# SUSTAINABLE AGRICULTURAL SOIL MANAGEMENT IN THE EU:
## What's stopping it? How can it be enabled?

RISE FOUNDATION

2022

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## Authors

Allan BUCKWELL | Elisabet NADEU | Annabelle WILLIAMS | RISE Foundation
Contributing author: Raquel LUJÁN SOTO | CEBAS-CSIC, Spain

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RURAL INVESTMENT FOR A SUSTAINABLE EUROPE

RISE Foundation 2022

# SUSTAINABLE AGRICULTURAL SOIL MANAGEMENT IN THE EU:
## What's stopping it? How can it be enabled?

Allan Buckwell
Elisabet Nadeu
Annabelle Williams

With the contribution of
Raquel Luján Soto

| | |
|---|---|
| AECMs | Agri-Environmental Climate Measures |
| AKIS | Agricultural Knowledge and Information Systems |
| EC | European Commission |
| ECA | European Court of Auditors |
| EEA | European Environment Agency |
| EFA | Ecological Focus Area |
| EGD | European Green Deal |
| CAP | Common Agricultural Policy |
| $CH_4$ | Methane |
| $CO_2$ | Carbon dioxide |
| EU | European Union |
| EC | European Commission |
| ECA | European Court of Auditors |
| FAO | Food and Agriculture Organisation of the United Nations |
| F2F | Farm to Fork Strategy |
| GAECS | Good Agricultural and Environmental Conditions |
| GHG | Greenhouse Gas |
| IPM | Integrated Pest Management |
| MS | Member State |
| NGOs | Non-Governmental Organisations |
| $N_2O$ | Nitrous oxide |
| RDR | Rural Development Regulation |
| SOC | Soil Organic Carbon |
| SOM | Soil Organic Matter |
| SMRS | Statutory Management Requirements |
| SSM | Sustainable Soil Management |
| UNCCD | United Nations Convention to Combat Desertification |
| UNFCCC | United Nations Framework Convention on Climate Change |

## PREFACE

Life on earth is entirely dependent on healthy functioning soils. They are the very foundation of the ecosystems upon which we rely. We count on their functioning to produce our food, cycle nutrients manage waterflows, sequester carbon and be the bedrock of the planet's biodiversity. Without healthy soils on earth, humankind as we know it could not exist.

Yet, despite the fundamental importance of our soils, we have failed to value and protect them. We continue to seal over some our most fertile soils to build new housing, industrial complexes and infrastructure. We face the enormous challenge of decontaminating polluted soils and continue to support a system of agriculture that generates soil loss, causes soil pollution, and deteriorates soil health.

This is not a new realisation, nor a new problem. Policy makers, NGOs, academics, and indeed certain groups of farmers have been sounding the alarm bell for decades, yet as this report will detail in its early chapters, progress has remained extremely limited and even more worrying, indicators show a worsening situation.

European policy makers are taking up the mantle of soil and moving forward with it, and its prominence in the Green Deal and its strategies is evidence of the priority this non-renewable natural resource is being given for the future of Europe. And they are not alone. Individual soil initiatives of all shapes and sizes have sprung up across Europe to help farmers sustainably manage our soils

But these top-level policies and grass root actions are still not enough. They are a welcome and essential start and this forward momentum must not waver. More commitment and action are required from National policy makers and mainstream farmers' organisations. Like so many of the challenges we face today – such as the climate emergency and biodiversity loss - we do not have the luxury of time. As we release this report, the war with Ukraine continues to shape our political landscape. There are already calls to reverse the Green Deal and all that it entails in order to focus on short term market disruption. Yet action for long term global food security cannot be postponed. Make no mistake, if we do not push forward to restore soil health, it will be our soils that are at the heart of future food security crises.

It is sometimes hard in these turbulent times to find a good news story, but I truly do believe that soil can be the good news story of our decade. Soil lies at the heart of a complex array of challenges we face today and if we can reverse soil deterioration, we can strengthen the resilience of our system to future crises, sequester carbon, support biodiversity, and continue to produce healthy, quality, affordable food for future generations.

This is a unique moment in time. The spotlight is shining on soil right now, we know what to do, resources are being mobilised. We know which way the path should take us to provide long term food security, so let's keep walking. This report is the RISE Foundation's contribution to helping us along that path and showing us the way forward.

Dr Janez Potočnik / Chairman the RISE Foundation

## EXECUTIVE SUMMARY

# Background and objectives

**1** Healthy soils are fundamental to our future food security and mitigating and adapting to the climate crisis. They are a critical part of society's natural capital and play a crucial role in supporting biodiversity and regulating our precious, and increasingly scarce and unpredictable, fresh water supply. Yet, despite their importance, we have been degrading our soils for decades. Soil sealing, soil contamination and the predominant system of farming are destroying soil health and causing soil erosion. They are also having a negative effect on biodiversity, water management, air quality, and climate. Collectively, these effects are seriously handicapping Europe's ability to reach its goals of reducing pollution and stabilising the climate. More seriously, soil degradation threatens long term food security and increases the exposure of the food system to the effects of climate change.

**2** Agricultural soil management, soil sealing – through building on fertile soils, and soil contamination from industrial sites, are all important soil threats that need to be tackled urgently, yet require a very different set of actions in order to reverse the damage they are causing. As a Foundation specialised in promoting sustainable agriculture in Europe, RISE's expertise lies in agricultural policy and therefore the natural focus of this report will be on the sustainable management of agricultural soils.

**3** The report seeks to contribute to the debate on how to best frame and encourage improvement in agricultural soil management. It synthesizes current knowledge on soils, explores the barriers that are inhibiting change in farming practices and suggests what is necessary to drive the transition towards a more sustainable agricultural soil management and food system in the EU.

# Healthy soils are an intrinsic part of agricultural ecosystem services

**4** The EU's 2006 Soil Thematic Strategy (COM (2006) 231) defines soil as "the top layer of the earth's crust, formed by mineral particles, organic matter, water, air and living organisms. It is the interface between earth, air and water and it hosts most of the biosphere". This top layer **enables life on earth** not only by being a physical support for vegetation and all our activities but most importantly by filtering and storing water and decomposing organic matter to cycle nutrients making them newly available for vegetation growth and thereby providing us with food, fibre, timber and many other materials.

**5** There are several terms used to describe the state of a soil, often relating to how well it can perform under agricultural use. A soil in "good condition" will have a combination of a good physical structure, chemistry, organic matter content, biodiversity and capacity to infiltrate and retain water. Traditionally, the term "soil fertility" was used, understood as the ability of soils to sustain plant growth. More recent terms which are still focussed on agriculture but have a wider view are "soil health" and "soil quality" which imply soil functioning beyond its fertility or productive capacity.

**6** Soils perform a large number of **functions**, often referred to as services or soil-based ecosystem services. Many soil functions are at the centre of global challenges: climate change, safeguarding biodiversity, ensuring food and water security and preventing land degradation and desertification. They range from very local functions such as providing anchorage for roots and source of raw materials to global ones such as climate regulation. Due to their complexity and the large number of functions they perform, soils are increasingly being considered ecosystems in themselves. It is estimated that the ecosystem services provided by cropland and grassland in the EU are worth annually EUR 76 billion, two thirds of which is not related to crop production itself[1].

**7** The definitions of soil functions have traditionally been anthropocentric. But acknowledging the multifunctionality of soils and their importance in sustaining all life on earth (not just human life) brings to light the conflicts and synergies in their use. The European Commission defines seven soil functions or ecosystem services, four of which are discussed in detail in the report in relation to agricultural activities, to: (i) provide the basis for life and biodiversity, (ii) act as a carbon reservoir, (iii) absorb, store and filter water and transform nutrients and substances thus protecting groundwater bodies and (iv) provide food and biomass production.

