soil seekers

Save Our Soils

The urgent need for political and social change to ensure soil health

Contribution of the Team Soil Seekers for the

WUR Student Challenge- Make all soils healthy again!

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Contents

Who are we? – Team Soil Seekers

We, Team Soil Seekers, are Pauline Eichenseer, Philippe Belliard and Julian Haller. Our team consists of Plant Sciences and Organic Agriculture master students. During our education and practical experience with soils we developed a passion for this precious resource. We are very much aware of the many profound challenges that face humanity today and the pressing need for thorough system change in our societies. We therefore all have the strong desire to contribute to a better world, and we see the tremendous importance of action for healthier soils to achieve our goals. We have extensive background knowledge on sustainable soil management in the context of agriculture and think we can make a useful contribution to this challenge. We need to improve and adjust soil management systems to tackle specific issues, in a changing world desperately in need of moving towards more healthy soils!

Acknowledgements

We would like to thank Eugène Hendrikx and Prof. Dr.Ir. Johan Bouma for the support and guidance during the challenge, the members of the healthy soils challenge Advisory Board, and the surveyed and interviewed farmers who provided us with valuable insights. A big thanks also goes to Viktoria Hartan for designing our Logo.

Preface

This manuscript is the product of the Team Soil Seekers developed for the Wageningen University Student Challenge 'Make all soils healthy again!'. We participated in the challenge and compiled transdisciplinary concepts in this piece of work because we want to contribute our ideas and convictions about how different approaches to tackling soil health issues could be a great chance for many burning problems in the European Union and worldwide. We are dependent on the soil - therefore we should take care of this precious resource! We want to highlight that our contribution to the challenge consists of a report which is supplemented with videos in each section. These videos are an important part of our work and should not be overseen. These videos will open after clicking on the respective pictures. In addition, we conducted several interviews with farmers from different countries to understand their perception of soil health and the relation to their business, policy and subsidies.

This report is aimed at people in the scientific community, political decision-makers, managers, educators, consumers, farmers and, last but not least, society as a whole - without whom a resilient transition towards soil health improvement cannot be achieved. We explain the necessity of soil for humanity and the environment. We also discuss soil health management measures to improve the perspective of land managers. In the following we show weaknesses in the existing agricultural policy and proposals for improvement in the new common agricultural policy. In the last chapter we explain how the transition towards more healthy soils can be achieved through a common societal transformation. We would like to thank everyone who contributed to the discussions and interviews that led to the final product of our work. We have grown together as a team, even though we were working full-time during this time for our diploma theses and internships in companies. We really appreciate the contribution of every single team member. Without them this work would never have come about. In conclusion, we hope that all who read this manuscript will enjoy it and find it a useful contribution to healthier soils.

The Soil Seekers

Julian Haller, Pauline Eichenseer and Philippe Belliard

Executive Summary

Soils are the foundation of terrestrial life and human societies. We are enormously dependent on good quality, healthy soils for the provision of a wide array of supporting, provisioning, regulating and cultural ecosystem services. These ecosystem services are essential for realizing the Sustainable Development Goals (SDGs) set by the United Nations to ensure better quality of life for all of humanity in the present and the future. However, the capacity of soils to deliver ecosystem services is critically threatened by land degradation caused by over-exploitation of soil resources and unsustainable land management, driven among others by practices of intensive industrial food production. Therefore it is of primordial importance that steps are taken to restore and protect soil health. To do so, we need to better define soil health and apply appropriate soil monitoring strategies, use information gained through monitoring to finetune soil health management and policies, and communicate the importance and issues of soil health to all facets of our societies.

» What is soil health and how can it be measured?

Soil health can be defined as *the capacity of a specific kind of soil to function, contributing towards achieving the UN Sustainable Development Goals*. Soil functions determine the extent to which soils can deliver ecosystem services. Measurable indicators of soil biological, chemical and physical properties are used to characterize soil health. Soil health assessments should make use of a baseline set of keystone soil health indicators that are responsive to changes in management, like organic matter content, nutrient levels and compaction, that can be expanded according to specific contexts and land uses. A combination of comparability and flexibility in a standardized framework of soil assessment with context-dependent interpretation is needed to enable widespread monitoring of soil health.

» How can land users and policy makers use soil health information to do a better job?

Soil health is perceived as very important by most land users, but there is a lack of policy instruments that adequately address soil health degradation. Land users emphasize that they would like to have more independent advice and more knowledge about soils. To make better use of the information that exists about soil health, policy makers and land users need to start a dialogue to steer policies and practices in a way that benefits all parties. The current CAP tackles soil health only indirectly through policies about biodiversity and climate change. The policies addressing soils are mostly non-binding and too flexible. Historic contamination is not addressed, and direct payments are inefficient and inequitable in tackling issues of socio-economic and environmental sustainability. In the meantime, soil contamination, sealing and erosion are continuing and threatening the health of European soils. Therefore, a change in policies is needed as enough information is available that needs to be translated into practice. The first step must be a new strategic plan in the CAP that tackles the issue of soil health directly. The CAP 2021-27 cuts on Rural Development Programmes, including Agri-Environmental Payments and gives individual countries a lot of freedom to adjust environmental measures. We avouch for more ambitious and binding goals for the fostering of soil health based on sustainable management practices, guided by independent advisors. Through regular soil testing, progress can be measured, and subsidies can be transformed into outcome-based payments. Payments for ecosystem services replacing direct payments and a tax on unsustainable practices must complement these reforms. Furthermore, the education of young farmers must be adjusted so they learn how to apply sustainable management practices to create a long-lasting change. Also, low-input agriculture like organic and circular agriculture must receive more attention and the dialogue between land users and policymakers bust be

enhanced for them to make a better use of the existing information about soil health.

» What are effective ways of communicating soil health to a wider audience (general public)?

We emphasise that awareness of healthy soil - particularly because of its important functions for humans and the environment - is the long-term key to a transition towards proper soil health care. Communication in its very different available forms must be used to raise awareness of the importance of soil health throughout society. As consumers of various goods (e.g. foods and textiles), we make unconscious decisions that have a major impact on soil. Whether these impacts are negative or positive depends on the decisions we make as consumers. Society needs citizens who make informed choices in their daily lives that contribute to healthy soils. Solutions to this issue are available today, now it is up to consumers, farmers, policy makers, educators and industries to use and implement them. An important element is communication at eye level between land managers and other stakeholders to understand each side's needs. These needs should be considered to find the best possible compromise for each stakeholder involved. This is necessary for a resilient transition towards soil health improvement. We advocate educating children from kindergarten age onwards about the importance of soil. Soil health should be part of the curriculum during school years with increasing complexity in theory and practice, in order to raise awareness of healthy soils starting from early childhood. Excursions and practical work with soils are an important part of this strategy. The same applies to the future training of land users. The health of the soil must be the focus of education. We should also support the education of young people and adults. This should be done on a large scale using digital media, targeted advertisement and human interactions. Awareness raising with informative video clips, advertisement for soil health and certified products in supermarkets are part of the strategy. Next to institutional and food industry action, bottom-up projects (such as Community Supported Agriculture and direct sales models) that involve a strong farmer-consumer relationship, in which soil health and food sovereignty are the basis, becoming increasingly popular and show many social, environmental and economic benefits that are not negligible. These multifaceted aspects of communication play an important role in the strategy presented.

1. Introduction to the importance of healthy soils

Video 1 Let´s Talk About Soil – IASS Potsdam

Since the advent of higher terrestrial life on this planet, soils and its building blocks have formed the vital basis for its existence. Soil, together with air and water, enabled life to thrive on this planet by providing habitat, a medium for conversion and transformation by chemical, physical and biological processes. As humans were dependent on the soils of our planet as foundation for the delivery of food and other resources from the very beginning of their existence onwards, we thank our developmental progress from insignificant apes to what we are today, to soil [1]. Since humans shifted from a hunter gatherer diet to farming around 8000 - 10000 years ago [1,2] fertile soil became more apparent to humans as a valuable resource utilizable to farm natural goods (food, wood, textiles and building materials). This laid the foundation stone for the emergence of specialization, new technologies and thereupon civilizations [1,3]. From this moment on, humankind went through many agricultural innovations that further increased yield and improved growing systems [1,3,4]. Nonetheless, many civilizations like the Mesopotamian empires, Roman empire, ancient China and many others perished by the consequences of the unsustainable exploitation and degradation of their soil resources [3,4]. With the green revolution, scientific inventions like the Haber-Bosch procedure and mineral fertilizer production (mining and purifying), plant protection agents, and progresses in engine-driven mechanization, yields further increased as a result of better plant nutrition, plant protection and management possibilities [5].

Land that is used for agriculture today accounts for one third of the worlds terrestrial surface (Antarctica excluded) [6]. In fact, our planets limited land area is covered by 12% cropland and permanent crops [7]. and around 25% pastures and meadows [6]. In the European Union cropland occupies 22.2% and grassland 20.7% of the total terrestrial area [8]. But due to a variety of factors (economic pressure, insufficient education, exploitation and ignorance) that lead to the over- or misuse of fertilizers, plant protection agents, intensive soil tillage and other mismanagement, soils around the world are subject to degradation. The degradation of soils (on a physical, chemical and biological level) through desertification, salinization, acidification, loss of favourable soil structure, compaction, soil organic matter decline, decreasing biotic activity and diversity, sealing (urban areas, streets etc.), pollution or nutrient depletion and erosion puts pressure on soil functions worldwide [9]. Humans already managed to contribute significantly to the loss of ecosystems and landscape degradation [9,10], and it is regrettable that worldwide large areas are already in a poor state today. Alarmingly, around 25% [11] of the global land area is already rated as highly degraded land (35 million km²).

In the EU, soils are also subject to degradation [12]. At this time 12.7% of Europe's land is affected by moderate to high erosion (>5t soil/ha/year). Soil loss due to water erosion is estimated 970 million tons/year [13] and expected to increase due to more extreme rain events [14]. An estimated mean water soil erosion rate in the EU is 2.46t soil/ha/year [15],

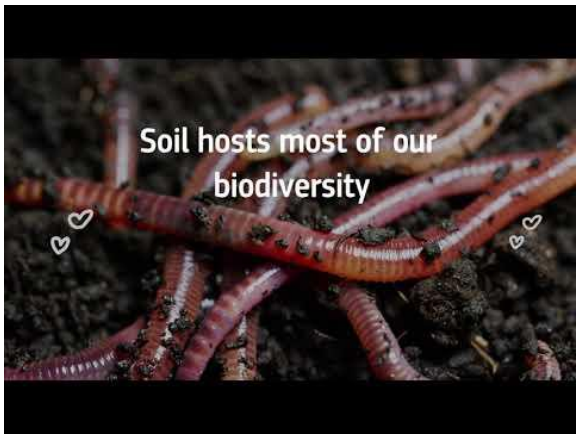
which is 1.6 times higher than average soil formation rate. The average estimated annual loss of soil due to wind erosion is 0.53 t/ha/ year in EU-28 (2001 -2010) [16]. These examples further show the necessity of action against erosion. Additionally, soil compaction decrease crops yields and increase risk of run-off and flooding [17]. An alarming proportion of 23% in EU-28 member countries soils is estimated to have critically high densities in their subsoils. But so far there is no European instrument against severe soil compaction. Intensive land use in EU-28 has already decreased soil biota and vegetation biodiversity [12]. Next to the mentioned threats and negative impacts, soil contamination is a problem for soil organisms and human health [18]. In Europe there is an estimated number of 2.8 million contaminated sites (only 24% are inventoried from which only 28% are investigated) [19]. Various contamination thresholds in European soils are exceeded already [12]. Alone between 2000 – 2018 there was an 7.1% increase of artificial surfaces areas thereby disrupting ecological soil functions which resulted in decline of unsealed land area. Additionally, there was a 1% loss of wetlands in two decades [12]. Today around 72% of EU population lives in or close to cities, towns and suburbs [20]. Further urban extension will lead to the need of more infrastructure and a decrease in long term availability of productive land. The absence of appropriate soil legislation on EU level further contributes to soil degradation [12].

