Annex 2. EJP SOIL call topics

Topic: Climate change Mitigation (CM)

CM1 - Plant below-ground inputs to enhance soil carbon sequestration in agricultural soils

Rationale/Specific challenge: Soil organic carbon sequestration qualifies as a significant GHG removal technology, at low cost compared to other negative emission technologies (IPCC 2019). The Green Deal increased Europe's ambitions regarding climate change mitigation with an objective of zero net GHG emissions by 2050 (European Commission, 2019)[1]. There will be the need to use the full potential of European soils for mitigation and adaptation strategies, in particular by increasing the soil organic carbon pool in agricultural soils by implementing sustainable soil management practices (Montanarella and Panagos, 2021)[2]. Agricultural soils have indeed a key role as they have lost huge amounts of soil organic C since the advent of agriculture (Sanderman et al. 2017)[3], and have thereby a large potential to store additional carbon and sequester CO2 from the atmosphere, through appropriate soil and crop management options (e.g. Smith et al. 2008)[4]. There is an increasing agreement that crop root systems are major determinants of increasing topsoil and subsoil SOC stocks. Increasing below ground C inputs to soil may be achieved by a variety of management options, from the selection of varieties of annual crops with deep rooting and large allocation to their belowground parts, to the implementation of cover crops, of multispecies cropping systems, of high diversity grasslands, or of silvo-arable or silvo-grassland agroforestry systems. The present knowledge does not allow, however, to predict root derived SOC storage nor its persistence in agricultural soils as related to root traits or functions, or to soil and climate characteristics in the different soil cover and management systems.

Scope: The project will aim to assess the contribution of belowground parts of plants to soil C and its persistence for a diversity of agricultural systems and management practices. Proposing relevant descriptors/root traits (e.g. root biomass, root architecture, rhizodeposition) is necessary to predict the effect of root systems on SOC stocks. Both experimental and modelling efforts are required to make progress in the understanding of the effects of the diversity of systems (e.g. intercrops, cover crops, diverse grassland plants, agroforestry) on C allocation to belowground parts of plants (shallow or deep roots, mycorrhizas and rhizomes) and their residues and rhizodeposits, as well as their control by soil type and climate. Combining syntheses and meta-analyses of field experiments with modeling approaches will be particularly useful to assess the C sequestration potential of the different rooting systems. The project should contribute to the root/shoot database for C-input data to the soil developed by the EJP SOIL CarboSeq project, and, to identify the co-benefits of deep rooting systems. The latter should consider adaptation to drought events and climate

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[1] European Commission, 2019. The European Green Deal. =COM (2019) 640 final

[2] Montanarella, L., Panagos, P., 2021. The relevance of sustainable soil management within the European Green Deal. Land Use Policy 100.

[3] Sanderman, J., Hengl, T., Fiske, G.J., 2017. Soil carbon debt of 12,000 years of human land use. Proc Natl Acad Sci U S A 114(36), 9575-9580.

[4] Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach, M., Smith, J., 2008. Greenhouse gas mitigation in agriculture. Phil. Trans. R. Soc. B 363, 789-813.

change, reduction of N leaching, promotion of habitats for soil biota, protection from erosion and evaluation of trade-offs with yield maintenance and potential additional GHG emissions.

Expected outcomes:

- Sound scientific evaluation of the C sequestration potential, co-benefits and trade-offs of selected management options and agricultural systems (e.g., annual crops or perennial systems) resulting in increased and deeper OC belowground inputs.
- Improved knowledge on root traits for annual and perennial plants usable by plant breeders.

Expected impacts:

- EJP SOIL EI1: Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment.
- EJP SOIL EI2: Understanding how soil carbon sequestration can contribute to climate change mitigation at regional level including accounting for carbon.

Project Type: Medium size research project (up to 2M€).

CM5 - Effects of the soil biome on the persistence SOC storage and its drivers

Rationale/Specific challenge: Agricultural soils are currently facing a decrease in soil biodiversity (abundance and diversity of soil biota) as a consequence of intensification, simplification of crop rotations or monocropping, mechanization and excess use of pesticides and fertilizers (FAO, ITPS, GSBI, SCBD and EC, 2020). Preserving and restoring soil biodiversity is now recognized as a major challenge at the EU level (Veerman et al. 2020)[5]. The EU Biodiversity Strategy expresses the ambition of the EU to reverse biodiversity loss (European Commission, 2020)[6] and its targets with that of the Farm do Fork Strategy (European Commission, 2020)[7] of reducing the use of pesticides by 50% in 2030, achieving 25% of total farmland under organic farming by 2030 and at least 10% agricultural land under landscape features with high biodiversity, should have a positive effect on soil biodiversity. Farming practices and agricultural systems have a major effect on the soil biome (fauna and microbial communities) and its functioning (e.g. carbon use efficiency). Yet, the extent to which soil biome controls SOC sequestration and whether this can be managed is not sufficiently known. Such knowledge is needed for recommendations of management options that preserve or increase soil organic carbon stocks. For instance, in organic agriculture, as yields are generally lower, organic inputs are consequently smaller, but SOC stocks can be maintained or even increased which is ascribed to changes in the carbon use efficiency of soil microorganisms. The importance of stoichiometry, especially carbon/nitrogen/phosphorus ratios, in controlling carbon use efficiency by soil organisms and its consequences on the balance between SOC storage and GHG emissions also warrants further research.

