October 2023

European Commission proposal for a Soil Monitoring Law

Technical Briefing on

introducing relevant soil biodiversity descriptors for soil monitoring

Policy recommendations for improvements needed in EC proposal

1. The mandatory soil biodiversity descriptor '*soil basal respiration*' in Annex I should be replaced with the following two soil biodiversity descriptors of which Member States should choose at least one:

   (1) **Community-level physiological profiling** (CLPP) and
   (2) **Metabarcoding** (eDNA).

   Annex I should also require the application of a suitable **biodiversity index**, such as the Shannon-Wiener Index, to evaluate soil biodiversity.

   The Commission should be empowered to adopt **delegated acts to amend Annex I** and adapt it to newest scientific and technical progress, specifically on soil biodiversity.

2. Member States should be required to **set criteria for at least one of these biodiversity descriptors after the first soil measurements are performed**, at the latest four years after date of entry into force of the Directive. These criteria can be set either at Member State- or at soil district-level.

3. Member States should be required to monitor at least one of the above-mentioned soil biodiversity descriptors and include the **results of this monitoring in the assessment of the soil health**.

4. When carrying out the evaluation and review of the Directive in accordance with Article 24, the Commission should **evaluate the soil biodiversity criteria** set by Member States and ensure EU-wide harmonisation of soil biodiversity assessment. As criteria have been set, the soil biodiversity descriptors should **consequently be relocated from part C to part B of Annex I**.

5. The Directive should include a **Recital acknowledging that soil biodiversity is a critical component of overall biodiversity** and plays a fundamental role in maintaining ecosystem functions and services, including provisioning of nutritious food and clean water, regulating water and climate and supporting carbon and nutrient cycling. The Recital should clearly state that soil biodiversity is essential for all four pillars of food security.

Introduction

The European Commission (EC) proposal for a Directive on Soil Monitoring and Resilience (Soil Monitoring Law, SML) aims to protect the most holistic and interlinked sphere of Europe's ecosystems – living soils. Healthy living soil ecosystems are the bedrock of biodiversity[1], ecosystem services[2], stable weather patterns[3], food security[4], and human health[5]. Unfortunately, the proposal falls short in capturing the key element of this ecosystem which is soil biodiversity. The legislative proposal is in line with traditional soil science that focusses on physical and chemical soil properties[6]. However, **decades of advances in living soil and plant sciences offer robust scientific descriptions and monitoring methods of soil biodiversity**[7]. More importantly, regenerative agricultural and forestry practices already pave the way to effectively regenerate the health of living soil ecosystems cost-efficiently in production-based land uses by focusing on soil biodiversity[8]. Therefore, we believe that for the **SML to overcome its scientific lag, the co-legislators need to put soil biodiversity at its core**.

I. How does the EC proposal for a Soil Monitoring Law include soil biodiversity?

The SML proposal recognizes the importance of soil biodiversity in theory (see Recital 19), however, this is **not sufficiently reflected in the actual requirements that the proposal imposes**. Although the definition of soil health and some elements in the Impact Assessment recognise the role of soil biodiversity for soil health and its functions, this understanding is not effectively translated into cost calculations in the Impact Assessment or clear obligations in the legal text. The proposal does not prioritise soil biodiversity as a central focus for monitoring and as a key lever for building soil, human and planetary health and resilience.

The proposal outlines a series of soil descriptors to assess soil health. These descriptors are divided into three categories: Part A descriptors with criteria for healthy soil condition established at EU level; Part B descriptors with criteria set at Member State level; and Part C descriptors without criteria. As a result, Part C descriptors, while subject to monitoring and trend analysis, are not attributed thresholds and thus are not factored into the assessment of soil health. **Soil biodiversity currently falls under Part C of Annex I, which means that Member States are not obliged to consider it when assessing soil health**.

Moreover, soil biodiversity is defined by a descriptor that does not align with the latest scientific understanding and offers an incomplete and easily manipulable picture of soil life. **The descriptor 'soil basal respiration' falls short in providing qualitatively meaningful and EU-wide harmonizable descriptions of soil biodiversity loss**. As shown below, there are scientifically well-established approaches that are much more effective in achieving this.