Degraded soils are the opposite of healthy soils. Healthy soils have the capacity to function as intended, deliver ecosystem services and contribute towards achieving the UN Sustainable Development Goals (SDGs; explained in more detail in the next sections). Industrial agriculture and its impact on soils and native ecosystems is the second largest contributor of greenhouse gas emissions (including land use change and forestry) [21,22]. Degraded soils entail important negative implications for humanity, our climate, global food security, biodiversity and finally they are impacting our whole planet [9,18]. Consequences like food insecurity, poverty and ensuing forced migrations are further exacerbated by the impact of climate change worldwide [23,24]. In a short negligible timeframe in relation to the existence of our planet, humans managed to significantly alter and thereby negatively impact the world soil resources, the water, nitrogen and carbon cycles and finally the climate and the environment [9]. But there is still hope, as in most cases soil degradation is reversible.

In this piece of work, we introduce sustainable integrated soil management, a strategy that tackles degraded soils and restore their functions to make them functional and healthy again. Sustainable integrated soil management is a systems approach to regain soil functions lost due to one or more degradation processes. Management and understanding of the underlying principles are vital to restore or keep soils healthy depended on the context. In this comprehensive toolbox we provide insights and approaches on an integrated management that not only considers soil management practices as vital component but also the social, economic, ecological and political factors to restore and even regenerate soils. We consider reasonable targeted monetary incentives for soil, crop and livestock management in the framework of the European Common Agricultural Policy (CAP) an important part. But we highlight that this transition is not to be made without rising societal and political awareness for healthy soils and land managers that are seeing the importance for change in the management to contribute and benefit to and from healthy soils. We see the regeneration of soils as a great opportunity to not only diminish the impact of climate change and environmental degradation but also to feed the world and preserve livelihoods (in relation to the EU), support public health by nutritious healthy food and finally reduce poverty and solve some burning environmental problems.

Significance: Ecosystem services delivered by healthy soil

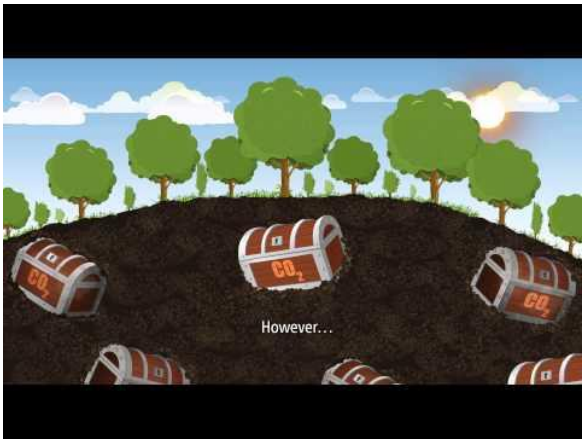
The concept of ecosystem services has emerged in the recent years as one of the most powerful guiding principles for ecology, biodiversity conservation and the management of natural resources. It can assess multiple values including the services soils can provide to humankind [25].



Video 2 Soil matters – EU Food & Farming

One of the most important ecosystem providers that are fundamental to life on earth are soils, which are also an important element of sustainable agriculture. But human pressures on soil resources are increasing and reaching critical limits. Soil functions and processes determine a soil's capacity to deliver ecosystem services, but soil functioning faces numerous threats (Figure 1). Therefore, careful management of soils are an essential element of sustainable agriculture and important for the delivery of ecosystem services [26]. Soils contribute to all categories of ecosystem services. These are often differentiated in supporting, regulating, providing and cultural services. Healthy soils fulfil basic human needs like food, fibre and fuel. To achieve food and energy security, the need in these resources is increasing which also expands the pressure on soils.

Soils provide for human needs by purifying and retaining water and providing raw materials. Furthermore, soils provide stables surfaces for human habitations, habitats for animals and they are the source of biological unique materials. To maintain or enhance the supply for food, water and energy, soils need to be kept healthy. Besides these provisioning services, supporting services are important services soils are contributing to. Weathering of minerals and the release of nutrients as well as accumulation of organic matter lead to soil formation. Healthy soils are important to support the root growth and seed germination and provide water and nutrients for plants as soils cycle nutrients. Among the regulating services, especially the regulation of the water quality is of importance as soils filter, buffer and transform substances. They also regulate water supply for plants (infiltration and drainage). Another very important regulating function is the influence soils have on the climate as soils regulate CO2, N2O, and CH4 emissions and therefore influence climate change.



Video 3 Soils: Our ally against climate change - FAO

Finally, soils are also important in preserving landscape diversity and the heritage of former populations [25,27]. As soils are results of complex interactions of processes in time and space, they are very diverse themselves in form and properties and the level of ecosystem services they deliver, which needs acknowledgement in management. The physical, biological and chemical properties of a soil govern its functions. Of concern is the right balance between the supporting and provisioning services for plants and the regulating services the soil provides for water quality and the regulation of greenhouse gas composition as there can be trade-offs. Furthermore, the biodiversity soils

support is fundamental for sustainable soil management. Land use changes have negative effects on the provision of services; however, restoration can help increasing the ecosystem services a soil provides [25].

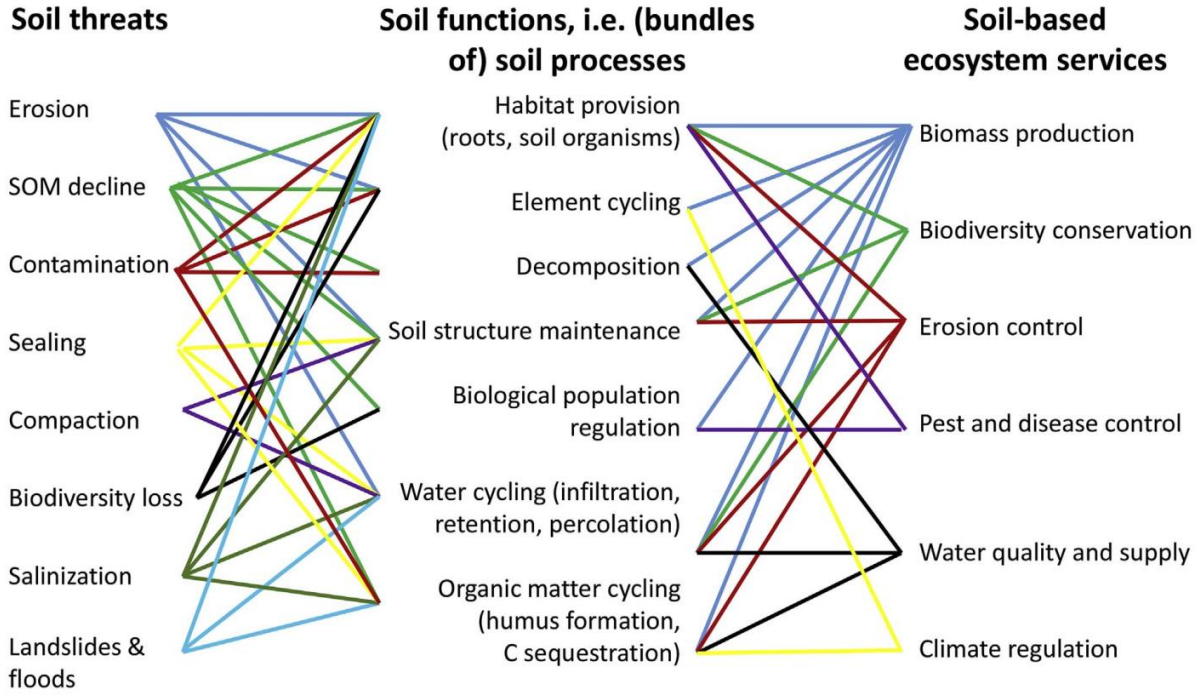


Figure 1 Soil threats that compromise soil functions underpinning soil-based ecosystem services [28]

Soil and the achievement of UN Sustainable Development Goals

Ecosystem services are essential for the health of the planet and humans as explained above.

Video 4 Sustainable soil management: A major step in achieving the Sustainable Development Goals – FAO

A reduction in soil health engenders the impairing of ecosystem services healthy soils could otherwise provide. This includes the regulation of climate, purification of water and biodiversity as well as agricultural production of food, fibre and fuel.

Video 5 Food wastage footprint -FAO

Often these functions are substituted by other resources, e.g. soil fertility and proper nutrient cycling is replaced by mineral fertilizers. However, mineral fertilizers and other measures lead to other environmental problems.

There is no sustainable replacement for healthy soils. Therefore, it is of utmost importance to pay attention to soils and to keep them healthy. Related to the issues the population is facing and will be facing in the future are the Sustainable Development Goals (SDGs) developed by the UN. Healthy soils indispensably contribute to most SDGs including ending poverty and hunger, ensuring the health of humans, taking urgent actions to combat climate change and protecting, restoring and promoting the sustainable use of terrestrial (and aquatic) ecosystems. These are only 6 of the 17 development goals, with soils contributing to almost all 17 (Table 1).

Fertile soils are the foundation of food security (SDGs 1,2,3) and require sustainable management strategies, while techniques of industrial agriculture are not effective at sustaining the productivity of soils over a longer period. Besides providing food, soils are also essential for human health (SDG 3) as they affect the livelihood of humans through quantity, quality and safety of food and water. Furthermore, soils are a source of essential medicines, whereas eutrophication of soils can lead to an increase in plant pathogens. Agricultural activities are threatening the quality and quantity of water as excess nutrients pollute freshwater sources and degrade ecosystems, with the agricultural sector being at the same time the biggest consumer of freshwater[9]. But healthy soils are important for filtering water and providing safe and affordable drinking water (SDGs 3,6). Soils also contain more carbon than the atmosphere and therefore play an important role in combatting climate change as a carbon sink (SDG 13). Rising temperatures and changing rainfall patterns lead to complex interactions as in general, more carbon will be stored in the soils, but peat and permafrost are also vulnerable to carbon losses. To sustainably use terrestrial ecosystems, land management (SDG 2,13,15) also needs to be adjusted and the importance of soil organic matter (SOM) must be emphasized. Degraded and compacted soils face erosion and low infiltration rates. Also, eutrophication and pollution need to be avoided. Finally, below-ground biodiversity plays an important role in healthy soils and is strongly linked to biodiversity above-ground. While land use changes and management intensification negatively affect biodiversity and soil functions, a sound management can enhance biodiversity (SDG 15) and the functioning of soils [28,29]

2. Soil Health Indicators, Ecosystem Services and SDGs

Soil health is characterized by a plethora of attributes that play fundamental roles in determining the extent to which a soil can fulfil its functions and deliver ecosystem services that will advance the achievement of SDGs. Measurable indicators of such attributes are essential tools that allow land users to assess the health status of their soils in terms of physical, chemical and biological properties (Figure 2). Soil health assessments enable land evaluators to make or advise on rationally informed decisions about land use and the implementation of soil health-promoting management practices, and to determine the effects of said practices. What is a healthy soil and how can soil health be measured?

An in-depth analysis of different soil health indicators, their meaning and mode of assessment is beyond the scope of the present work. A substantial body of literature already exists pertaining to diverse soil health indicators and their use in soil health assessments, including detailed standard protocols, pros and cons of their application, and context-dependent interpretation frameworks (e.g. [30,31]**)**. The list of potential soil health indicators from which to choose when carrying out soil health assessments is extensive (

Box 1).

Table 1 Relation of soil ecosystem services to UN Sustainable Development Goals[28]

Ecosystem Service	Provision of food, wood and fibre	Provision of raw materials	Support for human infrastructures and animals	Flood mitigation	Filtering of nutrients and contaminants	Carbon storage and greenhouse gas regulation	Detoxification and the recycling of wastes	Regulation of pests and disease population	Recreation	Aesthetics	Heritage values	Cultural identity
SDG topic	1	2	3	4	5	6	7	8	9	10	11	12
1 End poverty in all its forms everywhere	x	x	x	x								
2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture	x		x									
3 Ensure healthy lives and promote well-being for all at all ages	x							x	x	x	x	x
4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all												x
5 Achieve gender equality and empower all women girls												
6 Ensure availability and sustainable management of water and sanitation for all				x	x		x		x			
7 Ensure access to affordable, reliable, sustainable and modern energy for all	x	x										
8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	x	x	x									
9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation		x	x									
10 Reduce inequality within and among countries												
11 Make cities and human settlements inclusive, safe, resilient and sustainable		x	x									
12 Ensure sustainable consumption and production patterns	x	x			x	x	x					
13 Take urgent action to combat climate change and its impacts				x		X						
14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development												
15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	x	x	x	x	x	x	x	x	x		x	x
16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels			x						x		x	x
17 Strengthen the means of implementation and revitalize the global partnership for sustainable development												

Therefore, it is essential to initially select relevant indicators tailored to local conditions (e.g. soil type, climate) and land uses. Such is the approach, for instance, of the Soil Management Assessment Framework (SMAF) developed at the Soil Quality Institute, in which a selection from 81 indicators allows for flexible, context-based soil health monitoring. However, too much flexibility in the choice of indicators could hamper the comparability of soil health assessments when very different sets of indicators are employed. Thus, trade-offs between flexibility and comparability could be somewhat resolved by adopting sets of minimum baseline indicators, determined per land use. Baseline indicator sets can then be expanded according to context-specific necessities, land use purposes, and focal parameters of interest. The Cornell Framework for Comprehensive Assessment of Soil Health [31] is a good example of an assessment framework for agricultural land use purposes that recommends a limited set of baseline soil health indicators which can be extended with supplementary indicator analyses.