Scope: The project will aim to study the relationships between soil carbon cycling and the diversity of the soil microbiome and fauna. An important question is the effect of soil management practices, especially through the stoichiometry of organic matter inputs (crop residues, organic amendments, below ground inputs from plants) on the carbon use efficiency of soil microorganisms and, ultimately, on SOC sequestration. The effects of soil biome on SOC sequestration should be investigated in real case-studies (on-farm and/or experimental field sites) representing a diversity of soil management and pedo-climatic conditions. A special focus should be placed on the identification of the drivers related to soil status and management, which may favor or hamper the adequate functioning of soil microbial communities regulating SOC sequestration. The measures and agricultural systems included in the Green Deal targets could be considered. Improving existing biogeochemical SOM models by incorporating new knowledge on the effects of soil biome on carbon and nitrogen cycles should also be investigated in order to evaluate the trade-offs between SOC storage and GHG emissions.

Expected outcomes:

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[5] Veerman, C., Correia, T.P., Bastioli, C., Biro, B., Bouma, J., Cienciala, E., Emmett, B., Frison, E.A., Grand, A., Filchew, L.H., Kriaučiūnienė, Z., Pogrzeba, M., Soussana, J.-F., Olmo, C.V., Wittkowski., R., 2020. Caring for soil is caring for life – Ensure 75% of soils are healthy by 2030 for food, people, nature and climate. Report of the Mission Board for Soil health and food. ISBN 978-92-76-21602-5 European Commission Directorate-General for Research and Innovation and Directorate-General for Agriculture and Rural Development Directorate B — Quality, Research & Innovation, Outreach Unit B2 —Research and Innovation, Brussels.

[6] Commission, E., 2020. Biodiversity Strategy for 2030 Bringing nature back into our lives. COM/2020/380 final

[7] European Commission (2020). A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. COM/2020/381 final

- Identifying drivers related to soil management effects on soil biome which may enhance/prevent SOC sequestration and other co-benefits in different EU pedo-environmental zones.
- Qualifying farming systems promoting soil biodiversity in terms of their potential for mitigating climate change (increased SOC sequestration, decreased GHG emissions).

Expected impacts:

- EJP SOIL EI2: Understanding how soil carbon sequestration can contribute to climate change mitigation at regional level including accounting for carbon.

Project Type: Medium size research project (up to 2M€).

Topic: Climate change Adaptation (CA)

CA4/SP3 Contribution of soils to climate mitigation and adaptation, sustainable agricultural production and environment in agro-ecological systems

Rationale/Specific challenge: Agro-ecological systems are characterized by higher biodiversity at all levels (intra- and interspecies, cropping and farming systems, landscapes and non-agricultural elements) than traditional highly intense agricultural systems. Such agro-ecological systems are potentially better adapted to local environmental conditions and to social and economic requirements. Transition of current agriculture to agro-ecological systems leads to more sustainable and climate responsive agricultural production. Such a transition is a relevant contribution to the implementation and success of the EU Green Deal and EU policies on biodiversity, on circular economy and on climate change. This approach towards agro-ecological systems fits the recommendations by the Mission Board on Soil Health and Food and the Farm to Fork Strategy and will contribute to reach the target “25% of agricultural land under organic farming”.
This agro-ecological transition can be considered as a highly potential opportunity to respond in particular to changes and challenges posed by climate change across the European continent. Examples and experiences include better soil exploration by deep rooting in mixed crops or deep rooting crops to enhance water and nutrient availability. Also, facilitation of symbiosis of roots with microbes may enhance nutrient uptake. More soil carbon will stimulate soil biodiversity and enhance resilience to climate change and climate variability and ability of soils to sustain more frequent extreme events (prolonged drought, extreme wet conditions, extended warm periods, and higher risk for diseases to occur). However, the impact of the transition to agro-ecology on the resilience of agroecosystem to climate change in many European regions is poorly understood and documented, especially for its soil components. Understanding and quantifying this impact is particularly relevant when the climate is changing and forces local and regional agricultural systems to adapt.
To date, most long-term experimental studies and meta-analyses on the effects of management on agricultural soils have focused on the impact of a single practice or a specific technology. As a consequence, they have not considered scope and options of the full context of an agro-ecological farming system, nor considered the broad range and diversity of agricultural systems that exist in Europe. These alternative and new systems and practices need to meet multiple goals on soil health, agricultural production, climate change adaptation and mitigation and support and sustain ecosystem services. These systems also need to be recognized by local farmers to fit their specific conditions and socio-economic needs and perceptions.
Several recent H2020/FP7 projects among others have investigated elements concerning soil degradation processes and remediation practices, the assessment of soil’s contribution to the provision of ecosystem services and relations to climate change mitigation. This project will utilize and build upon the knowledge and data provided in these recent and completed FP7/H2020 projects.