## EU soils are not in a good state and continue to deteriorate

**8** Despite the importance of soil functions to sustain life on earth, soils have been deteriorating over many years and the outlook for 2030 does not show signs of improvement[2]. This deterioration represents one of the greatest challenges to human food security. Soil degradation remains widespread although at different rates across the EU. It is estimated that 60 to 70% of all soils in the EU are in an unhealthy state[3]. There are a large number of contaminated sites, unsustainable soil erosion rates, land at risk of desertification and excessive nutrient inputs that lead to the eutrophication of water bodies and biodiversity loss. Alarmingly, 50% of peatlands are being drained and consequently their carbon is oxidising, releasing carbon into the atmosphere, and accelerating climate change. Intensive land management is leading to negative impacts on soil biodiversity[4]. The total costs of soil degradation have been estimated to exceed 50 billion EUR annually, equivalent to around 30% of the EU budget[5].

**9** The most serious **soil threats** in the EU are: soil erosion by wind and water, decline in organic matter, decline in biodiversity, soil compaction, soil sealing, soil salinisation, soil contamination, desertification, and flooding and landslides. A short description of each is provided in the report.

## The practices needed to restore and enhance soil health are well known

**10** Halting and reversing soil degradation in agricultural areas is possible. The soil management practices needed to do this are sufficiently known to act with confidence. These are a set of **sustainable soil management (SSM) practices** that focus on reducing or eliminating soil threats and/or on improving soil quality and soil functions. These practices can be classified into five groups: **reducing soil disturbance, keeping soil covered, diversifying crops** and crop rotations, **minimising synthetic inputs** and **increasing soil organic matter**.

[1] European Commission. Statistical Office of the European Union, 2020. *Accounting for ecosystems and their services in the European Union (INCA): final report*. Publications Office, LU.

[2] EEA, 2019. *The European environment: state and outlook 2020: knowledge for transition to a sustainable Europe*. Publications Office, LU.

[3] European Commission. Directorate General for Research and Innovation, 2020. *Caring for soil is caring for life: ensure 75% of soils are healthy by 2030 for food, people, nature and climate: report of the Mission board for Soil health and food*. Publications Office, LU.

[4] EEA, 2019. *The European environment: state and outlook 2020: knowledge for transition to a sustainable Europe*. Publications Office, LU.

[5] European Commission, 2021. *EU Soil Strategy for 2030. Reaping the benefits of healthy soils for people, food, nature and climate {SWD(2021) 323 final}*.

**11** Over the years, the elements and practices which make up SSM have been grouped into sets of defined **agricultural systems**, including: organic farming, agroecology, conservation agriculture, regenerative agriculture, agroforestry, nature-inclusive agriculture, permaculture, biodynamic agriculture, carbon farming, climate-smart agriculture, high nature value farming, low external input agriculture, circular agriculture, ecological intensification, and sustainable intensification. Many of these approaches address not only soil degradation but are also intended to contribute to mitigation of and adaptation to climate change, to human health, to biodiversity protection and to wider food security.

**12** A critical element to move forward in achieving SSM is the establishment of **indicators** to assess soil quality and health and to monitor changes. This would be highly beneficial for results-based programmes which rely on monitoring, reporting and verification of results. To this end, researchers have been developing and using soil parameters for a long time. It has been acknowledged that indicators should not only reflect soil quality but also its functions to ensure the provision of ecosystem services. Indicators should not only have a sound scientific basis but should also be practicable for farmers to ensure their involvement.

## A number of barriers are hindering farmers' implementation of SSM

**13** From the literature on **farmer behaviour**, three levels of influence on land managers are distinguished: a societal drive, community involvement and personal farm-family commitment. These influences in turn shape the willingness to bring about change in farming practices. The ability of farmers to change involves a variety of economic, technical, informational and structural factors. Farmers then have to be engaged to embrace change and lessons of nudge theory can be useful in designing the choice architecture to make such engagement most effective.

**14** **Economic barriers** are perceived to be a significant factor in the ability of farmers to change. The greatest economic barrier to SSM relates to perceived operating costs and capital investment costs as well as the risks and uncertainties associated with the implementation of new practices. Short land tenancy can be an important factor inhibiting the adoption of SSM, incentives differ between those that own versus those who rent land.

**15** The **technical barriers** involved in transitioning to SSM are not negligible. An intrinsic characteristic of many of the SSM practices is that they must be adapted to local conditions in order to maximise their benefits. A universal set of practices cannot be imposed.

**16** This goes hand in hand with the **lack of information** which is also one of the primary barriers for farmers to move towards SSM. The type of knowledge being produced, the way it is developed and how it is communicated does not always reach nor is it always useful for the farmer to apply on the field. The lack of awareness and specific knowledge on SSM practices, and on locally tested practices vis a vis different soil types, crop types, weather conditions and local environments, and skills on how to implement them, have been widely cited as barriers to farmer uptake of SSM practices.

**17** **Independent advisory services** are crucial to translate technical information into practical advice for farmers. Yet there is a lack of advisers able to deliver credible and balanced advice at the farm level; with a good level of specialist soil knowledge; enough understanding to be able to take account of trades-off and synergies between soil functions, and the ability to accommodate different styles of farmer learning. As a result, farmers are often left to rely upon the advice of those whose knowledge is limited to the current system of agriculture and/or have an interest in selling inputs alongside advice.

**18** In addition, there can be **structural barriers** in farming and the food chain that lock farmers into a certain system of agriculture. These impact farmers' ability to change, representing inertial factors that are beyond the capacity of the individual farmer to overcome. Examples of such barriers are technological lock-ins (tying farmers into specific input use), data management (ownership and use of data obtained through precision farming), and the structure and power in the food chain with the strong influence of input providers on the one hand, and processors, buyers and retailers on the other hand, which fix the varieties of cultivated crops, the cultivation methods and even, in some cases, the harvesting dates.

## Many public policy initiatives have been in place to address soil challenges, but their effectiveness to date has been limited

**19** EU agricultural policy has tried for over 30 years to encourage more SSM, through cross compliance and agri-environment schemes but these efforts have been crowded-out by mis-directed CAP payments.

**20** The European Green Deal (EGD) and its key land-management strategies: Farm to Fork, Biodiversity, Forest and Soil, provide a strong top-level steer and clear targets for the desired direction of change which is to de-intensify some production systems.

**21** There is recognition that food consumption has to be part of the system transformation yet the measures on consumption are unclear and have no targets.

- In order to internalise externalities, society must credibly demonstrate to farmers how the costs will be paid, if necessary, with appropriate cost sharing in the food chain. The EGD could do more to show how this could be done.
- Just as for energy, a just transition in the food sector will require meaningful adjustments to social welfare policy to ensure the most vulnerable are assisted.
- Action to drive the changes in dietary habits which result in chronic ill health at large public cost are a further dimension of the necessary package of food system transformation. Reducing food waste is another necessary aspect of moving to sustainable consumption.

**22** Member States agriculture Ministries, encouraged by mainstream farming organisations, have not enthusiastically embraced the EGD targets. It remains to be seen how the new CAP Strategic Plans are finally agreed and implemented. The opportunities to deploy SSM practices under enhanced conditionality and eco-schemes exist, but the signs from Member States are not encouraging.

**23** For these reasons the new norms of sustainable production involving some displacement of conventional farming by organic/agro-ecological/regenerative farming at scale seems unlikely to happen during the current period for the CAP up to 2028. This signals the need to prepare the ground now for post-2028 reforms. Meanwhile it is possible, and everything should be done, to make significant progress on the adoption of SSM practices through the existing CAP mechanisms such as the eco-schemes.

