrete implementations was performed considering some determinant concepts, and particular key provisions, included in the EU-Directives.

Following the Article 3(5) of the Directive 2003/4/EC the Member States *should design **information officers** required to support the public in seeking access to information, should publish lists of public authorities (responsible for the environmental information), should establish and maintain **facilities** for the examination of the information, should establish and maintain **registers or lists** of the environmental information held by public authorities or information points, with clear indications of where such information can be found. All the above with the aim to ensure that the right of access to* *environmental information can be effectively exercised*. Therefore, we have investigated on the existence of ***soil information officers***, that is, information officers devoted specifically to soil information. We investigated on their existence, either in the case they were officially designed (pursuant the Directive 2003/4/EC), or in the case they were "*de facto*" acting as. We have also investigated on the existence of maintained ***public registers of soil information***. We found that the majority of EJP SOIL countries had ***"de facto" soil officers***, and that the term "***officer***" and its role were intended with different meanings by the respondents to the questionnaire. The terms "***registers***" and "***facilities***" were also subject to different interpretations, but the majority intended register as metadata registers, and facilities as online portals (network of services). We found that metadata registers and/or network of services for the examination of environmental data, as foreseen by the INSPIRE Directive, were available and maintained by the large majority of the EJP SOIL countries. Although their maintenance evidenced the need for capacity building and financial support, but the availability of soil spatial data inside those registers and facilities was less than the real information owned/hold in the European public institutions.

We investigated on the adoption of ***standards to ensure interoperability or harmonisation of spatial data sets*** (on the base of the art 7. Directive 2007/2/EC), ***and*** on the adoption of such standards ***specifically to the soil theme***. We found a general lack of knowledge of this topic by the respondents, several respondents explicitly declaring their self-ignorance, other giving misleading answers. In relation to the standard specific for soil only Switzerland, Italy, Netherlands, and Norway gave specific references, and only Italy cited the D2.8.III.3 Data Specification on Soil – Technical Guidelines. Even the terms "***soil***" and "***subsoil***" were found to have for some countries/institutions different and misleading interpretations, so that they were intended as a geological substratum, and not as in the definition given in the INSPIRE technical specifications, where ***soil*** is defined as "the upper part of the earth's crust, formed by mineral particles, organic matter, water, air and living organisms […] the interface between rock, air and water which hosts most of the biosphere, […] subject to a series of threats", and ***subsoil*** is "the natural soil material below the topsoil and overlying the unweathered parent material".

This finding has furtherly evidenced the need for national transpositions of the analysed EU Directives in relations to soil information, possibly inserted inside national integrated legislation for soil protection. **The proper management of soil information needs the official assignment of the role of soil information officers to soil experts**, instead, the officially appointed national environmental officers (officers for generic environmental information), and the INSPIRE contact points/reference institutions rarely coincide with soil experts. This suggests the **need to strengthen the national networks** between the institutions generically responsible for environmental information and for the INSPIRE implementation, and the institutions owning/holding soil information. This lack of networking, together with the lack of defined rules for soil data sharing, can partially explain the low proportion of soil spatial information finally shared in the national and INSPIRE portals by the European public institutions owner/holders of soil information. The technical difficulties in the INSPIRE implementation explain the rest.

The last section of the questionnaire was aimed at investigating on the **soil sharing policies** adopted by the institutions respondents to the questionnaire, therefore, it highlighted on the different practical implementations on this topic as reported from different countries, and from institutions of different nature inside the same country. The sharing policies were investigated for 3 kinds of soil spatial datasets: georeferenced point soil information, soil vector maps (polygons), and soil raster (grid) maps. We investigated on the existence of conditions and limitations to the public access to such a kind of soil information, and on possible incentives for sharing. On the base of the answers received, we were finally able to elaborate a ***draft general agreement for soil data sharing***, which consisted of a list of best suggested practices, and is somehow giving a direction to overcome the lack of a specific transposition of the 2003/4/EC Directive in relation to soil.

The following general rules/best practices, inserted in the draft general agreement (which does not substitute specific agreements for the sharing of specific soil datasets, which are still needed to be defined with the respective data owners) have been defined:

1. The point georeferenced soil data eventually shared among EJP SOIL partners, and towards public institutions external to the EJP SOIL consortium, will not be shared online, if there is not the declared consent from the data owner, which may imply obligatorily for some countries/regions/owners of the EJP SOIL consortium, to get the consent from landowners;
2. The consent for the disclosure of point georeferenced soil data may not be needed only in case of data on emissions into the environment, which disclosure can be denied only if the disclosure adversely affects the international relations, the public security or national defence, the course of justice, the ability of any person to receive a fair trial or the ability of a public authority to conduct an enquiry of a criminal or disciplinary nature, and the intellectual property rights;
3. The soil map data, in whichever format (vector or raster), eventually shared among EJP SOIL partners, and towards public institutions external to the EJP SOIL consortium, can be published online given that in the metadata the sharing rules are declared, such as intellectual property rights or specific licenses, as defined by the respective data owners;
4. The soil map data, in whichever format (vector or raster), eventually shared among EJP SOIL partners, and towards public institutions external to the EJP SOIL consortium, which are shared by their owners under the recognition of an economic payment, could be published in metadata repositories explicitly declaring in the sharing rules the respective fees defined by the owners;
5. A 'bottom-up' approach will be adopted in the soil mapping activities promoted by the EJP SOIL involving the national/regional/federal-state soil data officers/services (official or not), similarly as it is adopted by the pillar 4 of the Global Soil Partnership;
6. The signing of specific mutual agreements for soil data sharing between the EJP SOIL partners and external institutional owners of soil data will be promoted inside each EJP SOIL country.