Scope: The agro-ecological systems and the underlying climate-smart sustainable soil management practices considered in this project will be selected on their *a priori* positive effect on climate change adaptation and mitigation (e.g., agroforestry, conservation agriculture, organic farming, integrated crop-livestock-forestry systems).

This will be combined with their actual adoption or potential for adoption by farmers in climate regions and agro-ecological zones across the EU and relate to the projected climate change. This will require the sourcing and use of results of completed projects and existing data in EJP SOIL.
The research will evaluate soil functions and ecosystem services provided by soils in relation to climate change adaptation and mitigation. This will include the provisioning service for food, the ability of the soils to contribute to climate change mitigation (conserve or increase SOC stocks, decrease N_2O emissions), and the ability of soils to contribute to climate change adaptation (e.g. soil water infiltration & storage and yield stability). The research will use available tools (existing models and indicators). The project will identify and use, and adapt if needed, a series of long term and highly instrumented case studies in different pedo-climatic conditions. This will be based up on long term experiments (LTE's) of the EJP SOIL consortium allowing for retrospective analysis of soil conditions, crop yields and climate conditions and change. In complement, the project will also identify pioneer farmers in different EU countries as lighthouse farms to enhance the regional applicability and allow farmers to recognize their local conditions and systems. This research could also be performed by modelling the complex soil – plant interactions in agro-ecological systems, to evaluate them regarding their resistance and resilience under different climate scenarios (RCPs). These different research approaches can be combined.

Expected outcomes:

- Identify and report on the effect of climate variability across EU agro-ecological zones on soils and crop in various agro-ecological systems.
- Assess the impact and contribution of soils and soil management across the range of agroecological systems to climate mitigation and adaptation and relate to future regional climate conditions.
- Develop and propose guidelines for soil management to fit the complex and diverse agroecological systems in different EU pedo-climatological and environmental zones.

Project outcomes should feed into the to be realized partnership on agro-ecology and living labs.

Expected impacts:

- EJP SOIL EI1: Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment.
- EJP SOIL EI5: Fostering the uptake of soil management practices which are conducive to climate change adaptation and mitigation.

Project Type: Large size research project (up to 5M€).

Topic: Sustainable production (SP)

SP1 Alleviating soil compaction in a climate change context

Rationale/specific challenge: Soil compaction is considered a major European soil health challenge, and a threat for the soils' capacity to deal with climate mitigation and adaptation. The historical changes of compaction levels were shown to coincide with a stagnation in crop yields in the 1990s for cereals in many European countries (Keller et al. 2019)[8]. Soil compaction restricts root growth and thereby the uptake of nutrients and water leading to yield losses and reduced carbon input to both top- and subsoil. Soil compaction also affects the timeliness of soil operations especially in a changing climate, which may also affect crop yields (Kolberg et al. 2020)[9]. Thus, alleviation of soil compaction is critical for sustained or increased soil carbon storage and accounting for soil compaction effects may be necessary in forecasting the evolution of SOC stocks in European soils. Climate change is also expected to strongly worsen the soil compaction problem. Impeded root growth due to soil compaction will aggravate effects of more frequent droughts with detrimental effects on yields and carbon input. Soil compaction-induced restricted water transport will also exacerbate problems with flooding in a future climate with more extreme rainfall events (Keller et al. 2019). There is a strong need for an analysis of the impact of climate change on the extent and the effects of soil compaction. The extent and severity of the soil compaction challenge is strongly related to soil management in terms of field traffic with heavy machinery and livestock trampling. The extent of the soil compaction and the impacts on climate change adaptation, soil carbon storage and soil health in general needs to be quantified at EU scale for different pedo-climatic conditions and cropping systems. Strategies to limit the risk of soil compaction in a climate change context need to be developed with focus on traffic intensity, weight of machinery and timing of operations. Novel advanced technologies in the field of digital farming and robotisation may be applied to significantly reduce the soil compaction problem, but this has been scarcely researched. There is also a need for better knowledge on the recovery of compacted soil and the development of bio-based strategies to stimulate recovery.

