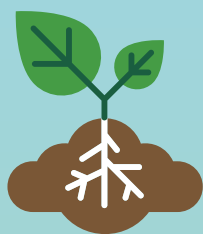


European Missions



A Soil Deal for Europe

100 living labs and
lighthouses to lead the
transition towards healthy
soils by 2030

Implementation Plan

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A Soil Deal for Europe:

100 Living labs and lighthouses to lead the transition towards healthy soils by 2030

The Green Deal needs healthy soils that can provide the (ecosystem) services that are crucial for our planet and society. Degradational pressures, mostly because of human activities linked to consumer demand and industrial processes, affect the health of the soil through physical damage or the introduction of pollutants. In turn, these processes disrupt the capacity of soils to supply a range of ecosystem services, with significant economic, environmental and societal consequences. Recent floods in Europe have shown how the effects of climate change are exacerbated by unhealthy, i.e. compacted, sealed and eroded soils. According to an assessment undertaken by the JRC and the Mission Board, 60-70% of soils in Europe are in an unhealthy condition. It is time to act.

Soil health can be restored through a range of measures. While some require longer timeframes, many can have a rapid beneficial impact. Several of these restoration processes could be easily implemented but - to be effective - require a step up in the extent of application. This increase should be driven by a greater societal understanding, demonstration of best practices, developments in research and innovation, of the factors driving soil health. This is where the mission comes into play.

The mission will pioneer, showcase and accelerate the transition to healthy soils through ambitious actions in 100 living labs and lighthouses within territorial settings. This will be combined with an ambitious transdisciplinary R&I programme, a robust, harmonised soil monitoring framework and increased soil literacy and communication to engage with citizens. Together with the effects of EU instruments funded under the Common Agricultural Policy other EU instruments and wide societal engagement, these measures are expected to result in a step change improvement on how we manage and use soils for wide societal benefits.

Recent scientific assessments have confirmed the mission's ambition and the viability of its goal to significantly increase the share of currently 30-40% of healthy soils to levels that are in line with Green Deal commitments and targets by 2030.

Table of contents

1. The mission explained	8
1.1. The vision	8
1.2. The need for healthy soils	8
1.3. The mission's added value	10
1.3.1. Mission's support to the Green Deal and buy-in to the mission	10
1.3.2. The mission and the Common Agricultural Policy	11
1.3.3. The mission's contribution to the Digital Age	12
1.3.4. Synergies with other EU policies and programmes	12
1.3.5. Contribution to the SDGs and other international commitments	13
1.3.6. Synergies with other missions	14
2. The mission's goal, intervention logic and approaches	14
2.1. Mission goal, objectives and wider impact	14
2.2. Overall intervention logic and approaches	18
3. The Mission in action: operational objectives and activities	20
3.1. Operational objective 1: build capacities and the knowledge base for soil stewardship	20
3.1.1. Context	21
3.1.2. Activities	22
3.1.3. Innovation hotspots	25
3.1.4. Expected outputs and outcomes	26
3.2. Operational objective 2: Co-create and upscale place-based innovations to improve soil health in all places	27
3.2.1. Context	28
3.2.2. Activities	29
3.2.3. Criteria for selecting individual living labs and lighthouses	31
3.2.4. Outputs and outcomes	32
3.3. Operational objective 3: Develop an integrated EU soil monitoring system and track progress towards soil health	33
3.3.1. Context	33
3.3.2. Activities	34
3.3.3. Innovation hotspots	38
3.3.4. Outputs and outcomes	38
3.4. Operational objective 4: Engage with the soil user community and society at large	39
3.4.1. Context	39
3.4.2. Activities	40
3.4.3. Communication hotspots	42
3.4.4. Outputs and outcomes	43
3.5. The mission's cross-cutting dimensions	44
3.5.1. The business dimension	44
3.5.2. The digital dimension	45
3.5.3. The territorial dimension	46
3.5.4. The international dimension	46
4. Mission specific governance	48
4.1. Coordination and implementation structures	48
4.2. Selection criteria/methodology for key implementing partners	48
5. Budget, funding, synergies and investment opportunities	49

5.1. Horizon Europe financial investment plan	49
5.2. The potential contribution of the CAP to soil health	50
5.3. EU and Member State policies and instruments to be mobilised for the soil health mission	52
5.3.1. Synergies within Horizon Europe and other EU programmes to increase impact of mission activities	52
5.3.2. Support to soil health mission through financial instruments – mobilising InvestEU and the EIB group	55
5.3.3. Mobilising Member States	57
6. Monitoring and evaluation framework	57
6.1. Monitoring mission objectives.....	57
6.2. Reporting and evaluation	59
7. Timeline of activities.....	61
8. Supporting Material.....	62
9. References	75

Figures

Figure 1. Ecosystem services and SDGs supported by healthy soils (source: FAO)	13
Figure 2. Schematic view of the mission's intervention logic	18
Figure 3. Soil Health drivers and impacts (centre of the figure), the four operational objectives and cross-cutting dimensions of the mission.....	19
Figure 4. The “Soil Knowledge framework” as illustrated by the EJP Soil project	21
Figure 5. Intervention logic in relation to operational objective 1	27
Figure 6. Visualisation of scales and activities of living labs and lighthouses	29
Figure 7 Living labs and lighthouses in relation with activities under other objectives	29
Figure 8. The phases of the creation of the European network of soil health living labs	31
Figure 9. Criteria for the selection and set-up of living labs and lighthouses	31
Figure 10. Intervention logic in relation to operational objective 2.....	33
Figure 11. Intervention logic in relation to operational objective 3.....	39
Figure 12. Intervention logic in relation to operational objective 4.....	44
Figure 13 Reporting and evaluation milestones	60

Tables

Table 1 The mission’s specific objectives, targets and proposed soil health indicators	16
Table 2 Indicative budget for first three years of mission “A Soil Deal for Europe” (€mio)	50
Table 3 Indicative financial allocation of CAP priorities 4, 5D and 5E in 2014-2020 for (€mio).....	51
Table 4 Examples of synergies and complementarities with other EU funding programmes.....	54
Table 5 Examples of Impact, Outcome and Output indicators for soil health and the mission’s operational objectives (tentative).....	58

Executive summary

The issue: Why do we need healthy soils?

Life on Earth depends on healthy soil: it is the basis of 95% of our food. If soils are healthy, they provide essential ecosystem services such as clean water and flourishing habitats for biodiversity. They are major carbon reservoirs, which help slow the onset of climate change while making us more resilient to extreme climatic events. Soils are a key part of the landscapes that we all cherish and are the basis of our economy and prosperity. It is evident that healthy soils are at the heart of the Green Deal and its ambitions for a green, fair, and just Europe.

Although we take it for granted, **soil is a fragile, non-renewable resource in our lifetime** that needs to be carefully managed and safeguarded for future generations. One centimetre of soil can take hundreds of years to form but can be lost in just a single rainstorm or industrial incident. Moreover, soils are threatened all over Europe and globally because of a range of human activities (e.g. through the competition for land, intensive land use, production, consumption patterns, and urbanisation) that are exacerbated by climate change. By 2050, 500 - 700 million people worldwide are likely to be forced to migrate due to a combination of climate change and land degradation. Following an analysis, the Mission Board Soil Health and Food and the JRC concluded that 60-70% of soils in the EU are in an unhealthy state.

The vision

We need healthy soils for healthy lives and a healthy environment. Maintaining and restoring soil health is a major and long-term endeavour. It requires transformative changes in practices by all sectors of society, across all types of land uses and scales in a joined-up manner. The mission describes a shared vision for Research and Innovation (R&I) and beyond to **accelerate Europe's trajectory towards sustainable soil management and restoration** as part of a wider, green transition in rural and urban areas.

A Soil Deal for Europe – 100 living labs and lighthouses to lead the transition towards healthy soils by 2030.

Soil health is defined as "the continued capacity of soils to support ecosystem services" and is assessed through a set of proposed, measurable indicators.



This vision - the mission's goal - is now more relevant than ever in the context of **Europe's twin green and digital transition** and its quest to progress towards zero net emission, resource efficient, smart and circular systems of production and consumption. The mission is fully integrated into the wider "One-Health" planetary concept, connecting soil health with the health of ecosystems, food systems and people.

The mission puts **people at the centre of change**. It will raise society's awareness of the relevance of soils and deliver the necessary knowledge and innovations to enable broad action. This covers farmers, foresters, urban planners, scientists, business communities, politicians and citizens including the consumers, we all are. By reaching out to international partners, the mission will support the EU's ambition to lead on global commitments and the Sustainable Development Goals (SDGs) with the aim to reduce pressures on planetary boundaries.

Testing the mission's goal and intervention logic

The mission aims at moving by 2030 well beyond the current status of having only 30-40% of healthy soils in Europe. This goal is substantiated with eight specific objectives that contribute to the achievement existing EU policy targets related to: soil degradation, soil sealing, pollution and erosion, the protection and restoration of soil ecosystems and soil biodiversity and soil carbon sequestration and protection. The mission also aims at reducing our global soil footprint.

The intervention logic has been developed based on a scientific analysis of soil threats and the review of existing data on soil regeneration undertaken by the Mission Board Soil Health and Food and the EU's Joint Research Centre. It has also built on an R&I gap analysis prepared by Horizon 2020 projects EJP Soil, SMS and INSPIRATON. Furthermore, the results of a call to the scientific community confirmed that the mission's goal, objectives and policy-based targets are grounded on realistic assumptions, recognising that rapid change and combined efforts at a large scale are needed for the 2030 timeline to be met. The evidence – mostly coming from the area of agriculture – illustrates that a range of practices exist that can significantly protect and improve soil health, particularly if their uptake was more widespread and applied over a larger scale. In the same vein, a recent study of the impact of the current CAP concluded that “the lack of technical knowledge and support appeared to be a key factor hindering the implementation of management practices addressing soil quality”. The mission will address this bottleneck.

In conclusion, the proposed **mission goal, objectives and targets are considered as ambitious, yet feasible and measurable.**

Mission implementation: Novelty and added value

The mission proposes a novel approach to R&I and its articulation with policies and mechanisms to promote the uptake of results from research on the ground: A comprehensive, co-created and cross-sectoral R&I agenda will help overcome the current landscape of fragmented research in the EU while mobilising public and private actors to work together towards a common goal. By implementing R&I activities together with local testing grounds, co-construction processes, monitoring and training activities in joined up manner, the mission will act as a catalyst and broker of innovations. Thereby, **the mission goes well beyond what could be achieved within single parts of Horizon Europe or other instruments at EU level.** The mission's focus on creating communities at local level will help mobilise actors across society in more systematic ways.

The mission will be carried out through

- (1) an ambitious cross-scale, inter and transdisciplinary R&I programme with a strong social science component to fill knowledge gaps and develop solutions for soil health and the provision of ecosystems services. The mission addresses all types of land use in rural and urban areas, while traditionally, R&I and soil monitoring have focused on agricultural soils. Innovations in carbon farming, soil pollution (incl. pesticides) and restoration, soil biodiversity and the circular economy will be given special attention;
- (2) an effective network of 100 living laboratories (LLs, for experimentation) and lighthouses (LHs, for demonstration of solutions) across rural and urban areas to accelerate the co-creation and uptake of solutions across farms, forest, natural landscapes and urban settings in a diversity of geographical and socio-economic contexts. Definitions, criteria and the plan for rolling out the LLs are the result of detailed discussions with the European Network of Living Labs, two ongoing Horizon 2020 projects, a G20 working group and Canadian partners with considerable experience in this area;
- (3) a robust, harmonised EU framework for soil monitoring and reporting. This will serve as a basis to track progress towards major policy objectives and assess the effectiveness of measures for soil management;
- (4) soil literacy, communication and citizen engagement, this representing a novelty of the mission's approach.

Special attention will be given to digitisation, business involvement, the territorial dimension and global cooperation as cross-cutting themes of the mission.

The mission A Soil Deal for Europe is key for the successful implementation of the other four missions: Healthy soils underpin resilience to extreme weather (Climate adaptation mission). Reducing pollution in soils and in consequence in food contamination is a major step towards reducing cancer and other diseases (Cancer mission). Sustainable soil management with reduced fertiliser and pesticide inputs ensures high water quality and helps diminish pollution of water bodies (Ocean mission). Finally, soil is at the heart of green infrastructures, sustainable urban planning and the well-being of people living in built up communities (Cities mission).

The mission comes at the right time. Together with the new EU Soil Strategy, the EU Soil Observatory (EUSO) and other policy developments under the Green Deal, the mission will be part of **a unique and robust framework to address soil and land stewardship** at the necessary scale and pace and to reap the multiple services of healthy soils.

Buy-in to the mission within and outside the Commission

The implementation plan has been co-created by a number of services from across the Commission (the Mission Owners' Group).

The Common Agricultural Policy (CAP) will support the mission through its new green architecture as well as through knowledge and innovation and investment measures. Other programmes such as LIFE, INTERREG and Smart Specialisation Strategies or Digital, Earth Observation and Education Programmes, will complement mission activities. Cooperation with the EIB has shown the potential of financial instruments for implementing several objectives of the mission and for scaling up its results, for example, through the InvestEU's R&I, digital policy or sustainable infrastructure policy windows.

The relevance of the mission and the buy-in of Commission services is reflected in its integration in a wide range of EU strategies and policy documents, notably the:

- Farm to Fork Strategy;
- EU Biodiversity Strategy for 2030;
- Climate Adaptation Strategy;
- Zero Pollution Action Plan for air, water and soil;
- Forest Strategy;
- Long-term Vision for Rural Areas;
- Organic Action Plan;
- new Soil Strategy (to come) and the EU Soil Observatory.

In its resolution from 28 April 2021 the European Parliament (EP) specifically "welcomes the launch of the Horizon Europe mission for soil health and food".

Beyond the "political buy-in", feedback from citizens and stakeholders at events or through a survey with more than 2.500 replies has been very encouraging and has shown that the mission resonates with people from all walks of life. The business sector (e.g. food industries and financial institutions) and land managers were particularly vocal about their expectations for a mission that would deliver solutions for measuring, valuing and improving soil health, thereby supporting their efforts to develop value chains based on sustainable soil management. Altogether, evidence, the work plan presented in the implementation plan, feedback from across society and an obvious political momentum for soil protection shows that **time is rife for the mission to contribute to "A Soil Deal for Europe" for food, people, nature and the climate!**

1. The mission explained

1.1. The vision

Life on Earth depends on healthy soils. Soil is the foundation of our food systems. It provides clean water and habitats for biodiversity while contributing to climate resilience. It supports our cultural heritage and landscapes and is the basis of our economy and prosperity. Although as citizens we pay very little attention to soil, it is a fragile resource that needs to be carefully managed and safeguarded for future generations. One centimetre of soil can take hundreds of years to form, but can be lost in just a single rainstorm or industrial incident.

The proposed mission aims at putting **Europe on a trajectory towards sustainable soil management and restoration as part of a wider, green transition in rural and urban areas.**

A Soil Deal for Europe – 100 living labs and lighthouses to lead the transition towards healthy soils by 2030.



Being **at the heart of the Green Deal**, this vision is now more relevant than ever in the context of Europe's quest to become carbon neutral by 2050 and to recover from the effects of the COVID-19 pandemic. Rather than being an end in itself, soil health is a necessary precondition to enhance ecosystems services supported by soils and to move towards zero net emission, resource efficient, smart and circular systems of production and consumption. The mission will be a central element in Europe's agenda for climate mitigation. Furthermore, the mission is rooted in a wider "One-Health" planetary concept and connects soil health with the health of ecosystems, food systems and people as part of the Farm to Fork and Biodiversity strategies.

Soils deliver public goods and restoring soil health is a long-term endeavour. Its restoration will require **transformative changes across all types of land uses, sectors of society and scales**, based on new incentives, policies and business models for soil health, and rooted in knowledge, making use of nature-based solutions and cutting-edge technologies, especially in the digital domain. The mission will fuel this transformation that will emerge from a truly **collective societal effort and shared sense of ownership** by researchers, land managers, spatial planners, policy-makers, industries and citizens alike. By reaching out to international partners, the mission will **support the EU's ambition to lead on global commitments regarding soils and the Sustainable Development Goals (SDGs).**

The Soil Deal mission has a key role in the successful implementation of the other four missions: healthy soils underpin resilience to extreme weather (Adaptation to climate change mission), food safety as a major component of disease prevention (Cancer mission), water quality (Ocean, seas and water mission) and green infrastructures (Climate neutral and smart cities mission).

The mission comes at the right time. Together with the upcoming EU Soil Strategy, the EU Soil Observatory (EUSO) and the new Common Agricultural Policy (CAP) with its reinforced environmental and climate ambition, the mission will be part of a **powerful framework to steer the systemic changes that need to happen across all sectors of society to reap the benefits of healthy soils.**

1.2. The need for healthy soils

Soils are essential for all life-sustaining processes on our planet. If soils are healthy and are managed sustainably, they provide essential environmental, economic, and social benefits for society. **Some ecosystem services provided by soils include:**

- producing adequate quantities of **safe and nutritious food**, feed, fibre and other biomass. About 95% of our food comes from terrestrial sourcesⁱ;
- **storing and purifying water, regulating flows, recharging aquifers**, and reducing the impact of droughts and floods thereby helping adaptation to climate change;
- **capturing carbon** from the atmosphere and reducing emission of greenhouse gases from soils, thereby contributing to climate mitigation; more carbon resides in soil than in the atmosphere and all plant life combinedⁱⁱ;
- **nutrient cycling** supporting crop productivity and **reducing contamination**;
- preserving and protecting **biodiversity** by preserving habitats above and within the soil;
- supporting the quality of our **landscapes, preserving our cultural heritage** and **greening of our towns and cities**.

However, soils, being a vital non-renewable resource in our lifetime, **are threatened all over Europe and globally** because of human activities, including anthropogenic climate change. Half of the topsoil on the planet has been lost in the last 150 years, and during the past 40 years nearly one third of the world's cropland has been abandoned due to degradation and erosionⁱⁱⁱ. Land degradation is caused by unsustainable management practices in agriculture and forestry, often compounded by a lack of understanding or education. Contamination by industrial processes, and soil sealing through urbanisation and infrastructures often lead to a total loss of soil functions. Dietary, clothing, and other consumption practices, together with processes in the production chains, and diverse waste streams are also affecting soil health.

The following examples reflect the **gravity of the problem in the EU** and the urgency to act. They are based on figures for which data from all EU Member States exist (see more details under section 8.A).

- 2.8 million potentially **contaminated sites**, but only 24% of the sites are inventoried and by 2018 only 65.500 have been remediated;
- 83% of agricultural soils with **residual pesticides**;
- 65-75% of agricultural soils with nutrient inputs at levels risking **eutrophication of soils and water** and affecting biodiversity;
- only 13% of urban development takes place development on recycled urban land;
- cropland soils **losing carbon** at a rate of 0.5% per year and 50% of peatlands are drained and losing carbon;
- 24% of land with **unsustainable water erosion rates**;
- 23% of land with high density subsoil indicating **compaction**;
- 25% of land at high or very high risk of **desertification** in Southern, Central and Eastern Europe
- 520 million tonnes of excavated soils treated as **waste** annually representing the largest source of waste produced in the EU despite the majority not being contaminated.

The costs associated with soil degradation in the EU exceed 50 billion € per year^{iv}.

The process of soil degradation can lead to a collapse of landscapes and ecosystems, making societies more vulnerable to extreme weather events, food insecurity and contamination, and political instability. It is estimated that by 2050, 50 - 700 million people worldwide are likely to be forced to migrate due to a combination of climate change and land degradation^v.

Degraded soils do not only lose their capacity to act as carbon stores, but also the capacity to filter and store contaminants, thereby releasing pollutants (e.g. heavy metals or residues of pesticides and antimicrobials), which may end up in the groundwater or enter the food chain and pose a threat to food safety. ^{vi}

It is time to act so that future generations inherit clean, productive and resilient soils as the very basis for sustainable food production and a healthy environment.

1.3. The mission's added value

While R&I is a key enabler for change, only its interaction with other instruments and with practices will result in major breakthroughs and deliver the following added value:

- Through its comprehensive, co-created R&I roadmap, the mission will serve to **overcome the current landscape of fragmented research in the EU**. This will help mobilising public and private actors to work in a more coordinated manner towards a common goal;
- The mission proposes a **novel approach to R&I for impact. This is based on open science and interactive, participatory innovation with strong stakeholder and citizen engagement** (incl. through living labs and lighthouses). By implementing R&I activities, local testing grounds, monitoring and training activities in joint up manner, the mission will act as a broker of innovation and will go well beyond what could be achieved within single parts of Horizon Europe or other instruments at EU level. Also, the mission is expected to mobilise actors across society in ways that would not happen otherwise;
- In the absence of a legal framework for soil protection (other than for water or air), measures for soil protection are scattered across several policy areas and legislation. **The mission together with the upcoming Soil Strategy and the European Soil Observatory (EUSO), will form a unique and robust framework to address soil and land stewardship at the necessary scale and pace and across all types of land use and sectors** (traditionally, most of R&I and soil monitoring have focused on agricultural soils). **The three instruments mutually reinforce each other and would have limited impact if implemented in isolation**. In its resolution from 28 April 2021, the European Parliament (EP)^{vii} specifically “welcomes the launch of the Horizon Europe mission for soil health and food”;
- **The mission is essential for the success of the upcoming Soil Strategy**. While the strategy provides the political framework for action on soils, the mission will be an operational arm of the strategy, providing the necessary research and innovation capacity and creating effective interfaces between research-policy and research and innovation. Both instruments have been closely co-developed. Having 2030 as a timeline, the soil health mission is a clear milestone in Europe's longer-term trajectory to achieving a healthy status of all soils by 2050, as implied by the Green Deal objectives;
- **The mission proposes clear targets, indicators, a baseline of current soil threats and mechanisms to monitor improvements in soil health in a harmonised manner across the EU**. The value of having evidence-based, targets has already become evident in current discussions on ecosystem restoration targets and in the preparation of the upcoming Soil Strategy;
- The mission will give **visibility to soils as a crucial, yet widely “unrecognised” societal asset and public good**. This will further encourage wide citizen and stakeholder engagement on soils. As the concept of “soil health” is gaining momentum at global level, both in research and policy, the mission will pioneer efforts to put this concept into practice;
- The mission complements existing programmes and is **central to reaching the objectives of the Green Deal and its policies and strategies** (see below).

1.3.1. Mission's support to the Green Deal and buy-in to the mission

Healthy soils are necessary for successful implementation of the Green Deal. None of the targets on chemical pesticides and nutrients, the conversion to organic farming, a pollution free environment or climate can be achieved without decisive action on soils.

The mission will contribute with an expansion of the knowledge base, ready-to-use innovations and mechanisms to solutions to meet the **Green Deal ambitions including**:

- increasing the **EU's climate performance** – by reducing land degradation, as well as preserving carbon rich soils and increasing soil organic carbon stocks;
- achieving **zero-pollution** - by reducing soil pollution from pesticides, other (agro and industrial) chemicals and contaminants and enhancing restoration;
- **preserving and restoring ecosystems and biodiversity** - by improving soil structure and reducing compaction to enhance habitat quality for soil biota and crops and promoting diversification in agriculture and forestry;
- **safeguarding forests and wetlands** - by reducing erosion, desertification, and protecting wetlands;
- supporting **vibrant rural areas and fair livelihoods** by preserving the natural basis which underpins life quality and economic activities;
- and promoting **healthy and environmentally friendly food systems** - by enhancing food safety, promoting agroecological practices and other soil-friendly practices (e.g. regenerative, organic agriculture, nature-based solutions) across food value chains and in consumption.

The political “**buy-in**” from across the Commission to the **Soil Deal mission** is reflected in the integration of the mission in the following Green Deal strategies and Green Deal Policies:

- the **Farm to Fork strategy**^{viii} and **EU Biodiversity Strategy for 2030**^{ix} to “develop solutions for restoring soil health and functions”
- **Climate Adaptation Strategy**^x
- **Zero Pollution Action Plan for air, water and soil**^{xi}
- **New EU Forest Strategy**^{xii}
- **Long-term Vision for Rural Areas**^{xiii}
- **Organic Action Plan**^{xiv}

The mission will also serve implementation of upcoming strategies

- **Soil strategy** (see above in 1.3)
- **Circular Economy Action Plan**
- **EU nature restoration targets**

1.3.2. The mission and the Common Agricultural Policy

The mission will work in tandem with the future Common Agricultural Policy (CAP) and its European Innovation Partnership on Agricultural Productivity and Sustainability, the EIP AGRI. In the process of preparing the CAP strategic plans, the Commission has provided advice to the Member States to make full use of soil improving measures and creating awareness for the possibilities provided by the mission at an early stage. On this basis, synergies can be built through the programming process in each Member State.

The importance of soils is reflected in the future CAP, not just because of one of its key objectives is to “Foster sustainable development and efficient management of natural resources such as water, soil and air” but because targeted improvements in soil management help improve farm sustainability in economic and environmental terms. The higher environmental ambition of the new CAP is channelled via stronger conditionality, new instruments such as eco-schemes, as well as the **Farm Sustainability Tool for Nutrient Management (FaST)**^{xv}.

A recent evaluation of the impact of the current CAP concluded that “the CAP’s contribution to mitigating soil threats was limited and largely depended on the implementation choices at

Member State or regional level". It also underlined that "the **lack of technical knowledge and support appeared to be a key factor hindering the implementation of management practices addressing soil quality**"^{xvi}.