**24** A combination of public money through the CAP, if effectively applied, combined with carbon farming payments should be sufficient to cover the costs of the transition to SSM for farmers. However, it should be recognised that the continuity of such a transition will only be sustained when the food prices reflect the full social end environmental costs of food production. Governments must recognise and communicate this message and lead the debate on how to make it happen.

## Private initiatives are successfully working with farmers and achieving positive results, but their impacts are localised and marginal

**25** Multiple private initiatives have stepped in to encourage farmers to adopt SSM practices – these are:

- Certification schemes especially for organic farming and integrated farm management.
- Food company sustainable sourcing schemes contracting with farmers to improve environmental management, including soil management.
- Bottom-up initiatives: ranging from support for conservation (low-till) farming to global schemes to restore degraded lands. Their focus is varied, although many share features such as providing access to trusted, tailored information and knowledge.

**26** These decentralised spontaneous initiatives are harnessing energy and enthusiasm and many are successfully working with farmers and achieving positive results. However, their impact currently remains limited, and in most cases, localised. These initiatives are not sufficient on their own. The more successful they are, and especially perhaps the commercially based sustainability initiatives, the more important their transparency and the need for scrutiny to guard against greenwashing.

**27** With the advent of carbon farming, there is also a risk of unregulated practices (e.g. certain soil organic additives) causing greater harm to soils as some farmers may prioritise carbon additions to soil to receive payments, without considering the possible trade-off effect on their overall soil health.

**28** Neither public policy alone, not private initiatives have yet sparked the required transition in production and especially SSM. It is important that both work together to create synergies.

## A set of actions are identified to enable widespread uptake of SSM

### Support and upscale what is already being done on the ground to achieve SSM

**29** **Provide farmers with locally specific and crop specific information** that has been tried, and scientifically tested at research farms in cooperation with farmers. By already narrowing down what practices will have the most effect and how they should be applied in a context specific situation, the risk to the farmers can be reduced and their motivation to engage increased. Start with universal SSM practices adapted to their local context: keep soils covered, minimise synthetic inputs (fertilisers and pesticides) and increase diversity (in crops and rotations). The information could be compiled by the EIP-Agri groups and distributed through the advisory services.

**30** **Support existing soil initiatives** and the development of local pilot farms and projects – at the regional and MSs level as well as through the EU Soil Mission's lighthouses/living labs. Investigate further the full range of private food sustainability initiatives across Europe which include soil management to discover how they are succeeding or not, how they are measuring soil health improvement, and what if any coordination of their efforts could multiply their effects.

**31** **Allow the transition to be gradual** and don't be dogmatic about the practices or farming system a farmer should implement, seek to focus on outcomes of healthier soils. Thus, it is unwise to require farmers to immediately and fully adopt no-till farming or complete cessation of using synthetic inputs across the whole farm – allow trial and error.

**32 Use carbon farming and carbon sequestration initiatives as a motivating force**. But assess trade-offs to ensure that the practices encouraged to improve soil health do not lead to further soil degradation. Many farmers are currently motivated and interested in their soil carbon and how much they can sequester. There is a strong research, education and communication task to help land managers understand the complex issues of additionality and permanence.

### Work to create an enabling framework and align incentives to mainstream SSM

**33 Clarify the sustainable food system model Europe is working towards**: be open and bold about the consumption, food price and consequential social welfare changes which will be necessary to bring this about. Integrate policies to make this happen.

**34 Complete the work of definitions of soil health and metrics**: What is a healthy soil and how do we measure it at each scale? Substantive efforts are now underway to resolve this, such work should be given high priority. It should include thorough examination of the numerous indices, and indicators of SSM devised by the private initiatives including certification organisations and food companies.

**35 Ensure the whole food system is onboard**. Farmers are under great pressure from downstream companies to deliver their crops in a certain form, at a certain time, and are reliant on buying in certain products to manage their crops. This is often in detriment to soil health. Adding new crops into rotations will also require opening new markets. The right alignment from markets can also help increase the speed of the transition. Help achieve transparency amongst food industry sustainable sourcing schemes and work towards harmonised reporting and verification of their outcomes.

**36 Ensure SSM is a core component of education, advisory and farmer training**. Some initiatives focus already on training advisors that go out in the fields and help farmers implement SSM practices. The CAP offers the possibility to fund this. Include and update soil science courses at universities, teach about the importance of soils and SSM soil as early as primary schools. Make it mandatory for farmers-to-be to take courses in SSM and natural resource management to understand the links between soils, water, air and biodiversity and the interactions between farms and other ecosystems. Include environmental sustainability courses at business schools to promote the involvement of the whole value chain in developing sustainable business models.

**37 Get clearer on the mix of incentives in agricultural and environmental policy**. More has to be done to clarify the respective roles of: CAP basic payments with cross-compliance, eco-schemes, agri-environment and climate measures, private and public C-farming payments, incentives for change of land use (for forestry and peat restoration), and biodiversity offsetting payments by developers. Don't underestimate the challenge of getting the policy signals right and avoiding a muddle which paralyses progress. These are not trivial issues, and many land managers may hold off making what may turn out to be irreversible, permanent, land use changes locking-in the room for manoeuvre for their successors. Consider how to adapt support to ensure both tenants and land owners are equally motivated to improve soil health for the long term.

**38 Research and resolve the international trade issue**. This is another issue which has the potential to undermine the credibility of EU policy in the eyes of land managers. High domestic standards which effectively diminish EU production in favour of imports from regions operating at lower standards are feared by farmers organisations and inhibit them in engaging in sustainable production. This issue is now on the table through the 'mirroring' ideas of the French Presidency, it requires thorough investigation.

**39 Increase citizens' awareness on the importance of soils** by sharing success stories and reporting about progress in soil health. Work together with food retailers and food service providers to achieve this.

Soil

## INTRODUCTION

Healthy soils are fundamental to our future food security and mitigating and adapting to the climate crisis. They are a critical part of society's natural capital and play a crucial role in supporting biodiversity and regulating our precious, and increasingly scarce and unpredictable, fresh water supply. Yet, despite their importance, we have been degrading our soils for decades. Soil sealing, soil contamination and the predominant system of farming are destroying soil health and causing soil erosion. They are also having a negative effect on biodiversity, water management, air quality, and climate. Collectively, these effects are seriously handicapping Europe's ability to reach its goals of reducing pollution and stabilising the climate. More seriously, soil degradation threatens long term food security and increases the exposure of the food system to the effects of climate change.

Soil degradation threatens long term food security and increases the exposure of the food system to the effects of climate change

Agricultural soil management, soil sealing and soil contamination from industrial sites, are all important soil threats that need to be tackled urgently, yet require a very different set of actions in order to reverse the damage they are causing. As a Foundation specialised in promoting sustainable agriculture in Europe, RISE's expertise lies in agricultural policy and therefore the natural focus of this report will be on agricultural soils.

There is already a wealth of established knowledge on how to protect and restore agricultural soils, yet together with a range of agricultural and environmental policy initiatives over the last the decades, we have failed to reverse soil degradation.