For instance, for agricultural land uses key indicative biological, physical and chemical features of a healthy soil include:

- High soil organic matter content (stable, labile and particulate)
- High biological activity (microbial, mesofaunal e.g. earthworms)
- Suppressiveness to soilborne diseases
- Good soil structure (stable micro- and macroaggregates)
- High infiltrability and drainage
- Porous (micropores and macropores)
- Good water retention capacity
- Low runoff and erosion
- Little compaction (density)
- Sufficient available nutrients
- Low leaching rates
- Good cation exchange capacity
- pH of 5.5 to 7.5 (related to nutrient bioavailability)
- Uncontaminated (heavy metals, pollutants)
- Low salinity

Several of these indicators are tightly related, with the measure of one indicator correlating with the measure of others. These 'keystone indicators' can not only serve as a proxy to predict the status of other indicators; they can be main drivers of general soil health. Soil organic matter (SOM) positively correlates to cation exchange capacity, water and nutrient retention, and biological activity for example [32–35]. Good soil structure enhances infiltrability, soil porosity, drainage and resistance to runoff and erosion, while the opposite is true for compaction [36,37]. Sufficient available nutrients increase biomass production which may lead to more carbon sequestration, whereas nutrient oversupply can entail high risks of leaching, ultimately leading to loss of water quality. Hence, including soil organic matter, soil structure, compaction and nutrient content in the baseline indicator set for soil health assessments can already provide agrarian land users with valuable insight in the health status of their soils.

It is important to note, however, that values of indicators that attest of a healthy soil may vary significantly dependent on local factors, in particular soil type. Generally, clay soils can have higher values of organic matter, aggregation and cation exchange capacity than sandy soils. Sandy soils are more prone to leaching but generally have better infiltrability and are less prone to compaction than clay soils. The interpretation of soil health indicators therefore needs to be adapted to reflect such site-specific disparities. The Cornell soil health assessment framework bases interpretation on score curves that assign indicator values to one of three principles: more is better, less is better, or an optimum range exists (Figure 3).

Box 1 Indicators of physical, biological and chemical soil health for agriculture [31]

Physical	Biological	Chemical
Texture	Root pathogen pressure assessment	Phosphorus
Bulk density	Beneficial nematode population	Nitrate nitrogen
Macro-porosity	Parasitic nematode population	Potassium
Meso-porosity	Potentially mineralizable nitrogen	pH
Micro-porosity	Cellulose decomposition rate	Magnesium
Available water capacity	Particulate organic matter	Calcium
Residual porosity	Active carbon	Iron
Penetration resistance at 10 kPa	Weed seed bank	Aluminum
Saturated hydraulic conductivity	Microbial respiration rate	Manganese
Dry aggregate size (<0.25 mm)	Soil proteins	Zinc
Dry aggregate size (0.25 - 2 mm)	Organic matter content	Copper
Dry aggregate size (2 - 8 mm)		Exchangeable acidity
Wet aggregate stability (0.25 - 2 mm)		Salinity
Wet aggregate stability (2 - 8 mm)		Sodicity
Surface hardness with penetrometer		Heavy metals
Subsurface hardness with penetrometer		
Field infiltrability		

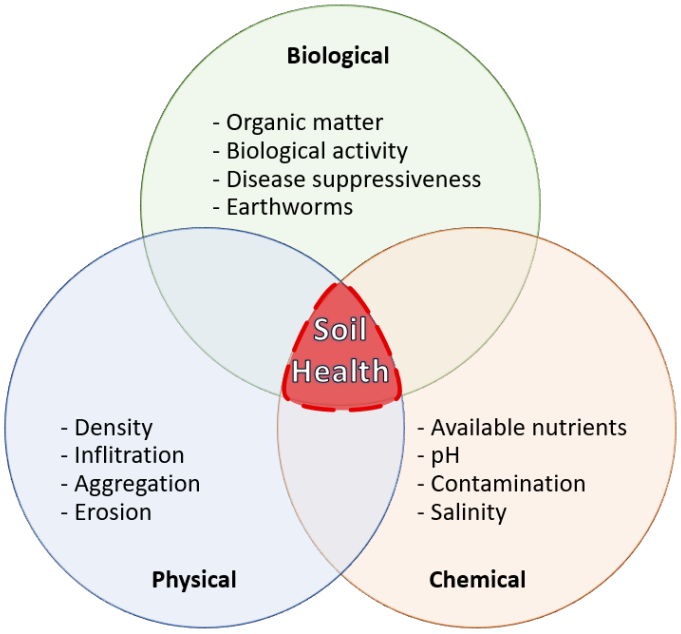
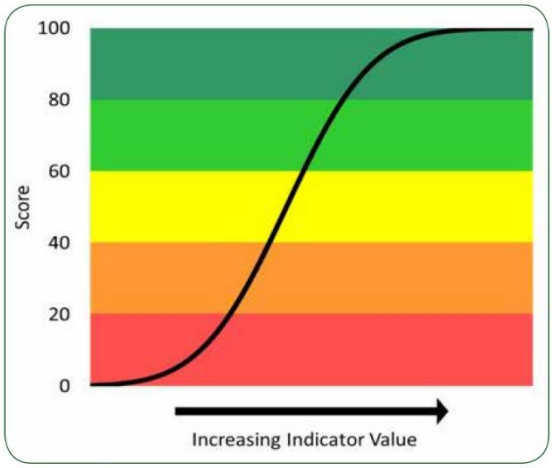


Figure 2 Soil health as an combination of biological, chemical and physical soil properties

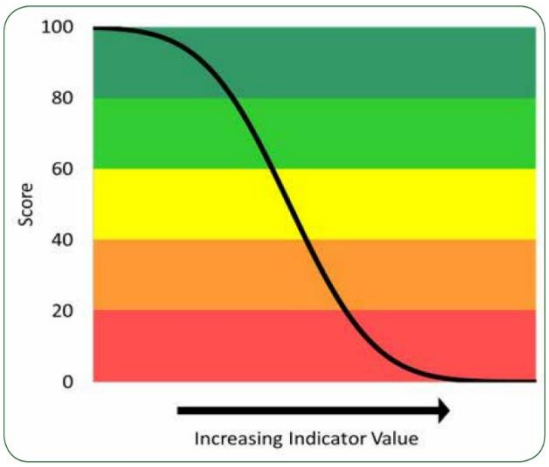
Video 6 Soil Health: Soil Physical Properties – Tianna DuPont

Soil type-dependent score graphs allow for the interpretation of indicator values account for large differences in normal ranges between very distinct soil types. Expanding the principles of such context-dependent soil health measurement frameworks to encompass all land uses (e.g. nature conservation, infrastructure, urbanization) would constitute an important step towards the more widespread consideration of soil health in all conditions, forming the basis for informed decision-making by land users and land governors to better promote soil health for the delivery of ecosystem services.

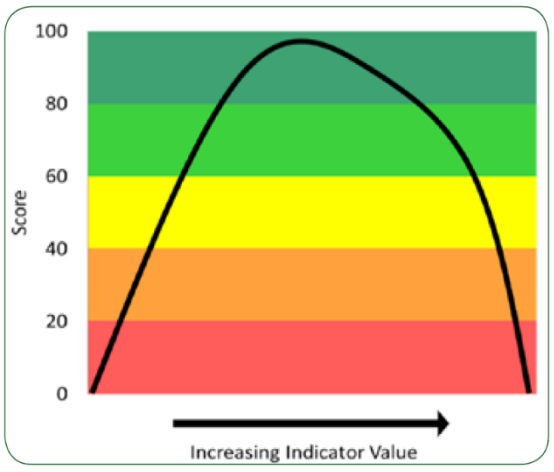
Different land use designations, associated to distinct soil ecosystem services that advance global SDGs, impel different selections of soil health indicators (Table 2). Nevertheless, in most cases a large degree of overlap exists between land uses, ecosystem services, SDGs and relevant indicators. For instance, plant production (agriculture, forestry and pastoralism) is intricately linked with watershed management when considering the ecosystem services fundamental to the SDG of clean water supply. Good water infiltrability, water retention and drainage, coupled with low rates of leaching and runoff and the absence of pollutants, will support the provisioning of food, fibre or fuel while enabling adequate filtration of groundwater as well as flood and drought mitigation. On the other hand, the presence of reasonable concentrations



A. More is better graph



B. Less is better graph



C. Optimum graph

Figure 3 Interpretation curves of indicator values based on the principles of A. More is better; B. Less is better; C. Optimum.

of certain pollutants in soils is less problematic when the soil is used as support for urban construction or for infrastructural elements such as roads and dikes. The interconnectedness of many soil ecosystem services, their associated land uses and SDGs further extends to the soil functions that underpin said ecosystem services and the many threats imperilling soil functioning (Figure 1). Hence, addressing a core set of soil health threats to ecosystem services relevant to several land uses and sharing common indicators would be a good starting point to focus efforts of soil health protection and regeneration.

The technical aspect of many of these indicators, as well as the cost of their assessment and difficulty of interpretation, can be prohibitive to many land users. This often restricts their use to academic stakeholders, from which informative and advisory feedback to land users is often limited. Moreover, understanding of soil health indicators and their implications for the delivery of ecosystem services is relatively confined to disciplinary spheres and therefore remains dim to public and gubernatorial awareness. Hence, there is a necessity to highlight directly assessable, interpretable and accessible indicators relevant for ecosystem services, SDGs and broader society. Putting a handful of simple but strongly impactful soil health indicators in the foreground of sustainability discourses surrounding the use of soil resources, from infrastructure to food supply chains, will help guide decision-making processes for land users, policymakers and the general public alike. Crucially, soil health indicators that are responsive to management practices – both on the short and long term – should be continuously monitored to substantiate the effectiveness of management in fostering soil health and certifying that land users and administrative institutions are ensuring the preservation of soil health. In order for land users, experts and policymakers to adequately use indicator information for better decision-making, proper analytical tools are needed to make better use of large amounts of data acquired from soil health assessments.

3. Soil management practices fostering soil health

Deterioration of soil health can be mitigated, or even reversed, by adopting management practices that positively steer soil properties in ways that promote soil functioning and the delivery of soil-based ecosystem services. Below are some key general management practices that can contribute to the aggradation of soil health and the sustainable stewardship of soil resources, based on four principles of soil health: minimize disturbances, maximize biodiversity, use organic amendments, and maximize (living) soil cover (Fout! Verwijzingsbron niet gevonden.).

Reduced soil disturbances

Thorough soil disturbance by means of tillage is among the most defining features of agriculture, and an important operation for short-term weed control, soil loosening and the incorporation of organic amendments. However, in the long term over-intensive soil disturbance through tillage, in particular inversion tillage coupled with the use of heavy machinery, has several negative consequences on soil health. Compaction is commonly associated with long-term tillage, which impedes root growth, infiltrability and drainage[38,39].

