

## Soil health and ecosystem services: monitoring and evaluation

### Summary

Environmental policy requires regular assessment of the state of the environment for evaluation purposes. While several EU Member States recently have produced a 'national ecosystem assessment' to this extent, these evaluations do not generally consider soil data. Soils are lagging behind in reporting environmental health including the provision of ecosystem services, primarily because of a lack of relevant indicators and evaluation criteria for monitoring. SIREN project reviewed the use of soil data in the assessment of soil-related ecosystem services in the various national approaches by 20 Member States associated to the EJP SOIL program and took stock of evaluation criteria for indicators of soil quality as implemented in national soil monitoring schemes. Policy-relevant soil quality indicators with high potential for harmonised application in national and European monitoring have been identified, and a tiered approach is proposed for implementation of such a minimum dataset. An elaborated conceptual framework linking soil quality to ecosystem services is provided, along with a glossary of consistent terminology. The approach is generally applicable for all land uses, and is exemplified for agriculture. The information and guidance may help to implement the EU Soil Health Law forthcoming in 2023.

### Key messages and recommendations

- **Problem:** To evaluate the state of our environment, including soils, concepts of soil health, ecosystem services and sustainable land use need clear, consistent and practical definition, and development of adequate indicators and reference values for harmonised monitoring and evaluation at national and European scales.
- **Recommendation 1:** Develop 'Soil Health' concept in ecosystem health assessment
- **Recommendation 2:** Develop a tiered approach for the implementation of soil monitoring, and agree on a minimum indicator set for pan-European harmonisation; use indicators currently implemented by >50% of Member States as a preliminary Tier 1.
- **Recommendation 3:** Link and synchronise soil monitoring and ecosystem assessment.
- **Recommendation 4:** Involve stakeholders in developing and implementing soil policy and management.

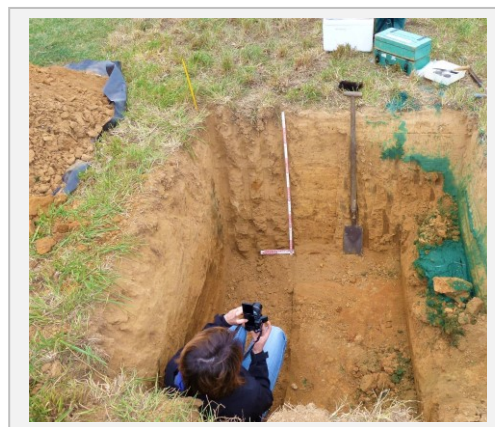
### Context

Soils are increasingly recognized as a key ecosystem compartment and natural resource that is non-renewable and endangered, and which requires focus in integrated environmental policy-making in Europe. 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 the Farm to Fork Strategy. The EU Soil Strategy has targeted 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: (i) climate, (ii) biodiversity, and (iii) circular economy. The Commission has therefore launched the coordination of soil policy to achieve healthy terrestrial and aquatic ecosystems through better soil and water management and nature restoration. A mid-term objective is that 70% of soils in Europe are under sustainable management by 2030, which will need to be evaluated on the basis of nationally established monitoring systems for soil health. Pan-European monitoring by Member States will require the development of harmonised indicators to assess current status of soils, and a common system of reference and target setting for evaluation of soil functioning and the associated provision of targeted ecosystem goods and services.

## About the project

High priority was given to the SIREN project ('Stocktaking for Agricultural Soil Quality and Ecosystem Services Indicators and their Reference Values') because of a lack in knowledge on existing evaluations frameworks for soil quality and ecosystem services in use in Europe, and their associated knowledge and development needs. SIREN took stock of the implementation of references and target values for soil quality indicators in national soil policies and the way there are used in 20 associated Member States to evaluate provision of soil-based ecosystem services. All consortium partners were approached by means of a questionnaire for background information on the national indicator systems concerning objectives and application (at national or lower spatial scales), the needs and priorities for future ecosystem assessment involving evaluation of soil indicators, and how these have been translated into policy implementation and land management in the participating countries.