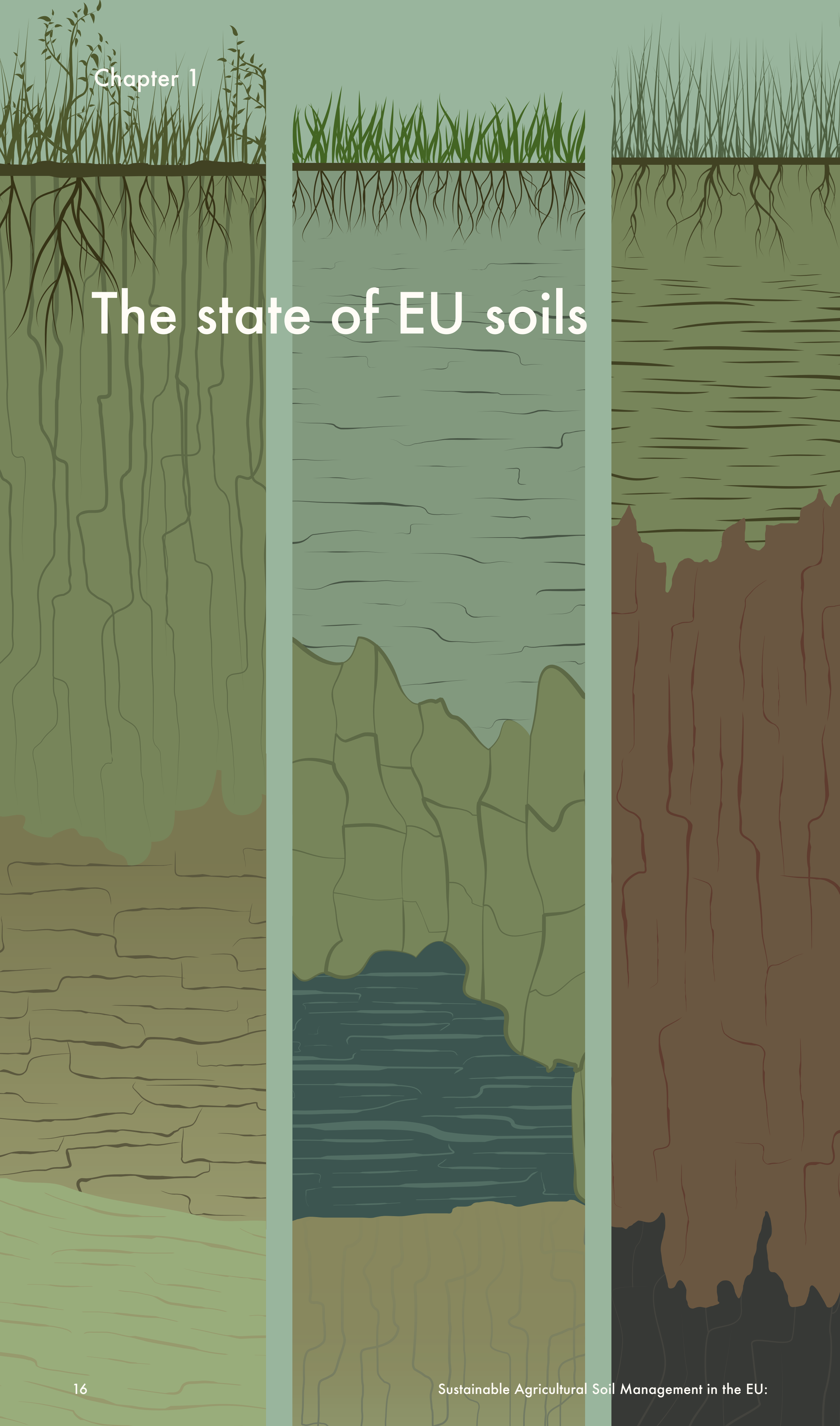
A new opportunity for soil protection has been created at the European Union (EU) level" level with the adoption of the European Green Deal (EGD) which, through its strategies, highlights soil as one of the key challenges that needs to be addressed in the coming decade. These initiatives have the potential to bring about substantial change, but in order for this new top-down commitment to succeed, we have to understand why current policy failed in order that the same mistake is not made twice.

The deterioration of soils has come to the attention not only of policy makers, academics and civil society, but also the private sector. Long established soil initiatives, such as organic farming, are expanding and new ones are opening across Europe with a common ambition: to improve soil health. Farmers are starting to see the effects of climate change on their land, municipalities are trying to limit the effect of violent weather changes and food companies are becoming aware of the vulnerability caused by soil deterioration in their own supply chains. These grass root movements are encouraging, but remain limited in scope. The advent of a new political focus on soil may be the impetus needed to help scale these private sector initiatives.

This report seeks to contribute to the debate on how to best frame and build on this momentum for a change in soil management. It synthesizes current knowledge on soils, unpacks the barriers that are inhibiting change in farming practices, explores the ever-growing sector of soil initiatives and suggests what is necessary to drive change towards a more sustainable soil management and food system in the EU.

Chapter 1

# The state of EU soils



## 1.1 What is soil?

The EU's 2006 Soil Thematic Strategy (COM (2006) 231) defines soil as "the top layer of the earth's crust, formed by mineral particles, organic matter, water, air and living organisms. It is the interface between earth, air and water and it hosts most of the biosphere[1]". This top layer enables life on earth not only by being a physical support for vegetation and all our activities but most importantly by performing crucial functions. These include filtering and storing water and decomposing organic matter while stocking carbon and cycling nutrients making them newly available for vegetation growth, thereby providing us with food, fibre, timber and many other materials.

> This top layer enables life on earth not only by being a physical support for vegetation and all our activities but most importantly by performing crucial functions.

Soil takes time to form. Due to its slow average formation rate, around 1 mm per decade, it is considered a finite non-renewable resource, not recoverable within a human lifespan[2]. Its formation depends on five main factors (parent material, topography, climate, biological activity, and time) and the resulting soil is a mix of the weathered parent material, water, air and organic matter. Several soil classification systems exist. Soil maps in the EU are based on the World Reference Base, the international standard used to classify soils based on the 32 existing Reference Soil Groups in combination with additional observations. To give an example, a very shallow soil over hard rock with a topsoil rich in organic matter, such as those found in mountain areas under forest, could be called Mollic Leptosol; Leptosol being the Reference Soil Group group and Mollic referring to the presence of a dark layer of organic matter, among other things. More than 10,000 different types of soil have been identified in the EU[3]. Soil mapping is challenging, not only because soils are hidden below our feet, but because they are three-dimensional and merge from one type to another often without a discernible physical boundary between soil types. Aboveground elements, such as plants, rock outcrops, are also recorded when analysing soil profiles in order to combine them and produce maps. In addition to field observation and sampling, soil scientists currently use a set of tools including digital elevation models, geological maps, climate data and remote and proximity sensing technologies that provide information on aboveground vegetation, soil organic matter content, salinity and other physical and chemical soil properties to produce the maps.

In practice, soil texture (the size distribution of the soil grains) is often used to quickly classify a soil to understand its behaviour in terms of its ability to store water and nutrients and the management it will need if used in agriculture. Soil texture is often represented visually as a triangle showing the proportion of sand, silt and clay of a soil.

Another critical characteristic of any soil is its depth, which can range from only a few centimetres to beyond 2 meters. A vertical section of a soil profile will show layers of different characteristics between the surface and the parent material at the bottom. These layers are called 'horizons' and are the result of weathering processes, including biological and human activity. The upper layer is called the "topsoil" and is rich in organic matter and biological activity. It's the most fertile horizon and is greatly affected by land management. Below this layer a group of "subsoil" layers contain less organic material but still host some roots, animals and micro-organisms. The bottom layer is called the "substrate", shows

[1] Soil Thematic Strategy: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52006DC0231

[2] Montgomery, D.R., 2007. Soil erosion and agricultural sustainability. P Natl Acad Sci USA 104, 13268–13272

[3] Soil Thematic Strategy (see ref 1)

little or no structural development and is very similar to the parent material. Under soil formation processes, water, nutrients and fine soil particles are slowly washed out from the surface to deeper soil layers. In this report we'll focus on the topsoil, the layer most susceptible to changes due to human activities.

The study of soils has greatly evolved over the last century. It has moved from describing soil formation and classifying soils according to their properties, linking soil types to climate regions to a more complex understanding of the links between soil, plants and other living organisms. More recently, the crucial role played by soils, in particular, soil organic matter and soil biota, in the broader ecosystem functioning has been brought to light and is seen with increasing interest, particularly in the context of the climate crisis, and as a fundamental component of socio-ecosystems[4].