The mission will have a clear role in closing this knowledge-practice divide. In addition to generating new insights from research, the mission will act as an enabler and a broker of knowledge and innovation. It will provide through its living labs the necessary spaces for participatory, practice-oriented research as well as for designing solutions and assessing their impacts at farm, landscape and ecosystem levels. Knowledge and solutions developed under the mission will be further replicated and mainstreamed in EIP operational groups in regions where no living labs and lighthouses are operating. Close cooperation between the mission and the EIP AGRI will allow to create synergies between the EIP's bottom-up local actions in various thematic domains and the regional, interregional and transnational mission activities targeting soil health. The EIP networking facilities will provide an effective exchange platform across Europe through which successful mission projects can be promoted for further inspiration and implementation under the EIP and, vice versa. Structures set-up under the mission such as the European network of soil health living labs and lighthouses, will support the EIP network by providing insights and tools to run open innovation projects. Agricultural advisory services as part of the CAP's reinforced **Agricultural and Knowledge Innovation Systems (AKIS)** will support the deployment of best available soil management practices under the mission and the EIP AGRI. For further details on the CAP and its support to soils, see section 5.

1.3.3. The mission's contribution to the Digital Age

The mission will contribute to, and benefit from the ambitions laid out under the Commission priority for a Digital Age; it will contribute to the sustainable digital transformation, making digital technologies work for land managers, citizens and businesses, while supporting the **twin green and digital transition**, including carbon neutrality. The mission will focus on the use of digital technologies to collect data and to increase the sustainability performance of businesses in the land-using sectors along with capacity building in digital skills and the tailored deployment of digital applications. The mission will pay particular attention to the **deployment and the upscaling of digital solutions through the network of living labs and the cooperation with Digital Innovation Hubs**. An important element of the mission will be the **communication of the benefits of digital and data technologies for soil health**, and thus for people, and the added value for businesses to foster the twin transition to increase their sustainability and economic performance. A concrete example is the generation of input data and information for digital applications used by farmers.

The mission supports the ambitions under the **European Strategy for Data**^{xvii}. It will create and capitalise on high quality data sets through the application of technologies, such as Artificial Intelligence (AI), and the targeted re-use of data. The mission will contribute to the **Common European Data Spaces**. A key asset of the mission for the capitalisation of data, are its networking and umbrella functions. These will allow to take stock, and strategically interlink data sets, and connect the efforts undertaken by scientists, farmers, statisticians and citizens. The strong focus of the mission on reaching out and involving citizens and businesses, will allow to communicate and promote the European values and standards in the digital sphere and the lines proposed in the Communication on the Digital Compass^{xviii}, and to further trust in data sharing, which in turn will be a key for the effectiveness and success of the mission (see also section 4.5.2 on the cross-cutting dimension of digital issues in the mission).

1.3.4. Synergies with other EU policies and programmes

The mission as main implementation tool is closely linked with the objectives of **the Water Framework Directive, the Habitats Directive, the Marine Strategy Framework Directive, the Bioeconomy Strategy, the Circular Economy Action Plan and the**

upcoming Long-term vision for rural areas. For the latter it will be central for the promotion of rural innovation. The mission will also contribute to the Commission's political priority of a stronger Europe in the world, and the objectives of the EU's Global Approach to Research and Innovation. Synergies with the **Industrial Strategy** clearly exist through the mission's contribution to generating knowledge and solutions for **building a circular economy and by helping businesses to achieve climate neutrality.**

The mission will link up with the **European Skills Agenda** and the **Pact for Skills** to promote the development of green skills in the agri-food sector. The mission is closely related to the Climate Target Plan and Climate Law, as well as climate adaptation and Land Use, land-use change, and forestry (LULUCF), and the upcoming proposal on restoration targets and the upcoming EU Forest Strategy. Finally, the mission will seek to link up with investments programmed by Member States under the **Recovery and Resilience Facility plans, for example,** in the areas of soil decontamination, reduction of soil sealing, the reuse of organic waste and carbon farming.

1.3.5. Contribution to the SDGs and other international commitments

Soil degradation goes hand in hand with an overall decline in environmental quality and threatens the livelihoods of millions of people around the world^{xix}. The mission will significantly contribute to reaching the targets of the **Sustainable Development Goals (SDGs)**. Critically, the SDGs which require action on soil are: SDG 2 (zero hunger); SDG 3 (Health); SDG 6 (clean water and sanitation); SDG 12 (sustainable consumption and production); SDG 13 (climate action) and SDG 15 (life on land). None of these can be achieved without improving the status of soils and their management.

In addition, the mission will contribute to the implementation of the **EU international commitments** towards Biodiversity, Climate Change, Nutrition, Hunger and Poverty Eradication through partnership with Actions implemented through the NDICI geographic or Global Challenges budget lines or the EU-AU R&I Partnership on Food and Nutrition Security and Sustainable Agriculture. Exchanges of experiences with international research institutions and third countries' academia EU-supported initiatives such as the Great Green Wall will allow to deepen the understanding on soil regeneration and preservation at a global scale, while drawing lessons for application within the EU.

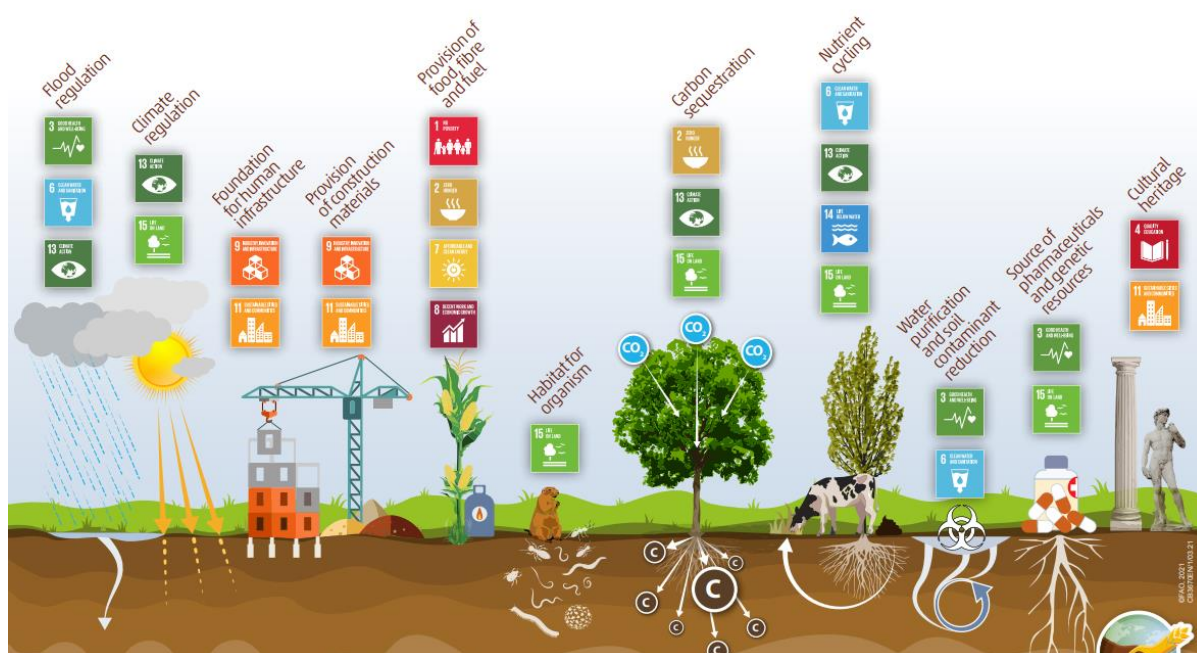


Figure 1. Ecosystem services and SDGs supported by healthy soils (source: FAO)

1.3.6. Synergies with other missions

The Soil Health Mission strongly supports **the success of the other missions**. Improved soil health will contribute to:

- Oceans, Seas and waters: by reducing pollution from fertilisers, pesticides and other contaminants and through reduced sediment inputs due to erosion, reduced flooding due to natural flood mitigation and changes in soil sealing;
- Adaptation to Climate change : by enhancing carbon and biodiverse rich soils as the basis for climate resilient agri-food systems and rural landscapes or by raising citizens and land managers awareness to the need for a transformative change in land use practices;
- Climate Neutral and Smart Cities: by reducing and progressively stopping soil sealing and enhancing soil health of city soils, contributing to the greening of European towns and cities and a better urban environment;
- Cancer: by promoting safe (non-polluted) food and healthy diets, based on clean, healthy soils as an important element of cancer prevention.

The network of living labs – whose concept has been developed in detail under the soil mission – is a major asset that can benefit also the other missions. All Missions envisage place-based actions such as demonstrators, lighthouses or living labs and will explore how to reinforce synergies through cross-mission initiatives. Obvious areas for synergies include work on water pollution from pesticides and nutrients or on the contribution of healthy soils to climate resilience. **Close cooperation between the five missions is therefore required** and will be ensured through the inter-service mission governance.

2. The mission's goal, intervention logic and approaches

2.1. Mission goal, objectives and wider impact

As requested by the Mazzucato criteria^{xx}, **the mission's goal, objectives and targets are bold and ambitious. They are measurable through clearly defined indicators and can be monitored over time against a well-founded baseline.**

Following a thorough data and literature analysis the Mission Board and the JRC concluded that 60-70% of soils in the EU are unhealthy as a direct result of current management practices or industrial emissions (see section 8.A).

This baseline shows the need for urgent action and for stepping up efforts to achieve by 2030 significant progress in soil improvement and soil restoration as part of the EU's ambition to reach 100% of healthy soils by 2050. This long-term goal is implicit in the EU's climate targets and in line with the headline ambition of the Biodiversity Strategy.

Mission goal:

A Soil Deal for Europe: 100 living labs and lighthouses to lead the transition to healthy soils by 2030.

Soil health has been defined as **"the continued capacity of soils to support ecosystem services¹".**



¹ Ecosystem services are understood as the services provided and the benefits people derive from these services, both at the ecosystem and at the landscape scale, including public goods related to the wider ecosystem functioning and society well-being" (Haines-Young and Potschin 2018; MA 2005)

This is in line with existing commitments and definitions². Most soils provide several ecosystems services simultaneously but at varying levels according to their characteristics. Degradation processes that change the inherent physical, chemical and biological characteristics of soil can inhibit this capacity.

Care has been taken to allow for a differentiated approach according to the individual situation in Member States (MS) and Associated Countries (AC). This includes measuring improvements relative to MS and AC baseline assessments of soil health as part of the mission. These improvements will move soils towards meeting thresholds accepted by MS/AC for soil indicators which are defined by soil type to support ecosystem services (see operational Objective 3).

The mission's goal is substantiated by:

- **eight specific objectives** as shown below in table 1, for which evidence of current problems are demonstrated in section 8.A. The mission's objectives are closely related to those of the European Green Deal, the Sustainable Development Goals and other EU policies and strategies (see section 1.3);
- **one or more policy based targets per specific objective:** The targets proposed have been tested against evidence gathered in 8.A and 8.C and are considered as challenging but feasible. They will be reviewed regularly reviewed and updated to take into account new policy developments such as the adoption of the new Soil Strategy and the Nature restoration targets;
- a definition and a set of eight indicators for soil health for each of the specific objectives. While seven indicators can be measured and monitored through a set of concrete physical, chemical, biological and landscape parameters, the eighth indicator requires socio-economic inputs (see Table 1 and section 8.B). Member States have confirmed the usefulness of these parameters to further developing and harmonising their approaches for soil monitoring;
- **four transversal, operational objectives** that reflect the mechanisms to address the eight interconnected specific objectives (section 2.2):
 - Operational objective 1: Build capacities and the knowledge base for soil stewardship
 - Operational objective 2: Co-create and upscale place-based innovations to improve soil health in all places
 - Operational objective 3: Develop an integrated EU soil monitoring system and track progress towards soil health
 - Operational objective 4: Engage with the soil user community and society at large.

The feasibility of the specific objectives was confirmed through a review of scientific evidence on the potential of current soil management practices, mostly coming from the area of agriculture (see 8.C). The evidence illustrates that there is already a wealth of scientific knowledge and available expertise which can inform better protection and improvement of soil health. **The review confirmed that significant improvements in soil health can be reached by 2030 beyond the current baseline of having only 30-40% of soils in a healthy state, provided that rapid and combined efforts are made at a large scale.** In fact, major improvements in soil health on an area equivalent to the one currently eligible for CAP payments (35-45% of EU land) would result in doubling the rate of healthy soils.

Moving towards healthy soils will have wide-reaching impact not only on soil health itself and its related ecosystem services but also on practices in agriculture, forestry and urban areas. The mission will improve the functioning of food and bio-based value chains, the conditions for

² This definition is in line e.g. with SDG target 15.3 which defines land degradation neutrality as a state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales and ecosystems.

restoring biodiversity and the capacity to mitigate and adapt to climate change. **Soil health will clearly be the starting point for systemic transformations across the whole food chain from primary production to food industries and consumer behaviour.** Foremost, the mission will result in society rethinking the ways in which it values and manages soils.

Table 1 The mission's specific objectives, targets and proposed soil health indicators

Mission Goal: 100 living labs and lighthouses to lead the transition towards healthy soils by 2030			
Objectives	Mission targets in line with EU and global commitments	Baseline (see 8.A)	Soil health indicators
1.Reduce land degradation relating to desertification	T 1.1: Halt desertification to help achieve land degradation neutrality and start restoration ----- In line with SDG 15.3	25% of land in Southern, Central and Eastern Europe at risk of desertification.	All eight soil health indicators
2.Conserve and increase soil organic carbon stocks	T 2.1: Current carbon concentration losses on cultivated land (0.5% per year) are reversed to an increase by 0.1-0.4% per year T 2.2: the area of peatlands and wetlands losing carbon is reduced and the natural sink is significantly increased to help meet GHG reduction targets by 2030 and the Climate law goal by 2050. ----- In line with the Fit for 55 Climate Energy Package (Climate Law, revised LULUCF regulation) and the Paris Agreement 4 per mille initiative.	Area of land with low and declining carbon stocks = 23%. Area of degraded peatland = 4.8%	Soil organic carbon stock Vegetation cover
3.No net soil sealing and increase the reuse of urban soils	T 3.1: increase urban recycling of land beyond 13% and switch from 2.4% to no net soil sealing as a contribution towards meeting the target of no net land take by 2050. ----- In line with Roadmap to a resource efficient Europe, and Biodiversity Strategy including upcoming nature restoration targets	Area of land affected by soil sealing = about <1% of EU, but can be as high as 2.4%, Current rate of recycling of urban land for development: 13%	Soil structure (incl. soil bulk density, absence of soil sealing, erosion and water infiltration) Vegetation cover
4.Reduce soil pollution and enhance restoration	T 4.1: reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% T 4.2 reducing fertilizer use by at least 20% T 4.3: reduce nutrient losses by at least 50% T 4.4: 25% of land under organic farming T 4.5: Reduce microplastics released to soils to meet 30% target of zero pollution action plan T.4.6 Halt and reduce secondary Salinization All to be achieved by 2030 to contribute to meeting the target by 2050 that soil pollution is reduced to levels no longer considered harmful to health and natural ecosystems. ----- In line with the Biodiversity strategy, the Farm to Fork Strategy and the Zero Pollution Action plan.	27% - 31% of land with excess nutrient pollution Soil contamination: 2.5% (non-agricultural), 21% (conventional arable), ca. 40-80% of land from atmospheric deposition depending on the pollutant. Farmland under organic agriculture: 8.5% (2019)	Presence of soil pollutants, excess nutrients and salts

5.Prevent erosion	T 5.1: reduce the area of land currently affected by unsustainable erosion from 25% to sustainable levels ----- In line with the Roadmap to a resource efficient Europe	Area of land with unsustainable soil water erosion is 25%, with 70% of this being agricultural land.	Soil structure, absence of soil sealing, erosion and water infiltration Vegetation cover Landscape heterogeneity Forest cover
6.Improve soil structure to enhance habitat quality for soil biota and crops	T 6.1: Reduce compaction of soils to go significantly below current levels of 23% - 33% ----- As for forest soils: in line with the new EU Forest Strategy	Area of land with critical levels of soil compaction = 23-33%, 7% of which is outside agricultural area.	Soil structure, absence of soil sealing, erosion and water infiltration. Vegetation cover Landscape heterogeneity
7.Reduce the EU global footprint on soils	T 7.1: Establish the EU's global soil footprint in line with international standards T 7.2: The impact of EU's food, timber and biomass imports on land degradation elsewhere is significantly reduced without creating trade-offs ----- In line with the Zero Pollution Action Plan	Baseline to be created by mission activities	Food, feed and fibre imports leading to land degradation and deforestation
8.Increase soil literacy in society across Member States	T. 8.1: awareness of the societal role and value of soil is increased amongst EU citizens, including in key stakeholder groups, and policy makers T. 8.2: soil health is firmly embedded in schools and educational curricula, to enable citizens' behavioural change towards the adoption of sustainable practices both individually and collectively. T 8.3: citizen involvement in soil and land-related issues is improved at all levels T 8.4: practitioners and stakeholders have access to appropriate information and training to improve skills and to support the adoption of sustainable land management practices.		All eight indicators (on a long term)

2.2. Overall intervention logic and approaches

The mission's intervention logic follows the guidance from the better regulation toolbox. Based on a clearly identified goal and specific objectives (see section 1), it describes the **operational objectives and activities along with the expected outputs and outcomes of mission activities**. Targets and indicators are shown in table 1. While figure 1 provides a synthetic view of the intervention logic, a more detailed view per operational objective is shown in section 4.

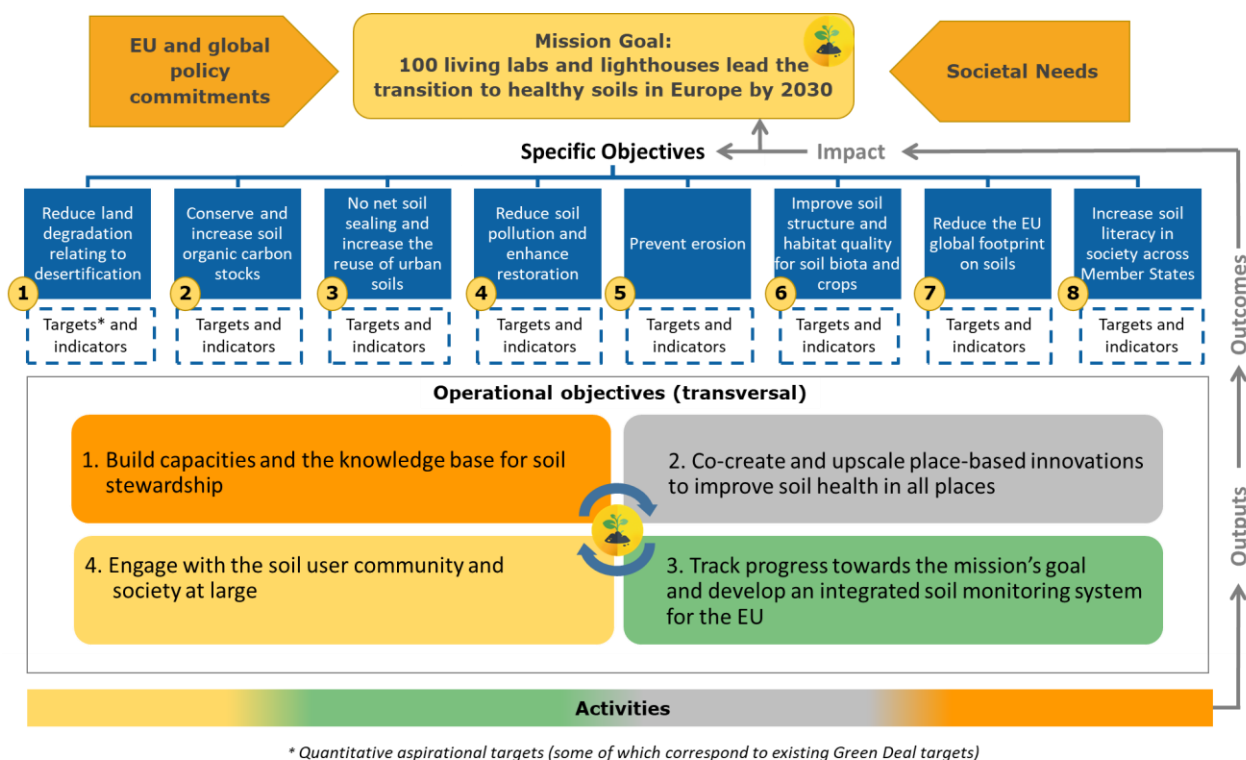


Figure 2. Schematic view of the mission's intervention logic

Achievement of soil health issues as defined in the specific objectives is largely hampered by (1) gaps and insufficient access to data and knowledge; (2) research results or technical solutions which are not adapted to local circumstances and land managers' needs, (3) a lack in capacities for monitoring soil health and (4) insufficient awareness and know-how on soil health related matters.

Four transversal, operational objectives address these shortcomings in an integrated manner (see above in figure 2) and will be implemented through activities summarised under "building blocks":

- (1) an ambitious cross-scale, inter and transdisciplinary **R&I programme with a strong social science component** to build the knowledge base for soil health (in line with the specific objectives) and its support to ecosystems services;
- (2) **living laboratories (LLs) and lighthouses (LHs)** to accelerate the creation and uptake of solutions to meet the specific objectives across farms, forest, landscapes and urban settings in a diversity of geographical and socio-economic contexts;
- (3) a robust **soil monitoring framework** at EU level and at the level of Member States to track progress towards the mission's specific objectives;
- (4) **soil literacy, communication and citizen engagement** on soil health objectives.

Innovation hotspots under the building blocks illustrate areas of reinforced action in relation to specific mission objectives, most of which have significant potential for private sector involvement and/or for nurturing bottom-up solutions.

The mission will be rolled out in **three, interconnected phases** (see timetable in section 7):

- the induction and pilot phase: to develop implementation structures, pool existing resources and bolster innovation capacity in Member States, regions and the sectors involved in the mission (2021 – 2025);
- the expansion and innovation phase: to expand activities, generate and test innovations (2025-2030);
- the scaling up and mainstreaming phase: to scale-up solutions, adapt to local needs of a broader set of regions and mainstream good practices across sectors and territories (2027-2030).

The overlaps between the various phases is due to the stepwise approach taken to build up the LLs: while some may still be scaling-up solutions, others may already be able to embark into mainstreaming good practices. Rigorous monitoring will assess progress and allow the planning to be adapted during the mission's lifetime.

Through its operational objectives, and the resulting portfolio of activities, the mission will provide pathways for **re-designing production systems, change consumption patterns and transform the ways by which land and soils are managed**. To trigger profound, systemic changes, mission activities address both, **soil health itself and the drivers of soil health** such as land use practices, markets and value chains across agri-food systems, consumer behaviour, policies, regulation and education and advice. Special attention will be given to business involvement, digitisation as well as the territorial and the global dimensions as cross-cutting themes of the mission.

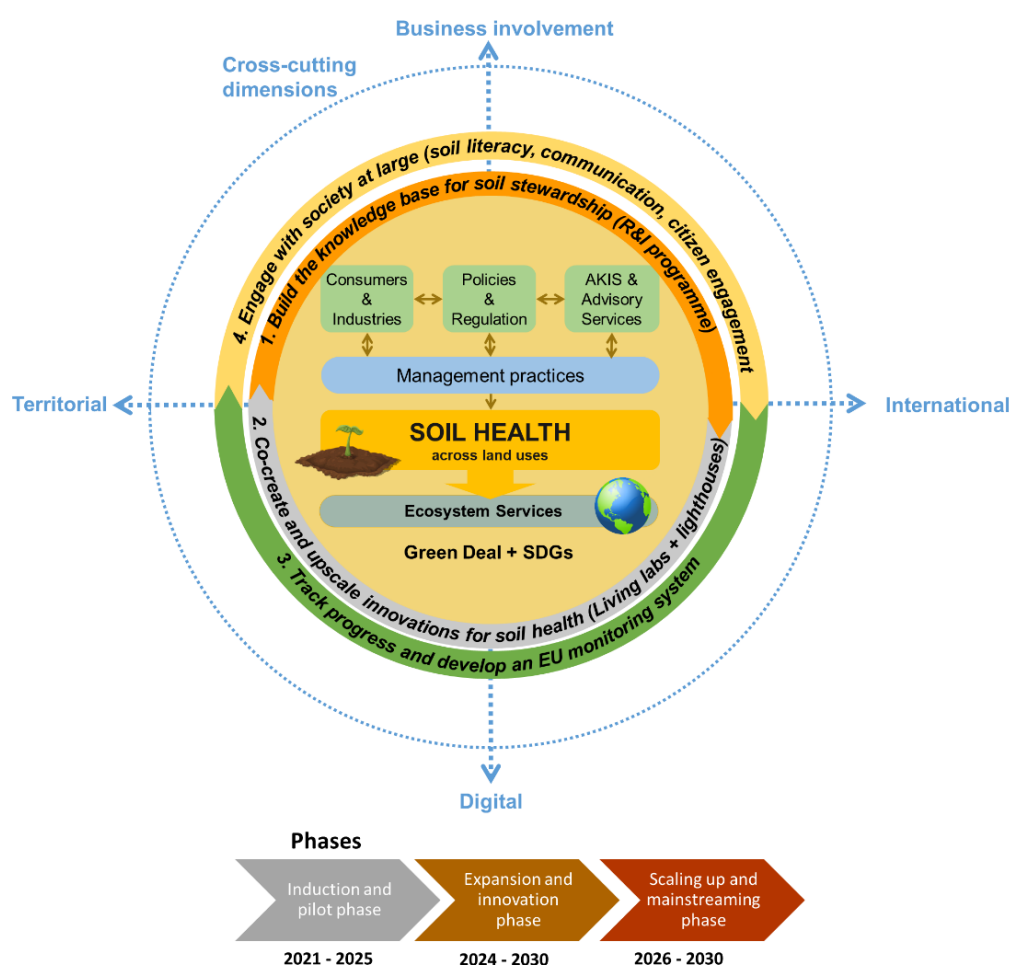


Figure 3. Soil Health drivers and impacts (centre of the figure), the four operational objectives and cross-cutting dimensions of the mission

3. The Mission in action: operational objectives and activities

Mission implementation is based on the recognition that:

- it is people and their actions that need to change to make a rapid shift happen. Hence, the **focus on societal change** (e.g. amongst land managers, spatial planners, civil society, consumers, researchers, advisors, regional stakeholders and policymakers, industries) **and citizen engagement**;
- the diversity of soils and their ecosystem services needs to be valued and considered in all actions at different scales. This calls for **place-based approaches that are adapted to the local/regional context**;
- soil health challenges can only be tackled within **a systems' approach**, addressing soil as a living system and its interfaces with ecosystems, food systems and landscapes along with the fluxes and flows of resources between rural and urban areas;
- **new (policy) incentives and business models** are needed to reward soil beneficial practices by land managers, agri-food system players and other actors across value chains.

