Joint Position Paper

by experts from soil, agricultural, biological, medical and law sciences as well as from farming, NGOs and regenerative business

Towards a functional understanding and regeneration of soil biology in the EU Soil Health Law and beyond

Executive Summary

In its EU Soil Strategy for 2030, from November 2021, the EU Commission sets out a vision of ensuring that "by 2050, all EU soil ecosystems are in healthy condition and are thus more resilient, which will require very decisive changes in this decade[1]." It is estimated that between 60 and 70 % of European soils are unhealthy to date[2]. Living soil ecosystems are the foundation of all terrestrial ecosystems and biodiversity. The health of our soils determines the health of all of us.

With the EU Soil Health Law (SHL), the EU Commission is aiming to establish the legislative framework to achieve the objectives of the strategy. The SHL germinated from a Citizens` Initiative and was inoculated by the EU Green Deal, the EU Soil Mission, the Farm to Fork and Biodiversity Strategy for 2030 and the EU Soil Strategy for 2030. Legislative soil protection is also called for in the plan of action for the conservation and sustainable use of soil biodiversity adopted at COP15 of the UN Convention on Biodiversity (CBD)[3]. The SHL will aim at setting a new legal basis for the protection and regeneration of living soil ecosystems.

As existing European environmental legislation does not target the bundled impacts of land use expressed in soil degradation, past legislation has failed to tip the balance of European land use from degradation to regeneration. This is however necessary to grapple with the climate emergency by reversing land use impacts on the water, carbon and nitrogen cycles as well as biodiversity, which are all significant for the health of both European ecosystems and citizens. **With the SHL targeting the most holistic and bundled part of terrestrial ecosystems and biodiversity**, this position paper focuses on how the SHL's legislative proposal in 2023 can be designed to integrate already existing scientifically validated approaches in the field[4] as well as the insights of the EU Commission's own research

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0699&from=EN

[2] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/soil-health-and-food_en

[3] https://www.encanetwork.eu/fileadmin/inhalte/enca/pdf/2023_enca_soil_biodiversity_and_sustainable_land_use_position.pdf

[4] https://repository.ipb.ac.id/handle/123456789/41690; https://www.biotrex.eu/

endeavours focusing on soil biodiversity (e.g. EJP Soil Programmes or SOILDIVERAGRO).

The perspectives of a variety of actors from science, civil society and the agri-food system on the relationship between the EU Soil Health Law (SHL), soil biology and agriculture are reflected in a critical evaluation of the current scientific, agricultural and socio-economic context and development of the law.

These result in recommendations on how to assure socio-ecological and -economic ambition of the law in full consideration of the political landscape of the legislative process and propose a **path to ensure policy coherence, inclusivity and broad socio-ecological and -economic synergies and effectiveness of the upcoming EU Soil Health Law**.

Our recommendations aim at informing decision makers towards a policy process that will lead to a robust and holistic approach in order to guarantee the effectiveness of the SHL and its implementation.

Accordingly, the EU SHL should aim for:

1. **A soil health definition up to date with the scientific evidence on the functional role of soil biology**
   We are concerned that the definition of soil health informing the EU SHL will be based on outdated scientific perceptions of soil health with strong emphasis on chemical and physical properties disregarding the **functional role of the soil's biological properties.** A soil health definition up to date with the scientific evidence on the functional role of soil biology in the provisioning and regulating ecosystem services is firstly necessary to be scientifically accurate. Secondly, such a soil health definition is of major importance to almost all impacts that the law will develop. These impacts should **give guidance to national and regional policy makers, scientific bodies and the agricultural sector** for regenerating our soils as the living foundation of our society.

2. **Harmonised & comprehensive soil health monitoring and reporting system**
   Several EU research and innovation programmes state that **indicators systematically monitoring functional biodiversity are rare and therefore underrepresented** in national soil surveys. A **harmonised and comprehensive system to monitor and report on functional soil biodiversity** is a chance for the Commission to produce extra value to European society and ecosystems while being responsive to the positions in the Council and adaptive to already existing national soil surveys. The

respective system should build, distribute and make accessible methods to systematically assess soil microbes and estimate microbiome activity as well as biodiversity and functional metagenomics in order to ensure desired outcomes in soil health regeneration and agronomic resilience and additionally provide farmers **affordable access to biological soil information.**

3. **An adaptive and farmer empowering benchmarking process**
   We are proposing to aim at a **regionalized, land use specific and transformative benchmarking system** derived from the monitoring and reporting system. Indicators and their metrics must have a guiding function for land users. They should not only indicate negative thresholds, but express a positive target reference and make continuous development visible. It will **allow farmers to actively participate in developing their regional benchmarks.** This, in turn, makes it possible to **measure relative developments and allows for targeted regulation and subsidy schemes,** building the infrastructure to **empower farmers to transition to regenerative agriculture**.

4. **Pedoclimatic soil districts**
   Delineating soil districts along pedoclimatic regions and not solely administrative regions is decisive for an **adaptive and farmer empowering benchmarking process**. We acknowledge living soil ecosystems as the foundations of terrestrial ecosystems and hold that such pedoclimatic soil districts could be of **great value for driving further European integration** by bringing public administrations, the agricultural sector and civil society from different EU nations together. This could be achieved in synergy with the building of **ecological antifragility and economic resilience** by driving projects for **regional circular bioeconomies**, building rural and rural-urban relationships and **strengthening social cohesion**.

The EU SHL as a guiding force towards regenerative sustainability in our European agri-food system

An ambitious and progressive EU Soil Health Law based on these four recommendations could contribute to

- giving **longer-term planning security for farmers** without extra bureaucratic burden while.
- fostering farmer motivation and their **ability for consequence capture and capacity building.**

- enabling positive feedback loops through **regional peer-to-peer learning infrastructures**.
- giving access to **cost-efficient** agronomically relevant soil health development information.
- establishing a more **level playing field in the agricultural sector** and fairness to regenerative leaders in farming.
- allowing for new **societal appreciation of the positive agency of farmers** in our climate and biodiversity crises.
- significantly **alleviating the demographic challenge** simmering in the agricultural sector.
- building **EU policy coherence**, efficiency and effectiveness.
- increasing **biodiversity** in agroecosystems.
- addressing **water quantity, cycling and quality** issues.
- addressing the **epidemic of non-communicable diseases** at its core root.
- significantly **decreasing the pressure of diseases** in animal and plant production.
- **regenerating** the biogenic carbon and nitrogen cycles.
- **building resilience** and climate adaptation of agricultural production.
- **deflating food prices** in the long term.

An action plan is needed for the mobilisation of adequate technical and financial resources for national, subnational and local governments dedicated to the regeneration and protection of living soil ecosystems in order to contribute to the ecologic, economic and social resilience of our European agri-food system.

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1 Introduction

This position paper proposes a path to assure policy coherence, inclusivity and broad socio-ecological and -economic synergies and effectiveness of the upcoming EU Soil Health Law. The paper's main arguments and proposals are the outcomes of a consolidation process among EU soil health pioneers from science, civil society and industry.