Desk studies were conducted with a focus on review papers, national ecosystem assessment reports, pan-European institutional approaches, and key European research projects, to establish current views on best practices and perspectives for harmonisation and standardisation, and promising innovations. SIREN produced both, the conceptual background for an assessment of soil health which includes the provision of ecosystem services, and a suggested shortlist for soil quality indicators that are low hanging fruit for short-term implementation in future pan-European soil monitoring to evaluate 2030 Soil Strategy objectives.



Soil profiling, © Jack Faber

## Study results and conclusions (1):

### Usage of soil data for ecosystem assessment in EU

The EU Biodiversity Strategy has set specific targets dedicated to ecosystem services and required Member States to map and assess the state of ecosystems and their services in their national territory and to integrate these values into accounting and reporting systems at EU and national level by 2020. As one form to comply with these targets, eight countries have conducted a national ecosystem assessment (NEA). In the absence of standards for conducting assessments and diverging national political contexts, resources, and interests, approaches in the NEAs differed among countries. In overview, the studies served different purposes: to assess the status and functioning of ecosystems under environmental change, or to inform decision-making in spatial planning or payments for services schemes. For the majority of Partners, soils are theoretically considered in these assessments by characterising soil functions. Soil quality data are poorly specified in NEA reports, however, and evaluated by mostly unclearly documented modelling approaches or expert judgement. Also, national soil monitoring and ecosystem assessments were generally found to be focused on a limited number of ecosystem services, and therefore have limited potential to assess trade-offs between bundles of ecosystem services.

The use of soil quality indicators in monitoring to assess soil functions and ecosystem services is not widely distributed across the participating EJP SOIL Member States. Those countries who do use indicators generally use a classification of ecosystem services based on the Common International Classification of Ecosystem Services (CICES), or a modification thereof. The largest **commonality** in indicators implemented by Member States is the quantification of **soil organic carbon** (stocks and changes). A clear **omission** for almost all countries relates to soil **biological indicators**, addressing soil biodiversity either with respect to structural aspects (species richness, etc.), or functional aspects (associated with soil functions and provision of services), *or both*. Indicators for **water regulation** and **persistent organic contaminants** are also scarcely implemented, whilst cost-effective methods have come available.

The concept of 'ecosystem services' has been incorporated in national environmental policy by only few Member States, and only for a limited number of services - never for an integrated full range, e.g., as classified by CICES. The challenges that hinder proper policy development are diverse, and highly variable among countries. Representatives of Member States in EJP SOIL concluded that national soil monitoring programs must be further improved (regional representativity, indicators addressing ecosystem services), and that references and target values are needed to evaluate the contribution by soils to service provision.

National evaluation criteria for soil quality indicators such as references and target values have been implemented scarcely; these primarily concern compost, sludge, soil and food contaminants or macronutrients in association to allowable fertilisation quota and ground- and surface water protection, rather than soil functions relating to service provision beyond food production and environmental standards. Particularly, **no references or target values exist for soil organic carbon stocks and sequestering** (except for ‘no nett loss’).

A key knowledge gap shared by most Partners is the selection and development of indicators that are *fit for purpose* (translatable to targeted ecosystem services) and *robust* (sufficient background data available, spatial and temporal variability understood), and the quantification of the relationship between indicators and associated ecosystem services. Also, the **contextualisation** of evaluation criteria by soil type, land use, climate zone, and 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. Also, capacity building and financial resourcing is limited.