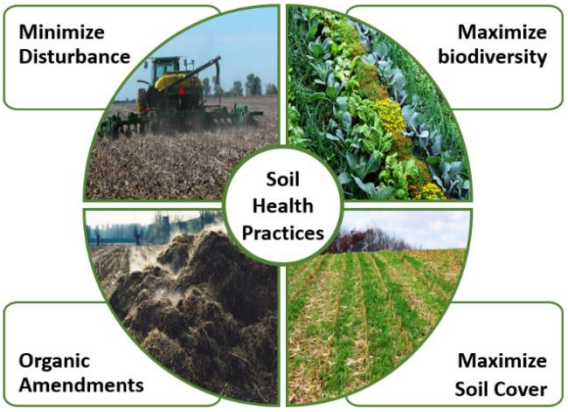


Figure 4 Core practices fostering soil health in cropping systems

Table 2 Indicators of ecosystem services associated with different land use designations and related Sustainable Development Goals. Adapted from Keestra et al. (2016) [28]

Ecosystem Services		Related SDGs	Associated land use	Soil Health Indicators
Supporting services	Soil formation	1, 2, 3, 9, 12, 15	Plant production, nature conservation	Soil depth, erosion
	Primary production	1, 2, 3, 7, 8, 9, 11, 12, 13, 15	Plant production, nature conservation	Available water capacity, infiltrability, drainage , water retention, porosity, total and bioavailable nutrients, cation exchange capacity, pH, salinity, aggregation, compaction, pollutants
	Nutrient cycling	1, 2, 3, 6, 9, 11, 12, 13, 14, 15	Plant production, waste management, watershed management	Potentially mineralizable nutrients, microbial turnover, total and bioavailable nutrients, organic matter content, water contamination, runoff, leaching, denitrification, volatilization
Provisioning services	Food, fibre and fuel supply	1, 2, 3, 7, 8, 12, 15	Plant production	Available water capacity, total and bioavailable nutrients, cation exchange capacity, pH, salinity, compaction, infiltrability, drainage , water retention, porosity, aggregation, pollutants, pest/pathogen pressure, beneficial microbial communities, organic matter content, erosion, runoff
	Provision of raw materials	1, 7, 8, 9, 11, 12, 15	Resource extraction	Resource availability, pollutants, water contamination
	Support for human infrastructure and animals	1, 2, 8, 9, 11, 15, 16	Infrastructure, urban development	Soil stability, drainage, erosion
	Water supply	2, 3, 6, 7, 9, 11, 12, 14, 15	Resource extraction, watershed management	Infiltrability, available water capacity, water retention, runoff, pollutants, water contamination
	Refugia	11, 12, 15	Nature conservation	Vegetation cover, organic matter content, soil disturbances, pollutants, sealing
	Source of unique biological materials	2, 3, 9, 12, 15	Nature conservation, medicine	Biodiversity, antibiotic production
Regulating services	Flood mitigation	1, 6, 13, 15	Watershed management	Infiltrability, porosity, drainage, runoff, erosion, sealing
	Filtering of nutrients and contaminants	6, 12, 15	Watershed management, waste management	Infiltrability, runoff, cation exchange capacity, pollutants, water contamination
	Carbon storage and greenhouse gas regulation	12, 13, 15	Plant production, nature conservation	Organic matter content, soil organism biomass, denitrification, microbial respiration rate, decomposition rate, drainage
	Detoxification and the recycling of wastes	6, 12, 14, 15	Watershed management, waste management	Detoxifying microbes, pollutants, water contamination
	Regulation of pests and disease populations	2, 3, 12, 15	Plant production, nature conservation	Pest/disease pressure, soil suppressiveness, beneficial microbial communities
Cultural services	Recreation	3, 6, 15, 16	Recreational areas, nature conservation	Pollutants, sealing, vegetation cover
	Aesthetics	3, 8	Recreational areas, nature conservation	Vegetation cover, sealing
	Heritage values and cultural identity	3, 4, 15, 16	Recreational areas, historical sites	Historical use, landmarks

In addition, tillage frequently results in the degradation of soil structure by breaking up aggregates and pores, leading to reduced infiltrability, drainage and water-holding capacity, and exacerbating erosion and runoff [37,40]. Furthermore, tillage can have negative effects on soil biota that are important for soil health, most notably earthworms, which are critical ecosystem engineers [41], while accelerating the decline of SOM by increasing decomposition rates [42]. Reducing the frequency and intensity of soil disturbance by practicing principles of conservation tillage can improve physical, chemical and biological soil health properties, especially on the long run [43]. Adopting less disturbing reduced plowing techniques, such as non-inversive chisel plowing, can already significantly alleviate many negative effects of tillage operations [39,40].

Avoiding plowing altogether in no-till farming has also been widely advocated as a mean to restore and maintain soil health. Zero-tillage practices are regularly reported to be beneficial to many physical, chemical and biological soil properties including structure, hydraulic conductivity, water and nutrient retention, SOM and biological activity [44–47]. However, the potential of zero-till systems to enhance soil health differs between soil types, with heavier soils generally showing less beneficial or in some cases even detrimental effects of zero-tillage as opposed to lighter soils [48]. Occasional non-intensive tillage may therefore still form a part of integrated soil health management in some cases. On the other hand, in the case of organic soils (i.e. peat) tillage should be avoided altogether due to its distinct fragility to soil disturbances that result in its degradation and consequent soil subsidence. Importantly, some studies have shown that the benefits of zero-tillage only occur when combined with broader and more diverse crop rotations [47,49]. The combination of reduced soil disturbance with more diverse plant production systems is therefore critical to foster soil health.

Video 7 Do not disturb – No-till farming - TheUSDANRCS

Vegetation diversity

In natural soils, often regarded as references for healthy soils, aboveground ecosystems linked to belowground ecosystems are generally characterized by relatively high vegetation diversity. There is an increasing awareness of the influence of vegetation diversity on various aspects of soil health. More diverse plant communities have been found to increase carbon input into soils, thereby offsetting greenhouse gas emissions while stimulating biological activity and biodiversity [50,51]. The suppression of soil-borne pests and pathogens can be promoted by higher plant diversity, reducing the need for chemical pesticides that negatively affect the environment and human health [52,53]. Moreover, greater diversity in vegetation structure and spatial distribution, driven by plant species richness and functional diversity, can reduce soil loss from runoff and erosion while improving soil structure [54–56].

Hence, interventions to increase vegetation diversity could enhance soil health in several ways that promote soil functioning, thereby promoting soil ecosystem services. For instance, infrastructure groundwork such as dikes, roadway slopes, waterbody banks, as well as coastal protection zones and hillslopes would greatly benefit from increased soil stability that can be conferred by higher plant species diversity [57,58]. The management of vegetation diversity in terms of species and structure should therefore be

incorporated into frameworks of landscape management in semi-natural as well as anthropic landscapes. Coupled with judicious landscape design, the enhancement of soil health by means of managed vegetation diversity could play a key role in the restoration and upkeep of crucial watersheds.

Vegetation diversity is particularly advantageous for agro-ecosystems with regard to its potential to aggrade soil health. Continuous monocultures of annual crops are detrimental to soil quality and can lead to an impairment of soil functions and loss of productivity [59,60].

Figure 5 Different forms of polyculture (top left to bottom right): Complete mixture, row intercropping, strip cropping and agroforestry.

Increasing vegetation diversity in crop sequences with crop rotation is essential to mitigate the degradation of soil structure, nutrient depletion and build-up of pests and pathogens associated with the repetitive monocrop cultivation of few crop species. It is clear that crop rotations with higher diversity of plant species, especially with more cereal and less root crops, positively affect nearly all soil health indicators and ecosystem services, including structure, hydraulic properties, SOM, and microbial diversity. Crop rotations must be implemented in plant production systems to develop and sustain healthy soils that function well and provide ecosystem services that support SDGs. Especially in arable farming crop rotations of a minimum of 4 years should be mandatory. However, even long crop rotation cycles that confer vegetation diversity in time maintain the sequencing of crop monocultures in space. Polyculture cropping systems offer a compelling alternative to monocultures by combining the cultivation of several crop species simultaneously. Different forms of polyculture – complete species mixtures, row intercropping, strip cropping and agroforestry (Figure 5) – can significantly contribute to the improvement of soil health by favoring ecosystem function [61,62]. Species-rich pastures are more productive, resource-efficient, resilient and positively affect carbon capture, soil physical properties, nutrient cycling and biological activity and diversity [62–64]. Likewise, polycultural approaches to crop production and forestry have immense potential to mitigate soil erosion, runoff, nutrient leaching, reduce pesticide use, and more [65,66]. In this way polycultures lead to multifunctional agroecosystems that can alleviate negative effects of industrial agriculture on water quality, biodiversity and food safety among others by better delivering agroecosystem services.

Video 8 Mixing it up—the power of diversity - TheUSDANRCS

Organic amendments

Shifting paradigms from the perception of soil as a simple mineral substrate for plant growth towards that of a complex biological system that can be characterized as 'healthy', often preach the need to "feed the soil" rather than "feed the plants". Feeding the soil refers to the addition of organic materials to soil to feed decomposer communities

that break down and mineralize organic matter, making nutrients available for plants to take up. Nutrient cycling is thereby stimulated, and because the organic amendments act as a slow-release fertilizer, the risk of nutrient leaching to groundwater is significantly decreased in comparison with inorganic fertilizer. In addition, the stimulation of biological activity in decomposition processes and its artifacts greatly contribute to the formation of stable aggregates, micro- and macropores, the build-up of SOM and microbial communities that may suppress soil-borne pests and pathogens, favoring plant health [67]. Soil water properties are also positively affected, as enhanced activity of earthworms and other soil fauna increase soil porosity, which together with an improved soil structure results in better infiltration and drainage. Erosion and runoff are reduced while water retention, hydraulic conductivity and plant available water are increased. Accordingly, organic amendments can be considered to be the cornerstone of soil health as they constitute the foundation for the aggradation of virtually all soil health attributes, most notably being the principal driver of SOM [68].

Organic amendment types differ in many attributes such as carbon to nitrogen ratio, nutrient content, state of decomposition and microbial communities. They therefore differ in their potential to affect specific soil health properties, depending on the specific needs of a soil as well. For instance, animal manures with high nutrient and low carbon content may be most appropriate for improving soil chemical fertility, while crop residues or straw-supplemented farmyard manure have the greatest effect on physical aspects of soil health such as improving infiltration and alleviating compaction [69–71]. Compost is particularly suitable for enhancing biological properties such as soil suppressiveness against pests and diseases [72] as well as contributing to carbon sequestration in soils [73,74]. Allocating organic amendments to where they have the largest potential to enhance soil health and its ecosystem services based on their properties and local soil conditions would contribute to a strategy to stimulate soil health most efficiently at regional scale.

Besides their manifold benefits for soil quality from agronomic perspectives, organic amendments can also significantly contribute to soil health in terms of restoration of degraded and polluted land. Many studies have highlighted the importance of organic amendments in (soil) ecosystem restoration projects, in which applications of organic amendments can lead to improved soil health properties – notably biological indicators – and the (natural) regeneration of vegetation [75–79]. Furthermore, the remediation of soils contaminated by heavy metals, hydrocarbons and other pollutants is greatly enhanced by the application of organic amendments [80–82].

Given the plethora of positive effects that organic amendments can have on soil health, land users and land managers could profit greatly from facilitated availability and accessibility of organic materials. Better management of industrial, municipal and household waste streams in emerging circular economies would help redirect flows of nutrients and organic matter back to the land where soil health can be restored.

Maintaining biological soil cover

One of the primordial pillars of conservation agriculture focalized on soil health is the maintenance of permanent biological soil cover with either an organic mulch of plant residues or living cover vegetation. Evidently, limiting the direct exposure of soil to wind and the impact of rainfall or irrigation by maintaining soil cover considerably reduces soil losses through erosion and runoff [83,84]. A protective layer of organic mulch furthermore significantly enhances water infiltration, retention, available water capacity, and soil porosity while decreasing risks of compaction and structure degradation [85,86]. Moreover, mulching can improve nutrient cycling, prevent nutrient leaching, raise soil organic matter levels, and help suppress weeds and soil-borne diseases

[85,87–89]. Likewise, integrating cover crops or living mulches into cropping systems, as part of rotations or as intercrops, conserves soil and ameliorates biological, physical and chemical aspects of soil health. The added presence of living roots is highly valuable, as they are primary drivers of carbon flows from air to soil which feed beneficial soil microbes that enhance plant health [90]. In addition, nitrogen-fixing cover crops reduce the need for chemical nitrogen fertilizers, and living roots retrieve nutrients from deeper soil layers, thereby reducing leaching to groundwater [91,92]. Thusly, cover crops contribute to reducing reliance on chemical inputs harmful to the environment and improve water quality as well as increasing crop production, along with other ecosystem services [93]. Resolutely promoting the adoption of farming practices that maintain permanent soil cover with mulch and cover crops would constitute a crucial step towards the rehabilitation of degrading land and the preservation of soil health.