The paper focuses on how the SHL's legislative proposal in 2023 can be designed in order to integrate already existing scientifically validated approaches in the field[5] combined with insights of the EU Commission's own research endeavours (EJP Soil Programmes, particularly SIREN and MINOTAUR or SOILDIVERAGRO) as well as the upcoming findings of the EU Mission 'A Soil Deal for Europe' research projects, particularly BENCHMARKS and AI4SoilHealth and of many more research programs focusing on soil biology[6].

The largest part of Europe's land is used for agriculture. Agricultural land is estimated to cover 42% of all EU land area. Arable land accounts for the largest share (56%), followed by grasslands (25%), mixed crops (13.5%) and various permanent crops (5.5%)[7].

To date, intensifying pressures on the health of our global and European living soil ecosystems contribute decisively to the multiple and converging crises and emergencies in our society, agricultural sectors and ecosystems.

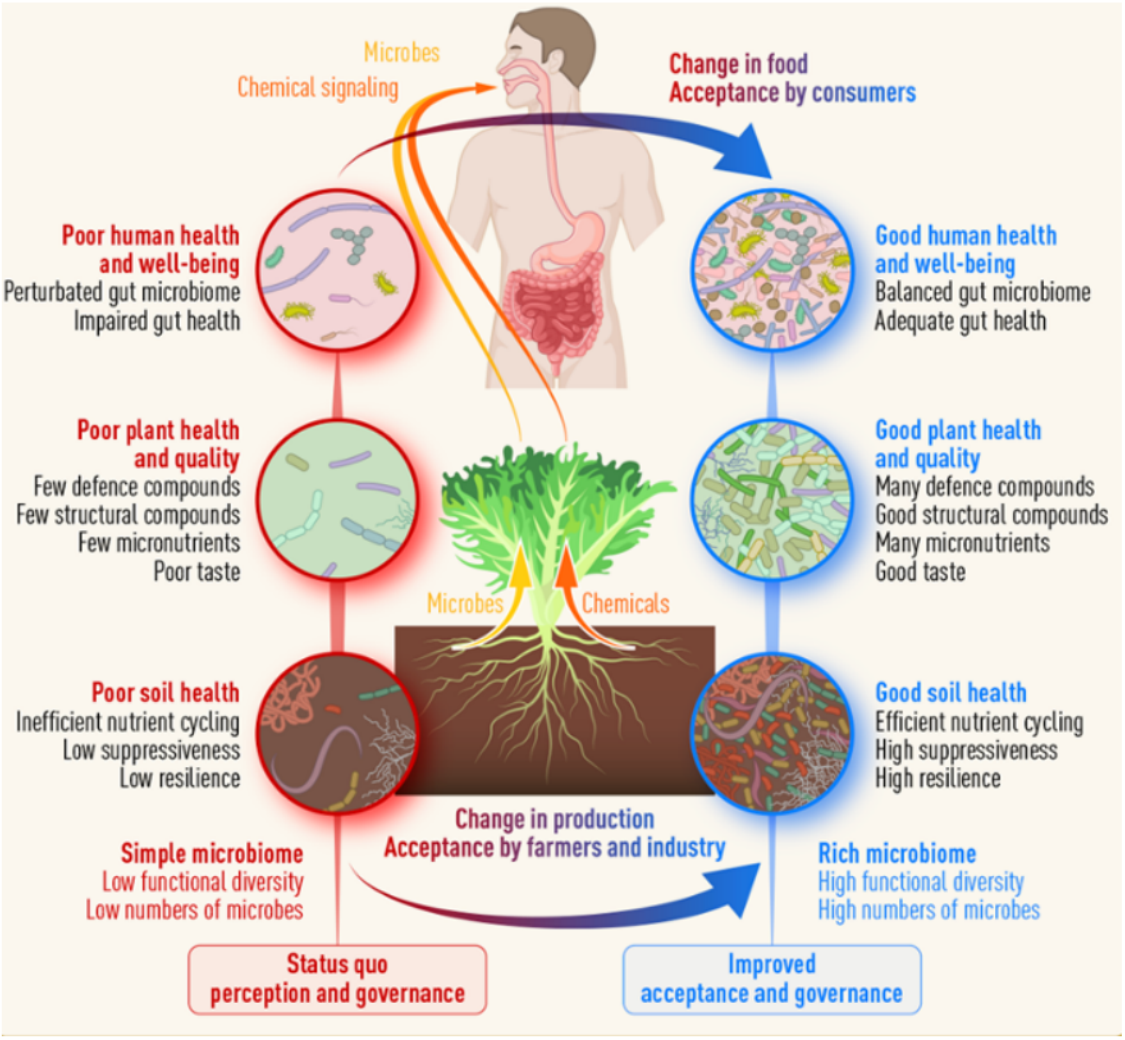
It is estimated that between 60 and 70% of EU soils are in an unhealthy state to date[8]. However, this can be considered a conservative estimate, as will be outlined below. The real state and development of the health of EU soils might very well be much worse. The consequences of degraded soil health are far reaching and have strong impacts on a wide range of ecologic, economic and societal challenges we are already facing today:

Food and health crises

Globally, acute food insecurity is spiralling and over 3 billion people cannot afford a healthy diet. Similarly in the EU, more than 8.6% of the population are unable to afford an adequate meal every second day[9]. Overweight, obesity and diet-related

[5] https://repository.ipb.ac.id/handle/123456789/41690; https://www.biotrex.eu/
[6] I.e. https://inog.de/wp-content/uploads/2020/12/Advert-ESR4-ARISTO_final.pdf
[7] We want to stress that also soil health of forest land is of major importance to society (39% of land in the EU), we hold similar dynamics are at play as in agriculture, but a more detailed discussion is outside of the focused scope of this paper.
[8] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/soil-health-and-food_en
[9] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220225-1

non-communicable diseases (NCDs) are a major public health challenge in Europe[10]. It is estimated that the major NCDs cost each EU citizen more than 411€ annually - the costs of all NCDs are considered to be much higher and to continue to rise rapidly[11]. In medical science, the epidemic of NCDs is increasingly associated with the destruction of soil microbiomes. In other words - the destruction of the health of soil biodiversity and living soil ecosystems[12].



"'We need a sufficient number of microbes, such as bacteria, viruses and yeasts, in order to have a healthy gut. And we mainly get these out of the food we eat.' A lack of these microbiomes causes an impaired health of the gut and results in diseases. 'These are called non-communicable diseases (NCDs): diseases that are not spread through infection or through other people, but are typically caused by unhealthy behaviours."[13]

[10] https://www.jpi-pen.eu/images/reports/Food-EPI_EU_FINAL_20210305.pdf
[11] https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/cost-non-communicable-diseases-eu_en; https://health.ec.europa.eu/system/files/2022-06/eu-ncd-initiative_publication_en_0.pdf
[12] https://doi.org/10.1038/s41579-022-00779-w;https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7399920/
[13]https://www.universiteitleiden.nl/en/news/2023/01/healthy-soil-for-a-healthy-gut?utm_content=236731167&utm_medium=social&utm_source=linkedin&hss_channel=lcp-10060063

Agro-economic resilience

From 2021 to 2022, *all* of EU agricultural production dropped significantly. The core reasons for this are animal diseases and droughts[14]. Drought is also the reason why the compound annual growth rate of per hectare production of the main crops in major EU agricultural sectors has come to a standstill in the last 20 years[15]. The impacts of droughts on EU agricultural production continue to intensify[16]. Water related soil functions such as water infiltration, storage and percolation are decisive variables for agricultural production in times when droughts and torrential rains alternate. **Moreover, incubating soil biology for qualitative and quantitative yield enhancement is probably the most promising frontier of innovation in agriculture to date**[17].