## Study results and conclusions (2):

### Towards harmonised pan-European soil health monitoring

The inventory amongst EJP SOIL Member States showed that there is substantial support for harmonisation of soil quality monitoring in Europe. However, where some partners plead for simple, low-cost and replicable soil indicators, others support the use of complex and integrated indicators. Nevertheless, simplicity and pragmatism seem key to success for short-term harmonisation of a first generation of indicators for national and pan-European monitoring of soil quality. Moreover, a fifth of the Partners phrased conditions to a harmonised approach. Flexibility in the choice of sampling protocols and analytical methods for harmonised indicators (i.e. limited standardisation) was motivated by the desire to be able to continue long-term measurement series already implemented in several EU countries. 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 soil health assessment would therefore require references and target values for indicators 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 Member States 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 indicators are selected to inform on predefined policy objectives (see also Fig. 1), rather than a bottom-up process where they are preselected on the basis of localised experience from historical use, cheap costs rather than cost-effectiveness, or scientific lobbyism. This hierarchy is exemplified below for a single ecosystem service that is required, amongst others, to realise EU and UN policy objectives regarding secure and sustainable food production (Fig.1). It can be concluded that **process guidance on indicator 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 (previous EJP SOIL stocktakes), SIREN has evaluated a longlist of policy-relevant 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 monitoring (see Table). It represents common ground for short-term implementation. However, this shortlist has use for assessment of a limited number of ecosystem services, and in due course complementary indicators would need to be included to facilitate a comprehensive assessment of soil health and associated provision of services and their trade-offs.

Policy Indicator	Soil Quality Indicator
Soil physical condition	Texture, Porosity, Bulk density
Soil fertility	C concentration, Total N, P and K, pH
Erosion evaluation	Based on calculation
Salinity	Electric conductivity
Contamination	Heavy metal trace elements
Other contaminants	Development recommended *
Soil biodiversity	
Water regulation	

*\* Based on our selection strategy we observe significant omissions regarding indicators for soil biodiversity, persistent organic contaminants and water regulation and filtration. As soil condition data in these areas are called for by policies and stakeholders, and analytical methods (standardised as well as novel) have come available, we recommend to also include relevant indicators for these soil functions in a comprehensive 1<sup>st</sup> tier minimum dataset.*

“At last, an approach that connects indicators to ecosystem services to environmental health, which is applicable to all soils and land uses.”

Dr. Joke van Wensem (Rijkswaterstaat Oost-Nederland)

### Study results and conclusions (3): A conceptual framework linking soil quality to ecosystem services

Environmental policies that address soil quality traditionally have been focussed on soil contamination and soil fertility. As defined by the Soil Mission reports (Veerman et al. 2020, Giuffr  et al. 2021), the current European understanding of ‘soil quality’ is widening up towards ‘healthy soils’ with a comprehensive scope on soil functioning and including the provision of a wide array of ecosystem services. Observing that a range of definitions exists in the literature and amongst the Member States, we consider that the concepts of soil quality and soil health need to be redefined in that comprehensive scope, integrating across soil functions and land uses, before being narrowed down for application in particular situations, for specific stakeholders and objectives.

Policy implementation of the soil health and ecosystem services approaches will require further integration of environmental policies, with consolidation of common concepts and frameworks, and harmonisation and synchronisation of monitoring in space and time, and between governance levels.

Monitoring then will require suitable indicators and evaluation criteria, that can facilitate the assessment of policy objectives being accomplished, and therefore should be selected top-down to ensure optimal policy-relevancy.

Soil quality can be seen as an integration of chemical, physical and biological aspects of soil ecosystem structure and function up to, and including, the continued potential delivery of ecosystem goods and services. While soil quality is the potential capability of a soil given soil type and land use, soil health is its actual (current) capacity to deliver goods and services (Fig.2).

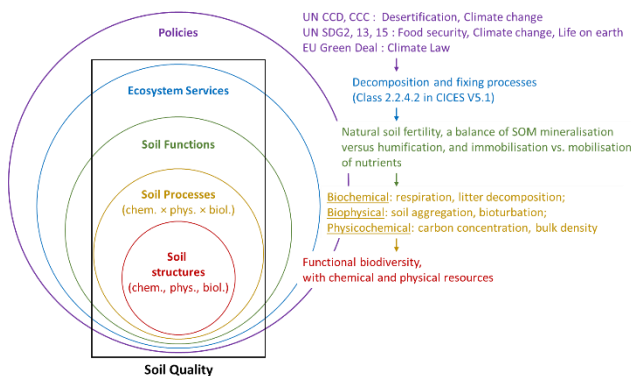


Figure 1.