The novelty in the approach lies in the **combination of R&I activities, local testing grounds, monitoring and training activities**, beyond what could be achieved within single parts of Horizon Europe or other instruments at EU level. The mission proposes to address soil health in a comprehensive manner, (i.e. for all types of land use and multiple challenges), where existing programmes focus on specific aspects, e.g. agricultural soils only. The mission's focus on creating communities for participatory actions at local level will help mobilise actors across society in more systematic ways.

Care will be taken to ensure that mission activities, images and language in communications are gender inclusive and consider a range of accessibility issues.

Activities identified under the four operational objectives require mostly R&I and will make use of all Horizon Europe instruments including Research and Innovation Actions with Technology Readiness Levels (TRL) 3-5, Innovation Actions aiming at TRL 6-7 and Coordination and Support Actions.

3.1. Operational objective 1: build capacities and the knowledge base for soil stewardship

Activities under this operational objective will be referred to as building block **"The R&I Programme"**. They address the need to close gaps in our knowledge on the mechanisms that determine the specific objectives and to improve access to this knowledge for potential users.

R&I activities have been developed taking into account the results of a **preliminary gap analysis** undertaken by the Mission Board, the Horizon 2020 EJP Soil programme, the SMS and INSPIRATION projects as well as a workshop with on-going projects from the "Soil Cluster", held on 13 January 2021. The gap analysis will be further refined in the pilot phase of the mission and feed into the overall programming of activities. It will be undertaken in co-creation between Commission services, Member States, the Mission Board and a wider "sounding board" of stakeholders and citizens (to be installed). **Proposed activities will be updated throughout the mission in response to new emerging knowledge and needs identified.**

Activities will be implemented in close coordination with the European Joint Partnership EJP Soil. The EJP Soil brings together research efforts from 24 European countries. Although addressing only one part of the mission (carbon sequestration in agricultural soils), the EJP is a formidable resource to feed into and complement mission activities on R&I.

3.1.1. Context

There is a need to increase a) our understanding of basic processes, drivers and mechanics that affect soil properties in relation to the specific mission objectives as well as b) our capacity to act on land management and other drivers of soil health. Where knowledge exists, it is often coming from within individual disciplines. There is hardly any integrated knowledge on soil health and its drivers, both biophysical as well as social, economic and cultural ones, which would combine insights from a sufficiently large number of disciplines, sectors and land uses. Also, knowledge on soils is largely limited to agricultural soils, while other land uses have received little attention. The mission will fill these gaps and **advance our capacities to improve and restore soil health across urban and rural areas**.

The proposed R&I programme reflects the need to synthesize, share, exchange and take up existing scientific, technical and practitioners' knowledge, in addition to generating **new insights, methods, practices, tools infrastructures and technologies**. The R&I programme recognises the need to embed research in societal innovation from the outset in order to achieve the mission's objectives. It will consequently **promote the role of social sciences and arts and humanities** to better understand and engage the societal, cultural, and economic mechanisms through which soil health outcomes can be achieved, including unlocking synergies and the innovation potential of different sectors. To do so, the R&I activities will apply a systemic approach as well as the principles of interdisciplinary (integration of natural and social sciences at an equal level), transdisciplinarity (development with stakeholders end users), contextualization (differentiation and specificities), societal engagement (including through citizen science and civic science) and cross-scale integration.

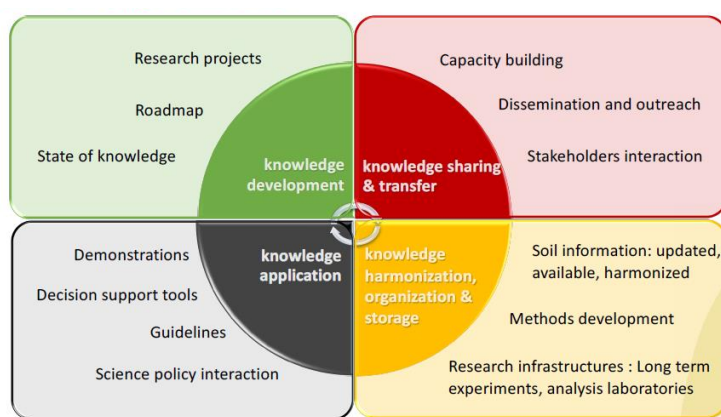


Figure 4. The "Soil Knowledge framework" as illustrated by the EJP Soil project

The mission will make use of existing **Research Infrastructures**. While none of the ESFRI infrastructures is focused exclusively on soils, the ones listed below can support experimentation on the various mission objectives.

eLTER, Integrated European Long-Term Ecosystem, critical zone and socio-ecological system Research Infrastructure

AnaEE, Infrastructure for Analysis and Experimentation on Ecosystems to test the impacts of biophysical drivers on managed soils across agricultural, forestry and freshwater systems

LifeWatch, an e-Infrastructure for Biodiversity and Ecosystem Research for the biodiversity challenge

ICOS, Integrated Carbon Observation System, to understand soil carbon and associated CO₂ fluxes between the atmosphere and managed ecosystems.

MIRRI, Microbial Resource Research Infrastructure collects and curates a large collection of microorganisms including those found in soils across Europe

3.1.2. Activities

Activity 1.1: Synthesise existing knowledge and gaps

This activity addresses the need to take stock of the existing wealth of knowledge and identify R&I gaps and provide the mission with the underpinning “intelligence” for an evidence-based roll-out of R&I activities.

- Refine the mission’s R&I gap analysis and develop R&I roadmaps for each of the mission objectives, capitalising on EJP Soil and SMS projects, the EIP AGRI and consultation of the stakeholder innovation group (see section 4. on governance). The roadmaps will set out in more detail the interdisciplinary and transdisciplinary R&I priorities and expected results and show the technical and socio-economic options to reach the mission’s specific objectives. They will help to monitor the emerging portfolio of mission projects against the identified priorities and expected outcomes;
- Assessing socio-economic solutions, market prospective, cost analysis models, incentives and financial support (from different sources, combining private and public support) to new business models around the concept of soil health and ecosystem services;
- The effects of soil health and quality on food quality and safety;
- Scale up services such as from the Horizon Results platform and JRC Knowledge Centres to synthesise key results of funded R&I projects across Horizon Europe (continuous activity).

Mission objectives supported: 1- 6

Use of Resources: HE mission budget; **cooperation and synergies with e.g.:** H2020 projects incl. EJP Soil and SMS, ERA-NETs, Horizon Results Platform, EIP AGRI, JRC Knowledge Centres for Bioeconomy, Food and nutrition security and biodiversity, EUSO.

Activity 1.2: Exploit and further develop research infrastructures and platforms

This activity will help to process and enhance access to existing data and information to support R&I activities, modelling and speed up the development of new services and applications. It will be closely coordinated with activities under building block 3 (Monitoring).

- Expand and ensure open access to databases and services of existing infrastructures and digital platforms (including for modelling) in relation to soil relevant information. This will include gathering information from long-term field experiments;
- Building the mission’s knowledge repository – a soil health cloud - to serve activities across the various mission building blocks. This activity will directly feed into the development of EUSO, so interoperability and sustainability of data and information will be ensured.

Mission objectives supported: 1- 6

TRL level(s): 6-7

Use of resources: HE mission budget; **cooperation and synergies with e.g.:** H2020, HE infrastructures and planned HE partnership on Agriculture of Data

Activity 1.3: Advance knowledge and capacities in relation to the specific mission objectives

- Across specific objectives, assess pressures on soil functions and their support to ecosystems services, e.g. the provision of food and other products, clean water, habitat for biodiversity, climate mitigation, also in the context of climate change;
- Across specific objectives, develop knowledge on the social, economic and cultural factors driving decisions of landowners and land managers’ and their advisors;

- Analyse the relation between current business models and soil degradation and develop business models allowing soil regeneration in various contexts;
- Assess and design mechanisms that need to be put in place to drive changes in practices at local and landscape levels, including mechanisms to reduce risk taking and enable collective action and social innovations.
- On land degradation (specific objective 1), erosion (specific objective 5) and soil structure (specific objective 6): Evaluate the level of ecosystem services restoration directly linked to reversing land degradation, soil erosion, and soil compaction and ways to reward this restoration.
- On land degradation (specific objective 1):
 - Develop practices, tools, technologies and approaches to map and assess socio-economic costs of land degradation vulnerability in the EU, and identify practices (including spatial planning) and methods which support land degradation neutrality;
 - Identify the societal (incl. legal), economic, and cultural drivers and enablers of land degradation, including land sealing and land pollution, in relation to all land uses. Co-develop and co-create pathways towards strengthening innovative solutions to land degradation with stakeholders in urban and rural areas (including related to business models, de-risking change and enhancing the spread of existing good practice).
- On conserving and increasing soil organic carbon stocks (specific objective 2): soil carbon balance and GHG balance monitoring in agriculture, rangelands and peatlands.
- On soil sealing and re-use of urban soils (specific objective 3): identification and assessment of the legal and socio-economic dimension of land take across Member States. Co-development of a roadmap for no net soil sealing strategies with MS and regional stakeholders.
- On soil pollution (specific objective 4) as part of innovation hotspot "soil pollution and restoration":
 - Understand and produce strategies for addressing the key drivers of soil pollution (including the use of pesticide and microplastic flows), including their legal, socio-economic, and cultural dimensions.
 - Develop tools and procedures for citizen science and civic science detection and monitoring of soil pollution.
 - Develop and support the deployment of strategies, methods and financial models for decontamination and reuse of land in urban and rural areas
 - Enhance the understanding and multi-scale action of the spatial and societal dimensions of the soil pollution challenge through an EU-wide citizen science soil pollution initiative.
 - Explore the effect of the complex set of mixtures on the soil biome and develop novel remediation approaches for contaminated land.
- On soil biodiversity (specific objective 6): Exploring the soil functional (micro)biome and its potential to deliver improved soil health and associated ecosystem services with a focus on non-agricultural soils. Identify efficient biomarkers and soil metapenome indicators to inform more effective and consistent soil health monitoring.

Mission objectives supported: 1-6

TRL levels: most activities address basic needs for knowledge and operate at levels 1-4.

Use of resources: HE mission budget; **cooperation and synergies with e.g.:** Article 185 partnership PRIMA, EJP Soil, Water4All, Climate-KIC, Rescuing Biodiversity, EU infrastructures (eLTER, ANAEE, MIRRI), HE partnership on agroecology.

Activity 1.4: Building the innovation ecosystem to accelerate innovation and deployment in practices, technologies, business models, value chains and policies

- Calls for bottom-up projects in areas of “innovation hotspots”: carbon farming, soil pollution and restoration, soil biodiversity, and circular economy solutions (see also 4.1.3);
- Develop soil health improving methods adapted to different agroecological, socio-economic, and cultural contexts. Producing strategies for addressing the existing barriers (including socio-economic) and enablers of more diversified and low-input farming and forestry systems (e.g. organic or regenerative farming, agro-forestry, mixed farming and other agroecological practices); activities are linked to hotspots “carbon farming” and “soil biodiversity”;
- Develop robust, ready-to-use, harmonised indicators and methods for carbon measuring, monitoring and certification appropriate to different land-based value chains (including agricultural, forestry, and other land-based production) to enable the tracking of low carbon products across the value chain;
- Develop innovative and user-oriented digital applications (e.g. precision (farming) tools and sensing technologies) to support decision making of land managers and actors across value chains, (e.g. in relation to the use of inputs such as nutrients and water). Activities will feed amongst others into the further development of the Farm Sustainability Tool for Nutrient management (FaST) as foreseen under the CAP and the Farm Sustainability Data Network (FSDN)^{xxi} as announced in the Farm to Fork Strategy;
- Management practices and (bio) technologies to enhance nutritional quality and reduce risks for safety of food and feed (linked to hotspot “soil pollution” and “biodiversity”);
- Strategies and solutions for valorisation of waste and by-products for soil health via circular approaches incl. urban-rural synergies, nutrient and biomass recovery and short value chains. Develop strategies and business models for enhancing waste valorisation and spreading of good practices with stakeholders at all levels (companies, civic organisations, regional authorities) (linked to innovation hotspot “circular economy solutions”);
- Co-development and implementation of business cases, blended finance, strategies, governance models and policies which proactively address soil pollution and reward soil health in primary production, across value chains and in consumption (linked to innovation hotspots “carbon farming”, “soil pollution and restoration” and “circular economy”);
- Strategies, methods and financial models for decontamination and reuse of land in urban and rural areas (linked to innovation hotspot “soil pollution and restoration”);
- Work in synergy with activity 4.4 to ensure the availability and development of adequate advisory services that can fill the knowledge and technical gaps identified as the cause of slow adoption soil health improving practices.

Mission objectives supported: 1- 6

TRL level(s): 4 – 8

Use of resources: HE mission budget; **cooperation and synergies with e.g.:** EIC, Article 185 partnerships PRIMA and BBI/CBE, LIFE programme, JP Soil, Water4All, Climate-KIC, eLTER, ANAEE, MIRRI and planned HE partnerships on biodiversity, agroecology, food systems and circular bioeconomy.

Activity 1.5: Going global – international cooperation; reducing the global soil footprint

International partners have raised huge interest in cooperating on soil health. Beyond the areas listed below, priorities for R&I cooperation over the 7-year Horizon Europe period will be developed within the established bilateral and multilateral mechanisms.

- Scale-up and coordinate cooperation with international partners on soil health, focusing first on aligning international research cooperation on soil carbon stocks, land degradation, net

soil sealing, contaminants and habitat quality, and building linkages between soil living labs and lighthouses in Europe (activity 2.3) and in third countries where relevant;

- Develop and test foot printing tools which can help assess the global soil health footprint of food and feed, wood and biomass use in the EU.

Mission objectives supported: 7

TRL level: 4-6

Use of resources: HE mission budget; **cooperation and synergies with e.g.:** Global Soil Partnership, structured dialogues at bilateral level with US, Canada, Japan and multilateral agreements with Africa and CELAC countries.

3.1.3. Innovation hotspots

Innovation hotspots are defined as clusters of activities in areas of strategic importance for the mission. They show significant potential for bottom-up solutions, business involvement and for testing a range of approaches including agro-ecological approaches or nature-based solutions.

Carbon farming

Carbon farming is as a highly dynamic sector, promoting a new green business model by which farmers and foresters are rewarded for undertaking soil management for increased carbon sequestration. R&I, testing and demonstrations under this hotspot will support the emerging ecosystem for carbon farming by developing robust, ready-to-use, harmonised indicators and methods for carbon measuring, monitoring and certification. This will support the development and tracking of low carbon products across the value chain. R&I will further help to improve management practices, methods and technologies for soil health and promote financial mechanisms for de-risking of carbon farming. Activities will build on existing experiences carried out by industries, “brokers” for carbon credits and certification, farmer networks as well the EIT Food and EIT KIC Climate. Activities under this hotspot will feed into the wider EU framework for carbon farming as specified in the Climate Pact and the EU’s aim to reduce GHG emissions by at least 55% by 2030. They will be synchronised with complementary activities on carbon farming such as pilots to be funded under the LIFE programme and the CAP.

Soil pollution and restoration

Soil contamination is a major concern both in the EU and globally, posing major threats to ecosystems and human health. Recent studies suggest that there are more microplastics in farm soils than in oceans and their effects on soil biodiversity, food safety and human health are far from being fully understood. Activities will provide the necessary solutions to avoid and remediate pollution in soils, notably from pesticides, heavy metals and microplastics. This will include innovative approaches to shift towards low input, biodiverse and resilient farming and forestry systems, the development of alternatives to problematic plant protection products as well as novel tools and technologies for detection and remediation of pollution. Agricultural Knowledge and Innovation Systems will be crucial to transforming farmers’ practices on the use of chemical inputs. Activities will promote the effective partnerships between land managers (including urban gardeners), fertiliser and pesticide companies, bio-based industries and waste managers. This hotspot will contribute to the implementation of the Zero pollution action plan for air, water and soil as well as the Farm to Fork’ and Biodiversity strategies and their concrete targets for reducing the use and risks of and the dependency on pesticides as well as the use of fertilisers and antimicrobials. Actions will team up with those under the Ocean mission to prevent diffuse pollution to underground and surface waters. They will also support the disease prevention component of the Cancer mission.

Soil biodiversity including the microbiome

Soil biodiversity is the Earth's biological engine, necessary for sustaining vital ecosystem processes and maintaining soil functions. Its interactions with plants, underpinning food production and food quality. Activities under this hotspot will advance our understanding of how soil functional biodiversity including the microbiome a) regulates soil functions and services, also against the effects of climate change and b) how it interacts with plants to deliver a range of services such as water and nutrient acquisition or increased resilience to pests and diseases. Activities will further support the translation of knowledge into diagnostic tools, soil management guidelines and practices as well as ground-breaking applications, for example in relation to fertilisation, pest control, food safety and quality or waste management.

Circular economy solutions

Soil as a carrier of activities and landscapes plays an important role in the circular economy and its principle to decouple economic activities from resource use. Currently, one fourth of biomass produced in the EU and imported - mainly from agriculture - is wasted and 520 million tonnes of excavated soils annually are treated as waste, representing the largest source of waste produced in the EU. The loss of nitrogen and phosphorus fertilisers is impacting on human health, air, soil, and water quality, biodiversity and GHG emissions.

Activities under this hotspot will advance strategies and speed up solutions to avoid losses and close loops (on-farm, between farms and rural-urban areas) to bring nutrients, excavated soil residues and biomass back to soils. This will include recovering P, N and micronutrients as well as biomass from biological residues and side streams and developing products and practices such as the application of fertilisers, compost and other bio-based soil improvement methods. Valorisation of waste and residues at farm level will provide new income streams to farmers and contribute to a dynamic market for circular bio-economy value chains and innovations.

Co-creation aided by social sciences and humanities will ensure that the developed solutions are societally appropriate and desirable while achieving their environmental objectives. Synergies will be sought with the R&I roadmaps of the current Bio-based Industry Joint Undertaking and the planned partnership Circular Bio-based Europe as well as with Art. 185 partnership PRIMA.

3.1.4. Expected outputs and outcomes

Outputs

- New knowledge and improved understanding of the nature and functions of soil health, i.e. the link between soil functions and ecosystem services supported by healthy soils;
- New knowledge and deep understanding of the socio-economic and behavioural drivers and conditions of change towards management practices and policies enhancing soil health in the variety of EU biogeographical and socio-economic contexts;
- Infrastructures, easily accessible tools and a repository for soil data and information on practices;
- Best practices, products, technologies and services for sustainable soil management and restoration for different land uses, soil types and pedo-climatic conditions targeted at land managers. Examples include (digital) decision-making and precision tools or alternatives to contentious plant protection products;
- New knowledge and improved understanding of soils and the nutritional quality of the food produced on them, i.e. biochemical interactions between soils and plants;
- A toolbox of incentives (business models, policies, financing) invest into soil health and enhance uptake of soil beneficial practices across value chains and land uses;

- An ecosystem of solutions, improved advisory services, practices, toolkits, and technologies linked to soil-friendly land management, including global soil health foot printing, is being tested and promoted across Europe.

Outcomes

- Better understanding of soil functions and ecosystem services, and of the barriers to and drivers of soil health restoration across sectors and land uses (integrating biophysical, societal, and cultural dimensions);
- Land managers, business, policy makers and citizens have a better understanding of barriers to transforming practices use the knowledge base to design actions to achieve the mission's specific objectives;
- Land managers, actors in value chains and in policy, and other stakeholders have access to knowledge, tools, and practices enabling them to assess soil health challenges and act appropriately to address them;
- Products, value chains and consumption patterns with a lower soil footprint are developed and promoted within and outside Europe;
- Knowledge on soil health and solutions accelerate the implementation of global commitments, e.g. on land degradation, climate, biodiversity and SDGs;
- Upgraded policy and incentive schemes are in place to enhance soil health.

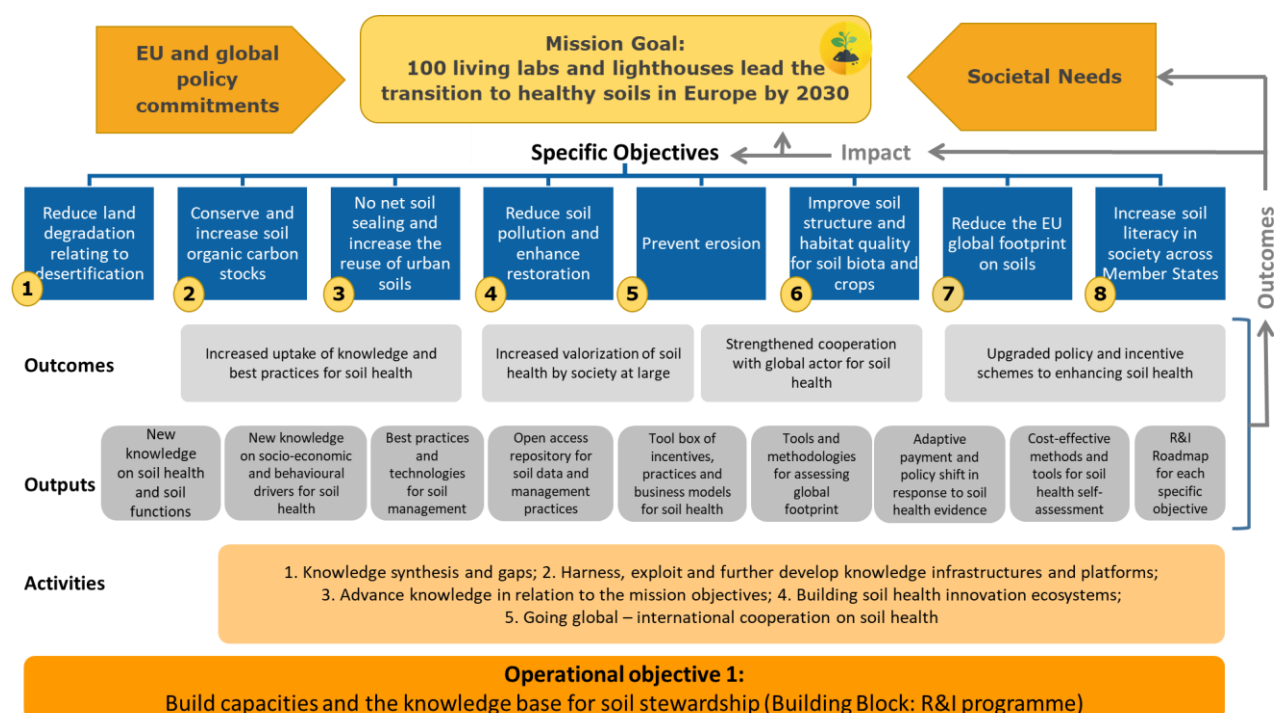


Figure 5. Intervention logic in relation to operational objective 1

3.2. Operational objective 2: Co-create and upscale place-based innovations to improve soil health in all places

Activities under this operational objective will be referred to as building block “**Living labs and lighthouses**”. They address the need to close the science-practice divide and co-develop and upscale innovations that are adapted to the diversity of soil, geographic and socio-economic conditions and likely to be adopted in all places.

3.2.1. Context

Living laboratories (or living labs) and lighthouses are a core element of the mission through which already existing and new knowledge created under the R&I programme (objective 1), and knowledge from actors on the ground will be further transformed into innovations with real impact and a high potential for rapid uptake by land managers and other relevant actors (e.g. industry, consumers etc.) across Europe.

By working directly with users in real-life settings, they will drastically improve the understanding of the cultural and socio-economic drivers of change, making sure that solutions developed improve soil health, ecosystem services and are in line with people's values, priorities and economic realities.

The mission will support co-creation of innovations that target the achievement of specific objectives 1 to 6, prioritising those of greatest relevance to each area in which a living lab is developed. The process of selecting living labs will ensure that all these specific objectives are covered by the activities of several labs.

Living labs are collaborative initiatives to **co-create knowledge and innovations** while **lighthouses** are places for **demonstration of solutions and exemplary achievements**.