Ecological Antifragility

It is estimated that one species goes extinct every seven minutes. However, most of the biodiversity that lives in soil ecosystems and enables them to function has not even been described yet[18]. Similarly, the functionality of the largest biogeochemical cycle, the cycle of water, the most important nutrient of life on earth, has only recently been fully ecologically comprehended[19]. This novel understanding of water cycles was translated into a planetary boundary last year– Green Water. Green Water describes terrestrial precipitation, evaporation and soil moisture and is fundamental to the planet's climate and agricultural production. Research found that we have significantly overstepped the planetary boundary of water[20]. This is largely due to soil use in agriculture and land use change. Likewise the disruption of the second and third largest biogeochemical cycles, carbon and nitrogen, is largely due to standard ways of agricultural production and contributes to climate change and weather extremes[21]. This could be very different. For example, it is estimated that free living soil organisms, like bacteria, make up at least a third of the terrestrial total biological nitrogen fixation[22].

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[14] https://capreform.eu/2022-a-record-year-for-farm-income/
[15] https://www.nabu.de/imperia/md/content/nabude/landwirtschaft/230323-the_case_for_regenerative_agriculture_longversion-engl.pdf,
[16] https://iopscience.iop.org/article/10.1088/1748-9326/abf004; https://www.unepfi.org/themes/climate-change/climate-risks-in-the-agriculture-sector/; https://www.euronews.com/green/2023/04/19/drought-threatens-grain-harvests-in-spain
[17] https://onlinelibrary.wiley.com/doi/full/10.1002/sae2.12028
[18] https://www.sciencedirect.com/science/article/pii/S0960982219310231
[19] http://www.waterparadigm.org/download/Water_for_the_Recovery_of_the_Climate_A_New_Water_Paradigm.pdf
[20] https://www.nature.com/articles/s43017-022-00287-8
[21] https://www.semanticscholar.org/paper/Agriculture-production-as-a-major-driver-of-the-Campbell-Beare/2ebe00e2ef4a203c33262fed907ea6899245778d
[22] https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GB006387

The most comprehensive multi-benefit strategy: Regenerating the health of living soil ecosystems

The sciences of ecology and climatology increasingly flag the significance of tipping points[23] for the functionality of ecosystems on which modern civilization depends. We hold that the tipping points of most European living soil ecosystems under agricultural use have been trespassed[24] and that immediate and comprehensive action is necessary to regenerate the living foundation of our terrestrial ecosystems and our society.

We believe that regenerating the functional biodiversity of soil ecosystems is the most comprehensive multi-benefit strategy to counteract the converging crises our society is facing:

- increase biodiversity in agroecosystems
- address water quantity, cycling and quality issues
- address the epidemic of non-communicable diseases at its core root
- significantly decrease the pressure of diseases in animal and plant production
- regenerate the biogenic carbon and nitrogen cycles
- build resilience and climate adaptation of agricultural production
- deflate food prices in the long term

Soil Health oriented farming - Regenerative Agriculture[25]

Agricultural principles to regenerate the functional biodiversity and health of soil ecosystems, while maintaining yields and building yield resilience, have long been invented by pioneering regenerative farmers and validated in scientific literature[26] (application of the principles and it immediate effects are, of course, context-specific to the local agroecosystem and management):

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[23] https://www.pik-potsdam.de/en/output/infodesk/tipping-elements/tipping-elements

[24] We acknowledge that in co-evolution with climate change as well as ecosystem and biodiversity destruction, soil ecosystems have trespassed or are approaching tipping points. Soils are at tipping points, not because their use inflicted degradation in Europe intensifies, but because the external shocks which soil functions must withstand are intensifying. Whenever soil functions fail in buffering these intensifying shocks, they themselves contribute to the intensification of these shocks. For example, as fast as desertification is proceeding, soil ecosystems are trespassing tipping points, which have a knock-on effect, pushing all soil ecosystems in the region closer to tipping points. https://link.springer.com/article/10.1007/s10980-021-01321-8; https://www.mdpi.com/2571-8789/6/1/22

[25] https://www.sciencedirect.com/science/article/pii/S2211912420300584

[26] https://ecaf.org/wp-content/uploads/2021/02/Conservation_Agriculture_climate_change_report.pdf; https://www.sciencedirect.com/science/article/abs/pii/S0743016718314608; https://peerj.com/articles/13750/?trk=public_post_comment-text

- Decrease mechanical soil disturbance to a minimum; avoid mechanical soil tillage as regular operation.
- Decrease use of synthetic inputs. *(Not relevant for organic agriculture)*
- Increase and improve production and use of on farm organic matter for co-fertilisation of soil biodiversity and crops.
- Optimise physical and chemical status of soil.
- Optimise soil cover.
- Optimise management of livestock, especially increase and optimise grazing.
- Diversify crop patterns.
- Diversify the on-farm agricultural landscape (semi-natural habitats with field margins and hedgerows, adopting agroforestry, creating water reservoirs).

2 The EU Soil Health Law

The SHL germinated from a Citizen Initiative and was inoculated by the EU Green Deal, the EU Soil Mission, the Farm to Fork Strategy, the Biodiversity Strategy for 2030 and the EU Soil Strategy for 2030. Legislative soil protection is also called for in the plan of action for the conservation and sustainable use of soil biodiversity adopted at COP15 of the UN Convention on Biodiversity (CBD)[27]. The EU Soil Health Law will aim at setting a new legal basis for the protection and regeneration of living soil ecosystems.

It must be emphasised that the EU Soil Health Law is the unique and last regulatory opportunity to effectively tip the balance of European land use from degradation to regeneration.

Why the EU SHL is a unique opportunity

Existing European environmental legislation does not target the bundled impacts of land use on soil degradation. Indeed, so far, environmental legislation is marked by a fragmented vision. All past environmental legislation has failed to tip the balance of European land use from degradation to regeneration. With climate change accelerating, land use impacts on the coupled water, carbon and nitrogen cycles are of increasing significance for the health of European ecosystems and citizens i.e. through exacerbating or alleviating droughts, heat waves and floods. **The SHL**

[27] https://www.encanetwork.eu/fileadmin/inhalte/enca/pdf/2023_enca_soil_biodiversity_and_sustainable_land_use_position.pdf

targets the most holistic and bundled part of terrestrial ecosystems and biodiversity. Soil is the immediate buffer for degrading or incubator for regenerative land use. The health of soil ecosystems determines the health of all other parts of our terrestrial ecosystems and of our fellow citizens. Further, the current problems of many Member States in complying with the Water Framework Directive are also due to the lack of a holistic soil management strategy that focuses on soil biodiversity.