Video 9 The Great Cover Up: How Nature Protects and Enriches the Soil - TheUSDANRCS

The soil health management practices described here are far from exhaustive and for the most part apply chiefly to agricultural land uses. Specific circumstances and land uses warrant distinct ensembles of practices that best address locally predominant issues based on past, present and prospective land uses. Industrial and urban land uses and the associated problems with toxic contaminants will require interventions directed more at depollution strategies, for example. Furthermore, several barriers and trade-offs to the implementation of such management practices may hamper their widespread adoption and must be addressed. For instance, retaining crop residues such as cereal straw on arable fields goes at the expense of its sale as an additional source of income, and soil cover has been reported to impede soil warming in spring in colder climates, delaying planting and possibly incurring losses in attainable yield. Incentivizing the implementation of soil health-enhancing practices with compensatory schemes coupled with regulatory frameworks (e.g. mandatory soil cover in erosion- and/or leaching-prone soils) could help alleviate such trade-offs and encourage the advancement of soil health.

Reference soils and lighthouse land users

Although the theoretical underpinnings of what qualifies a soil as healthy and which practices can enhance soil health are to a certain extent established, the large diversity of soil types, land uses and other context-dependent factors make it difficult to clearly determine the goals that land users and land managers can strive for. The identification of reference soils for different soil types and land uses, accounting for geographical contexts, can support land users and managers in understanding what a healthy soil means for their situation and what improvements are attainable.

In a pilot study, a report by the Dutch National Institute for Public Health and the Environment (RIVM) outlined the development and analysis of references for soil health, defined by biological quality, for clay, sand, peat and loess soils used for crop production, livestock farming, nature conservation, urban green spaces and other purposes [94]. This study sets a good groundwork and precedent for the designation of reference soils that show the levels of soil health that can be potentially achieved even under common management regimes, and how they relate to national standards. The index of reference soils

should be expanded by incorporating other essential aspects of soil health (i.e. physical, chemical, and additional biological properties), more soil types, and measures of ecosystem service delivery. This could be extremely helpful for land users and policymakers to more comprehensively assess the health statuses of soils and how they relate to their potential states, thereby pinpointing soils most in need of rehabilitation. In addition, the identification of key management practices that differentiate the healthiest reference soils from less healthy soils in similar pedoclimatic conditions would be highly valuable to help determine appropriate courses of action to improve soil health wherever possible.

Similarly, building up networks of exemplary land users that showcase best practices in sustainable soil health management could help pave the way to more widespread adoption of said practices. Furthermore, these networks could constitute a platform of co-innovation where a facilitated exchange of new ideas, original techniques, and practically grounded experiences and insights can take place. The Global Network of Lighthouse Farms is a collaborative project that aims to create such an "outdoor classroom and laboratory" through a network of farms around the world that provide real-world examples of sustainable foodscapes that support ecosystem services towards the achievement of SDGs (www.lighthousefarmnetwork.com). More localized and widespread networks of lighthouse farms, i.e. ranging from regional to national scales, should be founded that focalize on soil health and provide the framework in which outdoor classrooms and laboratories to concretize. Support from expert advisors, scientific institutions, governmental agencies and other multidisciplinary stakeholders should ensure the viability and effectiveness of these networks by administrating a registry of lighthouse farms, identifying key management practices and facilitating exchanges. Exchanges between land users, for instance by means of field days at lighthouse sites or experimental stations, will enable the sharing of knowledge and experiences, while creating an environment for peer to peer comparison of farm performance not only in terms of soil health, but also other facets of environmental, economic and social sustainability.

Video 10 What is a 'Lighthouse Farm'? – Global Farmers

4. The socioeconomic factor - Farmers perception of soil health management practices

Science has contributed to a multitude of practices and suggestions that could increase soil health in a wider context depended perspective. But all the evidence collected, and work invested over the years to find solutions to regenerate and protect soil will not fruit in a meaningful way if practices are not adopted by farmers and land managers. Therefore, it is indispensable to invest in the understanding of underlying principles of decision making by land users to understand and foster the adoption of practices increasing soil health. A study investigated the farmers attitude in seven European countries towards practices that could protect soils and benefit the environment. The outcome revealed that farmers prefer relatively simple practices that do not interfere much with the normal "business as usual" practices. Moreover, management that interfered with on-field practices where mostly disliked (Figure 6)

Interestingly, erosion management was the most unfamiliar practice for asked famers. In general, most farmers behaviour is likely to be driven by short-term economic benefits [95–97] as farmers are entrepreneurs and often take loans for investments, which need to be paid back. An important part of the decision making towards more sustainable practice adoption is that the farmers need to trust in the recommendation of a suggested management change and its positive impact that subsequently lead to an economic benefit and/or positive image. Next to economic factors, decisions of farmers are based on experience, proof of concept demonstration, interactions with other farmers, extensions services and the perceived risks [95,98]. An often-observed hurdle for the uptake is that recommendations from the scientific sector come from experiments that may not reflect on-farm conditions (soil type, weather, typical farm operations) which further foster the probability of rejection by farmers [99]. Also, the time until a certain measure proves to be beneficial to the farmer is often not a fast-appearing effect, which means it is not highly visible, quick or a short-term solution to a problem. Regarding these problems, integrated solutions have already been implemented by adventurous innovative and successful farmers which could serve as demonstration examples, knowledge exchange platforms for other farmers further accelerating positive change for the already existing bottom-up soil health movement. So far monetary incentives from the CAP did not influence the management practices enough to make a significant change in soil health improvement. This might change with a new approach to the CAP for 2021-2027.

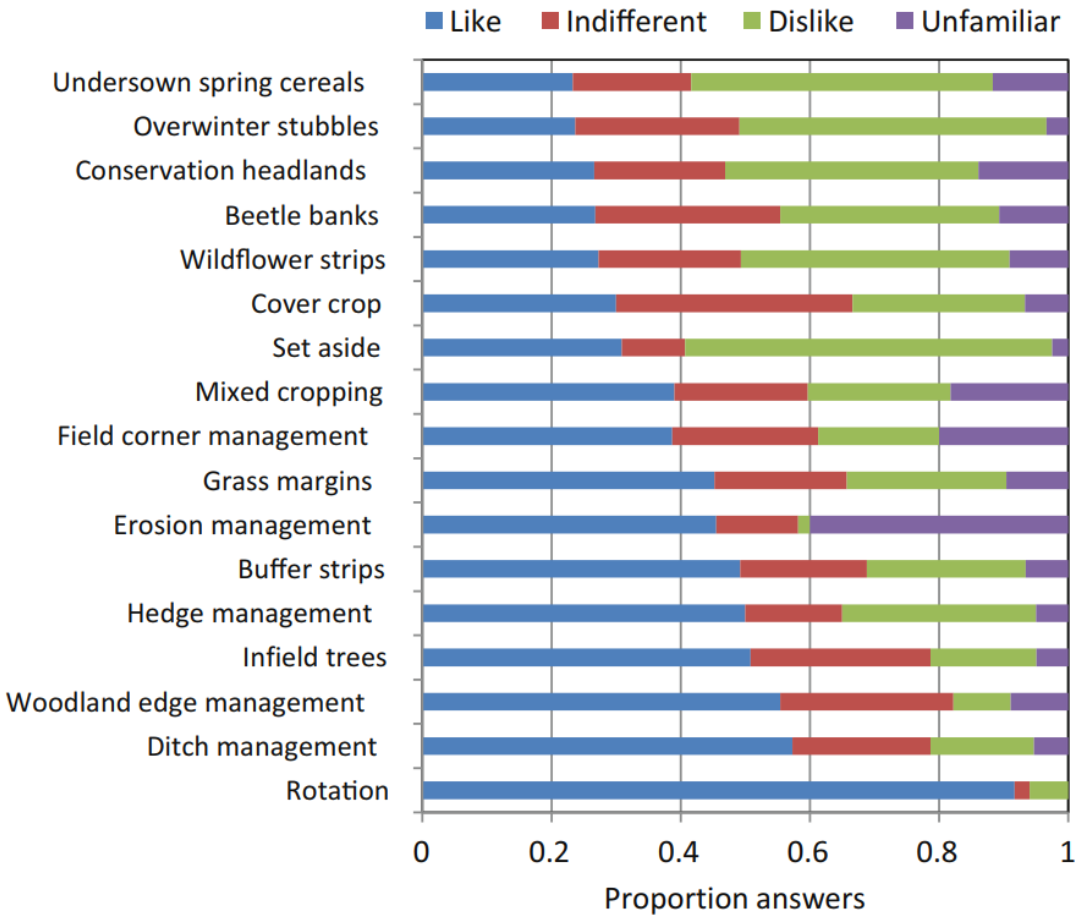


Figure 6 Farmers preferences for Management Practices found to enhance Ecosystem Services from seven European Countries [115]

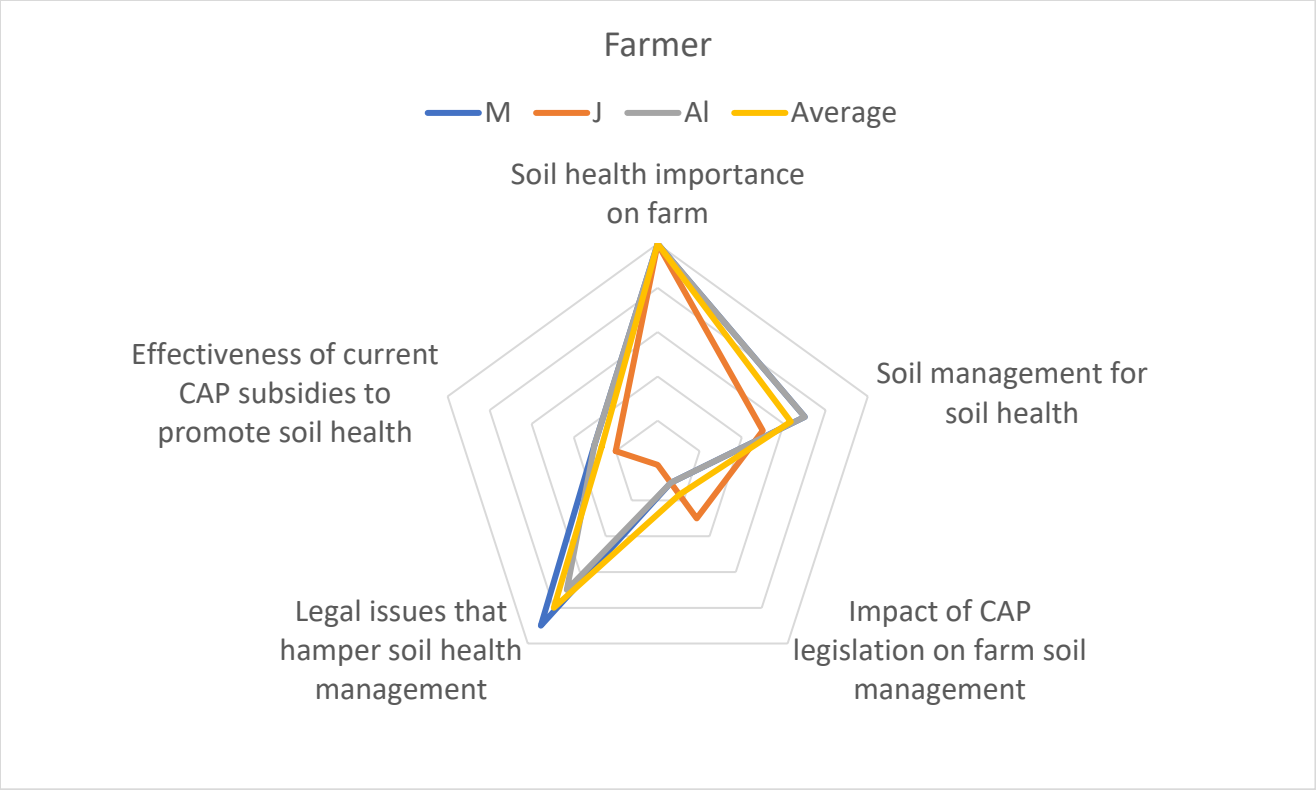


Figure 7 Farmers perception of soil health, subsidies and legislation, results from our conducted survey (original data)

A little survey on farmers' perception of soil health and policy

To assess the current farmers' perception of soil health related to their practices as well as their perception of EU subsidies and legislation we asked three farmers from two European Union countries five questions (listed below). We asked them to also score their opinion on a scale from 1 (not important/not useful) to 10 (very important/ very useful) the summary is depicted in (Figure 7).