Scope: The scope of project is to analyze how climate change affects the extent of soil compaction and how soil compaction affects the capacity of soils to adapt to climate change and mitigate it. For this the project will quantify the extent and severity of the soil compaction problem at EU scale for different pedo-climatic conditions and cropping systems considering both topsoil and subsoil compaction. The project will analyze and develop management strategies that reduce risk of compaction and stimulate the recovery of compacted soil. Management strategies will be developed and tested in collaboration with farmers. The project will gather knowledge from past and current EU and national activities and initiate targeted measurements and modelling activities to fill in significant knowledge gaps.

Expected outcomes:

[8] Keller, T., Sandin, M., Colombi, T., Horn, R., Or, D., 2019. Historical increase in agricultural machinery weights enhanced soil stress levels and adversely affected soil functioning. Soil and Tillage Research 194.

[9] Kolberg, D., Riley, H., Børresen, T., 2020. Timeliness and traffic intensity in spring fieldwork in Norway: Importance of soil physical properties, persistence of soil degradation, and consequences for cereal yield. AGRICULTURAL AND FOOD SCIENCE 29, 154–165.

- Analysis of the impact of soil compaction in a changing climate.
- Quantifying the extent and severity of the soil compaction problem for different pedo-climatic conditions and cropping systems under climate change.
- Improved knowledge of management strategies and technologies to reduce risk of soil compaction and the recovery of compacted soil in a climate change context.

Expected Impacts:

- EJP SOIL EI1: Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment.

Project Type: Medium size research project (up to 2M€).

SP2 - The use, processing and application of external sources of organic matter to mitigate climate change and improve soil health

Rationale/Specific challenge: Encouraging the recycling of organic wastes into renewable fertilizers or amendments and promotion of shorter value chains and circular (bio)-economy to improve soil health is a priority in the EU agenda (Farm to Fork Strategy, Green Deal, Mission Board for Soil Health and Food, Horizon Europe). The Green Deal increased Europe's ambitions regarding climate change mitigation with an objective of zero net GHG emissions by 2050 (European Commission, 2019)[10]. There will be the need to use the full potential of European Soils for mitigation and adaptation strategies, in particular by increasing the soil organic carbon pool in agricultural soils by implementing sustainable soils management practices (Montanarella and Panagos, 2021)[11]. Adding external sources of organic matter to soils as fertilizers or amendments is a sustainable management option (FAO, 2017)[11]. Adding manures and composts has been considered in several previous EU projects as part of soil improving cropping systems and best management practices. An increasing diversity of new organic resources are becoming available for farmers (biochars, digestates, human wastes derived fertilizers) besides more traditional ones (composts, manures). Yet, these resources remain insufficiently studied in terms of SOC storing capacities, GHG balance, improvement of the capacity of soils to infiltrate and retain water, fertilizing values and nutrient losses and environmental safety due to the potential presence of contaminants. More generally, the characterization of organic wastes is insufficiently developed to guide their use for selected objectives such as climate change mitigation. This lack of knowledge hinders the optimal integration of organic wastes in farming systems for climate change mitigation and sustainable production. Increasing organic waste valorization under a circular approach brings also new questions at the territory level, as related to the organizational links between arable crops and animal farming, urban and rural areas, agriculture and waste recycling sectors.

Scope: The aim is to gain knowledge on the use, processing and application of external sources of organic matter to mitigate climate change while maintaining sustainable production and improving soil health. The project will address following research questions:

- What is the impact of resource quality of the range of potential external organic matter sources on SOC storage and stabilization?
- What is the impact of climatic conditions, soil characteristics and initial soil organic matter contents (pedo-climatic zones) on the expected life time of organic C additions across soils?
- What - if any - restrictions apply to the amount of exogenous organic matter that can be added safely (no loss of soil quality) and effectively in terms of climate change mitigation (*net* gain of SOM and *net* reduction of GHG emissions without trade-offs)?
- What are preferred management options in terms of how and when to amend exogenous organic matter considering soil depth, ploughing, fertilization, irrigation, and accounting for approved standards for safe and effective use of organic amendments?

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[10] European Commission,, 2019. The European Green Deal COM/2019/640 final.

[11] FAO, 2017. Voluntary Guidelines for Sustainable Soil Management.