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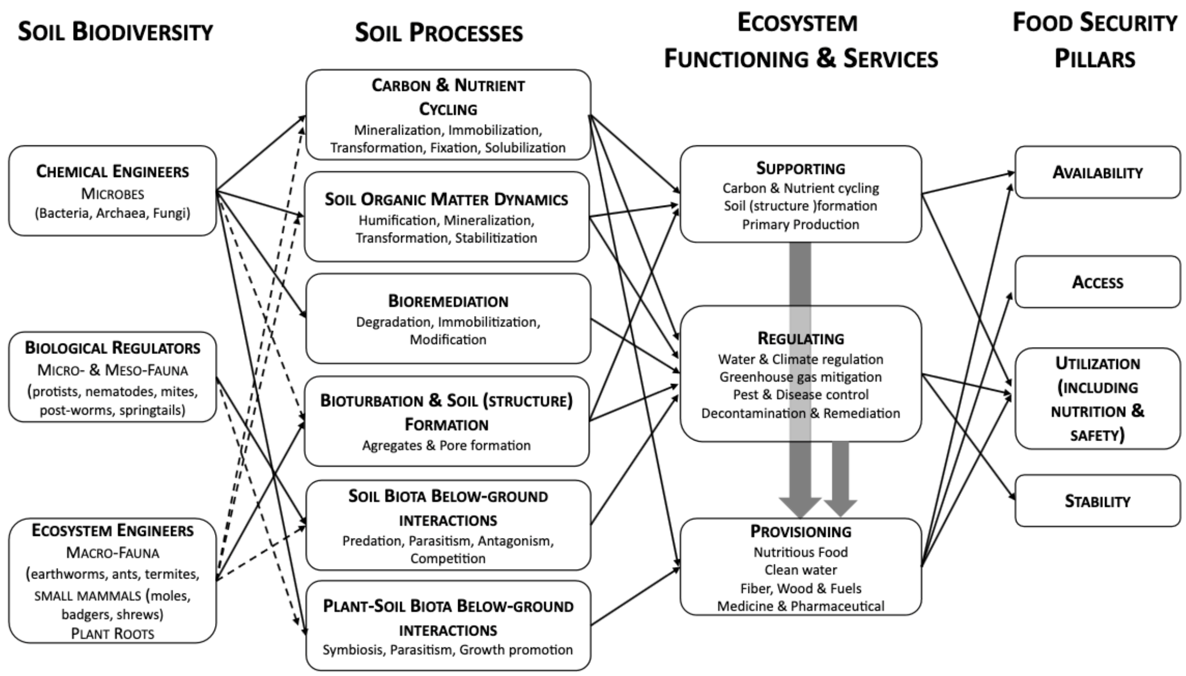
[1] M. Anthony et al. Enumerating soil biodiversity. 2023. https://www.pnas.org/doi/10.1073/pnas.2304663120.
[2] Soil biodiversity. FAO Soils portal. Food and Agriculture Organization of the United Nations. https://www.fao.org/soils-portal/soil-biodiversity/en/.
[3] G. J. Retallack. Soil Grown Tall. The Epic Saga of Life from Earth. Springer. 2022. https://link.springer.com/book/10.1007/978-3-030-88739-1.
[4] Mujtar et al. (2019): Role and management of soil biodiversity for food security and nutrition; where do we stand?. Global Food Security. Volume 20. Pages 132-144. https://www.sciencedirect.com/science/article/abs/pii/S2211912418300300.
[5] H. Hirt. Healthy soils for healthy plants for healthy humans. Science & Society. 2020. https://www.embopress.org/doi/full/10.15252/embr.202051069.
[6] The EEA report "Soil monitoring in Europe Indicators and thresholds for soil health assessments" (2020) seems to be a key scientific foundation of the proposal. However, Table 1-3 does not link soil biological degradation with the soil services of 'Growing crops' and 'Wood and fibre production'. This, however, contradicts their own presentation in Table 1-1, where soil biodiversity is clearly connected with these soil services.
[7] Soildiver Agro. http://soildiveragro.eu/it/publications/deliverables/.
[8] R. Lal. Regenerative agriculture for food and climate. Journal of Soil and Water Conservation. 2020. https://functionalfertiliser.co.nz/wp-content/uploads/2020/09/Lal-article-jswc.2020.0620A.full_.pdf.
E. Bach et al. Soil Biodiversity Integrates Solutions for a Sustainable Future. 2020. https://www.mdpi.com/2071-1050/12/7/2662.