- How important do you perceive Soil health in your farm?
    - Martin: 10, Very important because I aim for long-term utilisation and without keeping the soil healthy this would not be possible.
    - Jan: 10, The soil is the core of the whole production process. All starts with healthy soil!
    - Alex: 10, I am convinced of the concept: healthy soil, healthy plants and healthy people.
- To what extent do considerations of soil health influence your farm management?
    - Martin: 5, The considerations go far, however, as produced products are not adequately paid, I manage in a way that does not lead to bankruptcy but does not wear out the soil in the long run, but more could be done, definitely.
    - Jan: 5, I think we are lacking experience and knowledge and the potential risk when changing the common practice is unknown, what we do now works, but I agree there is room for improvements.
    - Alex: 7: We are working partly with the no-dig approach which costs time and money to set the system up, for now I still use the rotor tiller because it is faster. But I know that in the long term the no-dig approach would be more time efficient. Because it is time intensive, we accept a trade-off between time use and the (short-term) result.
- How does current legislation and policies (CAP) shape the on-farm soil management?

    - Martin: 1, Not really, there could be more incentives to foster soil management practices that lead to long term improvements.
    - Jan: 3, We would like to give the soil a longer rest with sown clover grass. But the problem is that if we do not uproot the system after a certain time the arable land would otherwise be converted to [a legal status of] permanent grassland
    - Alex: 1, For me this is minor, because I do not get subsidies because my operation is too small.
- Do you see any legal issues (regulations) that hamper the implementation of soil health management?
    - Martin: 10, In Germany the implementation of agroforestry systems is a hurdle because there is no usage code in Germany (EU implementation guidelines for agroforestry). Also, there is a problem for soil organic matter farming. SOM contains carbon as well as nitrogen. But if I want to store SOM in my soils, I am disadvantaged by the fertilizer ordinance because I bind the nitrogen in the SOM for a longer period of time, which is not directly available for plants or leaching. This nitrogen should be chargeable as long to mid-term output.
    - Jan: -
    - Alex: 7, There is uncertainty when investing in soil health because the soil is often only leased. With short leases, longer-term investments in soil health seem uncertain.
- How useful do you perceive the current subsidies to build healthy soil and what would you like to be changed?
    - Martin: 3, Not really, we need to move away from flat-rate to result-oriented subsidies based on measurable, meaningful parameters. There should be meaningful rules for the implementation of environment friendly practices that really promote the aim, also in practice. A bad example is that many farmers here plow the cover crop under in the end of February. But this does not promote the original objective to keep the soil covered.
    - Jan: 2, We need to have more diverse tools that help support useful practices.
    - Alex: 3, I think that the eco-scheme implementation recommendation from the IFOAM provide a good overview how subsidies could be used more goal oriented.

Despite the small sample size of the survey, the results suggest a strong prevalence of regulatory barriers for farmers who do want to tend to long-term soil health and perceive soil health as the critical core of sustainable production. Above all, there is a lack of incentives for farmers to invest in soil health, because they are primarily occupied with economic challenges associated with farming. These views of regulatory inadequacies and economic disincentives hampering better soil health stewardship were corroborated during interviews with two dairy farmers and one apple horticulturalist from the Netherlands, conducted in the framework of the present work. For instance, regulations on manure use limit its application as fertilizer because of very legitimate concerns for water quality with respect to nutrient overloads. However, dairy farmers compensate for obligatory manure exports off their farm by importing synthetic fertilizer, resulting in a paradoxical situation that's detrimental to both soil health and the circular use of nutrient resources. Most importantly, similar to our survey, the interviewed farmers emphasized the economical bottom line of their operations. Financial insecurity was cited as one of several reasons not to convert to organic farming, because the two years of transition to organic are marked by lower yields but with conventional prices. Generally, any additional environmental measures, including those specifically targeting soil health, would therefore need to be accompanied by full compensation for any eventual losses of income they may entail. The farmers also asserted their need and desire for

more knowledge and expert advice on how to manage soil health by making better use of extensive information gained from soil analyses. Notably, they highlighted a need for independent consultants, free of the conflicts of interest often associated with private industries (i.e. seed, fertilizer, and pesticide companies) and with a strong background in practical agronomy. Furthermore, they pointed out that a large divide existed between policymakers and practitioners like themselves. There was a lack of understanding of why certain regulations are implemented, as the farmers felt that policymakers had insufficient awareness of the practice of farm and soil management.

In short, personal insights from these agrarian farm users revealed that to encourage better soil health stewardship, policies need to genuinely promote - and not (unintentionally) discourage - farm management practices that are veritably beneficial to different aspects of soil health, and that support from financial incentives is key. In addition, cooperative communication between policymakers, practitioners, and experts must be improved for more comprehensive and inclusive approaches to soil health management that bolster mutual understanding: "Talk with each other and not about each other".

5. Soil Health Policies: past flaws and the way forward

Past and current policies

To keep soils healthy, policies need to be in place to protect soils and emphasize the importance of a sustainable soil management as they face ongoing degradation. This degradation is on costs not only of the society and the environment, but also the economy. Currently however, only few countries in the EU have policies related to soils. There is no coherent and comprehensive set of rules about soils. Other rules about agriculture, water, waste and the prevention of pollution contribute indirectly to soil health. However, these measures are insufficient to keep soils healthy. Moreover, unhealthy soils also contribute to the failure of biodiversity and climate change objectives of the European Union. Therefore, the Commission adopted a Soil Thematic Strategy in 2006 [100].

The overall aim of the strategy was to ensure protection and sustainable use of soils. The strategy is built around four key pillars: awareness raising, research, integration, and legislation. It includes a legislative proposal with references to already existing policies like the Nitrate Framework and the CAP. It also includes a cost-benefit calculation. The main problems related to soils addressed are:

- Erosion, organic matter decline, salinization, compaction and landslides
- Contamination
- Sealing
- Research (processes underlying soil functions (e.g. soil's role in global CO2 accounting and in the protection of biodiversity), spatial and temporal changes in soil processes, ecological, economic and social drivers of soil threats, factors influencing soil eco-services, and operational procedures and technologies for soil protection and restoration.)
- Integration of policies in other areas
- Awareness-raising through distribution of the Soil Atlas of Europe, Summer Schools, different initiatives, integration of knowledge about soils in community-funded information events, awards, initiatives with the UNCCS [101]

In 2012, a policy report has been published on the implementation of the Strategy and ongoing activities as well as an overview of the status of soils in Europe[102]. The proposal remained on the Council's table and was blocked by a minority of member countries at the Environmental Council in 2010. The Soil Thematic Strategy is a form of

Table 3 Threats to soil health and their estimated cost to society [103]

Threats to soil health	Erosion	Organic Matter decline	Compaction	Salinization	Landslides	Contamina-tion	Sealing	Biodiversity decline
Estimated costs to society (€)	0.7 - 14.0 billion	3.4-5.6 billion	No estimation possible	158-321 million	Up to 1.2 billion per event	2.4 - 17.3 billion	No estimate possible	No estimate possible

communication between the Council, the European Parliament, the European Economic and Social Committee, and the Committee of the Regions, but is not legislative [104].

In 2014, the Commission decided to withdraw the proposal for a Soil Directive Framework. However, in the same year the Seventh Environment Action Program recognized that soil degradation is a serious challenge. It commits the EU and its member states to efforts that increase SOM and decrease soil erosion and to the remediation of contaminated sites. Furthermore, it aspired that by 2020 land is managed sustainably in the EU and soil is adequately protected [100], which evidently was not achieved.

In 2016, a detailed report was published which showed that soil degradation continued and increased over the past years and looked at the current and past policies, identifying gaps in the protection of soil [105]. It also constructed a base of analysis on which future policies can be constructed on. Most of the member states apply regulatory instruments like regulations, ordinances and decrees and most of these instruments are binding. Also, non-regulatory instruments like monitoring, funding and awareness-raising schemes are included. Half of the policies are directly related to EU policies. The Seventh Environment Action Program also has set priorities that can be built upon. Furthermore, the climate and energy packet offer opportunities to emphasize the importance of soil organic matter and the reduction of inorganic fertilizer use. The CAP pillar 1 asks member states to define minimum soil protection standards as a condition of direct payments, which must be strengthened in the future. Furthermore, CAP pillar 2 payments can be used by member states to subsidize soil measures and offer opportunities for protecting several aspects of soils. However, in contrast to other environmental priorities like water, biodiversity and climate mitigation, the EU does not underpin soil protection [105]. The cross-policy analysis showed that an important gap in these policy measures is a common strategic policy framework.

In addition to the 2016 report [105], other recent publications put in the spotlight the failures of CAP policies to translate into real, impactful changes in practice that would mitigate soil health degradation, biodiversity loss, climate change and other environmental issues [106,107]. Key weaknesses were identified that prevented previous CAP environmental policies to really make a difference, including:

- protection is mostly derived indirectly, through other environmental measures
  The EU does not provide sufficient policies and measures that specifically and explicitly target soil health. The elaboration of what soil functions imply, and the actions require to address soil threats is very limited.
- Key policies that offer a strategic vision are non-binding and too flexible
  Member states have too much freedom in setting national goals and implementing recommended environmental measures. Member states thusly reduce requirements for receiving subsidies to practices that are already widespread and had little to no effects on biodiversity.
- Lack of control and controllable goals linked to subsidies

Environmental subsidies focus less on the goals and more on the means, and outcomes are insufficiently verified.

- Land protection does not equal soil protection
  Some policies are focused on protection from contamination, but land can be 'protected' while important soil functionality can still be lost. Moreover, land is not protected against soil sealing.
- Historic contamination is not addressed by EU laws
  There are no binding rules for detecting and addressing soil contamination that occurred before the introduction of EU policies on soil contamination
- Inequitable and inefficient 'Direct Payments'
  Area-based subsidies mean that large-scale farms may receive disproportionately more subsidies than small farms despite possibly needing them less. Moreover, in some cases subsidies benefit the landowners and not land managers, and non-agrarian landowners receive subsidies, including wealthy estate owners.
  Direct Payments are bound to low levels of environmental requirements, and contribute little to farmer income or environmental aims (<5% of area changed in management)
- Membership of farmer collectives that manage environmental funds is voluntary, meaning that subsidies often don't go to where they could have the strongest impact.
- Insufficient and underfunded programs
  Policy tools like 'Agri-Environment-Climate Measures' and other 'Rural Development Programs' that could be effective in supporting pro-environmental land use are often hampered by underfunding
- Subsidization of unsustainable practices
  The subsidization of unsustainable (input-)intensive production systems (e.g. through 'Coupled Payments') exacerbates threats to soil health and disincentivizes changes in practices.

All in all, despite some efforts by the EU to set up and implement environmental policies, more effective policies and measures are needed that genuinely tackle the threats to soil health and support soil health stewardship by land users and land managers.

Towards better policies for healthier soils

As none of the current and past measures managed to tackle the importance of soil health or offer enough and adequate solutions, a new approach is needed in the future. The future plans for the CAP (2021-2027) again do not mention soil as an explicit key point as soil management is mentioned only in relation to climate change. The new policies on Biodiversity Strategy and Farm to Fork Strategy are an improvement, but also these do not mention soils explicitly [108]. Furthermore, the new schemes under Pillar 1, the so-called 'Eco-schemes' and the continued 'Agri-Environment-Climate Measures' under Pillar 2 comprise a voluntary framework for farmers going voluntarily beyond the current measures by e.g. applying the principles of organic farming, agroecology or precision-farming. However, it is only voluntary and can be adjusted by each country [109]. Many soil scientists have expressed grave concern about the weakness of the post-2020 in addressing crucial environmental issues, including soil health, manifested in a recent paper that received widespread support from the scientific community with over 3,600 signatories [106]. In their call for action they denounced many components of the new CAP proposal that perpetuated ineffectual past policies, defunded critical support structures, and didn't go far enough in devising new solutions, including:

- the continuation of inequitable and environmentally inefficient Direct and Coupled Payments with limited revision, i.e. and only slightly expanded set of Cross Compliance environmental conditions.