## 1.2 Soil health and soil quality

There are several terms used to describe the state of a soil, often relating to how well it can perform under agricultural use. A soil in "good condition" will have a combination of a good physical structure, chemistry, organic matter content, biodiversity and capacity to infiltrate and retain water. Traditionally the term "**soil fertility**" was used and understood as the ability of soils to sustain plant growth by providing essential nutrients and favourable conditions for the growth of plants[5]. Fertility describes soils based on the characteristics that allow them to perform optimally for agriculture, but does not take into account good soil functioning per se. More recent terms which are still focussed on agricultural use but have a wider view are "**soil health**" and "**soil quality**". They imply soil functioning beyond its fertility or productive capacity. 'Soil quality' has been traditionally used to describe soil status relative to its properties and the capacity to provide humans with services. Within the EU, many concepts have been developed to define soil quality in Member States (MS) with links to indicators that allow measurement and monitoring over time. The term 'soil health' is generally used to assess the functional status of a soil from a broader perspective. The European Commission (EC) has defined healthy soils as soils that '*are in good chemical, biological and physical condition, and thus able to continuously provide as many ecosystem services as possible*'[6], while the FAO's definition of soil health emphasizes the role played by soil biodiversity. The terms health and quality are not exact synonyms but are often used interchangeably. To indicate how open to interpretation these concepts are it is interesting to note that China defines soil quality as having three components: soil fertility, soil environmental quality and soil health[7]. The first deals with the capacity of soils to provide biomass growth, the second to maintaining clean water and air and the third relates to human and animal health.

In this report we predominally use the term 'soil health'. There are a few mentions to 'soil quality' when the cited authors specifically used that term or when referring mostly to soil properties rather than the continuous provision of services. The term 'soil health' is currently embraced by policy makers, industry and farmers alike to talk about Sustainable Soil Management (SSM). This makes it a good starting point for action and helps attract public attention. The increased popularity of this term, and its use in the public sphere has however been received with scepticism among some scientists who fear that the term is too broad to be

[4] Albaladejo, J., Díaz-Pereira, E., de Vente, J., 2021. *Eco-Holistic Soil Conservation to support Land Degradation Neutrality and the Sustainable Development Goals.* CATENA 196, 104823.

[5] FAO definition

[6] European Commission. 2021. *EU Soil Strategy for 2030. Reaping the benefits of healthy soils for people, food, nature and climate* {SWD(2021) 323 final}

[7] Bünemann et al., 2016. *Concepts and indicators of soil quality – a review.* ISQAPER project www.isqaper-project.eu

used as a scientific concept. They suggest that without a reference to a specific function or use the term can become meaningless[8]. They argue that the fulfilment of soil functions will not only depend on the state or properties of a soil, but also in their use. For example, an acidic soil might allow a forest to flourish but will not provide the optimum growing conditions for wheat cultivation without specific management practices. Therefore, soil health should be evaluated in the context of the landscape where it exists. The challenge to find suitable and meaningful indicators for soil health that policy makers can interpret and farmers can reasonably measure is therefore a crucial one. The term 'soil health', however, is already in widespread use as a frame for discussing and achieving SSM goals[9]. The EC has adopted this terminology in its 2021 Soil Strategy and has used it to name one of their 5 missions for the new Horizon Europe programme with the goal of achieving 75% of soils "healthy" in each EU country by 2030[10].

## 1.3 Soil functions

Soils perform many functions, which are also referred to as services, and sometimes called soil-based ecosystem services. Many soil functions are at the centre of global challenges: climate change, safeguarding biodiversity, ensuring food and water security and preventing land degradation and desertification. They range from very local such as providing anchorage for roots and source of raw materials to global ones such as climate regulation. Due to their complexity and the large number of functions they perform, soils are increasingly considered ecosystems in themselves[11]. It is estimated that the ecosystem services provided by cropland and grassland in the EU are worth annually EUR 76 billion, two thirds of which is not related to crop production itself[12].

The written recognition that soils do more than provide humans with food and fibre dates back only to the 1960s and full acknowledgement of their multifunctionality did not come until the 1970s[13]. The description and categorisation of these functions is even more recent, and the range of functions attributed to soils has steadily increased as more scientists have taken approach. There are multiple ways of describing and classifying soil functions. These are commonly grouped into 6 to 11 soil functions. Blum[14] organised soil functions into six categories which were further developed and used as a framework for the EC's 'Thematic Strategy for Soil Protection'.

The EC defines seven[15] soil functions (or ecosystem services) which will be discussed in more detail below. These are: (i) provide the basis for life and biodiversity, (ii) act as a carbon reservoir, (iii) absorb, store and filter water and transform nutrients and substances thus protecting groundwater bodies, (iv) provide food and biomass production, (v) act as a source of raw materials, (vi) provide a physical platform and cultural services for humans and their activities, and (vii) constitute an archive of geological, geomorphological and archaeological heritage.

[8] Baveye, P.C., Baveye, J., Gowdy, J., 2016. *Soil "Ecosystem" Services and Natural Capital: Critical Appraisal of Research on Uncertain Ground*. Front Environ Sci. 4.

[9] Lehmann, J., et al., 2020. *The concept and future prospects of soil health*. Nat Rev Earth Environ 1, 544–553.

[10] Both the Soil Strategy and the Soil Mission will be discussed in Chapter 4

[11] Ponge, J.-F., 2015. *The soil as an ecosystem*. Biol Fertil Soils 51, 645–648.

[12] European Commission. Statistical Office of the European Union., 2020. *Accounting for ecosystems and their services in the European Union (INCA): final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU : 2021 edition*. Publications Office, LU.

[13] Baveye et al. 2016 (see ref 8)

[14] Blum, W.E.H., 2005. *Functions of Soil for Society and the Environment*. Rev Environ Sci Biotechnol 4, 75–79.

[15] EC 2021 (see ref 6)

The definitions of soil functions have traditionally been anthropocentric. But acknowledging the multifunctionality of soils and their importance in sustaining all life on earth (not just human life) brings to light the conflicts and synergies in their use. Synergies arise for example when increasing soil organic carbon, which can lead to improved nutrient cycling and water filtration and storage capacities and a better habitat for soil organisms. A conflict between functions can take place when soil is used for human infrastructure, e.g., housing or a paved road, because this will impede the soil performing most of the other functions, such as water filtration, or the establishment of vegetation. The links between soil properties, functions and ecosystem services is complex and not fully understood.

There are many documents which have explained in detail the soil functions. Below is an overview of the four functions with most relevance for agricultural soil management.

## Provide the basis for life and biodiversity

Soils are home to billions of organisms and form the largest gene pool on Earth[16]. These organisms, together with the communities they form and the ecological complexes they are involved in, are referred to as soil biodiversity[17] and they sustain life on earth[18]. The importance of this function cannot be over-stated. Soil biodiversity represents between one quarter to one third of the world's biodiversity[19] and 40% of the living organisms in terrestrial ecosystems are associated with soils during their life-cycle[20]. We still know very little about most of these soil organisms but their abundance in soils is thought to be strongly linked to soil's multifunctionality[21]. Scientists estimate that there are up to 1 billion organisms in 1 teaspoon of healthy soil[22] but more than 90% of these organisms remain unknown[23]. The fact that we know so little is partly due to the difficulties in sampling these organisms and understanding the functions they perform, and also to the fact that most have not been individually recognised[24].