II. Why is the monitoring and assessment of soil biodiversity crucial?

As the proposal states, "soil health means the physical, chemical and biological condition of the soil determining its capacity to function as a vital living system and to provide ecosystem services" (Article 3 (4)). However, none of the descriptors is currently capable of indicating the condition of that vital *living* system.

In agroeconomic and land use politics, biodiversity is often viewed as being in trade-off with agricultural production. The limits of this conception become particularly visible when it comes to soil biodiversity. **Soil biodiversity has a direct mutual beneficial relationship with agricultural production, farm income as well as farm and food system resilience as well as with the restoration of biodiversity and biogeochemical cycles**. The graphic below explains the core functional link between soil biodiversity, soils ecosystem multifunctionality and food security.

Soil biodiversity is decisive for soil's ecosystem multifunctionality and food security



Graph 1: Relationships between soil biodiversity and food security pillars through soil processes and ecosystem functioning and services. Black arrows and black dashed arrows indicate, respectively, major and minor roles of functional groups on soil processes. Gray arrows indicate the relationships among supporting, regulating and provisioning ecosystem services.[9]

We consider it crucial that, in line with more than a decade of advances in modern soil science[10], soil biology is accredited with the core functional role in provisioning and regulating ecosystem services of soils as well as with the driving role in influencing soil health. For example, research programs of the

[9] In: Mujtar et al. (2019): Role and management of soil biodiversity for food security and nutrition; where do we stand? Global Food Security. Volume 20. Pages 132-144. https://www.sciencedirect.com/science/article/abs/pii/S2211912418300300.

[10] D. Derrien et al. Current controversies on mechanisms controlling soil carbon storage: implications for interactions with practitioners and policy-makers. A review. Agronomy for Sustainable Development. 2023. https://link.springer.com/article/10.1007/s13593-023-00876-x.

European Joint Programme on Agricultural Soil Management (EJP SOIL), SIREN[11] and MINOTAUR[12] as well as many more, are doing important work towards that goal and should be fully leveraged in the SML. Within the EJP SOIL Programme, Austrian stakeholders have identified soil biodiversity enhancement as having the least trade-offs among all soil health regeneration options[13].

Within the currently proposed methodology based on descriptors and criteria harmonized at EU level, **it is scientifically and practically feasible for soil biodiversity to serve as a mandatory descriptor with context specific criteria set at Member State or soil district level, harmonized at EU level.**

III. Which biodiversity descriptors and monitoring methods are suitable?

The proposed descriptor on soil basal respiration is not suited to provide a qualitative assessment of soil biodiversity. The descriptor is scientifically as well as technologically not up to date. Soil basal respiration does not provide information about communities and species, or data for an appropriate index. **Soil biodiversity experts regard it as one of the least effective methods for the evaluation of soil biodiversity**[14]. It predominantly measures soil activity from bacterial respiration and little from fungal or other sources and is very easily manipulated (i.e. via manure application, potentially resulting in misleading positive outcomes due to the activity of low biodiverse microbiomes).

Methods that put soil respiration into a wider context are more powerful[15] and have proven to be relevant as indicators of soil microbial functions and functional diversity[16]. The descriptors to assess and monitor soil biodiversity **should accurately portray the (functional) diversity of soil** to be able to describe soil biodiversity's loss or development. Well established scientific literature suggests two core methodological approaches to achieve this:

- **(1) Community-level physiological profiling**[17] (CLPP) and
- **(2) Metabarcoding**[18] (eDNA).

CLPP approaches collect information about the soil's functional biodiversity whereas eDNA (environmental DNA) collects information mainly about the soil's taxonomic biodiversity. In both cases, the information can be operationalized by standard biodiversity indexes, for example the **(3) Shannon-Wiener Index**[19]. After standardization and cross-validation, an approach based on CLPP and eDNA can thus lead to a harmonized assessment of soil biodiversity at EU level as well as facilitate the setting of criteria at soil district or Member State level, taking into consideration land use.

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[11] SIREN. EJP SOIL. https://ejpsoil.eu/soil-research/siren.