- What processing options before returning organic matter to soils are available and effective to enhance formation of stable organic matter in soils as compared to direct return and how can technologies be evaluated? The project should determine what is the C budget and the impact on GHGs and nutrient release during processing and storage and after soil application. Potential trade-offs and thresholds between short-term nutrient release and long-term C sequestration should be analyzed.

The project should carry a synthesis of existing knowledge, integrate information from on-going experiments (including EJP SOIL long-term experiments) and perform targeted new studies on the short- and long-term effects of organic resources for different pedo-climatic conditions and cropping systems. The knowledge gained will be used to refine existing decision support tools for selecting suitable and cost-efficient strategies at the territorial level to make the best use of the local organic resources accounting for agro-pedo-climatic characteristics, crop and farming systems, organic resource availability, production and transport costs. The aim is to include in such decision support systems several criteria and soil functions (carbon sequestration and GHGs emission, nutrient cycling, soil structure, soil biodiversity) and to lead to recommendations of standards for safe and effective use of organic resources that allow for climate change mitigation (targeting farmers and also the waste recycling sector).

Expected outcomes:

- Improvement of knowledge of the capacity of traditional and new external organic resources to mitigate climate change, while maintaining sustainable production and soil health.
- Better capacity (knowledge and proposed tools) to make the best use of local organic resources, considering the advantages/ drawbacks of processing options before adding the organic resources to soil and considering organic resource availability at the territory scale.

Expected impacts:

- EJP SOIL EI1: Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment.
- EJP SOIL EI2: Understanding how soil carbon sequestration can contribute to climate change mitigation at regional level including accounting for carbon.
- EJP SOIL EI6: Developing region-specific fertilization practices considering the local soil, water and pedo-climatic conditions.

Project Type: Medium size research project (up to 2M€).

Topic: Harmonizing soil information (DATA)

DATA1 - Innovative techniques to monitor SOC stocks and soil degradation/restoration changes in the EU, using spectral systems/NIRS/MIRS, and other proximal sensing tools

Rationale/Specific challenge: SOC stocks and soil quality (degradation/restoration) evolve under the combined effects of land use, soil management and climate change. These dynamics may be quite fast (decades) and are insufficiently known and monitored as traditional monitoring methods are expensive and time consuming. Much faster and high throughput methodologies of soil characterization are needed to meet the needs of soil policies, such as assessing changes in soil condition, SOC and erosion rates under agricultural management in the CAP context, or assessing soil nutrient status in the context of the Farm to Fork strategy targets (European Commission, 2020)16. Soil spectroscopy (both near and mid infra-red, i.e. both NIRS and MIRS) has been developed in the last years and various proximal sensing techniques offer promising technologies to speed up and reduce the costs of the soil surveying activity. Spectral libraries already exist at different levels: national (or regional) spectral libraries in several of the EJP SOIL partner countries and the LUCAS spectral library that is the most comprehensive and freely available. Some initiatives for combining and harmonizing these spectral libraries also exist, such as the work made by the GLOSOLAN working group on spectroscopy. However, there is still a need for further harmonization of spectral measurements. Calibration in relation to the laboratory analysis as well as producing procedures to derive soil parameters from soil spectra are needed to fully validate these techniques and allow them to be deployed at a large scale in Europe. Proximal sensing is complementary to remote sensing approaches developed, e.g. for SOC monitoring, in the EJP SOIL STEROPES project and in the ESA WorldSoil projects.

Scope: The project will focus on the use of proximal sensing for soil monitoring in the field, and will aim to validate proximal sensing techniques for estimating soil properties (e.g. carbon content, soil texture, pH, nutrient contents etc.). The project should investigate the reliability and applicability of such spectroscopic techniques. A key point will concern calibration of the different estimated soil properties with actual measured data. Developing inter-comparisons is relevant for this topic, e.g. the same soil samples contemporarily analyzed by reference European laboratory and scanned for its spectra. Using freely available spectral libraries such as LUCAS, national and other spectral libraries and cooperation with international spectroscopic harmonization activities (like GLOSOLAN, IEEE) is encouraged. A critical analysis of innovative tools and methods in terms of accuracies and harmonization of soil spectral libraries is expected in order to evaluate their potential use for rapid and low-cost assessment of soil properties. The project should deliver a list of soil characteristics that can be determined by validated proximal sensing methods.
In a potential secondary step, this project could also determine the advantages and limitations of combining proximal and remote sensing. This combination would permit to enlarge the evaluations done at one site by proximal sensing, to larger areas, using the same sensors (for example VIS-NIR), For this step, cooperation should be sought with the EJP SOIL project STEROPES and WorldSoils and possibly other research initiatives.