Scientists estimate that there are up to 1 billion organisms in 1 teaspoon of healthy soil but more than 90% of these organisms remain unknown

Soil organisms are usually classified by size (body length or body width). By body width the resulting groups are (larger to smaller): megafauna (e.g. moles), macrofauna (e.g. earthworms), mesofauna (e.g. protozoa), microfauna (e.g. nematodes) and microorganisms. These organisms spend considerable part of their life below ground and collectively confer resilience to soils[25]. Soil biological activity is highest in the top 10cm of soil and is performed mostly by microorganisms and

[16] Lavelle, P., et al., 2006. *Soil invertebrates and ecosystem services.* Eur J Soil Biol 42, S3–S15.

[17] FAO, et al., 2020. *State of knowledge of soil biodiversity - Status, challenges and potentialities, Report 2020.* Rome, FAO.

[18] ESDAC. 2010. Atlas of Soil Biodiversity.

[19] EC's page on soil and land: https://ec.europa.eu/environment/soil/index_en.htm (accessed 20/5/22)

[20] Decaëns, T., et al., 2006. *The values of soil animals for conservation biology.* Eur J Soil Biol 42, S23–S38.

[21] Wagg, C., et al., 2014. *Soil biodiversity and soil community composition determine ecosystem multifunctionality.* P Natl Acad Sci USA 111, 5266–5270.

[22] Anton, T., 2017. *Planet of Microbes: The Perils and Potential of Earth's Essential Life Forms.* University of Chicago Press.

[23] Orgiazzi, A., 2016. *Global soil biodiversity atlas: supporting the EU Biodiversity Strategy and the Global Soil Biodiversity Initiative: preserving soil organisms through sustainable land management practices and environmental policies for the protection and enhancement of ecosystem services.* European Union, Office des publications, Luxembourg.

[24] Gardi, C., Jeffery, S., Saltelli, A., 2013. *An estimate of potential threats levels to soil biodiversity in EU.* Glob Change Biol 19, 1538–1548

[25] Downing, A.S., et al., 2012. *The Resilience and Resistance of an Ecosystem to a Collapse of Diversity.* PLOS ONE 7, e46135.

microfauna. These organisms include bacteria, fungi, protozoa, nematodes and algae. They are responsible for a large number of soil functions and services. Each soil organism has its own role to play, but some organisms are more specialised than others. Microorganisms and microfauna transform carbon and nutrients into accessible forms for plants, they also degrade and immobilise contaminants. Mesofauna degrade litter to facilitate the work of microorganisms and microfauna and keep their populations under control through predation. Larger organisms such as macrofauna and megafauna contribute to soil structure by providing porosity for gas and water transport and produce stable aggregates that protect soils against erosion. Altogether, these organisms and their activity allow soils to function and be able to provide services above and below ground[26]. In terms of biomass, a large proportion of soil fauna is represented by earthworms while in terms of numbers, nematodes are the most abundant[27].

Soil biodiversity is crucial for agriculture, both to boost plant growth and attenuate plant threats. It improves soil fertility and nutrient uptake, it is the basis of many biobased fertilisers and biological control of pests, it improves plant resistance against water stress and by immobilising and degrading contaminants (bioremediation) it improves plant growth in contaminated soils. To achieve all this, plants send chemical signals to microorganisms in the root zone which are just now starting to be explored by scientists. Through these signals, plants obtain nutrients from microorganisms in exchange of carbohydrates that help microorganisms live and grow and can also shape the microbial community in the root zone to find a balance between pathogens and beneficial microbes[28]. Of particular interest for agriculture is the role of soil organisms in contributing to nitrogen fixation. There are also a large number of symbiotic associations, most of which still not explored, between soil organisms and algae, lichens, plant roots and fungi or mycorrhiza[29].

The study of soil biodiversity has advanced greatly over the last 20 years with the development of novel tools and techniques[30]. New organisms have been identified and described and soil biodiversity maps produced[31]. Much remains to be done particularly in terms of monitoring, assessing biodiversity at different spatial scales, understanding the relationships between organisms within the food web and the direct relationships between soil biodiversity and crop production. Although not well studied, it is also thought that there can be important human health impacts of exposure to soils, for example early exposure to healthy soils could help prevent chronic inflammatory diseases in humans[32]. Clarifying these issues could help developing adequate policy frameworks that better protect and enhance soil biodiversity[33],[34].

[26] FAO et al. 2020 (see ref 17)

[27] van den Hoogen, J., et al., 2019. *Soil nematode abundance and functional group composition at a global scale*. Nature 572, 194–198.

[28] Pascale, A., et al., 2020. *Modulation of the Root Microbiome by Plant Molecules: The Basis for Targeted Disease Suppression and Plant Growth Promotion*. Front Plant Sci 10, 1741.

[29] A highly accessible account of these interactions between soil organisms is provided by Sheldrake M., 2020. *Entangled life, how fungi make our worlds, change our minds and shape our futures*, Bodley Head, London.

[30] Nielsen, U.N., Wall, D.H., Six, J., 2015. *Soil Biodiversity and the Environment*. Annu Rev Environ Resour 40, 63–90.

[31] Global Soil Biodiversity Atlas Maps : https://esdac.jrc.ec.europa.eu/content/global-soil-biodiversity-maps-0 (accessed 20/5/22)

[32] Roslund, M.I., et al., 2020. *Biodiversity intervention enhances immune regulation and health-associated commensal microbiota among daycare children*. Sci. Adv. 6, eaba2578.

[33] Nielsen 2015 (see ref 30)

[34] Geisen, S., et al., 2019. *A methodological framework to embrace soil biodiversity*. Soil Biol Biochem 136, 107536.

## Act as a carbon reservoir

Soils are the second largest global sink of carbon after the oceans. They are estimated to store 80% of the carbon present in terrestrial ecosystems[35], and thus soil carbon management is increasingly recognised as a crucial component to help meet climate targets. Carbon is found in soils as inorganic or organic carbon. Inorganic carbon, mostly calcium carbonate, derives from the parent material or results from reactions that take place in the soil with atmospheric carbon dioxide ($CO_2$). In the EU27, soil organic carbon (SOC) stocks were estimated to amount to 75–79 billion tonnes in 2017, half of it located in only three countries (Finland, Sweden, UK)[36]. Most of this soil carbon is found in peatland soils and is very susceptible to small changes in temperature and precipitation or soil water content, which will increasingly take place under a changing climate.

Soil organic carbon is essential to healthy soils. It is key to keeping soil in good physical, chemical and biological condition. It consists of a mixture of particulate organic matter and soil microbes, although a precise definition is not universally agreed. It is a dynamic material which complicates its definition and measurement. The particulate organic carbon is composed of dead or dying vegetable or animal compounds which is slowly being decomposed by microbes until there are no visual remains of the original material. Root biomass makes up a large percentage of carbon inputs to soil, but litter of plant shoots is also included[37]. Part of the SOC is mineralised by soil organisms, converting nutrients from organic to an inorganic form that plants can take up. The rest is decomposed, producing stable, more complex substances (i.e. humic substances). The rates of mineralisation depend on the conditions in which the process takes place (temperature, moisture, oxygen) and the characteristics of the material, most notably its carbon to nitrogen (C:N) ratio[38]. Management activities altering this ratio (nitrogen fertilisation) or changes in climatic and soil conditions, such as those expected with climate change, will therefore lead to changes in the decomposition of organic matter and nitrogen and carbon mineralisation. Mineralised carbon is emitted as $CO_2$ from soils, or methane ($CH_4$) if produced under anaerobic conditions, while the mineralisation of organic nitrogen produces ammonium that plants use to grow.