- budget cuts to potentially effective Rural Development Programs, including Agri-Environment-Climate Measures (AECM)
- the encouragement of a 'race to the bottom' in the new 'Green Architecture', by giving too much flexibility to member states in setting their own environmental goals while setting vague and unambitious minimum requirements and failing to provide options for concrete measures.
- insufficient 'impact' indicators for effective performance monitoring, in contradiction to the purposed result-based principles of the future CAP.

Video 11 What Policies Can Make Our Food System More Sustainable? – Evan Fraser

However, there are many ideas on future policies that could have an actual impact on securing healthy soils for our future. The crucial starting point is to make Soil Health an explicit and all-important objective in the new CAP and develop a concrete strategy for it that is binding. EU policy must define and implement S.M.A.R.T (specific, measurable, ambitious, realistic and time-bound) targets for member states. Here we present some propositions for soil health-centred policies that should be adopted to encourage the promotion of soil health, so as to ensure the delivery of crucial ecosystem services essential to the achievement of SDGs.

Address land degradation

The EU should take stronger action to counter land degradation, by introducing new rules for the detection and remediation of all contaminated soils, regardless of when contamination occurred. Funds should be allocated to remediation operations, and (private) organizations (e.g. mining companies, chemical factories, etc.) must be held financially accountable for the depollution of sites affected by their activities.

Soils should be protected from soil sealing and the losses of functionality it incurs, by obliging developers to prioritize alternative green infrastructures (e.g. green parking lots) and stimulating urban renewal to transform sealed developments.

Mass action programs need to be set up to continuously identify degraded land, and to execute mass ecosystem restoration projects to rehabilitate soil functioning and the delivery of ecosystem services. Coordination of such programs with existing initiatives and NGOs (e.g. Ecosystem Restoration Camps, Society for Ecological Restoration, RECARE) is key.

To prevent mitigate soil subsidence, greenhouse gas emissions and ecological deterioration, the EU should enforce a ban on the conversion of organic soils to arable land in all member states, and fund the rewetting of peatlands [106] as well as their territorial allotment to natural areas.

Stimulate ecological intensification

Among the many organizations proposing new strategies for the post-2020 CAP, IFOAM EU (**International Federation of Organic Agriculture Movements)** and others suggest that there should be more funding available through the CAP to target best soil practices in agriculture [110]. IFOAM emphasizes the role organic agriculture plays in holistic sustainable soil management and therefore advocates more support for organic farming. Organic agriculture sustains eco-functions in soils and delivers environmental benefits and therefore contributes to soil health [110].

Figure 8 The 9 objectives of the new CAP 2021-27 [111]

Support for more ecological production systems conducive to soil health such as organic agriculture can take several forms. The economic disincentive to convert to organic posed by the two-year transition period, with lower yields and conventional prices, should be alleviated through compensation to farmers that fills the conventional-organic price gap. The uptake of key soil health management practices can be stimulated through rational synergic combinations of subsidies and mandatory measures. Notably, practices that may only show benefits to soil health on the longer term like conservation tillage should receive adequate subsidies. In order to favour the use of organic amendments over chemical fertilizers, nutrient ordinances limiting nutrient application rates must make clear distinctions between immobile organically-bound nutrients, which are not immediately lost to leaching and runoff, and mobile inorganic nutrients. More financial incentives for polyculture systems including intercropping and agroforestry must also be provided.

From means-oriented to outcome-oriented

Many organizations and representatives of the scientific community advocate a shift from means-oriented to outcome-oriented or result-based approaches to the allocation of subsidies, which should be regularly updated [106]. Outcome-oriented approaches imply that the progress made towards achieving the goal of improved soil health is more important than the means employed, thereby giving more flexibility to land users to choose the practices best adapted to their situation. Result-based subsidization entails that regular soil monitoring must be conducted to properly assess progress, while case-specific recommendations can be made on the implementation of better practices (Figure 9). The extent of remuneration will then depend on whether there is a real improvement to or maintenance of soil health, and payments will thusly be subject to binding conditionality. For example, by continuously improving SOM levels in SOM-depleted soils, or maintaining high levels of SOM, farmers should receive subsidies.

Reference soils (mentioned in "Reference soils and lighthouse land users") can play an important role in the proper implementation of outcome-based policies, as they provide crucial information on what can be considered a healthy soil in specific contexts. Local adjustments can then be made to soil health goals according to climate and the soil type conditions, allowing to assess whether the outcome-oriented subsidies should be based on continuous improvement or, if the soil is already good, on the maintenance of the soil status. With a good database of reference soils these adjustments can be done easily, therefore the new CAP should include provisions for the extension of reference soil databases. For adequate monitoring within the outcome-oriented framework, it's necessary to redesign the set of soil health indicators in result assessments using expert knowledge and starting from a baseline set of keystone indicators. Timely monitoring and comparative assessments on a broad scale will help in setting priorities and rationally readjusting Strategic Plans. Monitoring data must be immediately freely available for science and independent impact evaluation to allow rapid assessment of progress against targets [106].

Knowledge-intensify

Pathways to sustainable soil management like ecological intensification are often technologically non-intensive but knowledge-intensive. Land users should be assisted in the acquisition and application of the best possible knowledge on soil health management to maximize the use of extensive knowledge gained through decades of soil science research. The EU and national to regional institutions of governance should facilitate the dissemination and utilization of soil health expertise to land users by training independent advisors that can help land users to identify and implement the most appropriate measures to enhance soil health on a tailored case-by-case basis.

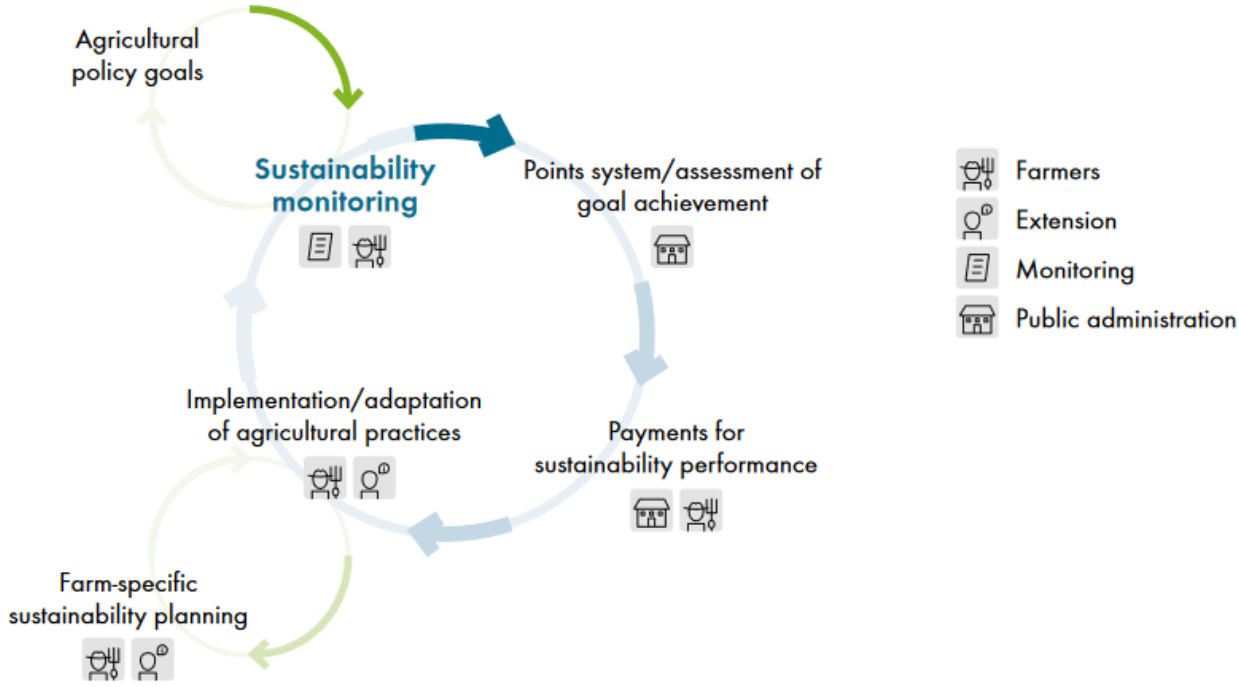


Figure 9 A scheme for outcome-based payments relying on routine sustainability (e.g. soil health) monitoring to assess the achievement of policy goals. An independent extension service needs to be included in the implementation[112]

Networks of independent advisors should be partially EU-funded so as to minimize costs for farmers and thereby maximize their avail. Advisors must furthermore be familiar with the local context and the environment so they can give more specific advice.

Subsidized trainings should also be provided to farmers that wish to gain more knowledge about soil health and sustainable soil management. Such trainings should be a prerequisite for the involvement in soil health certification schemes by means of which farmers could get higher payments in the form of subsidies or product price premiums.

Enhance participation

Ambitious policies set by the CAP should be less flexible for member states in terms of setting and reaching their goals, as member states have tended to diminish sustainability ambitions and requirements for receiving green subsidies in the past. This would to a certain extent prevent certain member states from not doing their part in taking action for a more sustainable future. Nevertheless, a degree of flexibility with regard to the means to reach policy goals will allow member states to choose the most adequate measures to implement depending on their environmental and socio-economic context. However, the EU should provide a list of viable options of measures to implement.

Farmers' motivation and participation in soil health schemes should be improved, not only by providing attractive incentives, but also by employing more participatory approaches and stimulating flexible, adaptive and collaborative implementation of new practices. Sponsored field days should be organized to facilitate peer-to-peer exchange of knowledge and experience. The future CAP needs to support and extend networks of 'lighthouse farms' that showcase the potentials of sustainable soil management. Likewise, local bottom-up initiatives, which often have better networks and connection with local land users, should be allocated financial and knowledge support to strengthen their positive impact.

Valuate Ecosystem Services

Payments for ecosystem services should be central part of the new CAP, as ecosystem services are a crucial part of sustainability and important for human health and well-being. Financial remuneration of soil-based ecosystem services will not only greatly stimulate the adoption of ecological practices, it will be pivotal in inducing a paradigm shift in mindsets that will recognize how important ecosystem services are for the achievement of SDGs and societal well-being. Payments for ecosystem services can be financed by diverting funds from the inequitable and inefficient Direct Payments and Coupled Payments, which at any rate are in need of fundamental reform. Similarly, IFOAM suggests that, next to enhancing the budgets for Eco-schemes and AECMs, an initial minimum fraction of Direct Payments under CAP Pillar 1 for Eco-schemes should be defined, that progressively increases to 100% during the 2021-2027 period of the new CAP[112].

In addition to payments for ecosystem services, an 'unsustainability tax' should be introduced, which will in the long run shift unsustainable management practices to more sustainable ones. That would calculate and monetize the external costs of unsustainable land management practices such as water pollution, erosion and greenhouse gas emissions. Consumers would thusly be compelled to opt for more sustainable products, while least sustainable products would be phased out.

Circularize agriculture

Finally, the EU must shift its focus from linear to circular agriculture to optimize resource use efficiency and minimize externalities by reducing energy and nutrients losses. The EU needs to lead and promote fundamental structural overhauls in supply chains and waste management to help close carbon and nutrient cycles in our food systems. Organic amendments are often regarded as a cornerstone of soil health, and better

management of organic waste streams from industries and households is crucial to direct more organic materials back to the soil. Policy support is needed to foster circular agriculture for soil health, for instance by setting up local composting facilities where organic materials can be processed from agro-industrial, municipal and household waste. The sorting and recycling of organic waste from all sources should be made mandatory in a way that's legally binding. To ease the production of good quality compost, regulations should be put into effect that ban unnecessary non-biodegradable product accessories such as stickers on fruits and vegetables. Furthermore, strategies and techniques must be developed and encouraged that allow for the recuperation and treatment of human waste streams to enable its transformation to fertilizers. This will reduce the import of synthetic fertilizers and other nutrients significantly while addressing a prominent nutrient leak in our societies as well as issues of water pollution.