**Soil Quality indicators** can be chosen top down to reflect any of these levels for a range of ecosystem services that are desired by policy and local stakeholders (“fit-for-purpose”).

A broad range of indicators is required if to assess trade-offs between services to evaluate sustainability of land use.

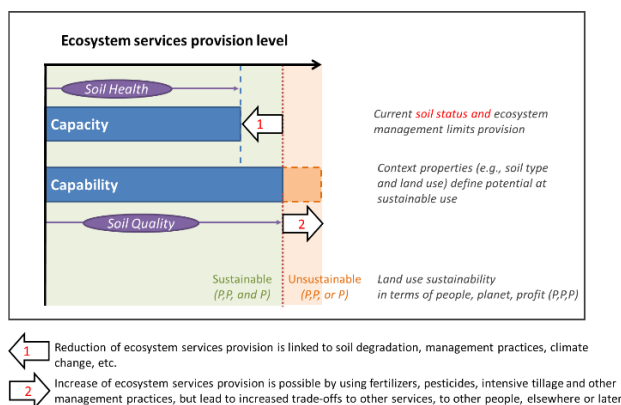


Figure 2.

**Soil quality** associates with the capability of the soil to potentially provide the desired ecosystem services (given soil type, land use and climate) when managed purposefully and sustainably. **Soil health** associates with the current capacity of the soil to supply goods and services. **Sustainable land use** addresses the mitigation of factors limiting the production of ecosystem services as well as factors reducing the flow of these services (see Fig. 3). Also, sustainable land use aims for the further development and continued provision of ecosystem goods and services without increased trade-offs (given the context of soil type and land use) in time or place, or between stakeholders.

To use soil quality indicators in a harmonised assessment of ecosystem services at European level, the relationships between soil structures, processes, functions and services need to be quantified under a **harmonised conceptual framework and standardised terminology** (Fig.3), and using a **common classification of ecosystem services**. The CICES classification system seems most appealing, but has been elaborated to varying specific requirements by many Member States.

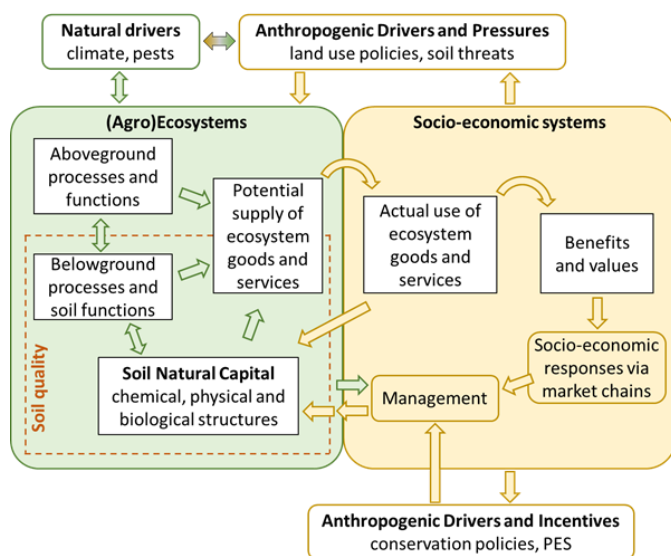


Figure 3. The SIREN **conceptual framework** integrates ecological (left, green) and socio-economic (right, yellow) systems, providing a comprehensively structured approach for evaluation and decision-making in policy and management regarding soil quality and ecosystem services. The square boxes in the framework are measurable/quantifiable, the rounded boxes are mechanistic forces from policy, management, market chains or natural drivers and pressures that soil quality indicators can directly or indirectly respond to (the DPSIR model).