There is still no wide agreement on how SOC should be defined or how its fractions, or pools, should be classified despite decades of research. This is perhaps partly because we are seeking a static definition of a dynamic process. There are three main issues over the appropriate way to define and measure SOC[39]: (i) Should living biomass be included or excluded? (ii) Should litter be included or excluded? (iii) What level of decomposition to be used as threshold? Yet another area debated concerning SOC pools is their definition regarding their stability which will determine their residence time in soil. It has been suggested that this stability may depend more on where the carbon molecule is sequestered (environmental, mineralogical and biological controls) than on its intrinsic properties[40],[41], but this is an area of research still in development.

[35] Lal, R. 2008. *Carbon sequestration*. Philos T R Soc B 363, 815-830.

[36] https://www.eea.europa.eu/data-and-maps/indicators/soil-organic-carbon-1/assessment (accessed 1/11/2021)

[37] Ontl, T. A. and Schulte, L. A., 2012. *Soil Carbon Storage*. Nature Education Knowledge 3(10):35

[38] In general, there´s mineralisation if the value is equal to or below 20-30.

[39] As defined by Huber, S. et al., 2008. *Environmental Assessment of Soil for Monitoring: Volume I Indicators & Criteria*. Office for the Official Publications of the European Communities. JRC, Ispra.

[40] Schmidt M. W. I., et al., 2011. *Persistence of soil organic matter as an ecosystem property*. Nature 478

[41] Wiesmeier, M., et al., 2019. *Soil organic carbon storage as a key function of soils - A review of drivers and indicators at various scales*. Geoderma 333, 149–162.

### Absorb, store and filter water and transform nutrients and substances

One of the key functions of soils is the cycling of nutrients which enables life on earth. The ability of a soil to cycle nutrients depends on its capacity to store organic matter and to host soil organisms. Soil organic matter is the main source of nutrients for soil organisms and it is soil organisms, in particular bacteria, which transform nutrients from an organic to an inorganic form that is available for vegetation to take up.

Of particular interest is the cycling of nitrogen, not only for agronomic reasons but also due to its links to climate change through nitrous oxide emissions. Nitrogen (N) constitutes 78% of the earth's atmosphere. Despite being so abundant in the air we breathe, N in the form of nitrogen gas ($N_2$) is inert. It does not interact easily with other compounds and cannot be used by plants. Even in soils, most of the nitrogen is found in an organic form, bound to soil organic matter, which is not available for plant uptake either. Plants feed on nitrogen from soils in the form of ammonium ($NH_4$) or nitrate ($NO_3$). These mineral nitrogen forms are produced through biological fixation and, to a smaller extent, by lightning and biomass burning. Biological fixation takes place in soils when bacteria convert organic nitrogen into inorganic nitrogen through a set of processes. The various nitrogen forms (organic and inorganic) are found in equilibrium in soils and their balance depends on environmental factors (moisture, temperature, oxygen) and soil properties such as texture, clay mineralogy and the presence or absence of other ions in soils.

Intensive agricultural systems based on high inputs of fertilisers have led to a disequilibrium of nitrogen in soils in a process called "the nitrogen cascade"[42]. Increasing inputs of reactive nitrogen into soil have accelerated the leaching and emissions of nitrogen to surface and groundwater and the atmosphere. The leaching of nitrates to surface and groundwater compromises water quality as a result of eutrophication a leading to algae blooms in surface waters. The risk of leaching is higher when soluble nitrogen fertiliser is applied, in particular on sandy and loamy soils[43]. Excessive N mineralisation from soils also leads to emissions of nitrous oxide ($N_2O$), a potent greenhouse gas. Globally, soils are responsible for 60% of the total $N_2O$ emissions[44]. The release of $N_2O$ from soils results mostly from intensive fertilisation, either from inorganic and organic fertilisers such as manure.

### Biomass production

The capacity of soils to sustain biomass production for food, fibre and energy is probably its best-known function and critical for human life on earth. Soils provide around 99% of the calories consumed by humans[45], the rest coming from aquatic systems. It is estimated that one third of ice-free land globally is used for agriculture[46]. Humans have increasingly managed soils throughout history towards the delivery of biomass production, by changing land use and intensifying the use of external inputs. This has increased the production of food fibre and energy although this has often come at the expense of other soil functions which will increasingly jeopardise our ability to continue to produce food at the same level.

[42] Galloway, J., et al., 2003. *The Nitrogen Cascade*. BioScience 53, 341–356.

[43] Hansen, B., et al., 2000. *Nitrogen leaching from conventional versus organic farming systems – a systems modelling approach*. Eur J Agron 13, 65–82.

[44] Tian, H., et al., 2019. *Global soil nitrous oxide emissions since the preindustrial era estimated by an ensemble of terrestrial biosphere models: Magnitude, attribution, and uncertainty*. Glob Change Biol 25, 640–659.

[45] Kopittke, et al., 2022. *Ensuring planetary survival: the centrality of organic carbon in balancing the multifunctional nature of soils*. Crit Rev Env Sci Tech 1–17.

[46] ibid

With a continuous population growth and the increased uncertainties and risks that come with the climate crisis, increased biomass production will be expected from soils and any deterioration in its function to produce biomass will inevitably lead to severe consequences for global food security.

## 1.4 The State of EU soils and soil threats

Globally, soils are degrading at worrying rates, and the EU is no exception[47],[48]. Soil degradation remains widespread and although at different rates across the EU[49] 60% to 70% of all soils in the EU are considered to be in an unhealthy state[50]. In EU agricultural soils this assessment is mostly a result of unsustainable soil erosion rates, excessive nutrient inputs that lead to the eutrophication of water bodies and biodiversity loss, land at risk of desertification, soil pollution from plant protection product residues, and more locally soil acidification and salinisation. Alarmingly, 50% of peatlands are being drained and consequently their carbon is oxidising, releasing $CO_2$ into the atmosphere, and accelerating climate change. Intensive land management is leading to negative impacts on soil biodiversity[51]. The total costs of soil degradation have been estimated to exceed 50 billion EUR annually, equivalent to around 30% of the EU budget[52].

This poor state of EU soil condition is not new. Soils have been deteriorating over several decades and the outlook for 2030 does not show signs of improvement[53]. Diffuse soil contamination on land is widespread, soil sealing for urban development continues at the expense of agricultural land, much of it the better-quality land, and intensive land management (mechanical and chemical) has reduced species richness of many soil organisms. 80% of EU soils contain plant protection product residues, trace elements and other contaminants whose cumulative impacts on soil biodiversity are slowly being understood[54,55]. In addition, around 13% of EU soils are affected by moderate to high erosion, and the annual losses this is causing the agricultural sector are estimated to be as high as 1.25 billion EUR[56]. These on-site costs are supported by farmers, who see their most valuable asset (soil) declines losing yields, nutrients and compromising future production[57]. The power of agricultural machinery increases the loss of soil and organic matter by inverting and pulverising agricultural soil through frequent ploughing.

Soils have been deteriorating over several decades and the outlook for 2030 does not show signs of improvement.

[47] IPBES, 2018. *The IPBES assessment report on land degradation and restoration*. Montanarella, L., Scholes, R., and Brainich, A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 744 pages.

[48] IPCC, 2019. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, et al.] https://www.ipcc.ch/srccl/

[49] EEA, 2019. *The European environment — state and outlook 2020 - Knowledge for transition to a sustainable Europe*. Publications Office, LU.

[50] European Commission. Directorate General for Research and Innovation., 2020. *Caring for soil is caring for life: ensure 75% of soils are healthy by 2030 for food, people, nature and climate: report of the Mission board for Soil health and food*. Publications Office, LU.

[51] EEA., 2019 (see ref 49)

[52] European Commission. Directorate General for Research and Innovation., 2020

[53] EEA., 2019 (see ref 49)

[54] FAO and UNEP. 2021. Global Assessment of Soil Pollution: Report. Rome.