More precisely, for the purpose of this mission:

- **"Soil health living labs"** are defined as **"user-centred, place-based and transdisciplinary research and innovation ecosystems, which involve land managers, scientists and other relevant partners in systemic research and co-design, testing, monitoring and evaluation of solutions, in real-life settings, to improve their effectiveness for soil health and accelerate adoption."**³ These living labs are collaborations between multiple partners that operate at regional or sub-regional level and coordinate experiments on several sites within a regional or sub-regional area (or working landscapes);
- **"Lighthouses"** are defined as **"places for demonstration of solutions, training and communication that are exemplary in their performance in terms of soil health improvement"**. They are local sites (one farm, one forest exploitation, one industrial site, one urban city green area, etc.) that can be included in a living lab area or be situated outside a living lab area.

Actors in the living labs will develop an understanding of the soil health and related ecosystem challenges in their area, of their knowledge and technology needs, build on existing or knowledge created under the R&I programme (objective 1), and come up with new research questions.

They will co-develop innovations to tackle the identified challenges, use the comprehensive soil health monitoring framework to assess impacts of these innovations and of their practices on soil health and ecosystems, and contribute to the testing and validation of monitoring techniques and approaches, helping the development of indicators that are practice-proof i.e. fit to drive behavioural and societal change. They will also be ideal places for citizen engagement and soil literacy improvement activities and practices.

³ This definition is customised for soil health living labs. It aggregates elements of definitions by the European network of living labs (ENOLL) and of a working group of the G20 agricultural chief scientists on agroecological living labs.

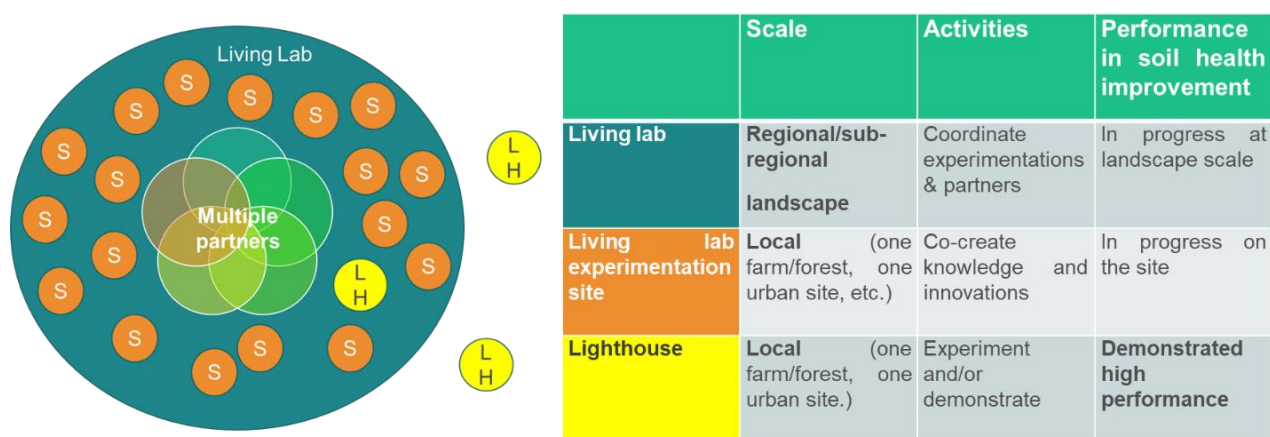


Figure 6. Visualisation of scales and activities of living labs and lighthouses

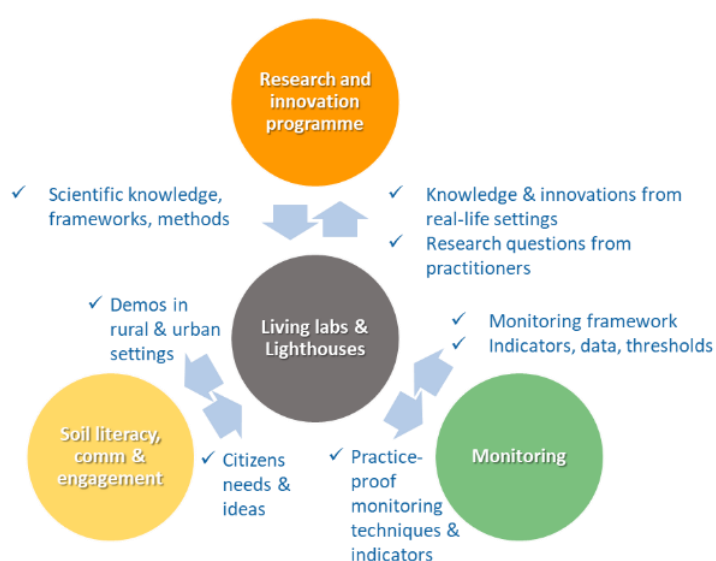


Figure 7 Living labs and lighthouses in relation with activities under other objectives

3.2.2. Activities

Activity 2.1: Engage with Member States and regions to build capacities for living labs and lighthouses

“Engagement sessions” will be carried out in the induction and pilot phase in each Member State (involving national and regional levels) with the aim of creating ownership of a wide range of stakeholders and citizens vis-a-vis the mission and the concepts of living labs and lighthouses. The sessions are expected to trigger the emergence of good proposals for the setup of living labs or mobilisation of existing ones and their participation in living lab clusters (see activity 2.3). Engagement sessions will be organised in early 2023 and will make use of existing networks, most of which have already shown significant capacity to reach out to land managers, businesses, regional and local authorities and citizens in rural and urban areas.

Mission objectives supported: 8

Use of resources; HE mission budget; **cooperation and synergies with e.g.:** EIP AGRI, European Network for Rural Development, Committee of the Regions, Covenant of mayors, Smart specialisation platform, Enterprise Europe Network, EITs, other stakeholders, e.g. ENOLL, Global lighthouse farm network, landowners organisations, soil and environmental networks and regional and local authorities, cities and community networks.

Activity 2.2: Create an EU support structure for the network of soil health living labs and lighthouses (Soil LL&LH network)

The structure will facilitate the creation of living labs and living lab clusters (activity 2.3), improve capacities of living lab managers, coordinate knowledge exchange on innovations of relevance to mission objectives, specific themes, disciplines or methodological approaches and connect the living lab projects with other activities under the mission, in the EU and beyond. The structure will provide feedback mechanisms between the mission's R&I programme and the living labs. It will conduct specific networking activities for lighthouses on how to best demonstrate exemplary soil-health improving management. It will also serve as a contact point for interaction with counterparts in third countries, in coordination with activity 1.5.

Mission objectives supported: 1-6 (with indirect contribution to objective 8)

Use of resources: HE mission budget, **cooperation and synergies with e.g.:** EIP AGRI, European Network for Rural Development (ENRD), Committee of the Regions (CoR), Covenant of mayors, Enterprise Europe Network, EITs (Food and Climate), stakeholder networks as mentioned under activity 2.1.

Activity 2.3: Create transnational clusters of living labs

This activity will serve to set-up transnational clusters of living labs, i.e. projects funded under Horizon Europe that bring together 3 to 5 living labs established in 3-5 different regions in different countries, which share common challenges or characteristics (soil challenges, production systems, land-use types etc.). These living labs will have to meet the criteria mentioned under sections 1.2.3., building or taking advantage of pre-existing initiatives and collaborations where relevant. A strong requirement for portfolio diversity will ensure a balanced coverage of countries and regions (administrative and biogeographical), mission objectives 1-6 and land-use types (urban, farm, forest, industrial etc.) across the projects. These living lab clusters will be interlinked and networked through the *Soil health LL&LH network (activity 2.2)*, that will play a key role in progressively building capacities of living lab managers to manage co-innovation processes effectively and efficiently. Living lab clusters will be created in three phases, ensuring learning by doing and strategy adjustment where needed:

- A first wave of *living labs cluster projects* in the induction and pilot phase will be spread over two years (3 clusters of 3-4 living labs per WP year representing 10 living labs per year in total), first lessons of which will be harvested at the end of the induction and pilot phase;
- In the expansion and innovation phase starting in 2025, the network will gradually expand through two additional larger waves of *living labs cluster projects*, supported by the gradually developing *Soil LL&LH network* that will facilitate an increasing inflow of knowledge from across mission activities;
- In the scaling up and mainstreaming phase, there will be a 4th and last wave of living lab cluster projects along with accompanying measures to support the mainstreaming and sustainability of the living labs beyond the mission, through the post-2027 policy framework.

Considering that each living lab included in the transnational cluster projects (around 24 cluster projects in total) would be included in at least one NUTS2 region (living lab areas could cut across regional or even national borders where this would make sense ecologically), the ambition would be to be present in the end in 100 regions, these representing 41% of the EU 242 NUTS2 regions. Each living lab would include between 10 and 20 experimental sites, meaning that the mission will support co-innovation activities on 1.000 – 2.000 sites all over Europe. There should be, by 2027, **at least one lighthouse in each of the covered regions** (100 lighthouses in total).

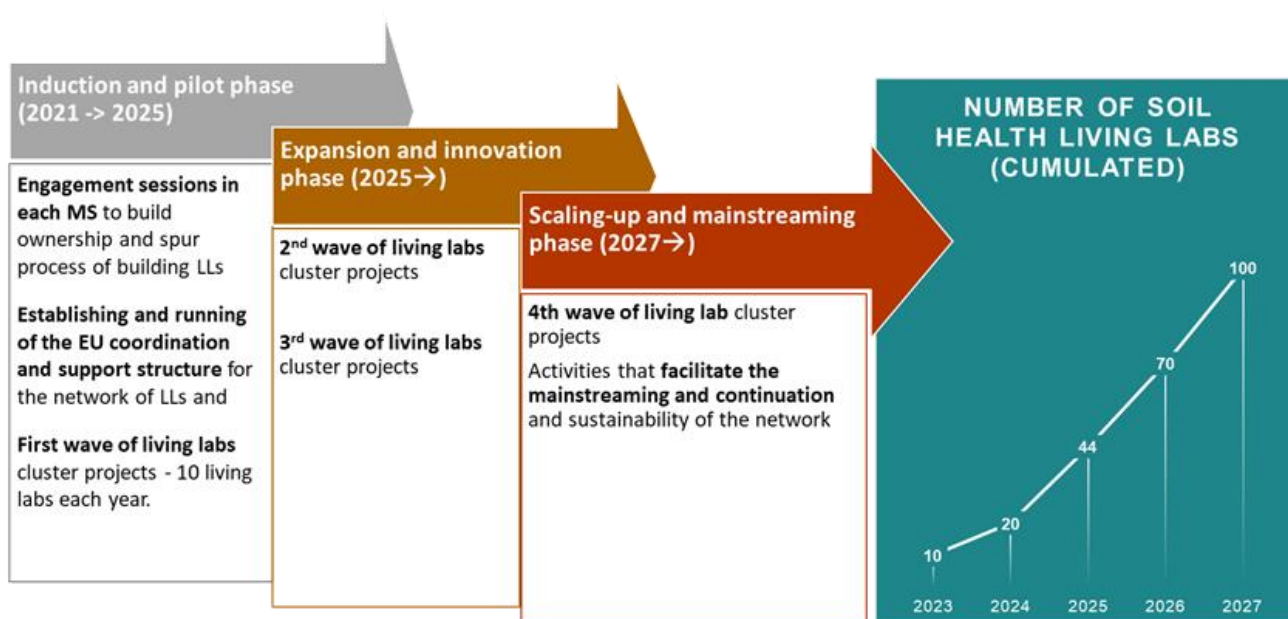


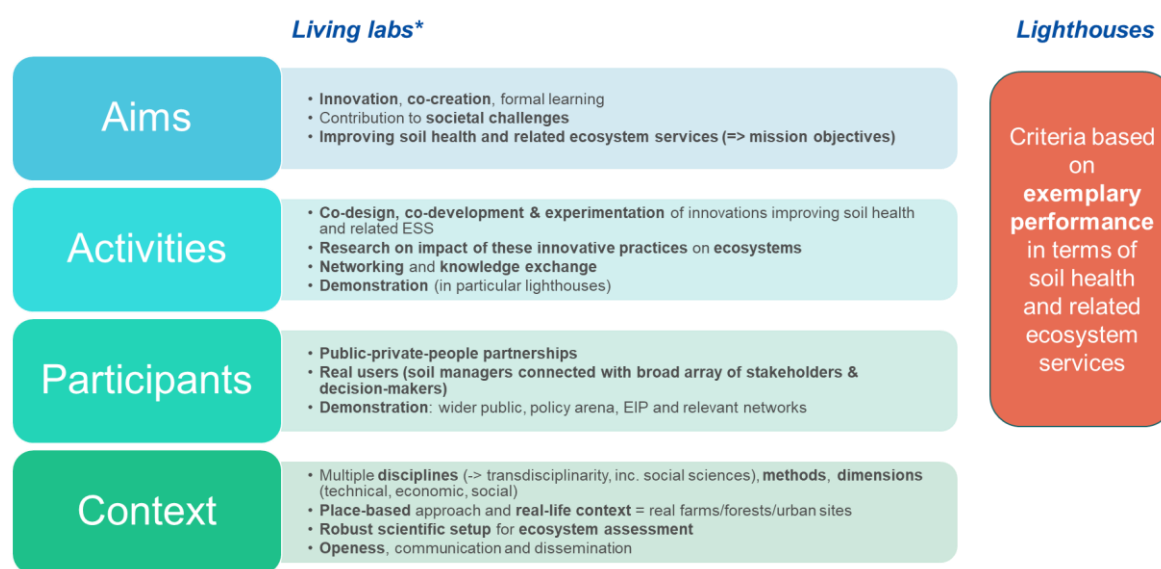
Figure 8. The phases of the creation of the European network of soil health living labs

Mission objectives supported: 1-6 (with indirect contribution to objective 8)

Use of resources: HE mission budget; **cooperation and synergies with** e.g.: EIP AGRI operational groups and LEADER Local action groups funded under EAFRD; HE partnerships in cluster 6; Smart specialisation strategies, interregional partnerships and pilots, European territorial cooperation (INTERREG) and community-led local development (ERDF); Covenant of mayors, Enterprise Europe Network, EITs (Food and Climate), stakeholder networks as mentioned in activity 2.1.

3.2.3. Criteria for selecting individual living labs and lighthouses

The following **new and detailed set of criteria has been developed** specifically for soil health living labs and aligned with the work of the Soil Mission Support (SMS) project, the ALL-READY project based on McPhee et al, (2021)^{xxii} and previous work at ENOLL and G20 level^{xxiii}. The main criteria are represented in the figure below (see detailed criteria in 8.D).



* adapted from McPhee et al. (2021)

Figure 9. Criteria for the selection and set-up of living labs and lighthouses

These criteria imply that living labs supported under the mission would aim at co-creating innovations for soil health and related ecosystem services (e.g. food, climate, biodiversity) and at widening societal involvement to contribute to the achievement of all mission objectives. Their activities should include co-design and development of practices alongside research on the impact of these practices on ecosystems and the various actors at various scales (including economic and social impacts), networking, knowledge exchange and demonstration. **A core criterion for the mission board is that real soil managers should be at the centre of the innovation process and that experimentation and innovation should take place in real conditions** (e.g. on real farms, contaminated sites, degraded peatlands, city parks). Beyond soil managers, the living labs should engage with the local authorities, NGOs, the wider public and the policy arena, the EIP-AGRI network and actors at local sites funded under other Horizon Europe Missions to create synergies and promote good practices. The presence of living labs and lighthouses in a region should also be a key enabler of good citizen engagement activities. The approach taken should be open, place-based, involve multiple disciplines (including a strong role for social and behavioural sciences and arts and humanities), multiple methods, and cover multiple dimensions simultaneously (technical, economic, social, and cultural).

As lighthouses are sites achieving exemplary performance in terms of soil health improvement, criteria for selecting them will be based on the mission objectives, indicators and thresholds as defined by the monitoring programme. While we expect to have at least one lighthouse in every living lab area, activities will allow to enrol lighthouses that are outside living lab areas. They will be included in the activities of the European network of LL and LH and will contribute to enhance territorial coverage.

Living labs and lighthouses will be selected through competitive calls for proposals under Horizon Europe, following in-depth engagement sessions to build stakeholders' understanding and ownership of these criteria.

3.2.4. Outputs and outcomes

Outputs

- **Activity 2.1 and 2.3: 100 living labs created in at least 100 regions** (41% of the EU 242 NUTS2 regions), each living lab being composed of 10-20 individual experimental sites and at least one lighthouse, delivering, for all land-use types (e.g. farm, forest, urban and industrial):
 - Knowledge on socio-economic, cultural and behavioural drivers of the adoption of innovations or beneficial practices (mission objectives 1-6);
 - Tested and validated land or soil management practices with significant soil health improvement and uptake potential (mission objectives 1-6);
 - Practice-proof monitoring technologies and indicators (mission objectives 1-6);
 - Demonstration activities and events on lighthouse and other experimental sites in rural and urban areas (mission objectives 1-6 and 8);
 - Input into research and innovation needs from practitioners and citizens.
- **Activity 2.2: One European soil health living lab and lighthouse network** delivering:
 - Methodological material on how to create living labs, of use to new ones to be created after the mission, and interactive map of all living labs and lighthouses;
 - Knowledge exchange activities on mission objectives 1-6 and 8, for all land-use and soil types, various production systems and biogeographical areas of Europe;
 - Inspirational training and dissemination material to trigger uptake and scaling-up of beneficial practices by land managers in and beyond the living lab areas (objectives 1-6 and 8).

- Insight into factors enabling or hindering transformative change, as input into the reflection on improving the innovation ecosystems around soil health;
- Cooperation and exchange of experience with living labs outside Europe.

Outcomes (All activities)

- Improved **awareness by land managers of soil health challenges** (objectives 1-6) and uptake of innovative solutions in living lab areas and beyond;
- **Measurable improvement of soil health**, at least in the living lab areas, as manifested by criteria developed under the soil health monitoring programme for mission objectives 1-6;
- **Increased social capital** (norms, networks, relations between actors) in **regions where living labs have been developed**, triggering further positive long-term developments in soil health and ecosystem services related domains;
- **Improved citizen awareness in the regions where living labs have been developed** (outcome achieved in cooperation with activities under operational objective 4).

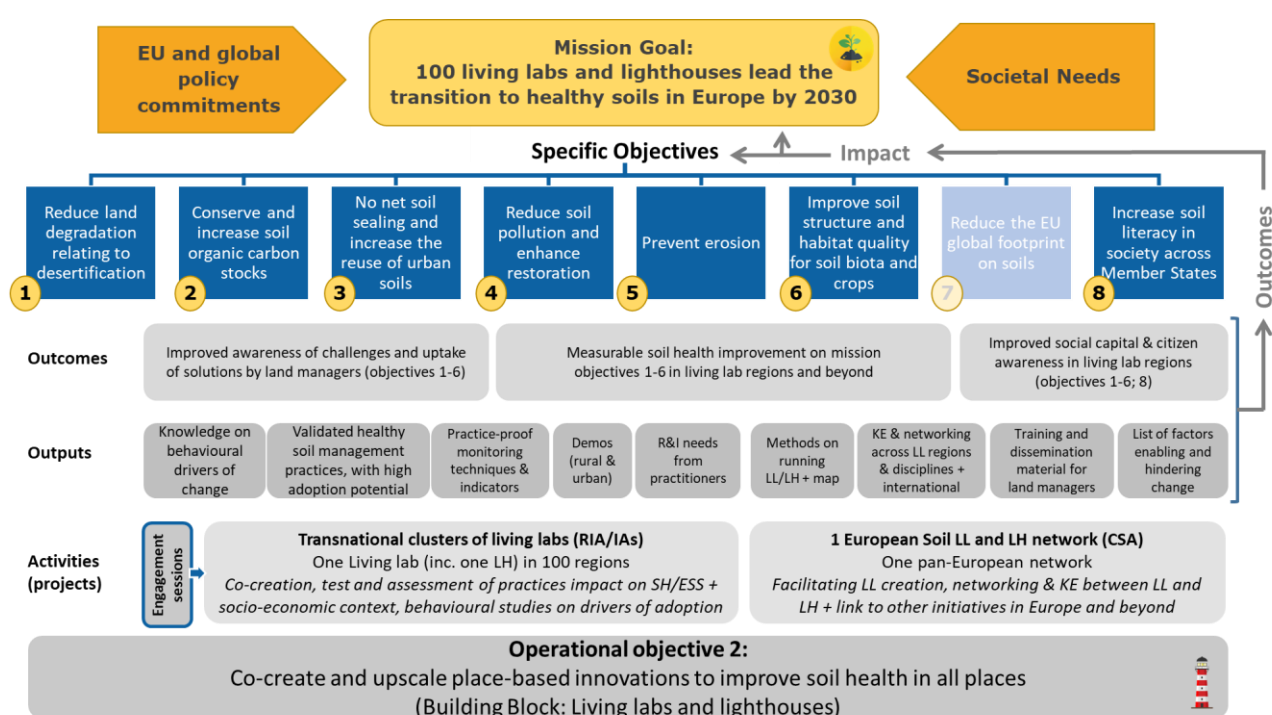


Figure 10. Intervention logic in relation to operational objective 2

3.3. Operational objective 3: Develop an integrated EU soil monitoring system and track progress towards soil health

Activities under this operational objective will be referred to as building block **"Monitoring and indicators"**. They address the urgency to scale up capacities in the EU and in MS/AC to monitor soils and to do so in harmonised way.

3.3.1. Context

Soil health monitoring is a key component of the mission. Demonstrating that health of European soils - as the basis for natural ecosystems, agri-food systems and the circular (bio)economy - is improving, would be a clear indicator of the success of the Mission and the Green Deal policies.

Both the EU and Member States (MS) have soil-related reporting obligations because of several international agreements in which the EU is a party⁴. Still, soil monitoring is not undertaken in a systematic, harmonised way. In contrast to other resources such as water, there is no legal requirement for EU Member States to report on soils. **Current EU wide soil monitoring is hampered by inadequate or inactive soil monitoring programmes in many Member States, which results in a lack of data to assess policy options.** Currently, only 6 or 7 Member States have active soil monitoring programmes. Where data exists, these are often not harmonised or incomplete in spatial, temporal, and thematic terms. While agricultural soils and their topsoil are most commonly sampled, fewer data exist on soils in forests, natural and urban areas with even less data available for deeper subsoils.

A further difficulty is the lack of a widely agreed definition for soil health as a novel concept. For the purpose of the mission soil health is defined as “the continued capacity of soils to support ecosystem services” (see 2.1). There is a lack of agreement around what a healthy soil is, and which indicator thresholds make sense in each soil type, land use and climate context for to support soil functions and services. Finally, exciting new technologies are coming on stream (e.g. proximal and remote sensing) and research into their application for soil monitoring needs to be accelerated so they can be included after robust testing e.g. in Living Labs, into the formal reporting process. The mission addresses all these issues to **ensure a step change in our ability to monitor soils more efficiently and effectively and thus track the impacts of the actions taken and the mission overall.**

Specifically, the mission will explore and exploit **new opportunities for soil monitoring arising from advances in the fields of earth observation, remote sensing, and machine learning including artificial intelligence (AI).** Specifically for satellite capabilities, open and free access to data and tools, and advances in algorithms and data processing offer opportunities for enhancing the use of Earth Observation (EO) in soil health monitoring. A review gathered by the Mission Board, with inputs from the Earth Observation community showed that there are many examples of EO data and products which can integrate soil-health indicators now or in the near future, either for the monitoring of soil properties directly or for monitoring proxies of land management. Many data are now coming from the Copernicus space programme and Sentinel satellites or NASA’s Landsat and MODIS platforms. As to the availability of geospatial and environmental data, further contribution of open data may be provided by the forthcoming Regulation on High Value Datasets, implementing measure to be adopted according to the Open Data Directive^{xxiv}. However, only few EO tools are fully operational regarding measuring the eight proposed soil health indicators. Most tools require the development of specific applications to meet the needs for soil monitoring and as with all EO applications need to be integrated with ongoing ground-truthing.

3.3.2. Activities

Soil data in the EU are gathered by **Member States (where monitoring programmes are active), the JRC, Eurostat, and the EEA.** They will be the main actors in this building block.

The mission will support the process by generating data, filling knowledge gaps and developing more robust methods and tools for soil monitoring as well as for evaluating the effects of soil management measures. It will help to advance further the development of the soil module of LUCAS⁵ and modern measuring and monitoring techniques, including proximal and remote

⁴ e.g. under the UN Sustainable Development Goals (SDGs), UN FCCC, UN CCD and UN CBD

⁵ LUCAS is hosted by the JRC. It is the largest harmonised and regularly updated assessment of topsoil for the entire EU. It has expanded its focus from core soil characteristics (e.g. texture, pH⁺, CEC) to more novel insights on soil biodiversity and pollution.

sensing. It will also provide the infrastructure of real-life living labs (see building block on living labs) to test and validate novel measuring techniques. Together with the EUSO, the mission will help to make data widely accessible to all types of users, also in view of supporting the self-assessment of soil health by land managers and citizens alike.

As a basis for reporting, **the mission proposes to use a set of eight soil health indicators** to assess current status and track change. These indicators will serve as a basis for discussion with Member States. More details can be found under section 8. (Supporting Material B).

- 1) Presence of pollutants, excess nutrients and salts
- 2) Soil organic carbon stock
- 3) Soil structure including soil bulk density and absence of soil sealing and erosion^{xxv}
- 4) Soil biodiversity
- 5) Soil nutrients and acidity (pH)
- 6) Vegetation cover
- 7) Landscape heterogeneity
- 8) Forest cover

Data from Member States programmes and LUCAS will help to populate performance indicators. In addition to these indicators, it is proposed to track management activities as a proxy for soil health. This is particularly relevant for measuring progress towards soil improvement where health indicators are slow to show changes and soil issues are slow to recover. However, whilst this is practical for early monitoring and reporting, the mission board highlights the importance of focusing on the longer term on a thorough monitoring of soil health indicators, the more as management practices may not deliver the intended outcomes.