Expected outcomes:

- Improving the development and availability of proximal sensing methods allowing to speed-up the monitoring of soil characteristics in the field, that could possibly be used directly by farmers (citizen science) or for soil monitoring at the national and the European scale.

Expected impacts:

- EJP SOIL EI1: Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment.
- EJP SOIL EI4: Supporting harmonized European soil information, including for international reporting.

Project Type: Medium size research project (up to 2M€).

SE2/INDICATORS 1 Modelling soil functions and soil threats for mapping soil functions and ecosystem services

Rationale/Specific challenge: Modern agriculture is in many cases contributing to continued soil degradation. The effects are severe depletion of soil organic matter (SOM) content, accelerated erosion, reduced soil water holding capacity, loss of soil biodiversity, salinization, soil pollution and increased GHG emissions (FAO and ITPS, 2015[12]; EEA, 2015; 2019[13]). These ongoing degradation processes impede agricultural soils to fully contribute to the provision of ecosystem services such as food and fibre production, climate change mitigation, disaster management (floods and droughts) and biodiversity-based control regulations (IPBES, 2018; 2019; IPCC, 2019; ECA, 2018[14]). In addition, there is an increasing need to be able to assess and predict the ability of soils to perform given functions for implementing climate-smart sustainable management options. Recently, several EU projects have concerned the reporting on soil degradation processes and the assessment of soil contribution to the provision of ecosystem services. Different concepts (e.g. soil quality, soil health) and indicators have been implemented across countries. Some indicators have been used in decision support tools to assess the multi-functionality of soils. However, indicators based on soil properties still need to be improved, tested on a variety of pedo-climatic conditions and shared with end-users (farmers). Also, common reference and/or threshold values have to be set, covering the diversity of soil types, climatic conditions and agricultural production systems at the European scale.

Scope: The EJP SOIL funded a first project to take stock on existing indicator systems for assessing soil quality and ecosystem services, including reference values for agricultural soils, as currently used by Member States associated in the EJP SOIL and beyond. However, the validity of these indicators and reference values remains to be tested to be able to produce detailed map of soil functions at the EU scale. Therefore, the main aim of the project is to use, test and improve the robustness and sensitivity of existing indicators and their interpretation values (e.g. reference and/or threshold values) to model and map soil functions and related ecosystem services, focusing especially on climate change adaptation and mitigation.

Interpretation/reference values should be evaluated and, or, developed for different combinations of soil types and agricultural land uses (cropland, grassland, agroforestry). Such values should ideally be defined in collaboration with the JRC/ESDAC and DG ENV. The project should consider region-specific challenges since soil threats differ among EU regions. Modelling and mapping issues should particularly concern the temporal dynamics of soil degradation and soil functions as related to climate change and changing agricultural practices and land-use (cropland, grassland, agroforestry). The project will release a geodatabase on soil degradation and soil functions based on tested indicators at the EU scale. The relevance and incurred cost of using these indicators will be analysed from a policy perspective. Participatory approaches involving end-users and farmers are encouraged, in order to

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[12] FAO and ITPS, 2015. Status of the World's Soil Resources (SWSR) – Main Report. . Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.

[13] EEA, 2015. The European environment — state and outlook 2015: an integrated assessment of the European Environment. - EEA, 2017. Climate change, impacts and vulnerability in Europe 2016 An indicator-based report.

[14] Scholes , R., Montanarella, L., 2018. Thematic assessment of land degradation and restoration. IPBES Report - IPCC, 2019. Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security,and greenhouse gas fluxes in terrestrial ecosystems. IPCC Special report.

share knowledge on the multi-functionality of soils, to test and improve soil indicators and decision-support tools in real local conditions and to demonstrate the benefits of climate-smart sustainable soil management.

Expected outcomes:

- Improving decision-support systems for farmers adapted to different EU agricultural systems and soil conditions and helping to evaluate and design best management options.
- Improving availability of models and geodatabase allowing to assess the effect of ongoing/possible soil threats and/or of agricultural soil management options on the provision of soil functions and ecosystem services.
- Knowledge allowing for a better harmonization of systems and references for evaluating soil functions and ecosystem services across Europe.

Expected impacts:

- EJP SOIL EI1: Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment.
- EJP SOIL EI4: Supporting harmonized European soil information, including for international reporting.
- EJP SOIL EI5: Fostering the uptake of soil management practices which are conducive to climate change adaptation and mitigation.

Project Type: Large size research project (up to 5M€).