We hope that the defined rules could become a use case, a procedural antecedent, in the long-term a vision to establish a permanent collaboration in Europe, between public institutions (inside and between European countries), finalized to the delivering of standard, harmonised and authoritative

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Annex 6

Towards climate-smart sustainable management of agricultural soils

Deliverable 6.3

Proposal of methodological development for the LUCAS programme in accordance with national monitoring programmes

Due date of deliverable: M18
Revised version Actual submission date: 31.07.2021

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Executive summary

This document presents the main questions when developing a soil monitoring programme, reviews previous existing studies and documents, analyses the survey made within EJP SOIL partners and underlines possible ways of harmonization and collaboration between national monitoring programmes and the EU LUCAS programme in the frame of the EU Soil Observatory.

Soils are constantly evolving due to natural factors as climate and soil organisms (pedogenesis), but also due to external pressures linked mainly to human activities (e.g. urbanization, management practices, diffuse inputs of nutrients or contaminants through atmospheric deposits or waste spreading). The evolution of soils makes it necessary to set up monitoring programmes to (i) define reference states of soil quality/health, (ii) monitor changes (e.g. estimation of contaminant fluxes, changes in the content of organic matter and trace elements), (iii) detect degradation at an early stage, (iv) evaluate the success of public policies or (in a broader sense) of sustainable management practices, or restoration actions set up to protect or remediate soils and finally, (v) support research for the development and validation of field and analytical methods, models of soil and related environmental processes.

Designing and implementing a Soil Monitoring System (SMS) requires at least to choose: (i) the statistical sampling design, (ii) the field sampling strategy in time and space (including the number of samples to be collected in the field and the area of collection), (iii) the entity that is sampled (i.e. pedogenic horizons or fixed depths increments) and how (e.g pits, augering, spade), (iv) the total thickness over which soil is sampled (i.e. topsoil, down to 1m, 2 m… or the parent material), (v) the way the samples are managed (e.g. composite sample), prepared and analysed and (vi) the metadata that is to be collected and stored (data about the sampling itself, its location and surroundings) to interpret the results. All those choices represent possible variations that enable the results to be compared.

Since 20 years, several projects and initiatives (e.g. ENVASSO, Landmark, SOIL4EU) underlined the existing difficulties to compare and share data from national SMS, either due to technical issues (e.g. sampling designs and protocols, analytical methods, data format) but also on motivations (e.g. why to share the data, for what purpose) and legal requirements (e.g. are we allowed to share the data, see also EJP SOIL D6.2. Report on the national and EU regulations on agricultural soil data sharing and national monitoring activities). The situation is not new and several possible ways of progress were previously identified but it is clear that we are still more or less in the same situation. With the objective of overcoming this blockage a questionnaire was designed and circulated within EJP SOIL partners taking part in WP6 activities (Supporting harmonised soil information and reporting) to identify the technical issues (main differences between SMS) and possible ways of harmonization/collaboration.

The questionnaire asked for information on the SMS design (why, when, how), the way monitoring sites are selected, sampled and the associated data, the soil sample preparation and conservation as well as the analytical menu. Last part of the questionnaire was dedicated to possible harmonization options and collaborations and/or synergies between Member States and LUCAS soil campaigns. We collected 27 answers, representing 18 countries as few countries have different SMS (i.e. designed for different purposes and/or have regional SMS as Italy and Belgium). A monography of each country SMS was proposed with the same frame for ease of reading, and a transversal analysis was also made to identify similarities and differences between SMS.

Most of SMS were developed and started in the 90ies to monitor soil quality (meaning that there are numerous parameters monitored). The main land use investigated is linked to agriculture (note that this may also be a bias from EJP SOIL partners mainly dedicated to agriculture). The majority of SMS have at least 2 sampling campaigns (done or currently running) or even more. The number of sites per country is highly variable but the majority have at least 1 site representing 300 km². In the majority of SMS, the monitoring sites were selected according to several criteria such as land use, soil types, main crops, climatic zone (i.e. identification of representative sites) but regular grids are also used for site selection. On those sites, 50 to 60% of the countries collect information on soil management (e.g. by interviews with farmers, for each campaign) and on the surroundings. The sampling protocol is quite variable as the sampling area ranges from less than 5 m² to 1ha, where subsamples (from 5 to more than 20) are collected according to a diversity of frames (circle, square, rectangle, triangle). The depths of sampling are also quite different as samples are taken according to soil horizons or just at one depth (0-20 or 0-30 cm) or at multiple depths (2 to 5). The analytical menus, even if not detailed, appear also to be quite variable with few parameters highly determined (e.g C, pH) and others rarely measured (e.g. those related to soil biodiversity).