The connection between all these indicators and the objectives of the mission has been shown in Table 1, and a justification for their selection and some previous applications are presented in section 8.B. Targets and expected ranges to provide benchmarks should be soil-specific showing characteristically different ranges of values for different soil types according to their land use. An unhealthy soil is present if any indicator is below an agreed threshold.

Activity 3.1: Set-up technical support for cooperation on monitoring

Create a mechanism for technical support to coordinate soil monitoring activities, discussions and exchanges between Member States, Associated Countries (AC), the JRC, the EEA and scientists. This technical team to provide oversight for all other monitoring activities and update approaches as new science from R&I activities becomes available (e.g. targets for the soil biome; new sensors, new metrics from EO).

Use of resources: HE mission budget; **Cooperation between:** JRC, EEA, MS, AC

Activity 3.2: Validated indicators and a harmonised reporting structure for soil health

This activity will serve to develop and implement a harmonised reporting structure at EU, national and local levels for soil health to be applied by all Member States and Associated Countries. To develop the structure, MS/AC will agree on a set of indicators (taking the eight indicators proposed by the Mission as a starting point for discussions) and commonly agreed ecosystem types, in which a set of harmonised soil and land use classes with similar properties and sensitivities are defined. MS/AC to assign existing mapped soil types to these classes for harmonised reporting.

Mission objectives supported: 1-6

Use of resources; cooperation and synergies with: MS/AC activities; JRC; EEA

Activity 3.3: Targets and thresholds for indicators of soil health and soil management

Under this activity, targets and thresholds will be proposed for the set of soil health indicators agreed by Member States as a basis for further action. In addition, R&I will result in identifying expected ranges to help benchmark soil health for the agreed set of soil health indicators. Activities will also identify a set of soil health promoting management practices along with targets for their uptake. These management indicators will be used for “provisional” reporting, recognising the fact that it will take time to re-establish national soil monitoring programmes and that response for some soil health indicators will be slow. For example: some indicators respond rapidly with large changes (e.g. erosion) whilst others can be relatively modest and slow (e.g. soil organic carbon). This work will build on that already developed for agricultural soils by the EJP for all ecosystem types. Where robust evidence is not available a logic chain approach can be used to ensure emerging innovative approaches can be adopted.

Mission objectives supported: 1-6

Use of resources: Horizon Europe mission budget; **cooperation and synergies with** e.g.: CAP; MS/AC activities; JRC; EEA

Activity 3.4: Promote national soil health monitoring programmes, integration with LUCAS

Activities will support the reactivation, enhancement or development of national soil health monitoring programmes and their integration with the LUCAS soil monitoring system. Programmes should go beyond agricultural soils (e.g. in support of the Alpine Convention, peatlands) and extend to forestry, urban and nature land and include soils at depth.

Mission objectives supported: 1-6

Use of resources: Horizon Europe mission budget; **cooperation and synergies with** e.g.: MS/AC activities; JRC; EEA

Activity 3.5 Promote citizen science for soil monitoring

Access to soil health monitoring knowledge and infrastructures is crucial for citizens’ and stakeholders’ to understand their impacts on soils and contribute to national soil monitoring efforts. This activity will serve to develop practical guidance and tools (incl. phone apps and online platforms) in all EU languages to each MS/AC in order to enable assessment of soil health by soil users and the wider community through a suite of platforms which support different uses, from individual learning to peer-to-peer learning, to civic and citizen science. There should be clear links to targets and benchmarking developed for national scale reporting. The civic and citizen science level assessments should ideally be able to deliver data to the MS soil health monitoring platforms and the EU Observatory.

Mission objectives supported: 1-6

Use of resources: Horizon Europe mission budget; **cooperation and synergies with** e.g.: MS/AC activities; JRC; EEA; of grass root organisations and organisations involved in citizen science.

Activity 3.6: Data integration across mission activities and integration of data with EU Soil Observatory

This activity will support the efficient and timely delivery of data from national monitoring programmes into the EU Soil Observatory and their integration with data streams from LUCAS. It will include methods to capture data from citizen science and new EO data streams. It will also allow a robust testing of new data streams emerging from new soil health monitoring technologies testing their compatibility with existing approaches and developing approaches for their adoption where this will increase efficiency and effectiveness of soil health monitoring. Novel integrated data streams and products (e.g. from EO) will be created through the combination of national soil monitoring data with other data streams to create accessible and robust soil health data and products for re-use.

Mission objectives supported: 1-8

Use of resources: Horizon Europe mission budget; **cooperation and synergies with** e.g.: MS/AC activities; JRC; EEA

Activity 3.7: Develop a harmonised Soil Health Report and EU Soil Health Certificate

Develop a harmonised Soil Health Report in each MS that establishes soil state and change and thereby provides a mechanism for tracking progress towards meeting the mission goal and objectives. These reports to be used to underpin a MS and EU Soil Health Certificate that provides rapid and accessible confirmation of good soil practice. In developing the certificate, the approach will be to align and enable re-use of data for multiple reporting requirements (e.g. EEA State of the Environment Report, Eurostat, Agri-Environment indicators) including those under development as part of the Green Deal (Biodiversity and Soil Thematic Strategy, Zero Pollution Action Plan, Farm to Fork Strategy and Circular Economy Action Plan etc.), building on INSPIRE principles. The certificate may be extended to meet the requirements for a soil passport for excavated soils.

Mission objectives supported: 1-6

Use of resources: Horizon Europe mission budget; **cooperation and synergies with** e.g.: MS/AC activities; JRC; EEA, Earth observation programmes

Activity 3.8: Develop robust approach to track the EU's global soil footprint

Activities will serve to develop a robust approach to track MS and EU's global soil footprint, i.e. measure the impacts of demands on soil and their capacity to deliver the resulting functions (including plant-based food and fiber products, livestock, timber, absorb waste, and mitigate carbon emissions). Such a footprint would ensure that improvements in soil stewardship for the EU do not simply result in an export of degradation beyond its borders. The footprint should be included in the reporting structure of ongoing progress to meeting the mission goal by reporting at a range of scales (continent, individual countries, eventually regions) and by activity. This work could follow The Ecological Footprints Standards 2009^{xxvi} ensuring compatibility with other sustainability footprint assessments and products (e.g. one could envisage Soil Balance Sheets or a Soil Footprint Explorer) but go beyond the traditional focus on managed land. The global soil footprint could become a vital communication tool for citizen engagement and consumer education.

Mission objectives supported: 8

Use of resources: Horizon Europe mission budget; **synergies and cooperation with** e.g.: Global Soil Partnership, International Consortium on Soil Carbon Sequestration; EU DeSIRA programme, Leap4fnssa

3.3.3. Innovation hotspots

The mission will advance monitoring of soils across Europe with regard to the agreed soil health indicators. It will particularly promote innovations in strategic areas including:

- methods for assessment of soil health by practitioners (e.g. farmers, foresters, gardeners, urban planners) and citizens;
- development of (digital) “soil health certificates” and labelling schemes to reward soil friendly practices and products (e.g. regenerative practices);
- integration of citizen science and crowd sourced data into monitoring systems, especially multimedia and data coming from real life testing in living labs and lighthouses;
- soil carbon stock monitoring: this is an area of high political relevance with numerous on-going initiatives. The mission will provide the coordinating framework for pooling R&I results and facilitating international cooperation;
- generating data linked to models to support the development of a dynamic Soil Digital Twin under Destination Earth;
- EO from airborne systems (including planes and drones) and other proximal sensing systems.

3.3.4. Outputs and outcomes

Outputs

- Harmonised methods, targets and thresholds for each soil indicator integrating with current LUCAS and Member States (MS) soil programmes;
- Harmonised reporting structure for soil monitoring in EU MS and Associated Countries (AC);
- Agreed management activities for each region. These will serve as management indicators for soil health for early reporting on all mission objectives;
- Interoperable soil data across EU MS and AC and provision of data into accessible open data platforms and the EU Soil Observatory;
- Soil health certificate; labelling schemes promoting soil health and PES (Payment for Ecosystem Services);
- Cost-effective and engaging methods and tools for (self)-assessing soil health and improved Knowledge and Information Systems;
- Methodology for defining the global soil footprint of our import-export trade balance for food, timber and biomass.

Outcomes

- MS have active soil monitoring programmes, can track progress towards mission objectives and can take (corrective) measures based on a sound evidence base;
- Land managers, businesses and consumers are engaged in assessing and promoting soil health and can make informed choices;
- Improved capacities for soil protection in the EU without exporting soil footprint globally;
- Mainstreaming of a robust soil evidence into all EU reporting and decision making through delivery of harmonised, robust, continually updated soil data platforms.



Figure 11. Intervention logic in relation to operational objective 3

3.4. Operational objective 4: Engage with the soil user community and society at large

Activities under this operational objective will be referred to as building block **“Soil literacy, communication and citizen engagement”**. They address the identified lack of awareness on the importance of soils and the need for more targeted advice and education in the area.

3.4.1. Context

The success of the mission depends on action being taken by citizens at all levels. However, the lack of soil literacy is a barrier to achieving soil health improvements. By soil literacy we mean both a popular awareness about the importance of soil, and specialised and practice-oriented knowledge related to achieving soil health. Under this building block, the mission will act to enhance awareness of the societal role of soils, to ensure access to soil health education and training, to strengthen citizen participation in soil and land-oriented activities, and to reward best practices.

To change societies’ behaviour around soils, **people’s awareness of the societal role and value of soils will be enhanced**. Communication activities throughout the mission should bring soils, as well as soil research and innovation, closer to the lives of citizens to trigger action and involvement. To value soils, people need more than to receive scientific information about them. Instead, it is crucial to start from people’s existing practices, values, and concerns.

Citizen engagement in identifying and addressing soil literacy needs is therefore key, and represents a key novelty of the mission’s approach. It will allow the mission to create effective messaging and design targeted actions which highlight and activate the link between citizen’s lives and soil health. While some messages may be widely applicable (e.g. soils underpinning achievement of physical and mental health, beautiful and healthy landscapes, good quality food), action on soil should also be linked with specific and locally relevant concerns.

To act on soil health, citizens must have access to both general and tailored education and training covering the different types and uses of soil. In addition to enhancing formal soil education, best practices sharing, practitioner-led research, and peer-to-peer knowledge

exchange will be key. The mission will improve access to information for all, assure adequate access to appropriately skilled advisory services, and make full use of new opportunities for education arising from digitisation.



Photo 1. Arianna Pasa © Salon de l'Agriculture 2020

Schools, training institutions and universities will play a key role in the green transition by engaging with pupils, teachers, parents, and the wider community on the changes needed for a successful transition. The mission can rely on the Education for Climate Coalition, a flagship initiative of the European Education Area implemented jointly by DG EAC and the JRC, which will mobilise available expertise, commitment and networks in education across the Member States and support the creation, testing and implementation of innovative solutions with pupils and school communities. By focusing on climate change education, which necessarily requires dedicated attention to soils, it will help the education

communities to focus on transformative adaptation and support innovation towards climate-neutrality, particularly in relation to skills development and behavioural change.

Creating effective and societally desirable ways of changing land use to achieve soil health outcomes will necessarily be **locally specific, and dynamic. Co-design, co-implementation and co-assessment of both problems and solutions is encouraged to make them more aligned with societal needs, values and expectations and ensure longevity.**

This will be achieved by enabling citizen participation in soil and land related activities on multiple levels, and via multiple routes (including local and regional governance, citizens' organisations, and citizen science). Further, citizens' and stakeholders' learning and awareness will be enhanced through access to soil health monitoring. The academic community should also see greater incentives to involve stakeholders and citizens in research throughout, and especially in relation to identifying research needs and delivering research activities (not just involving citizens as recipients at the end of the 'research pipeline').

3.4.2. Activities

The mission will, enable the EU, Member States and associated countries to understand the current levels of awareness and engagement with the mission's objectives. It will then enhance soil literacy in Member States and associated countries through a programme of multi-level actions on communication, education, and engagement, in synergy with the activities around R&I, living labs and lighthouses, and monitoring. Communication and citizen engagement strategies will be developed at the EU, national and regional levels. By improving awareness, expertise, communication, and engagement around soils, the mission will build collaboration between communities and stakeholders to achieve the mission's objectives. Direct involvement of citizens, communities and stakeholders in measures for soil protection and restoration is essential to trigger behavioural changes and the adoption of sustainable practices both at individual and collective levels. The following activities represent a core set of priorities that will be expanded depending on additional needs identified in the induction and pilot phase.

Activity 4.1: Foster soil education across society

This activity will allow to:

- Gain an understanding of the current state of soil education in school curricula at all levels, and monitor changes;

- Identify, map, and amplify good practices, including hands-on education (school gardens, vegetable gardens, composting spaces, digital tools);
- Co-develop with Member States and stakeholders (including schools) educational tool-kits and undertake outreach activities;
- Deliver an accessible and continuously developed soil education, communication and engagement 'best of resources' repository at EU level and in each Member State, including high-quality curricula co-developed with schools and educational authorities at the different levels.

Mission objectives supported: 8

Use of resources: Horizon Europe mission budget; **cooperation and synergies with e.g.:** EU Education for Climate Coalition, EJP Soil, MSs and ACs

Activity 4.2: Engage with and activate municipalities and regions to design their own strategies and actions for the protection of soil health

Engage with and activate municipalities and regions to design their own strategies and actions for the protection of soils in line with the mission objectives. The mission should support regional and local authorities to: i) identify and mobilise relevant actors (including civil society organisations, market actors, and research institutions), ii) create spaces and practices for a dialogue on soil health challenges, including creating a shared understanding of the nature of the challenges (both bio-physical and socio-economic dimensions), co-creation of public, private, and policy solutions, and a wide support for and participation in the solutions, iii) enhance knowledge sharing among municipalities and regions on best practice processes and outcomes. To be developed in synergy with activities under objective 2.

Mission objectives supported: 8

Use of resources: Horizon Europe mission budget; **cooperation and synergies with e.g.:** ENRD, Committee of the Regions, regional and local authorities

Activity 4.3: Engage with the private sector and consumers to embed soil health in business practices

This action aims at creating a network of companies and businesses, which operate in the EU, developing strategies for valorising soils in their production, supply chains, and consumer relations. The network enables peer-to-peer learning to produce a step-change in business culture and practice, to better shape policies and market incentives which produce soil health outcomes, and to enhance consumer engagement with soil health, while strengthening existing fora. To be developed in synergy with business oriented actions under the R&I operational objective.

Mission objectives supported: 1-6, 8

Use of resources: Horizon Europe mission budget

Activity 4.4: Strengthen soil health advice and improve access to training for practitioners in line with Agricultural Knowledge and Innovation Systems (AKIS)

The purpose of this action is to:

- Identify, map, and connect land managers (in relation to all land uses), AKIS communities working on soil health related practices, research bodies, and advisory services as well as produce a trans-national resources for peer-to-peer online learning and a series of engagement events to enhance bottom-up action on soil health. This will enhance peer-to-peer knowledge exchange, support the transformation of farming cultures towards soil

health, enable better connectivity with research communities, and encourage farmer-driven experimentation with soil health oriented land management methods. In addition it will increase training opportunities for advisory services. This action will be implemented in synergy with actions associated with living labs and lighthouses, and will create a broad and wide engagement with soil health to a) lower barriers to engagement and action for a large number of actors and b) to upskill farmers and advisors.

Mission objectives supported: 1-6, 8

Use of resources: Horizon Europe mission budget; **cooperation and synergies with e.g.:** EIP AGRI, AKIS, European network of agricultural advisors

Activity 4.5: Create citizen-led soil stewardship

This action recognises that everyone has the potential to become a soil steward, but that citizens' existing relations with soils are often unacknowledged. This action addresses the need to better understand how to create a positive relationship between citizen's practices and soil health outcomes. It i) identifies existing practices in rural and urban areas which link citizens with soils, ii) maps and connects civil society groups whose existing activities can be extended to include action on soils (e.g. environmental conservation groups, urban food initiatives and growing associations, city greening initiatives), iii) co-develops resources and strategies for amplifying the awareness of the value of soils and action on soils in relation to citizens' existing practices through a network of projects iv) form Mission Ambassadors to increase awareness at the local level, and enhance the knowledge of soil-related activists v) where possible, involve citizens in public decision-making on soil-related matters through participatory and deliberative democracy.

Mission objectives supported: 8

Use of resources: Horizon Europe mission budget; **cooperation and synergies with e.g.:** citizen science and soil networks and initiatives, Climate Pact Ambassadors

Activity 4.6: Bring soil closer to citizens' values

Arts and humanities provide methodologies for investigating the ways in which soils intersect with societies, and for engaging citizens with soils in multiple ways. This action creates a network of art and humanities projects, involving also creative industries, in order to elevate the importance and value of soils in the context of citizen's lives.

Activities will help to amplify the relevance of soils in people's daily lives in original, participatory, and engaging ways (e.g. by applying arts-based methods for transformative engagement) by highlighting the dependence of people's existing valued practices and experiences on soil health, and by demonstrating how healthy soils can enrich life experiences. This action has the potential to work in synergy with the New European Bauhaus initiative.

Mission objectives supported: 8

Use of resources: Horizon Europe mission budget; **cooperation and synergies with e.g.:** New European Bauhaus initiative

3.4.3. Communication hotspots

By starting engagement on the mission's objectives from citizen's real and locally-relevant concerns, the mission "brings Europe closer to its citizens". There are a number of exemplar initiatives that the mission is exploring for potential scaling up, such as:

- supporting agri-food companies to improve their soil health performance by creating tailored advice for their producers and developing strategies for embedding soil health in the supply chain (e.g. Earthworm Foundation, Future Food Solutions);

- national digital hubs bringing together the best information and communication on soils, and creating a forum for knowledge exchange (e.g. ELSA – The Alpine Soils Platform, UKSoils.org);
- co-designing a locally specific soil monitoring protocol with local growers (e.g. Good Food Brussels);
- an app and an online platform which was co-designed with farmers to support them to monitor and record the health of their soils and enable digital peer-to-peer learning (e.g. Soilmentor);
- an annual conference bringing together farmers to discuss soil health and exchange peer-to-peer learning (e.g. Groundswell);
- citizen science projects on soil health (e.g. OPAL);
- online courses to increase awareness on the importance of soil and its contribution to life on Earth (e.g. WWF One Planet School “Suolo: la pelle della Terra”);
- successful LIFE projects (e.g. Soil4Life).

3.4.4. Outputs and outcomes

Outputs

- A baseline understanding of the state of soil related education and training in the EU (in schools and amongst key stakeholder groups), and a baseline understanding of the levels of soil awareness and valuation amongst citizens;
- A ‘best of resources’ repository on soil communication, education, and engagement with high-quality materials oriented at different target groups, including accessible and continuously developed educational resources at EU level and in each MSs, and a network of Mission Ambassadors to enhance engagement;
- A network of municipalities and regions pursuing citizen-identified soil related objectives, engaged in peer-to-peer learning on delivering inclusive, effective, and impactful soil and land citizen engagement;
- A network of companies and businesses, which operate in the EU, developing strategies for valorising of soils in their production and supply chains, producing a step-change in business culture and practice (see also section on business engagement);
- An EU-level network composed of independent advisory services, farming groups, and research communities enhancing access to soil health training and education through peer-to-peer learning;
- A network of projects and resources, co-developed with citizens and stakeholders, developing strategies for amplifying the awareness of the value of soils and action on soils in relation to citizens’ and stakeholders’ existing practices;
- A programme of art-science-society events and products which valorise soils as part of a good and healthy life in diverse geographies and contexts.

Outcomes

- Improved awareness of the societal role and value of soil amongst EU citizens, including in key stakeholder groups, and policymakers;
- Embedding of soil health in educational curricula at all levels, to enable citizens’ behavioural change towards the adoption of sustainable practices both individually and collectively;
- Improved involvement of citizens in soil and land-related issues at all levels;
- Practitioners and stakeholders have access to appropriate information and training to improve skills and to support the adoption of sustainable land management practices.

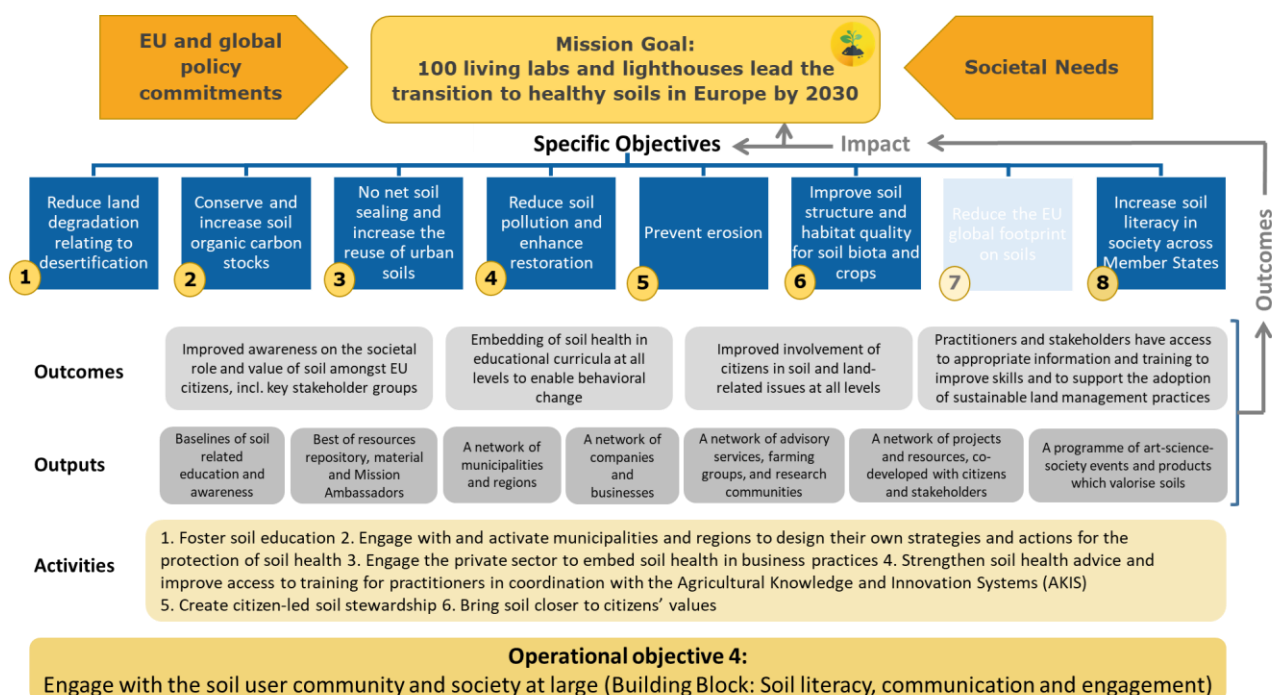


Figure 12. Intervention logic in relation to operational objective 4

3.5. The mission's cross-cutting dimensions

The following four cross-cutting dimensions are reflected across mission activities.

3.5.1. The business dimension

Involvement of the private sector and consumers is key to address drivers of soil health such as production methods in agriculture and forestry (e.g. the use of pesticides and fertilisers, monocultures, heavy machinery, irrigation), practices in food and other industries (e.g. microplastics from food packaging and clothing) or consumption habits. The food, beverage and textile industries for example are increasingly recognising the need to preserve soils as the very basis of their activities. Still, soil is missing from corporate environmental reporting standards, such as those of the Global Reporting Initiative (GRI).

A number of mostly regional initiatives are rapidly emerging involving farmers, (food) industries and retailers, working together to develop value chains with a low(er) soil footprint and to make sustainable soil management profitable for farmers and businesses alike. Also, certification and carbon-off setting schemes are developing and supporting the creation of a dynamic market place for investments into the various services provided by soils.

Investment in soils is a long-term endeavour. A supportive environment is therefore needed that encourages the private sector to take a longer perspective in its operations and investments. Through its R&I and monitoring activities, the mission will help to establish soil health as an operational concept which can be measured, valued, certified and tracked to support investments and the development of markets for products, services and value chains with a lower soil footprint. R&I activities will also support the development of business and finance models for soil health and the blending of financial instruments to address major investment needs, for instance, for the restoration of contaminated sites. Living labs and lighthouses under the mission will provide ample opportunities for business to work together with land managers, advisors and other stakeholders to test and establish soil health techniques. Land managers and advisors will also benefit from improved access to training and information supported under building block "Soil literacy, communication and engagement". Targeted communication campaigns and wider societal engagement under the mission will increase consumers' and citizens' awareness and

valuing of soil health and a better involvement of businesses will increase the availability of products based on sustainable soil practices.

A first exploratory business roundtable took place on 5 May 2021 with the participation of representatives from more than 20 organisations from food and beverage industries, business associations, finance and soil service “brokers”. The meeting served to hear the businesses expectations regarding the mission and how they could get involved. As the mission evolves, it is foreseen to establish a more structured dialogue with the private and financial sector. The mission will finance specific advice and more specific business round-tables. In addition to the European Investment Bank (EIB), the EITs will have an important role to play in developing an ecosystems for business opportunities to protect and restore soils.