SE4/INDICATORS 2 European soil biodiversity forecast towards resilient agroecosystems in response to climate change

Rationale/Specific challenge: Soil biota are key in the functioning of soils and their contribution to ecosystem services. Yet, relatively little is known about the functional role of soil biodiversity and how belowground functional biodiversity can be stimulated to enhance soil functioning or provide resilience to climate change and adverse conditions such as drought or soil borne diseases. Little is also known as to what levels of biomass or activity of the soil biota would be desirable in the perspective of sustainable and climate-smart agriculture and the provision of multiple ecosystem services including climate change mitigation and soil borne disease controls.
The current status of soil biodiversity in Europe waits to be assessed (FAO-GSP-ITPS 2020[15]). Therefore, both scientific research and policy instruments are needed. In particular in the light of EU Biodiversity Strategy, advances are expected concerning the development of functional indicators and target values for healthy soils and the expected soil functions and ecosystem services, in relation to soil types, land uses and climate zones to cover all relevant (soil) conditions.

Scope: The project is expected to use concepts, results and samples from previous projects and Long Term Experiments available through EJP SOIL partners. The project will be complementary to ongoing national and H2020 projects and in doing so will cover all regions and climate conditions across EU27. The objective is to provide at the European scale, regionalized maps of soil biodiversity and biodiversity decline, for various biological groups (bacteria, fungi, micro, meso and macro invertebrates) and selected associated functions (e.g. organic matter decomposition, nutrients provision, water retention, susceptibility to soil borne diseases) in agricultural soils. This will require the identification and selection of relevant indicators describing soil biodiversity from previous and ongoing projects. The focus will be especially on selected taxonomical and functional indicators and their evolution as a result from both climate conditions and from implementation of specific soil management actions to respond to climate change. Reference values for the selected functional indicators will be identified and time series established from archived soil samples to relate biodiversity to climate conditions and climate changes anticipated.
Time series of chrono sequences on soil biodiversity records in relation to climate sensitivity would be particularly helpful to indicate sensitivity to climate and agricultural soil use, e.g. from LUCAS or other archived soil samples and using PCR / DNA technology or other identification methods. The project will collect existing biodiversity data by EJP SOIL partners and EU countries. It will also use the existing knowledge and metadata related to soil type (national and commercial soil analyses; EJP SOIL Meta database), agricultural land use (cropland, grassland, agroforestry) and soil management in order to develop models for mapping soil biodiversity and related functions. Options will be identified to manage soil biodiversity and enhance soil quality and the challenges to adequately respond to climate change.

Expected outcomes:

[15] FAO, ITPS., GSBI, SCBD and EC., 2020. State of knowledge of soil biodiversity - Status, challenges and potentialities. Report 2020, FAO, Rome.

- Proposing functional indicators of soil biodiversity in relation to soil ecosystem services by connecting to existing and complementing the framework with the relevant parameters developed in e.g., SFS_21 projects and national programmes where appropriate;
- Sourcing data from previous projects and commercial soil analyses to produce maps of the current values and/or levels of these indicators at the EU scale to identify regional differences;
- Providing for climate responses and sensitivities of soil biodiversity indicators on the basis of archived soil analysis;
- Identifying thresholds and target values for biodiversity indicators and identification of policy instruments to address and enhance soil quality where appropriate with measures and actions.

Expected impacts:

- EJP SOIL EI1: Fostering understanding of soil management and its influence on climate mitigation and adaptation, sustainable agricultural production and environment.
- EJP SOIL EI4: Supporting harmonized European soil information, including for international reporting.

Project Type: Medium size research project (up to 2M€).

Topic: Science policy interfaces (POL)

POL2/ES7 - Enabling conditions for climate smart and sustainable soil policy: fair and functional incentives for ecosystem services related to climate mitigation and sustainable production

Rationale/Specific challenge: Soil is part of the natural environment in the same way as air and water, however, there is no direct policy at the EU level dedicated to soil protection or enhancing the capacity of soil to provide different functions (primary productivity, nutrient cycling, water purification and regulation, climate regulation with C sequestration and habitat for biodiversity and biological processes). Across the EU, and more globally, there is increasing awareness of climate change and biodiversity losses, their linkages and impacts amongst society. Growing concerns about soil health, carbon sequestration and climate mitigation are compelling governments to develop policies to protect their citizens' health and livelihoods, their natural environment and resources. Healthy soils, in direct line with human health and ecosystem health, are and become a more and more important topic for policy makers. The Mission Board on Soil Health and Food has proposed an ambitious target that 75% of European soils should be healthy by 2030 (Veerman et al. 2020)[16].
To enable the creation and updating of soil related policies, a number of conditions are currently prohibiting the payment schemes for ecosystem services provided by soils, that would help to give soil a higher value in policy and public perception. Farmers, especially from low-income categories should be encouraged with such payments, in particular through carbon farming schemes. A challenge is to account for the large diversity of farms between and within EU countries. Research is needed to support policy stakeholders to visualize the different challenges for climate-smart and sustainable soil management across different spatial scales, farming systems and environmental zones, to identify the best policies and their fair and effective implementation to support such payments.