Considering harmonization and collaboration with LUCAS campaigns, with few exceptions, the countries do not want to change their protocols (from the design to the analytical part). A majority of the countries would accept to add new monitoring sites (e.g. that could be in common with LUCAS) and some may also, with a proper budget, consider double sampling/analysis to compare their results with LUCAS ones. Such situation is quite normal as there are quite old SMS, with several campaigns already completed and that any change may impair the use of existing data, unless comparison exercises can be made to develop transfer functions from past situation to the new one. However, this will require more resources and as it was said by one of our colleagues "*lots of SMS struggle each year just to maintain the existing SMS!*"

How can we go further in the frame of the EU Soil Observatory (EUSO)? How to find a way to combine the efforts of Member States in monitoring soils to ones developed by EU-JRC within the LUCAS soil programme? Within EJP SOIL WP6, we identify and discuss several options from the full integration and harmonization of MS monitoring systems and LUCAS to a better collaboration between MS and EU-JRC to produce a coherent information on soils, even if data stay separate. An intermediate solution being that data from MS and LUCAS will populate the EUSO, finding a way to work on data even if not obtained the same way. Those options are presented and debated according to their advantages and limitations. They all need to be shared with EU-JRC in order to be effective and the resulting choices will be implemented in the coming years.

DISCLAIMER

The information released in this deliverable is based on the contribution given by the EJP SOIL partners. The final release of the deliverable has passed through a check and has been partly approved by EJP SOIL partners (some were on holidays or not available for reviewing the deliverable). Despite this, with the awareness that the information included could not be complete, sometimes not well interpreted or not up to date, and that the analysis and conclusion released could be misleading for some countries, the deliverable should be considered a first draft base to be used and tuned during the future activities of the WP6 and EJP SOIL.

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Annex 7

Towards climate-smart sustainable management of agricultural soils

Deliverable 2.13
Stocktake study and recommendations for harmonizing methodologies for fertilization guidelines

Due date of deliverable: M12
Submission date: 30.03.2021
Resubmission date: 30.09.2021

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1. Executive summary

This synthesis delivers the findings of Task 2.4.5 'A stocktake study and recommendations for harmonizing methodologies for fertilization guidelines across regions'. Task 2.4.5 is part of the EJP SOIL WP 2 'Developing a Roadmap for EU Agricultural Soil Management'. The synthesis involved a stocktake questionnaire which was sent to representatives within each participating country of the EJP SOIL. In total, twenty three of the twenty four countries completed the questionnaire. The questionnaire sought information around six main sub-objectives: (1) To complete a stocktake of current fertilization guidelines across regions within the EJP SOIL. (2) To identify key variables in directing these guidelines, e.g. climate, soil, cropping system, nutrient loss. (3) To identify synergies, similarities and differences between systems. (4) To assess the potential for harmonization of methodologies and barriers to harmonization. (5) To identify stakeholders involved in formulating fertilization guidelines. (6) To evaluate the importance of knowledge transfer and community engagement. The stocktake revealed substantial differences in the content, format and delivery of current fertilization guidelines across members of the EJP SOIL. Fertilization guidelines are developed within individual countries according to the agronomic requirements of the agricultural crops grown. The stocktake study revealed that numerous soil tests are used to analyse plant available nutrients and these are very different between one country to the next, and between neighbouring countries within the same environmental zone. Larger countries even have variation in soil analysis methods regionally within the same jurisdiction. Fertilization guidelines are largely developed by a committee of representative stakeholders within each country, who meet on a regular or in some cases infrequent basis. The general consensus from EJP SOIL participants was that harmonization across the EU could be increased in terms of shared learning in the delivery and format of fertilization guidelines and mechanisms to adhere to environmental legislation. However, it would be difficult, if not impossible, to harmonize soil test data and agronomic requirements at an EU-wide level due to differences in soil type and agro-ecosystem variations. Nevertheless, increased future collaboration between neighbouring countries within the same environmental zone was seen as potentially very beneficial. It is also essential that countries base fertilizer recommendations on robust scientific data such as crop-specific agronomic trials. This data should be updated regularly as knowledge increases, crop varieties change, and also in response to climate change. Precision technologies are playing an increasingly greater role in managing crops and soil nutrient inputs. Fertilizer guidelines should harness the advances in precision technologies, and mutual benefit could be achieved from collaborative research across a number of countries, with the sharing of methods, learning and understanding. Precision technologies have great potential for tailoring nutrient inputs at farm, field and landscape scale, which would contribute to the overall vision of the EJP SOIL research domains. The result of Task 2.4.5 has been the generation of knowledge on existing regional fertilization guidelines. This will be further disseminated through a workshop to be organised in EJP SOIL year 3, where selected members of the National Hub will be invited to participate. The workshop will evaluate the outcomes of stocktake 2.4.5 and will identify knowledge gaps and tools to enable improvements in region specific fertilization guidelines and updates to the EJP SOIL roadmap.

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