Why the EU SHL is our last chance

Soil is the last unregulated area in EU environmental law. Of more than two hundred European environmental directives and regulations, none so far focuses on soil. The last attempt to legislate on soil failed almost 10 years ago for reasons that will be discussed below. Next to the Nature Restoration Law, the SHL can be seen as the last chance of EU environmental law to tip the balance from degrading to regenerating land use amidst accelerating climate change and ecosystem collapse. For example, the implementation of the Water Framework Directive is failing in part because agricultural soils cannot deliver the necessary ecosystem services to reduce water pollution. A holistic and overarching environmental law is needed, which can only be ensured by a specific legislative framework on soil.

In the EU Soil Strategy, the EU Commission sets out a vision of ensuring that "by 2050, all EU soil ecosystems are in healthy condition and are thus more resilient, which will require very decisive changes in this decade[28]."

The EU Mission "Caring for Soil is Caring for Life" proposed an overarching and ambitious mid-term goal to realise this vision:

"By 2030, at least 75% of soils in each EU Member State are healthy, or show a significant improvement towards meeting accepted thresholds of indicators, to support ecosystem services[29]."

The level of ambition of such a goal is firstly determined by the definition of soil health, which in turn determines the indicators, their weighting and metric, and by the level and structure of the thresholds.

2.1 An evaluation of the Soil Science informing the EU Soil Health Law

When analysing the European Commission's publications such as the Soil Strategy from a political-economic and ecological perspective, it is concerning that of the

[28] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0699&from=EN
[29] https://op.europa.eu/en/publication-detail/-/publication/4ebd2586-fc85-11ea-b44f-01aa75ed71a1/

three properties of soil (biological, chemical and physical), biologic properties receive the least attention. This suggests that, contrary to advances in modern soil science,[30] soil biology is not yet given the importance needed for a practice- and regeneration-focused soil health definition in the SHL and i.e. a future Common Agricultural Policy.

Soil biology is largely overlooked even though living soil ecosystems, which are the birth giving ecosystems to all terrestrial ecosystems and complex life on land, have emerged through soil biology[31].

The European Environment Agency's (EEA) report "Soil monitoring in Europe — Indicators and thresholds for soil health assessments" is a very elaborate piece of work which, together with the work of the EU Joint Research Centre (JRC) and their EU Soil Health Dashboard, appears to be the core scientific foundation on which the SHL will be built.

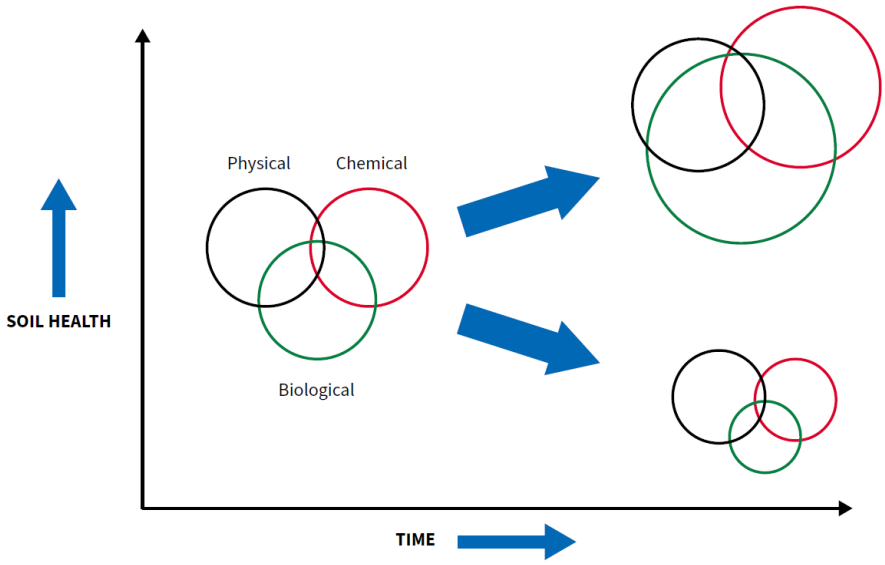
Both, the JRC and the EEA, do substantial, important and novel work. This position paper aims to contextualise their work within modern soil science and regenerative agricultural practice as well as to evaluate it from a critical perspective in order to most effectively advance the discussions around the SHL.

Soil Health & Soil Biology

We consider it is absolutely critical that, in line with more than a decade of advances in modern soil science[32], soil biology is accredited with the core functional role in the provisioning and regulating ecosystem services of soils as well as with the driving role in influencing soil health. For example, the European Joint Programme on Agricultural Soil Management (EJP) research programs SIREN and MINOTAUR are doing important work in that direction and should be fully leveraged in the SHL[33].

[30] https://www.sciencedirect.com/science/article/pii/B9780128164105000116; https://www.sciencedirect.com/science/article/abs/pii/S0169534716000616; https://www.tandfonline.com/doi/full/10.1080/00103624.2015.1005227
[31] https://www.science.org/doi/10.1126/science.289.5486.1920
[32] https://link.springer.com/article/10.1007/s13593-023-00876-x
[33] https://ejpsoil.eu/fileadmin/projects/ejpsoil/WP8/Workshops/Session_2_Prioritising_and_selecting_soil_health_biological_indicators_MINOTAUR.pdf; http://soildiveragro.eu/wp-content/uploads/2021/01/E-book.-Interactions-between-agricultural-management-and-soil-biodiversity.-An-overview-of-current-knowledge.pdf

A contemporary scientific conception of soil health development



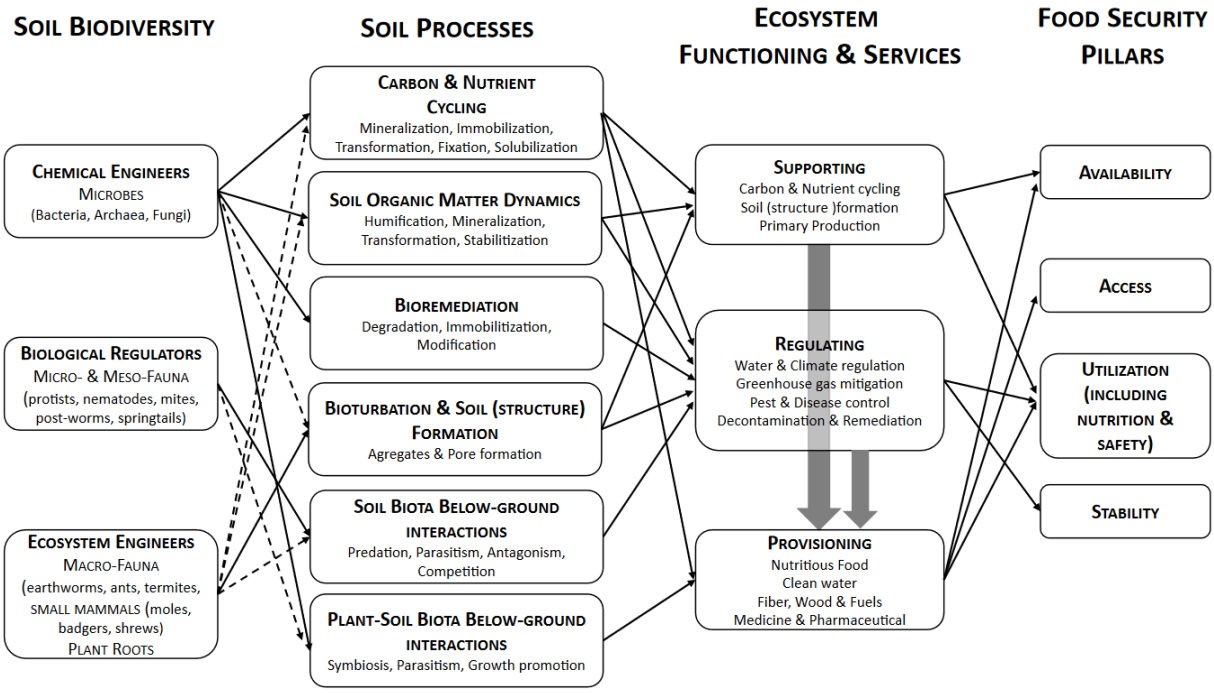
"The goal with time is to create a soil state in which the intersection of the optimal physical, chemical, and biological properties is as large as possible. Depending on soil management, soil health can therefore be improved (upper right) or degraded (lower right) if one or more of the supporting components is ignored or degraded[34]."