3.5.2. The digital dimension

Digital technologies (DTs) are revolutionising society, and the soil mission is well placed to contribute to the digital transformation of agri-food systems, the (bio)economy, value chains and of communities overall. The mission recognises that DTs can play multiple roles in relation to different societal objectives linked with improving the health of soils. DTs enable citizens, stakeholders, and researchers to create, communicate, and store soil health related data and information, as well as to mobilise data and information for specific purposes. Consequently, DTs can further improve already existing soil health-oriented practices and policies.

A wide-spread uptake of DTs would further enable ongoing, society-wide soil health learning through tools such as apps, digital civic science projects, online learning and peer-to-peer platforms, and digital information hubs. DTs can also enhance the connectivity between citizens, researchers, policy actors, and other stakeholders. The Pact for Skills can be used to support wider societal uptake of digital skills, for example by supporting specialised education and training to land managers and soil advisors. In addition to supporting these uses of DTs, the mission also aims to address the lack of soil data standardisation (e.g. satellite data with sensor-based field data and laboratory soil data), which is needed to strengthen data-driven land management and soil monitoring solutions.

The Soil mission will contribute to the ambitions of the European Strategy for data while creating synergies with other initiatives under the Digital Europe Programme. It will contribute to the Digital Innovation Hubs, especially in the field of agri-food, for example by deploying the Internet of Things applications in precision farming to better tailor them to soil health. It will supplement the activities carried out under the Testing and Experimentation Facilities (TEFs) for AI in agri-food through fostering R&I excellence in robotic applications. By bringing these AI-powered technologies closer to the market and offering independent testing and experimentation services, the TEFs will provide an important contribution to the soil health mission. The TEFs will benefit from the lessons learned by living labs earlier in the innovation lifecycle, fostering R&I excellence in AI-powered applications. The Mission will also contribute to other initiatives in the field of soil and agricultural data specifically, such as the development of the Farm Sustainability Data Network (FSDN)^{xxvii}, which has been announced in the Farm to Fork Strategy and which will evolve from the Farm Data Accountancy Network (FADN)^{xxviii}. It will also develop pathways for feeding standardised data into decision support tools such as the Farm Sustainability Tool for Nutrient management (FaST), which is proposed to form an inherent part of the CAP post 2020^{xxix}. Synergies will be also sought with the Horizon Europe Candidate Partnership Agriculture of Data. The mission will contribute to Destination Earth by providing the data to improve its modelling capacity of soil related processes with the aim to build, in co-design across Commission services and Destination Earth, a digital soil twin as a candidate of digital twin developments in the next programming round.

Data and knowledge on soil status and its changes will feed directly into the recently launched European Soil Observatory. The mission is expected to generate Big Data sets through citizen

science programmes, and provide input to data spaces and a data pools, e.g. for innovative SMEs and start-ups, to boost the data economy, and sustainable production, in agriculture, forestry, food and bio-based industries.

3.5.3. The territorial dimension

The Soil mission will contribute to sustainable land and soil management in line with the ambitions of the Territorial Agenda 2030, which makes several references to the importance of soils for the future of all places, and the upcoming long-term vision for rural areas, in which the Soil mission is proposed as a flagship under the resilience pillar. Healthy soils are the basis for production in agriculture and forestry and support the development of dynamic food and non-food businesses and value chains. For example, the food and drink industry is the largest manufacturing sector in the EU economy employing directly 4.25 million workers and processing 70% of EU agricultural production.

Healthy soils also support a range of ecosystems services and are therefore critical to the provision of public goods by rural areas such as clean water, biodiversity, green spaces for citizens. Furthermore, soil management is at the centre of efforts in rural areas to progress towards becoming the first net-zero greenhouse gas emission continent by 2050. Through its support to building a circular economy and by helping industries to achieve climate neutrality (for example, by counterbalancing greenhouse gas emissions from industries through soil carbon sequestration in soils) the mission addresses the objectives of the Industrial Strategy.

Overall, the mission contributes to achieving three of the five objectives of the new regional policy: “Smarter Europe” thanks to its focus on innovation and the prominent place of agri-food in regional smart specialisation strategies (75% of regions have innovation priorities in agri-food), a “Greener Europe” thanks to its high relevance to environmental objectives, and “Europe closer to citizens” by engaging citizens in innovative community-led initiatives favouring soil health in urban, semi-dense or rural areas, in particular in the context of the living labs that the mission will set up, with numerous possibilities for the regions to play a leading role, build synergies with the activities under smart specialisation strategies and even upgrade these strategies to make them more prone to enhancing soil health.

In doing so, it will connect with the New European Bauhaus (NEB) movement and its vision to integrate the built and natural environment in new ways, with citizens as drivers of the process. Structures for citizen engagement established by the soil mission such as living labs and lighthouses in rural and urban areas, as well as the development of new ways to value soils in society, will be a major asset for the NEB project.

The mission will contribute to the EU’s post coronavirus recovery package and investment plan, amongst others through its synergies with major initiatives for soil decontamination, reducing soil sealing, reusing organic waste and supporting carbon farming.

3.5.4. The international dimension

Soil health is a pressing global issue that sits at the heart of three UN conventions (UNCBD, UNCCD, and UNFCCC) and of the SDGs. With the proposed mission, the EU is setting a clear signal to take the lead in halting land degradation by protecting and restoring soils and the ecosystems services supported by soils. It will move forward the alignment of the soil health concept at international level and the reduction of its global soil footprint from food and timber imports.

International cooperation will be particularly channelled through the R&I and monitoring building blocks and will capitalise on existing international R&I initiatives and partnerships, as shown in the following examples .

The mission will work with Africa through the partnership **Food and Nutrition Security and Sustainable Agriculture (FNSSA)** under the High-Level Policy Dialogue (HLPD) on Science Technology and Innovation between the EU and the Africa Union. The partnership recognises that soil health is at the heart of sustainable and resilient food systems and will harness ongoing projects on soil research (e.g. Soils4Africa, LEAP4FNSSA) to harmonise international approaches to monitoring, build technical and human capacity building and identify investment opportunities around soil health. At the official launch of the Advisory Group on R&I for Africa-Europe Cooperation, the experts working on the 'green transition' topic highlighted that soil security is at the heart of Africa's green transition. Concrete actions were identified, among which where the creation of Living Labs/Lighthouses, following the European model.

Art. 185 **PRIMA** is an R&I partnership which aims to develop solutions for sustainable management of water and agri-food systems in the Mediterranean basin. PRIMA partners have raised the need to "avoid further degradation and to support the restoration of already degraded lands in Southern Mediterranean countries". Future actions under PRIMA will contribute to the Soil mission objectives, participating in communication activities and building synergies with living labs and lighthouses to align with those of the mission.

Cooperation with Latin America and the Caribbean will be pursued under the **EU-CELAC partnership**, as reflected in its 2021-2023 Strategic Roadmap for the implementation of the Brussels Declaration and EU-CELAC Action Plan on Science, Technology and Innovation: "The Participants underlined the importance of research and innovation on sustainable agriculture and the bioeconomy and circular economy... and took note of the efforts envisaged under the Horizon Europe programme in the framework of its proposed Mission on Soils."

Japan, has already expressed an interest in collaborating with EU in the Horizon Europe Missions in particular in the Soil mission, and would like to explore synergies and complementarities with the Japanese research and innovation programme Moonshoot, in particular objectives 4 and 5, in relation to soil health and food.

Canada, has already contributed with sound experience to the design of living labs under the mission, being a key actor also in the preparatory work under the candidate partnership on agroecology living labs and research infrastructures. It will continue to be a valuable partner under the mission. Further R&I bilateral collaboration and alignment of activities in relation to the mission are requested by Canada.

The mission will be a major vehicle to support the cooperation with the **Food and Agriculture Organisation of the United Nations (FAO)**, in particular under its **Global Soil Partnership**, as confirmed at a recent meeting (on 14 April 2021) with the FAO Chief Scientist and her cabinet. The Global Soil Partnership will benefit from a harmonised framework for measuring and exchanging data on soils and from the mission's efforts to build a future International Research Consortium on soil carbon. The mission will also actively contribute to newly launched initiatives by the FAO such as the Global Soil Biodiversity Observatory and its technical Network of Soil Biodiversity as well as the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity.

Similarly, the mission will be a driver for Member States' contribution to the **4per1000 initiative** launched 2015 at the COP 21 with the aim to increase the contribution of agriculture to climate mitigation efforts^{xxx}.

An **International Research Consortium (IRC)**⁶ will be established on soil and carbon with the aim to steer R&I cooperation at the **global level**. Global cooperation on soil and climate change

⁶ IRCs are a flexible instrument which allows coordination of global efforts in specific areas. For instance the STAR-IDAZ IRC, which is supported by the EU, on animal diseases was launched in 2016.

will also be sought through the Global Research Alliance on Agricultural Greenhouse Gases (the GRA) of which the European Commission is an official partner.

4. Mission specific governance

In line with the governance established in the Horizon Europe implementing rules^{xxxi}, the mission will be implemented as a truly cross-Commission undertaking. The buy-in of all Commission services to the mission is therefore essential.

The Mission Manager (Directorate General for Agriculture and Rural Development) and the Deputy Mission Manager (Directorate General for Research and Innovation) will ensure coordination and implementation of activities and act as mission Ambassadors within and outside the Commission. The Commission's mission secretariat at DG AGRI will oversee the day-to-day management of the mission, in close cooperation with the Mission Owner Group, i.e. the various DGs involved in the mission. The Research Executive Agency (REA) will manage the Horizon Europe mission project portfolio. Member States and Associated Countries will be regularly consulted and will approve mission work programmes via the Horizon Europe Programme Committee. A Mission Board will advise the Commission throughout all the phases of mission implementation (e.g. Work Programmes and the development of the mission's project portfolio).

4.1. Coordination and implementation structures

In addition to the overall mission governance, the mission foresees to set-up **specific support structures to prepare, coordinate and monitor the wealth of activities in Member States, regions and across sectors**. These structures include amongst others:

- an EU support structure for the network of soil health living labs and lighthouses that will:
 - prepare the ground at regional and local level for the setting-up of LLs and LHs;
 - undertake networking activities and interface with other relevant activities such as the EJP Soil, EIP AGRI, other missions and partnerships;
 - make use of regional and national structures established under the CAP including the European Network for Rural Development. This will support the mainstreaming and sustainability of mission activities well beyond the Horizon Europe funding period;
- knowledge and data hub to synthesise, process and make accessible outcomes of R&I activities to various target audiences;
- a soil monitoring mechanism to support national and EU capabilities in this area;
- a finance assistance and advice facility for SMEs and impact driven "soil investors". Banks and intermediaries will develop sound business cases and blended finance opportunities for investors. Together with instruments such as EIT KICs or the Smart Agri Platform, the finance assistance facility will support SMEs in developing products and creating markets for soil health innovations;
- a stakeholder innovation group acting as a wider steering and sounding board, similar to the EIP AGRI's Innovation Sub-Group and representing e.g. land managers, businesses, public administrations, farm advisory bodies, civil society organisations etc.

4.2. Selection criteria/methodology for key implementing partners

The proposed structures will be mainly funded under Horizon Europe. The entities responsible for implementation will be selected in a competitive manner based on calls under Horizon Europe Work Programmes and/or through Direct Actions and/or public procurement.

With regard to the finance assistance and advice facility, discussions are foreseen with institutions which have experience in the rapidly growing field of impact financing. Members of the stakeholder innovation group will be selected following a call for interest.

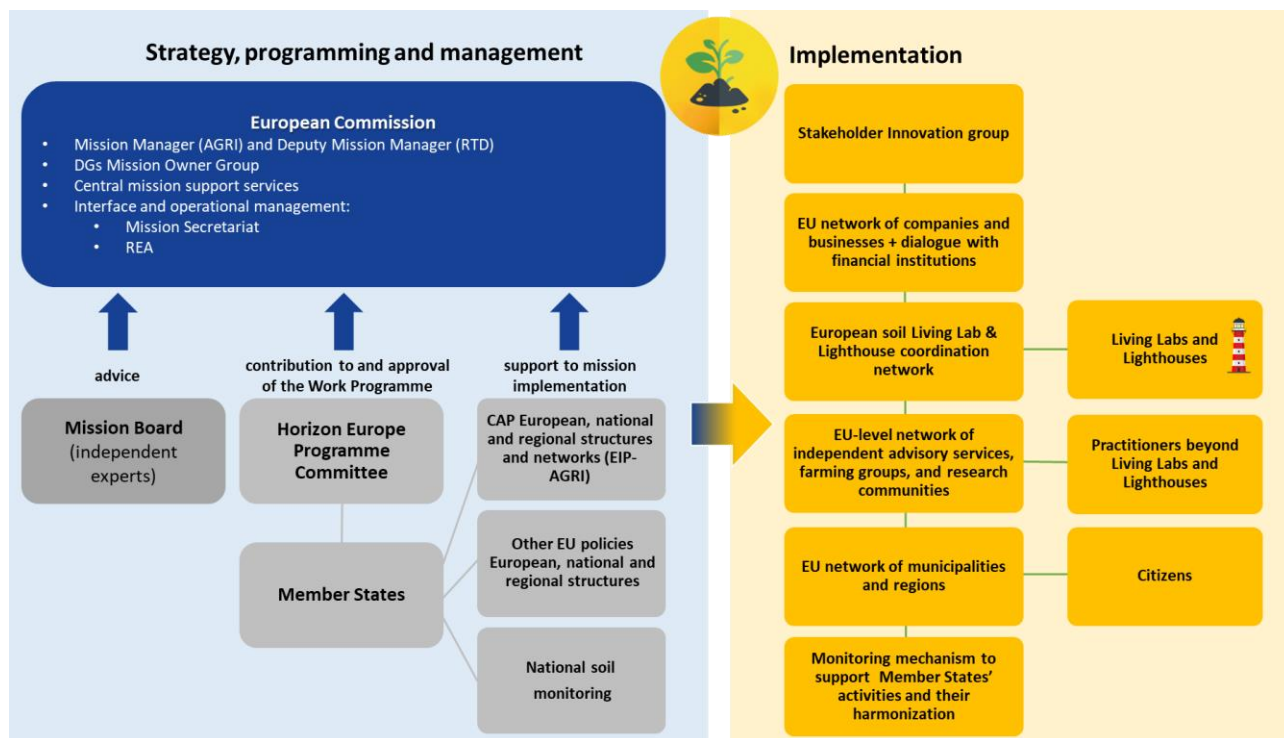


Figure 13. The Mission's governance: structures and actors for strategy, programming and implementation

5. Budget, funding, synergies and investment opportunities

Public support to the mission "soil health" will be organised around three main components⁷:

- First component: investments to be made from the mission's budget under Horizon Europe;
- Second component: support to be provided by the various parts of the Common Agricultural Policy (CAP). The variety of instruments of the CAP and their potential impact on agricultural and forestry soil health and downstream pollution prevention control justify a detailed depiction;
- Third component: EU and Member States' potential for investments in the mission area, be they in the form of grants or subsidies or financial instruments (FIs)⁸.

5.1. Horizon Europe financial investment plan

Horizon Europe investments will be organised around the main building blocks of the soil mission. The first one – the R&I programme will finance the establishment of knowledge infrastructures and platforms and will advance knowledge on soil health objectives. It will also aim to accelerate innovation and will include a component on cooperation at the global level. The second building block– the living labs and lighthouses –will be allocated a budget share of about 40% (see Table 2), reflecting that co-creation in the field will be a cornerstone of the mission. Investments in this building block will increase from the induction and pilot phase to the scaling up and

⁷ Preparation of this section has benefited from exploratory discussions with the European Investment Bank (EIB).

⁸ Loans, guarantees, equity, quasi-equity, etc.

mainstreaming phase and potential development of additional living labs will be sought from other funding sources (see also section 3).

A dedicated budget for monitoring (Building Block 3) will serve to develop the next generation monitoring system of soil health to track progress towards the mission's objectives. Training, communication and citizen engagement will be allocated a specific budget, supporting the capacity building which is necessary for the success of the mission in the medium to long term. A minor part of the budget will cater for support structures and governance of the mission.

The mission will benefit from the EIB Innovation Finance Advisory service as part of the InvestEU Advisory Hub. However, Horizon Europe mission's budget will also be used to obtain tailored access to this advisory function, with a view to develop a comprehensive and robust financial strategy of the mission and to ensure its scaling up beyond R&I and the mobilisation of EU and Member State financial instruments (e.g. EARDF of the CAP, resilience and recovery and resilience plans – RRP – ERDF). Under InvestEU, the opportunity to use specific instruments to support investments relevant to the Soil mission will be explored.

Table 2 Indicative budget for first three years of mission "A Soil Deal for Europe" (€mio)

	2021	2022	2023	2021 - 2023	<i>budget share 2021 - 2027 (%)</i>
1. R&I programme	33				32
2. Living labs and lighthouses	2				40
3. Monitoring and indicators	12				14
4. Soil literacy, communication and citizen engagement	15				7,5
5. Support structures and governance	5				1,5
6. Scaling out - InvestEU	0				5
TOTAL	67	95	158	320	100

5.2. The potential contribution of the CAP to soil health

The CAP will act in synergy with the mission's objectives and contribute to its implementation through a strengthened green architecture involving four main components: 1) an enhanced conditionality and the establishment of eco-scheme which will support sustainable practice as a part of direct payments; 2) support measures including agri-environment-climate measures or other measures such as capital expenditure investment; 3) support to knowledge and innovation mainly through the agricultural knowledge and innovation system (AKIS) and the European innovation partnership "Agricultural productivity and sustainability", the so-called EIP-AGRI; 4) potential use of FIs by Member States as foreseen in the CAP.

Although the CAP will considerably contribute to the mission's objectives, it is not possible to provide overall figures that will accrue specifically to soils. This is because the main element of support in the CAP – the direct payments – is an overall payment encompassing several objectives. Nevertheless, the specific objectives focusing on climate mitigation and adaptation and preservation of natural resources will address directly or indirectly soil aspects.

The CAP is implemented under shared management and spending depends on the programming undertaken at the national and regional level. The Commission is involved in a structured dialogue with Member States to develop the strategic CAP plans and a sizeable uptake of soil related measures under the new CAP can be expected.

Eco-schemes and agri-environment-climate measures under the new CAP will reinforce the link between payments and environment- and climate-friendly farming practices and standards. Several good agricultural and environmental conditions (GAEC) have a direct impact on soil health, five targeting directly soil (GAEC 2 and 3 and 6 to 8), a new one targeting preservation

of carbon rich soils such as peatlands and wetlands is created (GAEC 2)⁹. The eco-scheme is a new payment scheme, which with regards to soil will aim to reward effectively practices that improve and restore soil health through more diverse, regenerative and systems-based approaches in agriculture and compensation depending on the level of ecosystem services provision. They require the deployment of management practices which lead to increasing carbon sequestration and soil carbon content, reducing emissions from soils, increasing soil nutrient and soil fertility, reducing erosion, improving water retention and water penetration in soils and increasing drought resilience. The eco-schemes will support a variety of practices that will have a positive impact on soil health and downstream impact on water and biodiversity (for instance agro-ecology, agro-forestry, carbon farming, erosion prevention, nutrient management).

Agri-environment-climate measures (AECM) will be one of eight support measures under the EAFRD and interventions will support the following aspects having an impact on soil health: environmentally friendly production systems such as agroecology and agroforestry or systems increasing the use of perennial crops; forest environmental and climate services; precision farming methods; organic farming; renewable energy and the bio-economy.

Beyond CAP payments, it is important to recall current efforts made between the Commission and the EIB to pilot EAFRD-backed FIs. The option to develop innovative, EAFRD-backed FIs or a thematic investment focus on soil and biodiversity improvement, could be a powerful delivery mechanisms for the implementation of the mission. Moreover, the feasibility to create an innovation fund to support companies that provide innovative services to farmers and other land owners in the area of soil improvement and soil fertility monitoring and pollution prevention control will be explored.

The table below shows the indicative financial allocation in 2014-2020 under the CAP for the EU-28 for measures of which a significant proportion could be directly linked to soil measures¹⁰. With the new CAP, spending in areas impacting positively on soil health will be more important in relation to total CAP spending since CAP Strategic Plans to be prepared by Member State will have to have a higher environmental and climate ambition than the current CAP.

Table 3 Indicative financial allocation of CAP priorities 4, 5D and 5E in 2014-2020 for (€mio)

M01 - knowledge transfer and information actions	267
M10 - agri-environment- climate	16.405
M11 - organic farming	7.517
M12 - Natura 2000 and Water Framework Directive	579
M13 - areas facing natural or other specific constraints	16.727
M15 - forest-environmental and climate services and forest conservation	233
Total	41.728

Knowledge and innovation within the new CAP will make a significant contribution to the Soil Deal mission. The reinforced AKIS at Member State level will contribute to knowledge exchange and advice on soil-health related issues. Moreover, the EIP-AGRI will develop specific activities to support mission activities all along its implementation. This will include setting up a specific service to inform about the mission and disseminate practice-oriented results as well as organising events in the mission area and strengthening the connections with land managers and consumers. It will also cater for a stream of bottom-up innovation projects to be implemented in soil health or related areas (the so-called operational groups, OGs).

⁹ Statutory management requirements (SMRs) which are part of the eco-conditionality are also reinforced by two additional items related to the water framework directive and the sustainable use directive on pesticides.

¹⁰ Priority 4 (Restoring, Preserving and Enhancing Ecosystems) and Priority 5 (Resource-efficient, Climate-resilient Economy), Focus Area 5 D (GHG and ammonia emissions) and 5E (carbon sequestration).

In the current period (state of play June 2021), about 15% of all OGs have focused on soil and received support of about €90 mio. However, if one takes into account projects focusing on fertiliser applications and nutrient management, or on land and landscape management, the support would exceed €200 mio. With the CAP 2021/2027 it is expected that the number of OGs dealing with soil-related issues will increase significantly.

5.3. EU and Member State policies and instruments to be mobilised for the soil health mission

A range of instruments will complement the support provided by Horizon Europe and by the CAP to the mission, e.g. in view of widening the network of living labs and lighthouses or of supporting the provision of services relevant to soil health by the private sector (start-ups, SMEs, etc.). Volumes of necessary capital will be assessed more precisely in the future. While most instruments concern grants and financial instruments, attention will also need to be paid to carbon farming / ecoservice schemes and their relation to soil health. Such schemes would raise the interest by the farmers and the industry to invest in these measures. Result based payment schemes for ecoservices still need to be developed¹¹.

5.3.1. Synergies within Horizon Europe and other EU programmes to increase impact of mission activities

Horizon Europe will support a network of living labs that will create and test solutions for improving soil health. However, those will need to be complemented by additional projects piloting specific thematic areas or working at different geographical level (for instance at cross-border level or groups of regions sharing similar conditions). Those projects will be working in parallel to living labs or using some of their results and they will need to be supported by grants due to the need of proof-of-concept or due to low bankability.

EU programme LIFE, which deals with environment and climate change has the potential to contribute to the implementation of the mission through supporting projects in most of the objectives of the mission (sustainable soil management, peatland restoration, etc.). LIFE is complementary to Horizon Europe and LIFE projects stand more at the downstream part of R&I and can leverage results from Horizon Europe project. LIFE can make an important contribution by implementing new approaches on the ground and provide **test cases** and **pilots** in a variety of places and contexts in the EU. Synergies with Horizon Europe in the mission implementation will be achieved potentially through joint calls on specific topics, preparatory actions in view of knowledge implementation, LIFE integrated projects to build thematic strategies (at regional, local or cross-border levels) or through the Natural Capital Financing Facility (NCFF), see following section. Finally, LIFE will be mobilised under the climate mitigation and the climate governance theme for the development of actionable and scalable carbon farming solutions. Given its broad scope and its budget (€4.8 bio for 2021-2027), it will, however, need to be complemented by other instruments allowing large-scale initiatives and out-scaling.

Cohesion policy: The development of new approaches to address Soil health challenges and transformative solutions under this mission can help accelerate the uptake of best available technologies and encourage the development of new capabilities in public administration and the provision of new services. This is of particular relevance to less developed and peripheral regions. There is therefore scope in many of these regions to scale up demonstrators with resources from cohesion policy in order to support the delivery of programme objectives. The Mission will therefore provide guidance, support and technical assistance for downstream synergies to help

¹¹ Such schemes would include tradable carbon or biodiversity certificates, payment for result schemes, transfer mechanisms in compensation for ecosystem services, cheaper insurance schemes, interest rebates, etc.

the regions scale up transformative solutions developed in demonstrators through Cohesion policy programmes.

INTERREG: Specific support will be sought with the European Territorial Cooperation programmes which will aim at establishing cooperation across borders (cross-border, transnational and interregional cooperation), for instance: pilots or demonstrations of restoration of wetlands in cross-border areas or in north European transnational areas or dealing with water erosion in Southern European transnational areas, or cross-border river basin (e.g. Danube).

Beyond INTERREG, the ERDF may play a significant role regarding soil health. Three-quarters of NUTS 2 regions have smart specialisation strategies (S3 strategies) in agri-food, which means that there is a sizeable potential for projects contributing to mission's objectives from the research and innovation angle. The mission will make use of the thematic smart specialisation platform on agri-food to capitalise on cross-regional cooperation and favour the emergence of common innovation investment projects in areas relevant to the mission. More importantly for scaling out will be the thematic priority "Greener, carbon-free Europe" of the new EU Cohesion Policy. Regions which have identified priorities in their smart specialisation strategies related to soil health may develop synergies with the mission to support the development or downstream deployment of new approaches to the development of transformative pathways.

Synergies will be exploited with the **Joint Undertaking Circular Biobased Europe (CBE)** under Horizon Europe. CBE will also be sought to implement R&I activities in areas which are relevant to the soil health mission (for instance nutrient management, fertilisers and soil improvers, plastic biodegradation, etc.).