[12] EJP SOIL. Prioritizing and selection of soil health relevant biological indicators. Stefano Mocali, Jack Faber. 2023. https://ejpsoil.eu/fileadmin/projects/ejpsoil/WP8/Workshops/Session_2_Prioritising_and_selecting_soil_health_biological_indicators_MINOTAUR.pdf.

[13] Figure 2 Average weighting, by percentage, of barriers identified by stakeholders in Austria that contribute to gaps in policy with respect to the soil challenges identified. In: EJP SOIL. Towards climate-smart sustainable management of agricultural soils. Deliverable 8.3 Summary Report on Policy Needs Identified. 2021. https://edepot.wur.nl/587409.

[14] D. Stone et al. Selection of biological indicators appropriate for European soil monitoring. Applied Soil Ecology, Volume 97. 2016. https://www.sciencedirect.com/science/article/abs/pii/S0929139315300585.

[15] K. Ritz et al. Selecting biological indicators for monitoring soils: A framework for balancing scientific and technical opinion to assist policy development. Ecological Indicators. Volume 9, Issue 6. 2009. https://www.sciencedirect.com/science/article/abs/pii/S1470160X09000508.

[16] P. M. S. Ndour et al. Microbial Catabolic Activity : Methods, Pertinence, and Potential Interest for Improving Microbial Inoculant Efficiency. Microbial Ecology. 2023. https://link.springer.com/article/10.1007/s00248-023-02250-6.

[17] K. P. Weber and R. L. Legge. Community-Level Physiological Profiling. In: N.J. Clifton. Methods in molecular biology. 2010. https://www.researchgate.net/publication/38060479_Community-Level_Physiological_Profiling.

[18] A. Orgiazzi et al. LUCAS Soil Biodiversity and LUCAS Soil Pesticides, new tools for research and policy development. European Journal of Soil Science. Volumte 73, Issue 5. 2022. https://bsssjournals.onlinelibrary.wiley.com/doi/10.1111/ejss.13299.

[19] B.R. Kim et al. Deciphering Diversity Indices for a Better Understanding of Microbial Communities. J. Microbio. Biotechnol. Volume 27, Issue 12. 2017. https://www.jmb.or.kr/journal/view.html?doi=10.4014/jmb.1709.09027.

Undoubtedly, each of these methods alone offers unique insights soil biodiversity. However, combining them can provide the most robust understanding of both the function and composition of microbial communities in soil environments – albeit at higher costs. Both approaches are also on the **forefront of private sector initiatives**[20] aimed at enabling production integrated soil health regeneration in agroecosystems and have thus **proven their cost-efficiency as well as functional significance**.

More information on the approaches and methods mentioned above:

(1) Community-level physiological profiling (CLPP)

Community-level physiological profiling (CLPP) analysis is a technique used to characterize the metabolic activity of microorganisms in a mixed microbial community. By examining a community's ability to use a range of carbon sources, it gives insights into its overall functional versatility. In ecological studies, EcoPlates[21] are employed to measure the consistency of a standard microbial group and to identify and evaluate shifts when an environmental factor emerges. Those shifts in microbial populations frequently signal upcoming changes in the overall health and stability of the environment. Two main methods are widely acknowledged to evaluate microbial soil condition: MicroResp™[22] and Biolog EcoPlate™[23].

(2) Metabarcoding (eDNA)

Regarding soil ecosystem biodiversity analyses via metabarcoding, eDNA methodologies offer an efficient, reproducible, and scalable solution to characterise biodiversity, establish diversity thresholds, understand food web dynamics and monitor community changes as a result of activities, management decisions, or restoration programs. In this context, the use of eDNA methodologies has enabled the classification of the major biotic components of soil microbiomes in agricultural systems[24]. The Global Soil Biodiversity Conservation Network also recommends analytical methodologies based on eDNA to develop new ecological indicators for tracking soil health and biodiversity[25].