To overcome the current soil policy fragmentation and improve policy cohesiveness in relation to climate, soil protection and health and to enable policy stakeholders to develop, implement and monitor future agricultural soil policies, there is the need to (i) identify synergies and trade-offs between existing policies across different scales to enable strategic policy decision making and support the selection of integrated and cross cutting specific policies for soil protection measures and management practices; (ii) to support scientific knowledge sharing with policy stakeholders and develop new frameworks for future soil policy and eco-scheme development and for carbon accounting initiatives; possibly looking the other way: punish polluters/emitters instead of rewarding clean production; (iii) to provide suitable tools and indicators/guideline values to enable better policy implementation and monitoring at multiple scales. While rewarding organic carbon sequestration in soils receives much attention (e.g., on-going Carbon Farming study led by DG CLIMA16 and recent LIFE 2020 call on enabling

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[16] Veerman, C., Correia, T.P., Bastioli, C., Biro, B., Bouma, J., Cienciala, E., Emmett, B., Frison, E.A., Grand, A., Filchew, L.H., Kriaučiūnienė, Z., Pogrzeba, M., Soussana, J.-F., Olmo, C.V., Wittkowski., R., 2020. Caring for soil is caring for life – Ensure 75% of soils are healthy by 2030 for food, people, nature and climate. Report of the Mission Board for Soil health and food. ISBN 978-92-76-21602-5 European Commission Directorate-General for Research and Innovation and Directorate-General for Agriculture and Rural Development Directorate B — Quality, Research & Innovation, Outreach Unit B2 —Research and Innovation, Brussels.

carbon farming[17], solutions for promoting the delivery of ecosystem services by soils are less studied.

Scope: This research should analyze the proposed/perceived solutions (financial and market-based incentives, voluntary and mandatory initiatives) to address the identified socio-economic barriers and levers for increasing carbon sequestration and promoting soil health in agricultural soils, i.e., promoting the delivery of ecosystem services by soils. It should go beyond analyzing subsidy-based policies for adapting agricultural practices and systems (e.g., Common Agricultural Policy farm-level payments), to consider rewarding systems based on market solutions and/or sector-specific innovative contract schemes between farmers and agri-food industry and retailers. Such initiatives are best seen as complementary to policy instruments, or substitute if deemed more cost-effective.

Regarding rewarding farmers for SOC storage, the project should consider the following elements for a carbon farming scheme: (i) on-farm C balance and forward-looking calculations of C sequestration over 10-20 years (lifetime of the agreement), based on choices of changing practices and farming systems, (ii) an analysis of risks, responsibilities, and solutions to meet a target and deliver C sequestration and (iii) a payment scheme that covers benefits and returns to farmers in terms of risks and insurance, and defines responsibilities in the event of non-delivery or interruption of agreed services and performance. The study should analyze how rewarding schemes, in particular results based ones, taking explicitly into account soil properties, interactions between soils and agricultural practices, may be developed for ecosystem services delivered by agricultural soils, including C sequestration. As mentioned above, besides farm-level payments envisioned in the future CAP (Euro Schemes), the project should consider complementary actions to reward farmers, moving away from subsidy-based policies and bringing in more cost-effective market solutions.

This will require to consider different issues regarding: availability of soil properties, their spatial resolution and uncertainties, criteria for indicators selection, baseline, additionality, reversibility and long-term trends, control and verification of results, training and expertise required, accounting of previous work of pioneers, the design of the reward, cost-effectiveness of the payment scheme, agricultural product labelling, social perception from soil up to agri-food chain. These activities will be done in a multi-actor approach, involving stakeholders from all areas of Europe and associating different disciplines (soil scientists, economists and social scientists).

Outputs: An analysis of the strengths and weaknesses of a result-based payment approach for soils and proposals for appropriate payment schemes. Fair and transparent “strengths and weaknesses” analysis of expected impacts of subsidy systems and other rewarding schemes, including opinions of diversified stakeholders with an objective of equity. Criteria for indicators selection. Analysis of a result-based payment approach or polluter/emitter pays schemes.

Expected outcomes:

- Development of carbon farming schemes and payment schemes for ecosystem services, adapted to regional conditions.

[17] https://ec.europa.eu/easme/en/section/life/2020-call-proposals-preparatory-projects-second-round

Expected impact:

- EJP SOIL EI5: Fostering the uptake of soil management practices which are conducive to climate change adaptation and mitigation.

Project Type: Medium size research project (up to 2M€)