By connecting activities between various EU programmes, initiatives and infrastructures, it will be possible to gain efficiencies in funding and use the specificities of each programme in a more targeted way. Table 5 provides examples of these instruments.

Specific examples of synergies in the area of soil literacy, communication and citizen engagement:

- There are already a number of initiatives in education both in Member States^{xxxii} and at EU level relevant to the mission's objectives. The *Green and digital transitions* is one of the six priority dimensions through which the European Education Area will contribute to addressing climate change (this includes climate mitigation through soil management). For this, the establishment of the **Education for Climate Coalition**, will be key for generating a behavioural change towards sustainability. The Erasmus + programme will prioritise the development of competences in various environmental sustainability relevant sectors, developing green sectorial skills strategies, methodologies and future-orientated curricula that better meet the needs of individuals regarding environmental sustainability. Also, the **European Universities alliances** will integrate and mainstream higher education learning and training for Sustainable Development across all disciplines and all levels, including potentially sustainable land management. The Erasmus+ programme and European Universities Initiative as well as Marie Skłodowska-Curie Actions (MSCA) and European Institute of Innovation and Technology (EIT) support bottom-up activities and approaches. These instruments will feed the mission with project results, data and knowledge, best practices, as well as contribute to citizens' engagement through various platforms and networks. This large network of alumni, stakeholders and beneficiaries will be contacted to promote the mission and increase attention to soil related topics, **encouraging pledges and concrete actions** by pupils, teachers and education institutions related to soil health;
- Moreover, the mission will be linked with the **Council Recommendation on education for environmental sustainability**, and in particular through the **European Competence Framework** on climate change and sustainable development to invite Member States to embed soil education into school curricula;

- The mission also aims at maximising synergies with the **Climate Pact**, in particular the Climate Pact Ambassadors, the **Future of Europe Conference**, the **New European Bauhaus**, the **REGIOSTARS awards** to reward good practices, and the **European Network of Soil Awareness**. At global level, important synergies with the Global Soil Partnership will be sought.

Table 4 Examples of synergies and complementarities with other EU funding programmes

Instrument	Description
Mission HE budget	Operational obj. 1: Building capacities and the knowledge base for soil stewardship
Horizon Europe Pillar 1: Research Infrastructures and ERC	R&I activities, mainly: - generating additional knowledge in relation to eight specific objectives; - expanding existing or building new knowledge platforms and infrastructures
Other instruments: Digital Europe Programme	Cooperation with Digital Innovation Hubs; elements towards “ digital twin of soil ” could be envisaged to be incorporated in the Destination Earth system in the next programming period 23-24, e.g. as parts or extensions of the digital twins funded from DEP WP 2021-22. The core platform will also support data handling and analysis.
Mission HE budget	Operational obj. 2: Co-creation and upscale of place-based innovations to improve soil health in all places
Horizon Europe Pillar 3: EIC, EIT KICs	EIT KICs: bring together businesses, research centres and higher education institutions for innovation across the entire innovation chain (training, education, transition to the market) EIC: support to entrepreneurs to create new markets (also internationally) through: EIC pathfinder, EIC transition, EIC Accelerator, Business Accelerator Services European innovation ecosystems: complements EIC and EIT supporting the overall ecosystem for innovation in Europe.
Horizon Europe partnerships	Horizon Europe Partnerships on: Agro-ecology: cooperation on agroecological practices and Living labs Data for Agriculture: cooperation on the use of digital and data technologies for soil Food Systems: cooperation on the benefits of healthy soils for food production, food safety and food value chains. Circular biobased Europe (CBE) as follow-up to the Bio-based Industries Joint Undertaking, (BBI): cooperation on adoption of circular principles for soil management, e.g. through alignment of roadmaps PRIMA is a H2020 art.185 co-fund programme on sustainable agriculture and water availability in the Mediterranean region. Coordination of PRIMA and mission activities to address soil health within and outside the EU.
Other EU funding: Common Agricultural Policy	The mission will work in tandem with the future CAP incl. the European Innovation Partnership (EIP AGRI). EIP-AGRI to boost the number of Operational Groups (OGs) relevant to the mission. OGs bring together multiple actors such as farmers, researchers, advisors, businesses, consumers to advance innovation in the agricultural and forestry sectors. Reinforced eco-conditionality, introduction of the ecoschemes for direct payments, agri-environment-climate measures will all contribute to improvement of soil health

Other EU funding: LIFE Programme	The LIFE programme is the EU's funding instrument for the environment and climate action. It will contain two main portfolios, Environment and Climate Action, and cover four sub-programmes: • Nature and Biodiversity • Circular Economy and Quality of Life • Climate Change Mitigation and Adaptation • Clean Energy Transition
Other EU funding : Cohesion Policy	Through INTERREG, Europe offers opportunities for regional and local public authorities across Europe to share ideas and experience on public policy in practice, therefore improving strategies for their citizens and communities.
Other EU funding: Recovery and Resilience Facility (RRF)	Many of the draft Recovery and Resilience Plans include investments in areas that require action on land and soil management. Mission will seek to create synergies at regional level.
Other EU funding: InvestEU/EIB Group	The mission cooperates with the EIB financial instruments for implementing several objectives and scaling up its results. In particular, the EIB Innovation Finance Advisory service (part of the InvestEU Advisory Hub), Direct/intermediated lending; policy window of the InvestEU
HE Mission Budget	Operational obj. 3: Develop an integrated soil monitoring system
Other funding: MS Soil Monitoring and EUSO	The JRC will contribute to the mission and the development of a harmonized EU Soil Monitoring framework. Data and indicators will be made available to all stakeholders over the European Soil Data Center (ESDAC) and the EU Soil Observatory (EUSO) indicator dashboard.
HE Mission budget	Operational obj. 4: Engage with the soil user community
Other EU funding : Marie Skłodowska-Curie Actions (MSCA)	MSCA fund the development of excellent doctoral and postdoctoral training and programmes, as well as international, cross-sectoral and institutional collaboration, contributing to knowledge transfer and scientific breakthroughs.
Other EU funding: Erasmus+	Erasmus+ supports education, training, youth and sport in Europe. The 2021-2027 programme places a strong focus the green and digital transitions.
Other EU funding: European Solidarity Corps (ESC)	The ESC brings together young people to build a more inclusive society, support vulnerable people and respond to challenges in areas such as environment, inclusion or youth work.

5.3.2. Support to soil health mission through financial instruments – mobilising InvestEU and the EIB group

Advisory support

With a view to develop a comprehensive investment and financial plan and to build capacity in Member States for its implementation, it is foreseen to finance from Horizon Europe's budget for the soil health mission specifically tailored advice from the EIB as part of the Advisory Hub of InvestEU. This advice will cover horizontal issues, ensuring soil related objectives are catered for in the various existing instruments. It will tackle specific market gaps or needs and also provide the necessary technical and financial advice. This will allow to carry out an in-depth investment and financial analysis at the outset of the implementation of the mission. This is considered to be useful to ensure a comprehensive mobilisation of instruments and also provide the necessary capacity building and mobilisation at EU and Member State levels.

Direct / intermediated lending

The EIB Group has a long history of supporting the bioeconomy, including the agriculture and forest sectors and industries as well as rural infrastructure and afforestation, either through own

risk loans or under EU financial instruments (EFSI or Horizon 2020 for instance). The EIB Group seems well placed to mobilise direct lending, intermediated loans or equity (European Investment Fund, EIF) in the sector to contribute to mission's objectives in order to complement FIs backed by EU policies and instruments (InvestEU).

Potential use of InvestEU to support the mission

Support to the agriculture and forest sectors and industries has also been backed by EU policies – most recently under EFSI (Agriculture and Bioeconomy programme loan)¹², InnovFIN (the European Circular Bioeconomy Fund)¹³ or LIFE (Natural Capital Financing Fund)¹⁴. This support will be mobilised to contribute to the objectives of the European Green Deal and the Farm-to-Fork strategy and, more specifically, to the implementation of the mission. Depending on potential uptake and feasibility, either current vehicles could be adjusted and scaled up or new ones could be created under the umbrella of InvestEU.

R&I and digital policy window of InvestEU

The mission's operational objective "Develop an integrated soil monitoring system" implies the development of an ecosystem of service providers to land managers for a broad range of services (soil health monitoring, pollution prevention control, precision farming, crop health, crop modelling, etc.). This ecosystem is developing with a variety of enterprises (start-ups, SMEs, etc.) and has good prospects to further expand. The feasibility of using existing instruments or setting up a fund that would provide loans and equity to innovative SMEs / start-ups within the R&I and digital policy window of InvestEU will be tested. This would provide similar support to SMEs / start-ups which are active in other priority areas of the soil health mission, for instance on the specific objective "reduce pollution and enhance restoration", for instance pesticide use and risk reduction (e.g. robots for mechanical weeding, biological pesticides, bio-control, etc.) or fertiliser applications. This would also support the participation of the private sector in the living labs / lighthouses developed for the mission.

Sustainable infrastructures policy window of InvestEU

Implementation at scale of mission objectives "**Conserve and increase soil organic carbon stock**" and "**Reduce pollution and enhance restoration**" could imply mobilising support from the ERDF and InvestEU:

Feasibility of the use of FIs, including if necessary through the creation of a fund within the sustainable infrastructures policy window of InvestEU will be explored. This fund would provide loans to several major activities that are crucial for the implementation of the soil mission, including:

- Restoration of soils in urban and peri-urban areas and conversion to urban/peri-urban farming or to natural habitat, supporting local governance development projects, reduction of soil sealing;
- Rehabilitation of brownfield, landfill and other contaminated sites;
- Restoration of peatlands and wetlands, development of paludiculture.
- Agricultural land: reduction of soil tillage, use of perennial crops, agro-ecology, integrated pest management, fertiliser use reduction, conversion of low productive land into agro-forestry or for wood production (short-rotation coppice), etc.

¹² E.g. the Agriculture and Bioeconomy programme loan under European Fund for Strategic Investments (EFSI).

¹³ The European Circular Bioeconomy Fund (ECBF) is a EUR 250 million private equity/venture capital fund aiming to invest in early stage innovative bioeconomy and circular bioeconomy companies and projects in the EU and Horizon 2020 associated countries.

¹⁴ The Natural Capital Financing Fund (NCFF) combines EIB financing and Commission's funding under the LIFE Programme, the EU's funding instrument for the environment and climate action.

5.3.3. Mobilising Member States

In their Resilience and Recovery Plans (RRP), several Member States are foreseeing to fund projects related to soils (soil erosion, soil carbon, nutrient management, restoration of wetlands, soil and water management, forest soils carbon sinks, organic farming). Possibilities for mobilising the Member State compartment of InvestEU and involving resources from the Resilience and Recovery Facility as well as European Structural and Investment Funds, will be explored to create impact at scale.

6. Monitoring and evaluation framework

The overall monitoring and evaluation framework for Horizon Europe will apply to all missions and will be developed by the Commission in a harmonised manner to assess the performance of the Mission as a new delivery instrument. The internal and external governance bodies of the mission will receive regular reports on the progress made in implementing the mission (see chapter 4.).

6.1. Monitoring mission objectives

The mission recognises the central role of monitoring for tracking progress towards healthy soils by 2030 within and beyond the area addressed by the network of living labs and lighthouses. Monitoring is also essential to establish progress towards the targets set for each of the specific objectives, in line with Green Deal ambitions.

The mission proposes a robust monitoring framework through activities under a dedicated operational objective for “Monitoring and Indicators” (see detailed description under section 3.3).

The main elements of the monitoring framework include:

- definitions of soil health and what constitutes “unhealthy soils”;
- a set of eight indicators for soil health which can be measured to assess changes on soil health over time, i.e. the overall impact of the mission. These soil health indicators will be validated and assigned thresholds at the level of MS and the EU;
- management indicators which will be developed under the mission as proxies for soil health in particular for indicators that are “slow” to show significant changes (see 8.B);
- a baseline and one or more aspirational targets for each of the missions’ specific objectives (see 8.A);
- defined inputs, outputs and outcomes as described in section 3.

In addition to the eight soil health indicators (these correspond to impact indicators, see below in table), the monitoring framework includes the output and outcomes indicators reflecting scientific, economic, environmental and social dimensions of the mission. The overview below provides a first, succinct overview. It will be further refined and validated throughout the mission, in particular to include the corresponding baselines, targets and milestones.

Table 5 Examples of Impact, Outcome and Output indicators for soil health and the mission's operational objectives (tentative)

	Impact indicators
Mission goal: 100 living labs and lighthouses leading the transition towards healthy soils by 2030 8 specific objectives to which specific indicators have been assigned (see table 1 in section 2.1)	- Presence of soil pollutants, excess nutrients and salts - Soil organic carbon stock - Soil structure including soil bulk density and absence of soil sealing and erosion - Soil biodiversity - Soil nutrients and acidity (pH) - Vegetation cover - Landscape heterogeneity - Forest cover
	Outcome indicators (examples)
Operational objective 1: Build capacities and the knowledge base	- Level of access to knowledge on soil health issues and solutions - Uptake of knowledge and solutions by land managers as shown by changes in management practices (land use monitoring, surveys) - Product information about global soil footprint
Operational objective 2: Co-create and upscale place-based innovations	- Rate of awareness of land managers with regards to soil health challenges (survey based) - % of land managers having changed or adopted one or more of their practices in a direction improving soil health (in the living lab areas and outside) - Level of soil health indicators and ecosystem services <u>in</u> the living lab areas - Level of social capital (norms, values, networks, governance) in living lab areas (using quantitative and qualitative methodologies documented in literature)
Operational objective 3: Develop an integrated soil monitoring system	Number of - active soil monitoring programmes in Member States - EU reporting making use of up-to-date and harmonised reporting - Member States introducing a soil health certificate
Operational objective 4: Engage with the soil user community	- Level of awareness of citizen and key stakeholder groups with regards to societal role and value of soil (survey based) - Level of access to information and trainings to improve skills and to support the adoption of sustainable land management practices.
	Output indicators (examples)
Operational objective 1: Build capacities and the knowledge base	Number of - publications on knowledge in relation to the mission's specific objectives and soil health indicators - roadmaps developed per specific objective - infrastructures, platforms and other resources for experimentation and ready-to use knowledge on solutions for soil management t - land managers and other "users" of soil health services involved in R&I activities - best practices and solutions developed and tested in relation to specific objectives and land uses (e.g. apps, techniques for reduction of contentious inputs and remediation)

Operational objective 2: Co-create and upscale place-based innovations	Number of - living labs, lighthouses and experimental sites, active and present on the interactive map - stakeholders involved in the living labs - innovative soil management technologies or practices developed/adopted in the living lab area/adopted in other areas - demonstration/upscaling/training activities undertaken, number of participants in these demonstration activities - reports, scientific publications, professional articles and media articles on lessons learnt in the living labs R&I activities (in particular focused on systems approaches, transdisciplinarity, socio-economic, behavioural and cultural drivers of change). - knowledge exchange activities conducted between living labs, indicators qualifying the intensity of community exchange (e.g. through social media) - cooperation activities with living labs and lighthouses outside Europe
Operational objective 3: Develop an integrated soil monitoring system	- Availability of targets and thresholds for each soil health indicator - Level of harmonisation of monitoring protocols and reporting across Member States - Extent of operability of data sets across Member States - number (existence) of tools for self-assessment of soil health
Operational objective 4: Engage with the soil user community	- Rate of soil awareness amongst citizens (survey based); - Number of national school curricula on soil related subjects, number of tool-kits, and of good practices (school gardens, vegetable gardens, composting spaces, digital tools); - Existence of a 'best of resources' repository on soil communication, education, and engagement with high-quality materials for different target groups (measured by number of visits); - Number of municipalities and regions pursuing citizen-identified soil related objectives; - Number of businesses and companies developing strategies for valorising of soils in their production and supply chains; - Number of trainings for advisors and practitioners; - Number of people involved in soil related art-science-society events

6.2. Reporting and evaluation

In addition to the overall evaluation framework, specific arrangements will be put in place to ensure that the mission process and the effectiveness of its measures are documented and closely followed. Reporting on the soil mission will be closely linked to the governance provision as outlined in section 4 of this implementation plan. The feedback from evaluation is essential to ensure that measures, milestones, targets can be adapted in best ways to meet the mission objectives and take into account new developments.

Reporting:

- yearly Commission internal activity reports with an overview of past activities and an forward looking milestones;
- on a continuous basis to: the Mission Board, to stakeholders' innovation group and to the Member States on the state of play on the implementation.

Evaluation steps:

- a mission's progress report at the end of 2023 for evaluation of activities in the induction and pilot phase, in line with Article 8 (3) of the HE Regulation;

- a mid-term review in 2025. The assessment will be a comprehensive exercise, establishing the mobilisation of resources and milestones achieved. It will also serve to validate the overall intervention and monitoring logic;
- an assessment after 2027 as part of the overall Horizon Europe monitoring and evaluation;
- a final review in 2030 to assess the mission's performance following the scaling up and mainstreaming phase in 2030. The review will benefit from a solid soil monitoring programme and the data available through the European Soil Observatory.

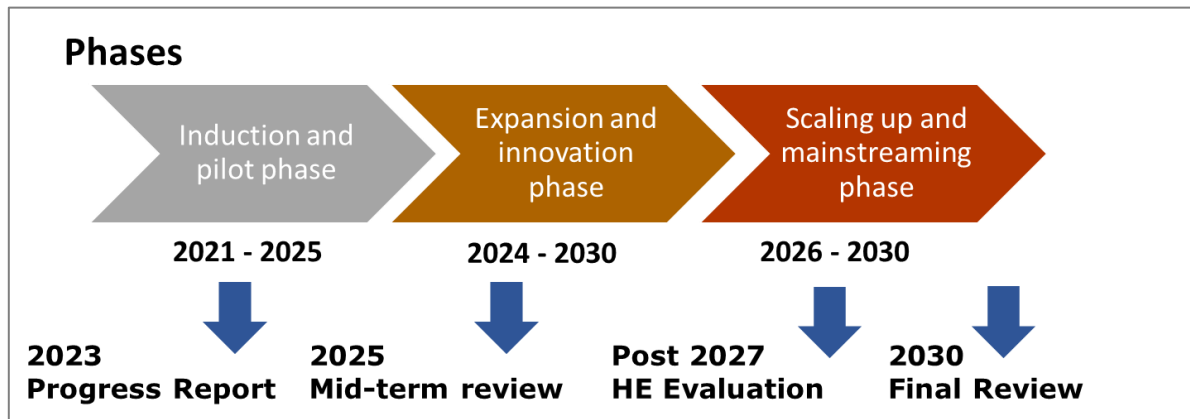


Figure 13 Reporting and evaluation milestones

7. Timeline of activities

	Year	Horizon Europe						Beyond Horizon Europe			
		'21	'22	'23	'24	'25	'26	'27	'28	'29	'30
Phases		Induction and Pilot									
					Expansion and Innovation						
							Scaling up and Mainstreaming				
(1) Building capacities and the knowledge base: the R&I Programme											
Exploiting and further developing knowledge infrastructures and platforms											
Advancing knowledge focused on mission’s soil health objectives											
Accelerating innovation (practices, business models, technologies, value chains, policies)											
International cooperation and reducing the global soil footprint											
(2) Co-create and upscaling innovations to improve soil health in all places: lighthouses and living labs											
Engagement sessions in Member States											
Setting-up a European network of LLs and LHs											
Launching and running regional LLs and LHs across regions in Europe; building transnational clusters				First wave of LLs	2 nd wave	3d wave	4 th wave				
Activities and business models to support sustainability of the LLs network											
(3) Tracking progress towards the mission’s goal and develop an integrated soil monitoring system: Monitoring and indicators											
Technical support for cooperation of Member States on monitoring											
Agreement on indicators and thresholds for monitoring all eight soil health indicators; identification on management practices as proxies for soil health											
R&I to support monitoring tools including for remote sensing and EO											
Development of soil health certificate											
Developing harmonised reporting structure for soil health at EU and MS level and data integration with EUSO											
(4) Engage with the soil user community and society at large: Soil literacy, communication and citizen engagement											
Communication and citizen engagement											
Support to (Agricultural) Knowledge and Innovation Systems											
Cross-cutting activities											
Setting-up and running of support structures											
Building business cases for soils; advise to “soil investors”, development of models for blended finance											

8. Supporting Material

A. Review of the evidence base: status of soil health across Europe in 2020

This section represents a review of the latest literature by the Soil Health and Food Mission Board (MB) and the European Commission's Joint Research Centre (JRC) to help define **the ambition of the mission. In its original proposal that Mission Board has advocated to aim for 75% of the soils of the European Union (EU) to be healthy or improving by 2030.** The review concludes:

A review of the current evidence of the state of EU soils by the MB and JRC is that current management practices result in, approximately, 60-70% of EU soils being unhealthy, with a further, as yet, uncertain percentage of soils unhealthy due to poorly quantified pollution issues. A radical change in current land management practices is both feasible and necessary. Soils will also benefit from improvement to indirect drivers of change such as reductions in air pollution and carbon emissions.

The following sections provides the evidence base for this statement.

Some basic assumptions:

- EU Land area: 4,233,255 km²
- Agricultural area of EU is 39% of land area: 1,730,000 km²
- Croplands occupies 23% of the EU: 1,060,000 km²
- Artificial areas occupy 5% of the EU: 222,592 km²
- 'Natural' soils (i.e. without intensive management regimes): 52% of the EU

1. Nutrients

The Gross Nutrient Balance Indicator (EUROSTAT 2020) shows that there is currently an excess of fertilizer applications in the EU: data show that for agricultural land there is a surplus of 50 kg N/ha and 2 kg P/ha.

The European Commission (EC 2018) reports that Nitrates Vulnerable Zones (NVZ) cover 2,175,861 km² of the EU (latest figures for 2015 and includes MS that apply a whole-territory approach). NVZ represent approximately 61% of agricultural land. This means that there are obligations to reach a balanced fertilisation for 61% of agricultural soils (arable and grasslands).

SOER 2020 (EEA) reports that for 65-75% of agricultural soils, nitrogen values exceed critical values beyond which eutrophication can be expected (De Vries et al., in prep).

There are also issues from atmospheric deposition of nutrient nitrogen in non-agricultural systems. CIAM/IIASA (2018) reported that critical loads for eutrophication were determined for 2.65 million km² (62%) of European land in 2017 (see also point 6. on Contamination).

Therefore, area of land with failure of soil health indicator due to direct inputs nutrient issues in agricultural systems (excluding air pollution issues) = 27% – 31.5%

2. Organic carbon

LUCAS Soil data, covering surface soil, show that cultivated and permanent crops have the lowest SOC concentrations of all major land cover classes (around 17 g/kg C). By comparison, average levels for permanent grasslands in the EU are 2.4 times higher (Hiederer 2018).

Most croplands in EU are most likely to be already at sub-optimal levels – 1.5% of all land use have SOC levels below 1% C. This rises to 2.6% of arable soils (JRC LUCAS). This would account for approx. 0.6% of land outside of agriculture.

LUCAS soil organic carbon concentration change analysis (2009-2015) for points where land cover was the same in both dates, show a decrease of about 0.5 % per year on croplands which was statistically significant on the most carbon poor soils (Hiederer 2018). Subsequent estimates of overall

SOC stock changes (all soils) indicate that the total SOC change between LUCAS 2009/12 and 2015 show that about 60 % of EU agricultural areas experienced changes below 0.2% of the average stock. The trend in carbon stocks in grassland was loss of about 0.04 % and in arable land a loss of about 0.06% (Panagos et al 2020). 10% of the area is predicted to have changes larger than $\pm 12 \text{ g kg}^{-1}$ over the 6 year interval.

Area of land with failure of soil health indicator due to low and declining carbon stocks = 23% (BUT there will be overlap with (1)). 0.6% falls outside of agricultural areas.

3. Peat

Byrne et al. (2004) reported an area of 340,000 km² of peat soils in the EU Member States and Candidate Countries (Tanneberger et al. 2017, has updated figures on extent per country, which indicates that the extent of peatlands in the EU is closer to 270,000 km², although the figures for some countries are still approximations). On this basis, peats cover 8% of EU land area, of which 50% of peatlands are estimated to be drained which will result in the oxidising of the peat and loss carbon to the atmosphere (JRC 2016). Results from hydrological reconstructions indicated 60% of peatlands are drier than they were 1000 years ago due to these direct human impacts and climatic drying (Swindles et al. 2019).

Not all peat being degraded is under agriculture. Schils et al., 2008 estimates about 20,000 km² of drained peat (ca. 7.4% of peatland) is not in agricultural use as cropland or grassland (0.5% of EU).

Area of land failing soil health indicator due to peatland degradation = 4.8% under (1) or (2) but 0.5% is outside agricultural areas.

4. Water Erosion

Pangos et al. (2015) reports that 25% of land has unsustainable soil water erosion rates ($>2 \text{ t/ha}$). Mean soil erosion by water for EU is $2.46 \text{ t ha}^{-1} \text{ yr}^{-1}$, resulting in a total annual soil loss of 970 Mt. This covers a wide range of land use types with around 70% of the land in agricultural systems. This means that area not overlapping with (1) and (2) could be estimated as 17% (47% of 24% eroding land).

However, a new report by JRC (Panagos et al. 2020) shows erosion by water on arable land is 10% greater than the mean for the EU (this means that we can consider all 23% of cropland as affected). Permanent crops have highest soil erosion rates. Arable and permanent crops cover 30% of EU land.