However, the current work of the EEA or the JRC appears not to sufficiently incorporate this understanding of soil biology. For example, Table 1-3 of the EEA report[35] does not link soil biological degradation with the soil services of 'Growing crops' and 'Wood and fibre production' which contradicts their own presentation in Table 1-1, where soil biodiversity is clearly connected with these soil services. It is very concerning that the understanding of functional soil biodiversity is not reflected in the central Table 1-6 of the EEA report, where the aforementioned relationships are translated into objectives, targets and recommended indicators. The EAA thus appears to overlook in their recommended objectives, targets and indicators the functional role of soil biodiversity, i.e. in cycling nutrients and making them available to plants, just as much as the role of soil biodiversity in soil structuring, water infiltration and water storage.

Not to not attribute a functional role to soil biodiversity, whereas progressive soil and agricultural sciences emphasise this role[36], has a variety of serious negative consequences. First, the role of land use management in soil health development is heavily underestimated and thus wrongly discounted. Further, when calculating impact assessments, costs are misjudged or not considered (we will elaborate on this point in more detail below).

[34] https://www.mdpi.com/2571-8789/6/1/22
[35] https://www.eea.europa.eu/publications/soil-monitoring-in-europe
[36] https://www.sciencedirect.com/science/article/abs/pii/S2211912418300300?via%3Dihub; http://soildiveragro.eu/wp-content/uploads/2021/01/E-book.-Interactions-between-agricultural-management-and-soil-biodiversity.-An-overview-of-current-knowledge.pdf

Functional role of soil biodiversity in soil processes and ecosystem functioning and services



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. Grey arrows indicate the relationships among supporting, regulating and provisioning ecosystem services[37].

Soil Health Thresholds

We hold that defining soil health by using static thresholds which are based on literature reviews and operationalized by compounding threats to or pressures on soils, has a variety of drawbacks:

- Conservativeness of threshold assumptions due to 'old' studies or lack of data
- Static thresholds cannot be leveraged for inoculating soil health regeneration
- No potential to build resilience of soil functions under accelerating climate change and biodiversity loss

Using soil organic carbon (SOC) and soil compaction issues in Germany as examples, we discuss what we mean by "Conservativeness of thresholds":

[37] https://www.sciencedirect.com/science/article/abs/pii/S2211912418300300

Soil Organic Carbon

SOC, the carbon stored in soil organic matter, is crucial to soil health and ecosystem services. The EEA judges that most of Germany's land experiences neither a critical SOC loss nor an intermediate risk of critical SOC loss[38]. We consider this to be a scientifically incorrect as well as a politically and agro-economically detrimental message to convey at this point in time. Sandermann et al. (2017) conclude that Germany lost about 2 Pg of SOC over the last 2000 years[39]. Further, Riggers et al. 2021 hold that Germany's soils might lose another 10 Mg ha^{-1} in the next 100 years[40]. Annually, Germany's arable lands are currently losing about 0,19 t SOC ha^{-1} [41]. De Rosa D. et al. of the JRC define the threshold for 'healthy' carbon management of soil ecosystems according to their 'Distance from 'maximum' SOC > 60%'. In the EUSO soil health dashboard, this approach shows that a large part of Germany's land has exceeded this threshold. This judgement by De Rosa D. et al. better conveys the political, agro-economic and -ecologic message needed: *Reverse the loss of soil organic carbon in agricultural land*.[42]

Defining a maximum value for SOC suggests establishing a static target or reference value. This raises the question of how a maximum value can be adaptive to the regenerative innovations by farmers or the accelerating impacts of climate change. If the 'maximum' SOC is static, it could act as disincentive. Moreover, if the reference value comes from natural ecosystems, it is not responsive to the ordinal utility of farmers and can discourage farmer action. Because regenerative farmers can (and in the near future may need to) achieve higher SOC values than natural reference values can indicate, such targets unnecessarily limit the horizon of what is empirically possible.

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[38] https://www.compostnetwork.info/wordpress/wp-content/uploads/EEA-for-ECN-Dec2022.pdf
[39] https://www.pnas.org/doi/10.1073/pnas.1706103114
[40] https://link.springer.com/article/10.1007/s11104-020-04806-8
[41] https://www.thuenen.de/media/institute/ak/Allgemein/news/Bodenzustandserhebung_Landwirtschaft_Kurzfassung.pdf
[42] The key for reversing this trend, key for achieving a net-positive carbon balance in agricultural soils, is (next to avoiding soil loss in areas at risk - as riverbanks and hillside situations - by conversion into grasslands) ensuring that agricultural systems have an optimum of photosynthesizing plants in the climatic conditions per growing season, in the optimal quality crop and grass diversity, while assuring that the soil structure is disturbed as little as possible. This can be best achieved by using a diversity of correctly managed species, including agroforestry, to ensure that they can optimally utilise available water resources to capture the maximum amount of sunlight per hectare as the energy needed to convert CO2 into the organic molecules that build SOC through the plants' cooperation with soil biodiversity.
Above all, plants with fine roots, especially perennial grassland ecosystem plant communities, share a large part of their produced organic molecules via exudates with their soil ecosystem thus feeding soil biodiversity and building SOC. These characteristics are part of the special potential that permanent grasslands and the introduction of 'temporary grasslands' (in form of cover crops, undersown crops or in crop rotation) to arable land hold for building up SOC in agroecosystems and thus for both climate mitigation and climate adaptation in agriculture. Grasses are of increasing importance for SOC developments as climate change proceeds (Terrer et al. 2021).
To make use of this potential grazing management is of decisive importance to soil health and SOC developments. Adaptive multi-paddock grazing can drastically optimise the plants' ability for carbon capture via photosynthesis, optimise the soil's biological, physical and chemical health and optimise the drought resilience of grasslands while simultaneously increasing the nutritional quality of yield as well as the quantity of yield (Montgomery et al. 2022; Johnson et al. 2022).
https://www.nature.com/articles/s41586-021-03306-8; https://peerj.com/articles/12848/;
https://peerj.com/articles/13750/?trk=public_post_comment-text

This could lead to an underestimation of the possibilities of and appreciation for soil health regeneration and therefore hamper the potential of innovative ecosystem regeneration achievements by farmers.