*“Only well-defined indicators of soil health, with appropriate thresholds values, can assess the contributions of soils to a variety of ecosystem services in line with the UN SDGs and the EU-Green Deal.”*  
Em. Prof. Dr. Johan Bouma (Soil Mission Support)

## Recommendations

### 1. Develop ‘Soil Health’ concept in ecosystem assessment.

Promote soil quality monitoring, develop the use of soil data in national ecosystem assessment, and define references and target values in the context of soil type and land use. Facilitate this by introducing standardised terminology.

Based on review of scientific literature and feedback from EJP SOIL Partners, 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. The CICES classification needs elaboration to become more inclusive for soils. Further standardisation and harmonisation of terminology will facilitate the use and comparability of soil data in ecosystem assessment by Member States.

### 2. Develop a tiered approach and agree on a minimum indicator set to harmonise pan-European soil monitoring; Use indicators currently implemented by at least half of the Member States as Tier 1.

Develop a modular system of soil quality indicators, constructed as packages associated to specific soil threats and trade-offs between ecosystem services, depending on the monitoring objectives and available resources. Address a broad array of goods and services, rather than a single function approach, to facilitate assessment of trade-offs and true costs. Select fit-for-purpose indicators on the basis of leading policy objectives and desired ecosystem services. Develop guidance on soil indicator selection for ecosystem assessment, based on a top-down derivation following policy objectives. Implementing a tiered approach will allow to progress in a pragmatic way, leaving opportunity for integration of forthcoming science development. SIREN proposed a set based on policy relevancy, wider implementation in the Member States, and scientific usage. Harmonise the use of soil quality indicators, but refrain from standardising methods of analysis to allow for the continuation of long-term data sequences. Soil profile depth for evaluation should be commonly defined, however.

### 3. Link and synchronise soil monitoring and ecosystem assessment.

To date, soil monitoring and data collection for ecosystem assessments use different sites and sampling times, limiting the potential for integration. National ecosystem assessment reporting can be improved by specifying what methods were used to extrapolate soil data to quantify service provision. To this extend, it is a research priority to collate robust ecological production functions to replace the generally common expert judgement approaches. Assessments should not stop at the level of soil functions, but aggregate to national assessment area levels, and preferably also include socio-economic evaluations to quantify the flow of services towards relevant stakeholders with consequent valuation of costs and benefits (true pricing). Social aspects are not explicitly represented in the current conceptualisations of soil health in Europe, and indicators for cultural services are missing in all soil monitoring schemes. It is recommended to include a cultural dimension in order to evaluate social equity in sustainable land use.

### 4. Involve stakeholders in developing and implementing soil policy and management.

The development of national soil monitoring programs will profit from an early involvement of stakeholders by promoting acceptance and shared interest in indicators, reference values and target values for soil quality as derived from policy objectives, as well as from incorporation of practical knowledge on land management, service flow and the possibility to introduce payments for ecosystem services.

*“The SIREN study provides information and guidance for the implementation of the policy proposal on European soil health.”*

Dr. Arwyn Jones (JRC-EUSO Technical Working Group on Monitoring)

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### References and further information

1. Link to SIREN project webpage, including final report, executive summary, policy brief and webinar video: <https://eipsoil.eu/soil-research/siren>
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Faber, J.H., I. Cousin, K.H.E. Meurer, C.M.J. Hendriks, A. Bispo, M. Viketoft, L. ten Damme, D. Montagne, M.C. Hanegraaf, A. Gillikin, P. Kuikman, G. Obiang-Ndong, J. Bengtsson, A.R. Taylor (2022). Stocktaking for Agricultural Soil Quality and Ecosystem Services Indicators and their Reference Values. EJP SOIL Internal Project SIREN, Deliverable 2. Report, 153 pp.

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