In addition, there are notable erosion rates on shrubland and sparse vegetation with mean soil loss rate of $2.69 \text{ t ha}^{-1} \text{ yr}^{-1}$ and $40 \text{ t ha}^{-1} \text{ yr}^{-1}$, respectively. Together, these land cover types occupy 30.8% of the EU (not under agriculture).

A JRC erosion model (Borelli et al. 2017) shows wind erosion in EU is $0.53 \text{ Mg ha}^{-1} \text{ yr}^{-1}$. 9.7% of arable land has problems with wind erosion, with 5.3% and 4.4% displaying moderate and high rates of wind erosion, respectively. However, these will fall in the above estimates of agricultural land.

Area of land failing soil health indicator due to soil erosion = 23% in cropland and 30% in non-agricultural areas.

5. Compaction

There are very uncertain numbers for compaction. Based on partial data coverage for the EU (modelling of representative soil profiles), the best available estimates suggests that 23% of land assessed had critically high densities (JRC 2016). JRC 2009 estimated that 33% of soils are susceptible to compaction, of which 20% moderately so. The issue is more likely in agricultural soils but it is also found in organic-rich forest soils so some overlap with (1) and (2). Confirms the multiple pressures on soil.

Area of land failing soil health indicator due to soil compaction = 23-33%, 7% of which are outside agricultural area.

6. Pollution including risks to food

There are many unknowns especially in relation to diffuse soil pollution in natural landscapes (i.e. 52% of EU) and there are more than 700 recognised soil pollutants (NORMAN, 2014).

In terms of local soil pollution, JRC (Paya Perez et al. 2018) reported 2.8 million potentially contaminated sites in EEA-39 but the area of land is not known. There is no standardised agreement on a definition of contaminated sites which can range from petrochemical plants to petrol stations. An indicator on "Progress on the remediation of contaminated sites" is based on risk assessment approach where efforts are mainly focused on investigation of sites where polluting activities took/are taking place. The report noted the occurrence of 650,000 registered sites where polluting activities took/are taking place in national and regional inventories. 65,500 sites have been remediated.

The Cocoom InterReg Project estimated that there are more than 500,000 landfills in EU. 90% are regarded as non-sanitary landfills (i.e. predating the Landfill Directive (1999)). NASA estimates that the average size of landfills in US is 200 ha. Even if we take just 10% of that value for EU, it would mean that landfills occupy 100,000 km² (2.3%) of EU territory (no actual figures exist).

The situation is more complex for diffuse pollution. Numerous studies show the impact of pollution on soil but it is difficult to assess area or extent. For example, there are no data on the extent of pesticide contamination, POPs, microplastics, veterinary products/pharmaceutical, and emerging concerns such as pFAS. Of LUCAS soils tested, 83% of soils contained one or more residue of pesticides and 58% contained mixtures. (Silva et al. 2019).

De Vries et al. (In prep) and cited in EEA (2020) state 21% of agricultural soils have cadmium concentrations in the topsoils which exceed groundwater limits used for drinking waters.

There are 2.93 million km² (69%) of European land where critical loads are exceeded for acidification and 2.65 million km² (62%) of semi-natural ecosystems are subjected to nutrient nitrogen deposition leading to eutrophication in 2017 (CIAM IIASA 2018). Critical loads are defined where inputs of a pollutant may impact on ecosystem structure and function. Slootweg et al. (2007) reported that the EU ecosystem land at risk from deposition of some heavy metals such as mercury and lead in 2000 were as high as 51% and 29% respectively.

Lema & Martinez (2017) report 10 million tons of sewage sludge production for EU-27, 37% of the sludge produced in the EU is being utilized in agriculture.

Plastics Europe (2016) reported that 3.3% of total EU plastic demand (49 million tonnes) was used in agriculture. Agriculture produced 5% of plastic waste of EU (EC, 2018).

Organic farming covered 13.4 million hectares of agricultural land in the EU-28 in 2018. This corresponds to 7.5 % of the total utilised agricultural area of the EU-28 (EUROSTAT 2020b). Organic production also involves use of pesticides – albeit a smaller number of active substances, including copper compounds. We can assume that pesticides are applied in most of the remaining 92.5% of arable area (21% of EU). This overlaps again with (1) and (2).

With respect to contamination of food, the bioavailability of soil contaminants for plant uptake is a complex area as is the pathways of their uptake and the mechanisms by which they can impact on human health (Gregory and Oliver 2015). Due to this complexity, links between contaminants and specific diseases in individual people needs further study (Hough et al. 2007) as does the impact of mixtures in food of different contaminants on human health (Hernandez et al. 2013). Some specific examples for the EU are available however such as a study of the level of heavy metals in agricultural soils in the EU identified over 6% of soils had levels which could be above those considered adequately safe for food production. The main source of POP exposure in the Czech Republic is through intake of polluted food (Bányiová et al., 2017). A FAO report on soil pollution (Rodriguez-Eugenio et al. 2018) also highlights the potential risk to human health from contaminated soil from unintentional uptake from dust and vapours by farm workers, skin contact, ingestion of contaminants. This can include the risk from pathogens which occur in the soil.

Area of land failing soil health indicator due to soil contamination = 2.5% (non-agricultural) – 21% (conventional arable) – ca. 40-80% of land from atmospheric deposition depending on the pollutant.

7. Soil sealing and net land take

Artificial areas cover 4.2% of the EU (EUROSTAT 2017) of which about 50% is sealed. This would imply that 2.5% of urban land is exposed to pressures (e.g. low inputs, compaction, pollution)

The rate of net land take was estimated to be around 539 km² per year during the period 2012-2018, with (EEA 2019). Between 2000 and 2018, 78 % of land take in the EU-28 affected agricultural areas (EEA 2018). As the rate of recycling of urban land for development is currently only 13% (EEA 2020), this effectively means that every ten years an area the size of Cyprus is paved over (9,300 km²) from agricultural, forestry and conservation land.

Between 2000 and 2006, the average increase in artificial areas in the EU was 3%, however, this masks local issues. Figures exceeding 14% in Cyprus, Ireland and Spain. However, sealing generally consumes high quality agricultural soil, so some overlap with (1) and (2).

Area of land failing soil health indicator due to soil sealing = probably <1% of EU, but can be as high as 2.5%, and can be very important locally.

8. Salinization

The extent of salinization in EU is still uncertain. Ranges estimate 1 to 4 million hectares (enlarged EU), mainly in the Mediterranean and Central European countries (JRC 2008). Taking the higher end of the range means that 0.95% of land is estimated to be affected in the EU. There is an increased risk of salinization due to increased temperatures or decreasing precipitation.

In 2016, 10.2 million hectares was actually irrigated (5.9 % of EU). 25% of this area is at risk of secondary salinization i.e. 1.5% of EU. Spain (15.7 %) and Italy (32.6 %) had the largest shares of irrigable areas in the agricultural areas of the EU (JRC 2016).

There again will be an overlap with (1) and (2).

Finally, the area at risk of saline intrusions in coastal areas due to sea-level rise is unknown.

Area of land failing soil health indicator due to secondary salinization = 1.5% (greater impact in certain member States)

9. Desertification

The most recent estimate of sensitivity to desertification in Southern, Central and Eastern Europe in 2017 suggested 25% (411.000 out of 1.7 million km²) was at High or Very High Risk. This was an increase from 14% in 2008 (Právělie et al. 2017). Due to improved data quality, the extent of land under these high risks was 75% more than the previous estimation done in 2008. Almost half of the land area of Spain (~ 240,000 km²) is deemed highly or very highly susceptible to degradation while large parts of Greece (34%), Bulgaria (29%) and Portugal (28%) are at high risk. There are also concerns for Italy and Romania, where around 10% of their territories are highlighted.

10. Soil biodiversity

It is likely that all of the above drivers are probably singly or in combination resulting in a decline in biodiversity but there are no actual EU data demonstrating soil biodiversity change.

11. Soil as waste

Excavated soils accounted for more than 520 million tonnes of waste in 2018 (Eurostat 2018). Soil is by far the biggest source of waste produced in the EU as excavated soils are currently considered waste under EU law and are therefore disposed of in landfills. However, a majority of those soils are not contaminated and could be safely reutilised if a recovery target coupled with a comprehensive traceability system was put in place.

Summary

Based on the convergence of evidence presented in the previous section, **we can conclude that soil degradation is prevalent and extensive in the context of the EU territory**. One could conclude that all soils are under pressure, even if just indirect pressure, from air pollution and climate change.

It seems that 25-30% of our EU soils are currently either losing organic carbon, receiving more nutrients than they need, are eroding or are compacted or suffer secondary salinization, or have some combination. These are all occurring on agricultural land.

An additional 30% of non-agricultural soils are eroding at an unsustainable level.

A minimum of 12.9% of non-agricultural land experiences soil pressures [0.6 (low SOC) + 0.5 (peat) + 7 (compaction) + 2.3 (landfills) + 2.5 (urban)], of which 50% (i.e. 6-7%) is probably not connected with erosion.

Contamination and waste management are probably the biggest unknowns. They include local hotspots (e.g. ex-industrial land, landfills, etc.), widespread air pollution legacy, agricultural land (pesticides, metals, sewage sludge, plastics) as well as unquantified emerging pollutants.

Conclusion

A review of the current evidence of the state of EU soils by the MB and JRC is that current management practices result in, approximately, 60-70% of EU soils being unhealthy with a further as yet uncertain percentage unhealthy due to poorly quantified pollution issues or disposed unnecessarily as waste. A radical change in current land management practices is both feasible and necessary. Soils will also benefit from improvement to indirect drivers of change such as reductions in air pollution and carbon emissions.

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B. Proposed indicators for soil health in support of the mission

Background

Soil health depends on an active and biodiverse vegetation cover that support carbon inputs, supports soil biota and creates good structure, and appropriate management regimes ensuring no compaction or salinisation and protection from contaminants.

Soils, that are low in organic matter for their type, compacted or contaminated by chemicals such as nutrients, heavy metals, remnants of biocides, hormones and drugs at higher concentrations than allowed by health regulations or plant requirements are considered to be unhealthy.

Proposed indicators as a basis for discussion

The following indicators are well tested (Bünemann et al. 2018) and used widely at national, regional and global levels (Emmett et al. 2010; Orgiazzi et al. 2018; Moebius-Clune et al. 2018) and are proposed as a first step to coordinate and harmonise approaches for soil health monitoring. The list is modest relative to those already in place for water and air quality. If sampled correctly (e.g. not after a fertiliser application) they provide stable indicators for soil health at a given time and of change if repeated at permanent locations. They include two indicators which relate to drivers of change in soil health at the landscape scale:

- 1. Presence of soil pollutants, excess nutrients and salts.** When present in higher concentrations than allowed by health regulations or plant requirements: soils are unhealthy. A reduction in levels below recognized threshold values indicates an improvement in soil health.
- 2. Soil organic carbon.** Organic matter is important for adsorbing nutrients, retaining water and for improving soil structure and workability of soils as well as plant productivity. Soil organic carbon (SOC) is a major constituent (56%) of soil organic matter and the global soil organic carbon reservoir of soils is two to three times bigger than the carbon as atmospheric CO₂. Therefore, an increase in SOC concentration and stock allows drawing down CO₂ from the atmosphere and an improvement in soil health.
- 3. Soil structure including bulk density and the absence of soil sealing and erosion.** Good soil structure as indicated by reduced bulk density, the absence of soil sealing and erosion allows for healthy root growth, reaching all parts of the soil and allowing infiltration of rainwater to prevent runoff and soil loss.
- 4. Soil biodiversity.** Presence of functional diversity of appropriate bacteria and fungi and of soil animal communities that are important for soil functions and services, such as soil structure, litter decomposition, organic carbon storage and nutrients cycling promotes all soil functions. Currently, nematodes and earthworms are well tested. Ongoing research will soon deliver indicators for soil microbial parameters.
- 5. Soil nutrients and pH.** Essential nutrients for plant growth in part at least, derived from soils include N, P, K, S, Ca. A range of plant micro-nutrients usually found at very low concentrations (parts per million) in soils may limit plant growth, such as boron (B), chlorine (Cl), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). Soil pH affects many chemical and biological processes, including plant nutrients availability and the balance and functions of soil microbial communities. In farmland and forestry soils, an optimal balance is required for growth. In supporting biodiversity-rich ecosystems, nutrient limitations provide an essential set of sub-optimal conditions to support a diversity of biota above and below-ground.
- 6. Vegetation cover.** The annual duration and diversity of the vegetation cover and its net primary productivity is essential for soil health, providing nutrients for soil biodiversity and carbon inputs to soil organic matter, also reducing erosion and surface runoff. A more diverse and long duration cover indicates conditions favourable to soil biodiversity and health and increasing vegetation cover is also valuable for urban settings.
- 7. Landscape heterogeneity,** including farmland (field size, fragmentation, presence of natural green elements), forestry (types of forest, monocultures, clear-cuts with bare land) and urban green infrastructures (adequate presence). The diversity of landscape elements (composition) and the way these elements are distributed, including their relative size and their location in relation to the morphology (configuration) strongly influence biodiversity, the water cycle and soil erosion.

8. Area of forest and other wooded lands, classified by the number of species, the share of non-native tree species, and the proportion of natural and artificial regeneration. In forests, soil health is influenced by the naturalness in terms of species composition and the management practices, including disturbance by clear cuts.

Note that measurements are soil-specific showing characteristically different ranges of values for different soil types, land uses and climate zones. Methods for capturing information, which can be combined in different ways, include: visual assessments in field; soil sampling with professional laboratory analysis; remote sensing; modelling, crowd sourcing and citizen science. Many methods are already well described but need standardising if time series are to be robust.

How to determine overall soil health of a given soil?

Once indicators have been measured for a given soil they have to be compared with threshold or standard values that separate healthy from unhealthy conditions. Such considerations are land use and climate specific and cannot be generalized. Work will be needed to define such thresholds or standards for each indicator for each soil type set within a land use and climate context using an agreed standard approach.

Methods for their integration to determine if a soil meets or falls below the threshold / standard and thus if a soil can be defined as 'healthy' or 'unhealthy' also requires further testing and a standard method agreed. Different health categories above or below this threshold / standard can also be defined to indicate the relative state of soil health to help inform the urgency and magnitude of action needed. This integration into an overall measure of soil health is critical to be able to monitor the improvements in soil health by 2030. Different approaches for this integration are already used operationally for other natural resources e.g. the one out/all approach for surface waters in the Water Framework Directive, with various new potential approaches also proposed for soils (e.g. Bonfante et al. 2020). The suitability of options needs to be robustly tested and an approach agreed.

When thresholds for any indicator are exceeded, a soil is below the agreed threshold / standard context specific management actions have to be considered to improve conditions relating to the specific issue(s) which has caused failure. Evidence from experiences obtained at living labs or lighthouses in the area can be helpful here. Continuation of monitoring can then be used to track success of action taken.

C. Summary of evidence submitted by the scientific community on management practices and outcomes in relation to mission objectives

1. Introduction

Ambitious goals, objectives and targets are proposed by the mission. A rapid review of evidence has been undertaken to test if these targets, and thus the overall objectives and goals, are realistic. The rapid review involved new evidence submitted by the community to determine the extent, magnitude and rate of soil health improvement from current management practices.

Returns were received from 16 countries covering all parts of Europe (i.e. Northern, Southern, Central and Western regions), together with submissions from the UK, Turkey, USA and some worldwide syntheses. More than 560 separate pieces of evidence were submitted for a wide range of management practices covering four land use types, with the majority (93%) relating to farmland (submissions of forestry accounted for 5%; peatland <1% and urban <1%). The returns also covered most aspects of the soil issues prioritised in the mission although some were missing (e.g. salinization).

The outcome clearly identifies a broad array of well-tested management practices, which both support and improve soil health. They reflect fundamental change in our management systems which are common across all different land use types (i.e. farmland, forestry, nature land and urban systems) and thus addresses all soil and land use types which is a critical ambition of the mission. These can be grouped under four broad headings:

- Efficient use, re-use and management of organic matter, nutrients and water in more integrated systems;
- Reduced use of control chemicals, a move to integrated pest management and bio-degradable control chemicals, and improved registration and restoration of contaminated sites;
- Soil structure protection including improved tillage, traffic and animal management, appropriate drainage to conserve soil carbon; sediment transport regimes and rewetting of peatlands;
- Improved soil cover through increased vegetation cover, more diverse land management systems and enhanced landscape features including woody species; reduced harvesting intensity.

Evidence submitted was reported against the 8 mission soil health indicators providing clear sight between the management practices and mission targets. Many practices have multiple benefits for several indicators. The potential for 'soil sparing' practices was also raised by some countries (e.g. hydroponics, vertical farming, cellular agriculture) but are not considered further here as the mission has agreed to focus on improvement to direct soil management.

2. Summary of community submissions

A summary of the evidence submitted is presented below, organised by outcomes relating to the mission soil health indicators. It should be noted that this is not a formal systematic review or meta-analysis. It does not replace more detailed EU or global reviews and syntheses already available or underway.

Some clear messages are:

- Reduction in **erosion rates, nutrient and chemical leaching losses, runoff and infiltration rates** are reported are often large and rapid (> 25 - 90% in a few years) in response to a wide range of practices including improved water and traffic management, use of organic fertilisers, reduced tillage and grazing, and increased vegetation cover. Few trade-

offs or unexpected outcomes were reported although some loss of productive land area may result.

- Increase in **soil organic carbon (SOC) stock** are highly variable but in many cases positive if relatively small in scale. Effects are context dependent on soil texture, climate and management practice. Rates most often reported are limited to topsoil layers but some examples are provided of large and rapid increases and can include increases throughout the profile. However, it should also be noted some evidence submitted identified no increase in SOC. Rates reported vary from 0 to < 1 - to 4% per year; or 0 - 3 MtC/ha/yr)). Evidence was also submitted for the overall reduction in greenhouse gas emissions (e.g. - 50% in rewetted peatlands) which can be rapid. Some management practices such as reduced or no till proposed for SOC increase may have greater potential for soil biodiversity and erosion prevention. There is a trade-off reported for some practices (e.g. reduced tillage) with increases in bulk density in lower soil horizons reported in some cases. Use of nitrogen fertilisers to increase biomass and soil carbon in forestry can result in the loss of understorey biodiversity. Use of organic composts to replace the use of peat is an example of the multiple potential benefits of a circular bio-economy.
- Benefits for the **soil biome** are reported for a wide range of management practices although no change is also reported. Practices associated with positive outcomes are often associated with organic systems and reduced, no inversion and no-till. These benefits are most often associated with benefits for soil fauna (up to +600% reported). Liming on woodland systems can increase numbers by +2,000%. Impacts on microbiome composition from these and a wider range of practices are also reported with some cases specifically identifying increases in 'beneficial' bacteria and fungi although there is clearly more work to do done to better quantify the optimum indicators for soil biodiversity. Biodiversity indicators reported included: biomass, diversity, evenness, number of keystone taxa, network connectivity and activity highlighting the lack of current consensus on the most relevant indicators.
- Improved **nutrient** and harvesting management are reported to have variable responses in both magnitude and timing with outcomes being highly dependent on the practice and context. Use of organic fertilisers is reported to both reduce and increase nutrient availability. Use of more legumes was evidenced to provide more nitrogen for crops/trees and potentially reduce nitrogen export (-40%), and could increase in SOC but was context dependent. Reduced harvesting in nutrient poor or biodiversity rich sites was proposed for forestry systems. Use of wood ash to replace lost nutrients could result in loss of biodiversity in acid systems. Improved water management is also reported to have a role in improving nutrient and water use efficiency.
- Improved **soil structure** were variable depending on the indicator. Bulk density was usually in the order of +/- 0 - 1% per year and both improvements and declines were reported depending on the practice. Soil aggregates changes were often of a similar magnitude. However land use change e.g. restoration of woodland on agricultural land could result in much large change larger (e.g. +25%).
- Use of organic mulches from a range of sources to remediate **contaminated sites** were reported to result in rapid improved **vegetation cover** (50-90%) and reduce contaminant levels in various land uses types. Use of wood ash outcomes were more variable. Many other nature-based solutions as well as industrial practices are available e.g. use of thermal desorption and we would highlight the emconsoil initiative for more information <https://www.ovamenglish.be/emconsoil>.
- Agroforestry by definition will improve one of the mission soil health indicators i.e. **tree cover** and is reported to have many other co-benefits including increased SOC, earthworms and reduced erosion although loss of land for food production could occur. The use of circular

wood prunings and other organic fertilisers associated with tree cover and woodlands in the food production system was highlighted in some returns as were the benefits of organic products from the pulp and paper industry emphasising the potential benefits of creating a circular economy for both soils and organic resources between food and fibre production and our urban systems.

3. Conclusions

In summary, the magnitude of change reported varied greatly depending on the initial status of the soil, the soil type, the specific practice and soil health indicator. For example, some practices can result in rapid (< 2-3 years) and result in large changes (> 80%) whilst others can be more gradual (> 5 years) and have relatively small incremental changes (1-10%), with all combinations reported in between these extremes. Improvement is generally more marked where degradation is most severe and thus not all soils have the same potential for improvement and reversal back into degradation is always a possibility which need to be avoided. Some practices also have potential to cause unintended outcomes such as pollutant swapping or biodiversity loss and in some cases where production may be reduced there is the potential for global export of our soil footprint unless EU diets and the need for other products change.

The evidence illustrates clearly that there is already a wealth of knowledge and expertise available which can better protect and improve soil health if it was more widely practiced. Thus, it can be concluded that the mission targets are constrained in particular by the area of land which will be subjected to a change in management practices to improve soil health. For example, significant improvements on an area equivalent to the one currently eligible for CAP support (1.43M km²), would result in healthy soils on another 35-45% of EU land.

4. Additional information coming from the GEO community

Table: State of play of EO and airborne system opportunities to measure soil health

Use of satellite systems for measuring soil health indicators	
Operational or near operational for	Vegetation cover and dynamics; woodland cover; landscape heterogeneity; soil erosion and soil sealing.
Active on-going research	Soil organic carbon (ESA project); nutrients; some management activities for early reporting.
Further development needed	Uncertain potential for measuring changes in pollution; potential for establishing proxies of soil health which will require integration with many other data sets.
Satellite data	
For contextual data (e.g. land cover data) to integrate and upscale from ground-based measurements and to provide data streams for soil models	
Airborne systems (planes and drones)	
Many opportunities relating to in-field assessments, canopy and landscape feature mapping	
Proximal sensing systems	
Many opportunities relating to precision agriculture and field-based soil sensing	

D. Draft Criteria for the selection and set-up of living labs (LL) in the context of the soil health mission

Type of criteria	
Aims	• Innovation and co-creation. • Formal learning. • Contributing to societal challenges, sustainability, and resilience. • Improving soil health and ecosystem services, thereby achieving the soil mission objectives in a holistic manner (minimising trade-offs) in the specific context of the region in which it operates.
Activities	• Outreach and facilitation of engagement of the land users. • Co-design/co-development/co-creation of innovations focused on improving soil health and ecosystem services, in major soils and land use systems in a given region/area. • Experimentation of innovative practices and solutions using transdisciplinary, multi-actor, systems approaches, in real-life settings, seeking to adapt scientifically-proven solutions to local conditions (on real farms, forest exploitation or urban soil management sites). • Measurement/monitoring/evaluation of impact of innovative practices/approaches on soil health and related ecosystem services at site and landscape levels, involving research and innovative measurement technologies (data management, sensing, monitoring, assessment modelling). • Evaluation of socio-economic impacts and behavioural drivers and lock-ins related to the adoption of the innovations by soil managers. • Contributing to networking and knowledge exchange with other sites/LL/LH & EIP-AGRI. • Testing, validating and improving the comprehensive soil and ecosystem monitoring system through co-creation (including assessment, training and education on tools). <u>For sites that have reached a high level of performance (lighthouses):</u> • Demonstration, dissemination and promotion to soil managers, the public and the policy arena, at landscape scale and beyond, of land-use systems that satisfy criteria for sustainable development, in particular in terms of soil health and related ecosystem services. • Reaching out to the policy arena linking results of the LH's to environmental rules and regulations. This in line with science based policy support and governance.
Participants	• Public-private-people partnership involving if possible four groups: science, policy, practice, citizens. • Active engagement in co-development and experimentation of the multiplicity of users having an impact on the achievement of the societal goals. • Users of primary importance to achieve the soil mission objectives: soil managers (farmers, advisors, foresters, city greens managers, allotment holder, industries with impacts on soils etc.) and researchers. They would have the responsibility early in the process to connect with other interests such as: associations and organisations with an interest in soil health and related ecosystem services, local or regional government, scientists from a variety of fields outside soils (natural sciences, social and behavioural sciences etc.). The list of users may depend on the specificities of the places and challenges that are specific to that place. • For demonstration activities: target audiences include soil managers, the public arena and relevant networks such as for example EIP-AGRI.
Context	• Transdisciplinary and participatory approach. • Multi-method approach. • Place-based; well defined system boundaries (e.g. farm, (sub)-watershed, neighbourhood, NUTS region, value chain) of relevance to soil challenges. This relates to specific regions and sectors. • Real-life context = real farms/forest or urban/industrial sites, seeking to go beyond current practice. • Long-term set-up. • Openness, communication and dissemination and connection with networks. • Multiple dimensions: technical, economic, social. • Robust scientific set-up for ecosystem assessment.

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 - Cidésol Co-create, <https://cocreate.brussels/projet/cidesol>;
 - THINK EAT: Urban Alternatives, Région Bruxelloise, www.sciences.brussels/printemps/events/think-eat-urban-alternatives;
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