Soil Compaction

With climate change rapidly advancing and severe weather events increasing, the impact of compacted soils is experienced foremost through soils' hampered functions in relation to water. Soil's functions of water infiltration, storage and percolation to refill groundwater aquifers are decisive for the future of agriculture that must manage alternating droughts and torrential rains.

Infiltration is the downward entry of water into the soil. Rainwater must first enter the soil for it to be of value. Infiltration is affected by soil management practices that affect surface crusting, compaction, pore formation, biopore structure and soil organic matter. Without the protective benefits of vegetative or residue cover, bare soil is hydrophobic after droughts and subjected to the erosive forces of raindrops that dislodge soil particles. Soil biota mediated soil organic matter affects infiltration, storage and percolation through its positive effect on the development of stable soil aggregates. Highly aggregated soil has increased pore space and infiltration. Soil biota such as earthworms, also directly increase pore space through their burrowing activities and create continuous pores linking surface to subsurface soil layers and thus contribute to water percolation, refilling groundwater aquifers.

Data on the extent and severity of compaction in agricultural soils is sparse. The EUSO soil health dashboard references a study from 2008 which deduces the state of compaction of soils "from their natural susceptibility to compaction if they were to be exposed to compaction"[43]. According to the dashboard, only very few areas of Germany are at a high level of risk of being susceptible to compaction. However, this statement was derived from an arbitrary establishment of threshold limits for water infiltration and compaction which do not reflect actual requirements in times of an accelerating climate change and altered rainfall patterns.

Using an inductive approach results in a very different assessment. An inductive method uses reasoning from specific observations to more general assumptions i.e. judging the state of soil compaction in Germany according to annual precipitation development and groundwater anomalies.

According to German weather data from national inventories, annual mean precipitation has been slowly rising over the last 100 years[44]. However, according to the Technical University of Graz, Germany is experiencing the worst water storage

[43] https://esdac.jrc.ec.europa.eu/euso/euso-dashboard-sources
[44] https://www.umweltbundesamt.de/bild/mittlere-jaehrliche-niederschlagshoehe-in

anomalies in Europe[45]. Additionally, increasing impacts from floods[46] indicate problems of compacted soils in Germany. We hold that it is most responsible to assume that Germany's arable- and grasslands widely suffer from grave compaction caused by heavy machinery and soil use, leading to plowing pans or compaction horizons.

Using conservative thresholds to judge the state of soil compaction sends a political and agroeconomic message to both policy makers and farmers that there is no widespread problem of soil compaction. Such a message is highly concerning and has potentially a detrimental impact at a time when the soil's water related functions which are heavily influenced by compaction, are of increasing significance to society and agriculture. Instead of mobilising societal and agricultural efforts to decompact agricultural soils, it gives the false impression that there is no problem of compacted soils in Germany. It should also be noted that soil compaction stimulates the emission of nitrous oxide (N2O) and methane (CH4) from agricultural soils[47].

In summary, these two examples on SOC and soil compaction highlight the risks of defining soil health along static thresholds which can lead to an underestimation of the urgency to act.

2.2 An evaluation of the Economics informing the EU Soil Health Law

The EU Commission states, that the cost of taking action on soil degradation is much smaller than the cost of inaction: "Halting and reversing current trends of soil degradation could generate up to 1.2 trillion euros per year of economic benefits globally"[48].

However, we believe that the SHL's impact assessment, the description of the environmental, social and economic impacts of a legislative initiative, produced by DG ENV with the help of the consultancy trinomics, left out or misjudged major variables in the cost-benefit calculation.

We hold that the insufficient comprehension of soil biology in the soil health definition both artificially reduces the costs attributed to inaction and soil degradation as well as artificially inflates the costs of regenerating soil health in agriculture. Further we hold that static thresholds as discussed above artificially decrease the perceived costs of soil degradation.

[45] https://www.tugraz.at/en/tu-graz/services/news-stories/media-service/singleview/article/satellitendaten-belegen-anhaltend-schwere-duerre-in-europa
[46] https://www.prognos.com/sites/default/files/2022-07/Prognos_KlimawandelfolgenDeutschland_Detailuntersuchung%20Flut_AP2_3b_.pdf
[47] https://edepot.wur.nl/29524
[48] https://ec.europa.eu/commission/presscorner/detail/en/ganda_21_5917

Ultimately, the increasing significance of soil health to agricultural production is undervalued. As noted above, from 2021 to 2022 *all* of European edible agricultural outputs dropped. The reasons given by the EU Commission are drought and animal diseases[49]. Droughts will further intensify, and the most important lever to adapt EU agricultural production to intensifying droughts is soil health and management[50]. Further, the pressure of animal diseases can only be significantly and continuously be reduced if the soil microbiome is regenerated[51].

Development of EU agricultural production

Item	2020	2021	2022	2022/2021
		2015=100		%
AGRICULTURAL GOODS OUTPUT	103.95	104.73	101.11	-3.5%
CROP OUTPUT	103.79	105.12	100.04	-4.8%
CEREALS	97.21	101.87	92.19	-9.5%
VEGETABLES AND HORTICULTURAL PRODUCTS	103.32	104.75	97.95	-6.5%
FRUITS	107.29	105.38	101.64	-3.5%
ANIMAL OUTPUT	103.62	103.62	102.07	-1.5%
ANIMALS	102.29	102.81	100.45	-2.3%
PIGS	104.6	105.47	101.31	-3.9%
ANIMAL PRODUCTS	105.37	104.49	103.98	-0.5%
TOTAL INTERMEDIATE CONSUMPTION	104.11	104.8	101.53	-3.1%

Volume index, Production af basic prices, 2015=100, EU 27[52]

Consequently, the main costs of inaction/soil degradation that are most likely not represented or undervalued in the SHL impact assessment are:

- Epidemic of NCDs
- Green Water / Water cycles / groundwater management
- Agricultural production (drought resilience and animal diseases)
- Tipping points of soil ecosystems

Combined, this leads to an inaccurate assessment of the costs of soil health degradation and the development of these costs. Rather than assuming linearly rising costs, it must be emphasised that costs of soil health degradation are increasing much faster.