6. Societal transformation – Communication, Certification, and Consumer Awareness

Making the change happen - Communication between stakeholders

In order to make the change towards more healthy soils possible, several factors need to be considered. We need to demonstrate that each stakeholder can gain from transitions towards healthy soils, instead of being left behind or unnoticed. We need to facilitate an open conversation between farmers, policymakers, consumers and the scientific community, but on somewhat the same level, and with mutual understanding of each other's needs and interests. If we communicate at eye level, real positive progress can be made possible. Top-down interventions have their limitations, as explained under the section communication between stakeholders will lead to a better understanding of each party and the issues that hamper targeted action for healthier soils.

First and foremost, we need to ask ourselves what each party needs for this transition:

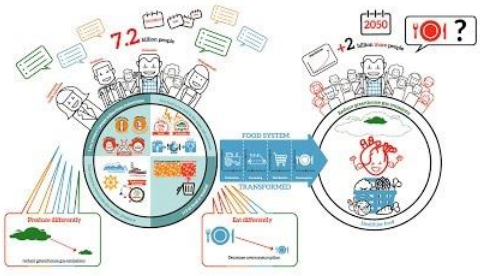
- Farmer
  - Needs financial security to pay the bills and loans
  - Incentives and fair prices to invest in healthy soils and produce high-quality produce
  - Acknowledgement for the hard job and a future perspective
  - Sometimes more knowledge, independent consultants
  - Functioning soils that deliver ecosystem services
- Consumer
  - Affordable, nutritious and healthy food
  - Sustainably grown food that is supporting soil health
  - Trust in the producer, strong bond to producers with reasonable practices
  - Climate-smart food (local)
  - Functioning soils that provide ecosystem services

- Resilient market for food grown with low environmental impact
  - Strong, educated customer base that sees the importance for soil health and makes decisions based on rational considerations for a better planet (soil, climate, communities)
  - Subsidies to make change happen on the mid-term
  - Functioning soils that provide ecosystem services
  - Local suppliers, short supply chains

- Politicians
  - Soils contributing towards SDGs
  - Soils that are healthy and protected
  - The achievement of policy goals
  - Fast effects during their legislation

    - Functioning soils that provide ecosystem services

- What does the soil (environment) need?
    - Soil health regeneration
    - Carbon sequestration
    - Functioning soils that provide ecosystem services
- Proper care as explained in section on soil management practices



Video 12 Why do we need to change our food system? – UN Environment Programme

After identifying the issues on each side and formulating goals towards the implementation of soil health action, consultation and accompaniment will guide the efforts. Town hall-like meetings, and field days at exemplary lighthouse farms where land users, policymakers and consumers can get together and witness soil management in practice, could be terrain where interactions between stakeholders can take place.

To facilitate knowledge transfers and mediate help exchanges between policymakers and land users, consultants without conflicts of interest are needed that have an agricultural background to understand what farmers need but also what needs to be done for soil and environmental health, and how that can be combined in a best possible compromise dependent on local contexts. In the end it boils down to the action of everyone involved in the transition – the society.

Certification and labelling

A society that's educated about the impact of their consumption habits can show more awareness than uninformed societies. By buying mostly locally and seasonally produced food with benefits for soil health and directly supporting farmers, consumers can help accelerate a much-needed conversion to more sustainable food systems. Farmers that adopt best practices of soil health management, and are open about their production techniques, can be unofficially certified by consumers (direct sales model) or officially certified based on an institutionalized framework (supply chain) with minimum criteria linked to management practices and measurable soil health indicators. The food business chain should support farmers by paying fair price premiums and taking a smaller profit margin for certified produce (soil health-improving, locally and seasonally produced).

Video 13 Second Barcode - NourishLife

In conjunction or in parallel with certifications, a labelling system for agricultural products that show to what extent the product is good for soil health would help nudge consumers towards more sustainable consumption. Labels in supermarkets would make it easier for consumers to make good decisions without the need of investing time to figure out what products are most sustainable. A soil health label can take inspiration for instance from the 'Beter Leven' (better life) label for animal welfare in the Netherlands, or the 'Nutri-score' label for food products (Figure 10). Not only will

labels and certification help consumers identify and select products that are more sustainable and foster soil health, they will also help spread awareness about the importance of soil health to consumers. In addition, putting certified products at eye level on supermarket shelves without extra charge would nudge consumers more to make sustainable choices by enhancing the visibility of certified goods.

Figure 10 Examples of soil health labels modelled on the Dutch 'Beter Leven' ('Better Life') label for animal welfare or the French 'Nutri-score' label for nutritional quality.

Farmer - Consumer interaction: a crucial component of sustainable food systems

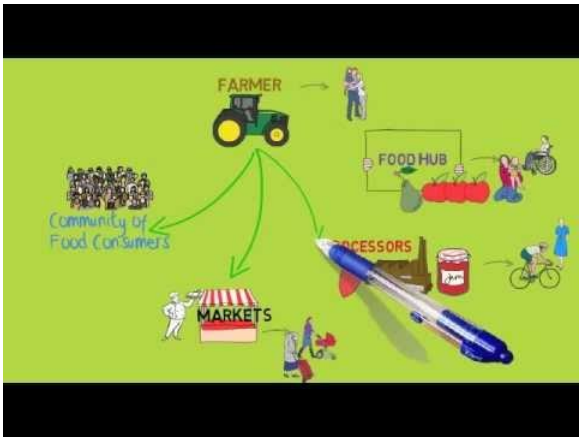
Today, we consume a whole range of products with ingredients from all over the world. We are used to an incredible variety and year-round availability of foodstuff that come from all over the world. We import produce from faraway, which need to be transported over long distances with non-negligible use of fossil fuels and environmental consequences. However, long transport does not necessarily lead to a higher carbon footprint of transported products compared to local produce, again everything needs to be assessed context dependently[113]. But local products can be fresher and have more potential to stimulate consumer awareness of soil health because of closer producer-consumer proximity.

Many farmers are still being price-pressured by companies higher up in the supply chain. Agricultural production systems that produce crops which are traded on the world market compete with world market prices, which do not reflect the regional production conditions and actual need for soil health action and associated costs, and just may be another reason why soils are degrading globally. Farmers need to live from what they do and most of them work hard in the existing system to deliver food based on their best knowledge. If the prices or margins that the farmers get for their produce were more equitable, they would have the chance to invest in their soils instead of unwillingly depleting them due to economic pressure.

Additionally, consumers aren't well enough educated about how soil and humans are treated in food production systems. As consumers we tend to be unaware or suppress facts about the environmental impacts of our consumption behaviour on other regions of this world. Have you ever asked yourself how soil is treated in intensive export banana plantations? If consumers would have more knowledge and awareness about how most of their food is produced and what is happening over there, more aversion towards the current prevailing food system would arise. Instead of focusing on regenerating and using existing resources in each EU country, we consume on the expense of other countries and the environment while missing the multitude of benefits of local, seasonal and soil health-oriented production in our closer environment.

We need a fundamental change.

If farmers do not get adequate prices that allow for social, economic and environmental (soil health care) sustainability, farmers and consumers can act on their own collaboratively. This collaboration can reduce the influence of prices predetermined by the food industry on the choice of the production system and flexibility of the farmer. A transition is already happening by means of bottom-up projects all over the world, not initiated by governmental or retailers but by farmers and consumers. These initiatives are mostly founded on the need for a fundamental change in our food systems that damage indispensable resources and reduce the quality of life for future generations.



Video 14 What is a Local Food System? - Frances Einterz

Most of these projects involve a strong farmer-consumer relationship, in which soil health and food sovereignty are the basis, and where the consumer is interested in getting the best local produce while supporting farmers from the nearby countryside. Some of these models are the direct sales model from farmer to consumer (off- or online for restaurant and private households) and farmers markets. These sales models imply that farmers are transparent about how they produce, and consumers express what they like or not, that both sides can adjust (production techniques and prices). Farmers can also initiate cooperatives in which they produce, process and market their products based on the three pillars of sustainability together. Making sure they get a fair price, taking care of the environment and having a decent life. This could be further improved by farm open days, offering other parts of the society the chance to see where their food is coming from.

Video 15 CSA = Community Supported Agriculture – The Lexicon

Another system is Community Supported Agriculture (CSA) in which a farmer is growing food for a community. In CSA, food is no longer sold on the market, but flows into its own transparent economic cycle, which is co-organised and financed by the consumers. CSA promotes and maintains a rural and diverse agriculture, provides regional food and enables people to gain new experience and education. By implementing different kinds of these models taking care of the soils and farmers on a local scale, many local economies could build a resilient food system in Europe.

Video 16 Farmers Markets - NourishLife

Education – The basis of informed decision makers

Many attempts have been made to promote the importance of soil health. The year 2015 was proclaimed as the "International Year of the Soil" and an International Day of Soils was introduced in 2014 to show the importance of policies. Over the course of the International Year of the Soil, a lot of informative materials, including audio-visuals, maps, scientific studies, websites and education material in different languages, were developed and made public. Several events about soil were held [100].

The aims of that special year were

- to raise awareness among civil society and decision makers
- to educate the public about the crucial role soils play for food security, climate change adaptation and mitigation, essential ecosystem services
- poverty alleviation and sustainable development
- Support effective policies and actions for the sustainable management and protection of soil resources
- Promote investment in sustainable soil management activities to develop and maintain healthy soils for different land users and population groups
- Strengthen initiatives in connection with the SDG process (Sustainable Development Goals) and Post-2015 agenda
- Advocate for rapid capacity enhancement for soil information collection and monitoring at all levels (global, regional and national) [114].

All these materials call for action to protect soils, however the EU still does not have a concrete plan to introduce specific soil health policies and to spread knowledge about soils to the public further.

Video 17 What's wrong with our food system – TEDx Talks

There is sufficient educational material, however it does not seem to reach wider audiences and create awareness among the public to the extent needed to truly highlight the importance of soil health. For instance, the World Soil Day takes place on the 5th of December each year with a different focus every year, however it does not seem to reach a wide public. Therefore, we need a new agenda for the education of the society. Children from kindergarten age up to adults must follow education about the importance of soil health.

Video 18 Stop soil erosion, keep soil where it belongs! - FAO

Video 19 What's the Dirt on ... Dirt? – SciShow Kids

Education for children

Our ideas for educating children about soil health include a broad spectrum of actions that complement each other but can also be used as single measures. Children of kindergarten and school age should have the possibility to participate in growing their own food in school gardens to be able get in contact with and value good soils and fresh produce. Furthermore, a week (around the World Soil Day) filled with different activities that teach about soils can be implemented, where movies can be watched a about soils or about earthworms or about the different layers of soil. Many of them can be found already available on Youtube on channels like SciShowKids or Crash Course Kids. They are all educational videos and should be complemented by visits to (organic) farms that pay attention to soil health where children can gain more insights into soil health. There are also comics and games and all kind of different material about soil health. The web page www.soil-net.com provides a huge selection of experiments, card games, action sheets and ideas to fill a week at school. One of the most important part of the educational programme is also that children grow their own vegetables. By growing tomatoes e.g., they will learn about the importance of soils and also that it is the base for good-tasting vegetables. Besides the special week children should have the possibility to regularly visit a farm in the neighbourhood to become aware about where their food comes from and what farming looks like. With increasing age, the programme for children can increase in complexity in theory and practice.

Young farmers

For young farmers that are in training, the programme needs to be adjusted to put soil health at the centre of focus. New farmers must receive extensive knowledge on the practices that can enhance soil health and also be properly informed of new, more sustainable policies and regulations so they can perform better than previous generations in terms of sustainable soil management. The immediate updating of education programmes is of particular importance, because if the change does not happen now, it may take another generation of young farmers to make the change happen.

Adults

Education about soil health should not end for adults when they enter the professional life. Instead, through advertisement of some of the videos suggested above in social media like YouTube, facebook and the TV, the level of awareness must be raised until it is as prominent as other environmental issues like climate change. Besides the advertisements, there should be regular open farm days, where the consumers that are not in touch with the producers yet, can learn about farming and get in dialogue about the farmers' concerns and goals. Furthermore, mass awareness campaigns, product labels, and other means of informing the public should be continuously supported.

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