(3) Shannon-Wiener Index

The Shannon-Wiener Index is a key indicator used to evaluate biodiversity in ecology. However, it is important to understand differences and similarities in its application in both CLPP and eDNA methods. In both cases, the index is used to quantify biodiversity, taking into account the number and abundance of species (in the case of eDNA) or metabolic patterns (in the case of CLPP). In both cases, the Shannon-Wiener Index allows for assessing the complexity of an ecosystem, where higher values indicate greater biodiversity. For CLPP, the index is based on metabolic profiles, which indicate the ability of microorganisms to utilize various carbon substrates. For eDNA, the index is based on the

[20] Biome Makers. Impact Report. 2022. https://online.fliphtml5.com/yduxb/lsmu/?__hstc=13025832.b0d76b5b116b67ee314650896306461e.1696234887326.1696234887326.1696234887326.1&__hssc=13025832.1.1696234887326&__hsfp=1418899832&hsCtaTracking=294c7f90-e2ba-4d35-80dd-cbef649b9645%7C3a6da3f2-ca4d-4ee8-842a-239c91513a2f#p=1; EIT-Food Regenerative Agriculture Projects with Biotrex. https://www.eitfood.eu/projects/regenag-revolution; https://dgc.co.jp/en/.

[21] T. Miki et al. Statistical recipe for quantifying microbial functional diversity from EcoPlate metabolic profiling. Ecological Research. Volume 33, Issue 1. 2017. https://esj-journals.onlinelibrary.wiley.com/doi/10.1007/s11284-017-1554-0.

[22] R.E. Creamer et al. Measuring respiration profiles of soil microbial communities across Europe using MicroResp™ method. Applied Soil Ecology. Volume 97. 2016. https://www.sciencedirect.com/science/article/abs/pii/S0929139315300573.

[23] C. Floch et al. Indicators of pesticide contamination: Soil enzyme compared to functional diversity of bacterial communities via Biolog® Ecoplates. European Journal of Soil Biology. Volume 47, Issue 4. 2011. https://www.sciencedirect.com/science/article/abs/pii/S1164556311000458.

[24] J. H. Kestel et al. Applications of environmental DNA (eDNA) in agricultural systems: Current uses, limitations and future prospects. Science of the Total Environment. Volume 847. 2022. https://www.sciencedirect.com/science/article/pii/S004896972204654X?via%3Dihub.

[25] C. A. Guerra et al. Tracking, targeting, and conserving soil biodiversity. A monitoring and indicator system can inform policy. Science. Volume 371, Issue 6526. 2021. https://www.science.org/doi/10.1126/science.abd7926.

presence and abundance of specific DNA sequences corresponding to different species. CLPP results provide insight into the functional diversity of microorganisms, while eDNA provides information mainly on taxonomic biodiversity. While indexing is a process of simplification and may not capture the full complexity of soil ecosystems and their communities, the method brings significant advantages. Its universality allows for application across different ecological domains and its capacity to provide a single value representing biodiversity facilitates standardization, cross-validation, setting of future criteria and harmonization.

IV. How should soil biodiversity monitoring and assessment be anchored in the SML?

To ensure proper recognition of soil biodiversity within the SML, it is imperative to require Member States to monitor at least one of the above-mentioned soil biodiversity descriptors and to include the results in the assessment of soil health.

In order to achieve this, specific soil biodiversity criteria must be set. While the data required for establishing criteria for soil biodiversity descriptors is presently unavailable due to incomplete monitoring practices in Member States in the previous years, we recommend setting the criteria after a first round of monitoring with transparent, standardized, and cross-validated methodologies, four years after entry into force of the Directive. This monitoring phase will facilitate the collection of the data necessary for establishing the criteria accurately. The results of the monitoring of the descriptors should then be included in the assessment of the soil health.

When carrying out the evaluation and review of the Directive, the Commission should evaluate the soil biodiversity criteria which should be integrated into a process of standardization, cross-validation and harmonization, for example led by the JRC. As criteria have been set, the soil biodiversity descriptors should consequently be relocated from part C to part B of Annex I. In addition, the Commission should be empowered to adopt delegated acts to amend Annex I and adapt it to newest scientific and technical progress on soil biodiversity.

Conclusion

The approaches described above, together with a clear legal anchoring of soil biodiversity assessment within the proposal, will allow to put soil biodiversity at the core of the Soil Law. This not only offers the prospect of addressing persistent data gaps but also allows soil policy to advance with a complete understanding of soil ecosystems, thus fostering adequate solutions to enhance soil health. Instead of setting ourselves obstacles by working with a partial grasp of soil health, we should recognise the vital role of soil biodiversity for soil functions and ecosystem services. This will empower us to address challenges like food security in an effective and proactive manner.

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