[49] https://capreform.eu/2022-a-record-year-for-farm-income/
[50] https://iopscience.iop.org/article/10.1088/1748-9326/abf004
[51] https://www.sciencedirect.com/science/article/pii/S0929139300000676 https://www.mdpi.com/2571-8789/6/4/87; https://www.nature.com/articles/s41579-022-00779-w.epdf?sharing_token=_pnVwWBRD90XS_F-Dfcz6NRgN0jAjWel9jnR3ZoTv0PvNzUhFDZu0quiRcwC-pt0erHO3yoSoAmsi9EBXmEOFfokwJ92r9GQy4EVDu7qco9xbt-Q1Gb477pClRxli9dxZMIMOKKSvvesnaivYSx3EWZsVd424TLXaS3ppGbQdeQ%3D
[52] https://ec.europa.eu/eurostat/databrowser/view/AACT_EAA05__custom_4391549/default/table?lang=en

Global warming is accelerating and so do the impacts of climate change[53]. Soils play a critical role in buffering against climate extremes as well as in climate change mitigation and adaptation in the agricultural sector. Without changes in agricultural management, soil degradation due to climate change will continue to accelerate. For example, "climate projections, for all global dynamics scenarios, indicate a trend, moving toward a more vigorous hydrological cycle, which could increase global soil water erosion (+30 to +66%)" by 2070[54]. Also, the value of soil health to society in an environment of increasingly extreme weather patterns and growing frequency of epidemics[55] rises as climate change accelerates and ecosystems collapse. Additionally, the value of soil health to an agricultural sector that is expected to decarbonize grows.

We conclude that calculating soil health degradation costs must take into account a large number of variables, many of which are mutually reinforcing and all of which are accelerating. In our view, the assumption of a linear cost development carries major risks to EU society at large. Therefore, the cost-benefit analysis informing the EU SHL must take a holistic and long-term perspective which more accurately mirrors the current development trajectory.

Trade-offs and opportunity costs

When assessing the costs of soil health regeneration, it is commonly assumed that the costs of measures include not only the actual intervention costs weighed against the standard management costs,but also significant opportunity costs. Those occur when soil health regeneration in agriculture is framed as being solely in trade-off, not also symbiotic, relationship to yield, more precisely 'standard output'. We want to challenge this approach and instead foster an understanding that does not contribute to the lock-in of the status quo by focusing on supposedly conflicting goals in the short term. Rather, we want to acknowledge complementary measures **that reduce input costs and incentivize action by representing long term strategies with multiple benefits**.

Regenerating soil health by adapting agricultural management to foster soil biodiversity, "should be considered "win-win" strategies that promote the storage of carbon, nitrogen, and other nutrients in the form of organic matter and a better coupling of biogeochemical cycles"[56].

In addition, there is growing evidence that such agroecological "win-win" strategies of promoting the health of soil biodiversity also provide long-term agroeconomic

[53] http://www.mari-odu.org/academics/2018s_adaptation/commons/library/Gleick2010_Article_ClimateChangeExponentialCurves.pdf
[54] https://www.pnas.org/doi/abs/10.1073/pnas.2001403117
[55] https://apps.who.int/iris/bitstream/handle/10665/148114/9789241564854_eng.pdf
[56] https://link.springer.com/article/10.1007/s13593-023-00876-x

benefits for farm income as well as reduce external costs of agricultural production to society[57].

Derrien et al. (2023) write "given the current challenges of climate change mitigation, food security, and bioeconomy growth, we consider that the practices favouring (i) soil life and the efficient nutrient cycling in the ecosystem and (ii) C input to the soil may be recommended more confidently than others.[58]"

To leverage this "win-win-win" potential for society, farmers and ecosystems, it is fundamental to recognize, as we argue above, that the costs of soil health degradation to European citizens, businesses, ecosystems and biodiversity are growing much faster than in a linear way. These rapidly rising costs are accompanied by declining costs of soil health monitoring as well as rapidly decreasing opportunity costs of soil health regeneration in the agri-food system.

2.3 A comparative assessment of the political landscape of the EU Soil Health Law

The last attempt to establish a European legislative framework for soil protection, the proposal for a Soil Framework Directive (2006-2014), failed mainly because of three core arguments:

Cost-benefit assessments

During the last legislative attempt, Member States argued that the costs of soil health monitoring and restoration were too high and the benefits too low[59]. As shown above, this cost-benefit relationship has changed fundamentally because of intensifying climate change impacts and new scientific understandings, which also heavily impact the cost-benefit analysis of soil health action. While the costs of soil health degradation show a runaway development, costs of monitoring and reporting show ever faster decreasing marginal costs. The cost structure of production integrated measures for soil health regeneration in agriculture has also changed significantly. Long-term income reductions might only be expected for the slowly adapting parts of the agricultural input sector.

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[57] https://academic.oup.com/erae/article/48/2/253/6134529; https://easac.eu/fileadmin/PDF_s/reports_statements/Regenerative_Agriculture/EASAC_RegAgri_Web_290422.pdf; https://www.nabu.de/imperia/md/content/nabude/landwirtschaft/230323-the_case_for_regenerative_agriculture_longversion-engl.pdf; https://link.springer.com/article/10.1007/s00267-020-01273-w; https://www.wbcsd.org/contentwbc/download/15911/229509/1; https://www.solsvivants.org/en/initiatives/

[58] https://link.springer.com/article/10.1007/s13593-023-00876-x

[59] The most important opposing arguments of the Soil Framework Directive (SFD), held it would impose a 'disproportionate' cost with a negligible environmental benefit while unfairly placing the burden of liability on land users. Costs were considered by the opposing member states to be not only excessive, but what was feared most is that the SFD could constitute a stumbling block in earnings. https://www.researchgate.net/publication/337770618_Withdrawal_of_European_Soil_Framework_Directive_Reasons_and_Recommendations

Member States' positions in the Council

In 2006, a group of Member States showed significant opposition to the legislative proposal, including the United Kingdom (UK), France, Germany[60], Austria and the Netherlands. Since 2006, the UK has left the EU. Germany appears supportive of European soil legislation. France's stand can be judged as positive, and the Netherlands' and Austria's positions are to be developed.

During the last legislative attempt to protect soils, Member States argued a breach of the subsidiarity principle, a principle whereby the EU only takes action when the objectives cannot be sufficiently achieved at Member State level and when EU level action brings additional value. To date, the body of evidence for the subsidiarity argument in regard to soils has changed significantly. As the new planetary boundary of Green Water indicates[61], we now have a better scientific understanding of how soil health relates to the earth's biogeochemical cycles and climate change impacts such as heat waves and floods[62], none of which stop at national borders.

This also constitutes a significant argument for the Commission to push for pedoclimatic rather than solely administrative soil districts. Soil ecosystems form a continuum comprising many biological, chemical and physical characteristics that, together with climatic zones, make pedoclimatic districts an extremely valuable pattern of ecological and economic information[63]. This information is necessary for constructing a functional and integrated baseline infrastructure for ecological governance in the EU. Ecological governance is of increasing importance to the Union's economic resilience and social stability and can foster regional collaboration, democratic agency and innovation[64].

Although significant opposition is still to be expected in the Council and the Parliament, we believe that the political landscape for the co-decision process and trilogue negotiations have changed significantly for the better since the Soil Framework Directive proposal. We will continue to express our full support for an ambitious and progressive Soil Health Law throughout the legislative process - as did innovative and important actors from the EU agri-food system with more than €215 billion in annual turnover in an Open Letter to the EU Commission in March 2023.

[60] https://www.umweltbundesamt.de/publikationen/the-upcoming-european-soil-health-law-chances
[61] https://www.nature.com/articles/s43017-022-00287-8
[62] https://www.unep.org/resources/emerging-issues/working-plants-soils-and-water-cool-climate-and-rehydrate-earths
[63] https://nhess.copernicus.org/articles/22/2201/2022/;
https://agroinnovationedu.imagelinenetwork.com/sitocommon/UserFiles/File/EDU/Tesi_Award_2017/Paladini_Satellite_crop_mapping.pdf
[64] https://ec.europa.eu/environment/enveco/economics_policy/pdf/studies/KH0319438ENN.pdf;
https://ec.europa.eu/environment/enveco/growth_jobs_social/pdf/studies/Study%20Resource%20labour%20productivity%20.pdf;
https://ec.europa.eu/environment/enveco/circular_economy/pdf/studies/Impacts%20of%20Circular%20Economy%20-%20FinalReport_V2_clean.pdf

3 Policy Recommendations: Towards ambitious goals and actions to regenerate and protect soil health in Europe

We make four recommendations to ensure that the SHL will neither be dropped after publication nor become a toothless (paper) tiger. By considering these aspects, the SHL can become a holistic baseline law that enables policy coherence and the achievements of the European Green Deal targets and Biodiversity and Farm to Fork strategy goals such as 50% pesticide and 20% fertiliser reduction. It will also allow to build yield resilience and provide the foundation for effective EU wide soil health regeneration. targets while building yield resilience and providing the foundation for effective EU wide soil health regeneration.

1. A soil health definition up to date with the scientific evidence on the functional role of soil biology

A soil health definition up to date with the scientific evidence on the functional role of soil biology in the provisioning and regulating ecosystem services is firstly necessary to be scientifically accurate. We are concerned that the definition of soil health informing the EU SHL will be based on outdated scientific perceptions of soil health with strong emphasis on chemical and physical properties disregarding the **functional role of the soil's biological properties**. Therefore the **functional role of soil biology in the provisioning and regulating ecosystem services of soils should be at the centre** of the soil health definition in the SHL. Secondly, such a soil health definition is of major importance to almost all impacts that the law will develop. These impacts should **give guidance to national and regional policy makers, scientific bodies and the agricultural sector** for regenerating our soils as the living foundation of our society.

2. Harmonised, comprehensive and cost-efficient soil health monitoring and reporting system

As difficult as it is for policy makers to act on new science, it is also an opportunity and a necessity. As the MINOTAUR program shows, functional biological indicators are extremely sparse in national soil surveys. This is despite the fact that the European Food Safety Authority (EFSA) acknowledged soil microorganisms' key role in soil ecosystem functioning already in 2010. The SHL is an opportunity for the Commission to add value to European society and ecosystems while being responsive to the positions in the Council and adaptive to already existing national soil surveys. The latter could be harmonised for monitoring physical and chemical soil properties, while functional soil biological indicators could be developed and coordinated at the European level.

The EJP programmes SIREN and MINOTAUR[65] take a **systematic approach to soil biology monitoring** that could involve public-private partnerships with soil laboratories and institutes using, for example, innovative eDNA and microplate-based respiration testing technologies. The respective system **should integrate and disseminate methods to systematically assess** soil microbes, estimate microbiome activity as well as biodiversity and functional metagenomics.

Together with technologies such as soil pattern analysis based on AI and remote sensing (i.e. AI4SoilHealth), this could **enable cost-efficient as well as spatially and temporally comprehensive measurement** of the relative development of soil health indicators. It could also **grant farmers affordable access to biological soil information**, which has to date been mostly prohibitively expensive for small farms. This carries an immense potential to drive the regenerative transformation of agriculture.

Standardised, accessible data and an impact assessment that allows comparability and quality assurance of soil management are the foundation of solid planning. For this reason, the **involvement of local and regional governments** in these processes is pivotal to ensuring a harmonised and comprehensive monitoring process, as they are very often the ones implementing and monitoring soil action on the ground[66].

3. Establish an adaptive and farmer empowering benchmarking process

The extent and severity of multiple converging crises demand that policy making continues to evolve its own ways of working. A Soil Health Law must therefore **give public administrations, civil society and farmers the necessary resources** for the transition to regenerative soil management, carefully managing risks of adverse effects on market and power concentrations.

As argued above, farmers are the key players in regenerating the health of our soils. Hence, it is critical that the SHL **empowers farmers to transition to regenerative agriculture** through the choice of indicators, benchmarking and accompanying policy schemes. Those indicators will also support the visibility of innovations of pioneering regenerative farmers in the agricultural sector.

Indicators and their metrics must have a guiding function for land users. They should not only indicate negative thresholds but express a positive target reference and make continuous development visible. This, in turn, makes it possible to measure relative developments and allows for regulation and subsidy schemes.

[65] https://ejpsoil.eu/science-to-policy/workshop-carbon-farming-1
[66] ICLEI Europe: Cities for an Integrated Landscape Approach - Curbing Land Degradation and Restoring Europe's Soil Ecosystems

Hence, we recommend striving for a regionalized and land use specific benchmarking system that is transformative and enables continuous soil health regeneration. Such a system would **allow farmers to actively participate in developing their regional benchmarks** and therefore address agroecological and agroeconomic health in an integrative manner. The newly funded **EU research program BENCHMARKS holds great potential in operationalizing such an approach**[67].

4. Identify pedoclimatic soil districts

Decisive for an adaptive and farmer empowering benchmarking process is that soil districts are defined along pedoclimatic regions and not only along the lines of administrative zones. As living soil ecosystems are the foundation of terrestrial ecosystems, pedoclimatic soil districts would be of great value for driving further European integration by bringing public administrations, the agricultural sector and civil society from different Member States together. This could be achieved together with **building ecological antifragility and economic resilience** by driving projects for **regional circular bioeconomies**, fostering rural as much as rural-urban relationships and **strengthening social cohesion**.

The EU SHL as a guiding force towards regenerative sustainability[68] in our European agri-food system

An ambitious and progressive EU Soil Health Law could contribute to **longer planning security for farmers** and give **access to cost-efficient agronomically relevant information** while **fostering farmer motivation and their ability for consequence capture and capacity building**. A SHL can further enable positive feedback loops through regional peer to peer learning infrastructures. It is also key for establishing a **more level playing field in the agricultural sector**, fairness to regenerative leaders in farming and a new **societal appreciation of the positive agency of farmers in our climate and biodiversity crises**. The latter is of significant importance to **alleviate the demographic challenge** simmering in the agricultural sector. All are of significant importance to **decrease the transfer costs of farmers to regenerative production systems**.

Significant is also the possible contribution of such an SHL to building **EU policy coherence, efficiency and effectiveness**. Thus **increasing biodiversity** in agroecosystems, **addressing water quantity, cycling and quality issues**, addressing **the epidemic of non-communicable diseases** at its core root, significantly **decreasing the pressure of diseases** in animal and plant

[67] https://soilhealthbenchmarks.eu/
[68] https://www.mdpi.com/2071-1050/12/13/5483

production, regenerating the biogenic carbon and nitrogen cycles and **building resilience** and climate **adaptation** of agricultural production **deflating food prices in the long term**.

An action plan is needed to mobilise adequate technical and financial resources for national, subnational and local governments appling a whole-of-government approach[69] dedicated to the regeneration and protection of living soil ecosystems.

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[69] https://iclei-europe.org/publications-tools/?c=search&uid=c2JErpOg

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