[55] Geissen, V., *et al.*, 2021. Cocktails of pesticide residues in conventional and organic farming systems in Europe – Legacy of the past and turning point for the future. Environ Pollut 278, 116827

[56] Panagos, P., *et al.*, 2018. Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models. Land Degrad Develop 29, 471–484.

[57] ibid

The lack of progress on improving soil health is hindering the fulfilment of international commitments, and the EC has decided to take action through the Soil Strategy to more effectively protect land and soil. A Soil Health Law is to come in 2023. Restoring soil health is also central to achieve the objectives of the EGD such as climate neutrality, biodiversity restoration, zero pollution, healthy and sustainable food systems and a resilient environment. The recently established EU Soil Observatory will be a crucial tool to assess the state of EU soils in the coming decades and measure progress.

The most serious soil threats are: soil erosion by wind and water, decline in organic matter, decline in biodiversity, soil compaction, soil sealing, soil salinisation, soil contamination, desertification, and flooding and landslides[58]. A short description of each is provided below. These are for the most part localised threats, but some, like soil erosion, can have important off-site impacts.

## Soil erosion

Soil erosion by water, wind and agricultural practices such as tillage or root crop harvesting is a well-studied soil threat. It is defined as a three-stage process which consists of the detachment of soil particles, their transport and their deposition. Soil erosion is often cited as the main driver of soil loss and degradation in agricultural areas due to water, wind and tillage, and is expected to become more important as rainfall erosivity increases due to climate change[59],[60]. Soil erosion generally removes and redistributes the upper most layer of soil, the most fertile one, reducing the productivity of the eroded land. This has been estimated to translate to productivity decreases of up to 8% in intensively cultivated fields with high erosion rates[61]. Within the EU alone it is estimated that 3 million Tn of wheat and 0.6 million Tn of maize are annually lost due to severe erosion, with economic losses amounting to 0.43% of the contribution of the agricultural sector to the EU's gross domestic product[62].

Soil erosion is often cited as the main driver of soil loss and degradation in agricultural areas due to water, wind and tillage, and is expected to become more important as rainfall erosivity increases due to climate change.

Estimating soil erosion rates is not always a straightforward task. The main factors affecting soil erosion are vegetation cover, climate, soil and topography. In managed land such as agricultural sites, soil erosion is also greatly affected by human intervention. In 1978 these factors were brought together into a model called the Universal Soil Loss Equation (USLE) which allowed calculation of soil erosion rates on experimental plots[63]. Since then, the model has been revised and new models have been also developed expanding on these parameters[64] or building on alternative regression or process-based model concepts[65] and most recently using ensemble model predictions[66]. Despite ongoing scientific discussion on model

[58] Montanarella, L. 2002. *The EU Thematic Strategy on Soil Protection* pp. 275-288.

[59] Sun, Y., *et al.*, 2007. *How Often Will It Rain?* J Climate 20, 4801–4818.

[60] Panagos, P., et al., 2022. *Global rainfall erosivity projections for 2050 and 2070*. J Hydrol 610, 127865.

[61] Panagos, P., et al., 2018 (see ref 56)

[62] ibid

[63] Wischmeier, W.H. and Smith, D.D., 1978. *Predicting Rainfall Erosion Losses. A Guide to Conservation Planning*. The USDA Agricultural Handbook No. 537, Maryland.

[64] Borrelli, P., et al., 2021. *Soil erosion modelling: A global review and statistical analysis*. Sci Total Environ 780, 146494.

[65] de Vente, J., et al., 2013. *Predicting soil erosion and sediment yield at regional scales: Where do we stand?* Earth-Sci Rev, 127.

[66] See for instance Eekhout, J.P.C., et al., 2021. *A process-based soil erosion model ensemble to assess model uncertainty in climate-change impact assessments*. Land Degrad Dev 32, 2409–2422.

concepts and high uncertainty on actual local erosion rates, these models are used to estimate average soil erosion rates over large areas and are the basis of EU soil erosion maps under current and future land use and climate conditions.

The main forms of water erosion are rain splash, sheet wash, rill formation and the development of gullies. All these, to a higher or lesser degree, result in the loss of the fertile topsoil and degradation of the soil structure on eroded sites. However, soil erosion can also cause damage downstream where eroded soil is deposited. It pollutes water, creates flood risks by silting dams, canals and destroys infrastructure. It is estimated that the social costs of erosion due to the off-site effects are 11 times higher than their on-site costs[67]. By modifying land cover and disturbing soil mechanically, chemically and biologically, our agricultural systems contribute to soil erosion, while at the same time suffering its effects. Land levelling and the removal of landscape elements such as hedges and trees has accelerated these processes in agricultural areas. Management practices to combat soil erosion are well known. They include: reducing tillage, keeping soils covered, planting row crops on sloping land along and not across contours, as well as and introducing landscape structures that retain soil.

EU agricultural land is estimated to be losing soil to water erosion at an unsustainable rate. Erosion is estimated as twice as fast as soil formation resulting in annual losses of 970 Mt of soil[68]. While this is an average, around 18% of erosion-prone agriculture and natural grasslands were considered to be affected by moderate to severe soil erosion rates in 2016. This is almost one fifth of agricultural land. 80% of the area classified as erosion-prone land by Eurostat in the EU is agricultural land and natural grasslands. Water erosion rates under these land uses averages 3.4 Tn/ha/y[69].

## Decline in organic matter

Soil Organic Matter (SOM) loss from agricultural land is particularly worrying because of the central role it plays in many soil functions. A decline in SOM leaves the soil more exposed to other soil threats. A soil that has lost SOM is more susceptible to erosion, holds less biodiversity, has an increased degree of compaction due to reduced porosity and is more prone to desertification because it is able to hold less water[70].

A decline in SOM leaves the soil more exposed to other soil threats.

It is not straightforward to measure SOM. The most common proxy for soil organic matter is soil organic carbon (SOC) and a conversion and a conversion factor is used to derive total organic matter from SOC[71]. SOC stocks are defined for a fixed depth, in which the bulk density of the soil is known as well as the SOC content.

Scientists talk about a historical carbon loss of between 42-78 Gt of carbon in global agricultural land[72], although locally these losses can be masked by its inherent variability[73]. Such numbers are usually obtained through modelling approaches and are surrounded by high uncertainty[74].

[67] Görlach, B., et al., 2004. *Assessing the Economic Impacts of Soil Degradation. Volume III: Empirical Estimation of the Impacts*. Study commissioned by the European Commission, DG Environment, Study Contract ENV.B.1/ETU/2003/0024. Berlin: Ecologic.

[68] Panagos, P., et al., 2016. *Soil conservation in Europe: wish or reality?* Land Degrad Dev 27 (6), 1547–1551.

[69] All info here comes from Eurostat's https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_soil_erosion&oldid=473348#Analysis_at_EU_and_country_level

[70] Stolte, J., et al., 2015. *Soil threats in Europe*. JRC, Publications Office, LU. doi:10.2788/828742 (online)

[71] ibid

[72] Lal, R., 2004. *Soil carbon sequestration impacts on global climate change and food security*. Science 304, 1623-1627.

[73] Ciais P, et al., 2010. *The European carbon balance Part 2: croplands*. Glob Change Biol, 16, 1409–1428.

[74] Stolte, J., et al., 2015 (see ref 70)

In the EU the main driver of SOM loss is the mineralisation of peat soils[75]. Peat soils store between 20-30% of the world´s SOC[76], and between 20-50% of SOC in the EU[77]. Approximately, 17% of the total peat area in the EU had been drained by 2016, mostly to convert it into grasslands and also cropland, but also as a source of raw materials for energy and horticulture. Drained peat soils can emit up to 40 Tn $CO_2$/ha/y[78].

In mineral soils, the depletion of SOM reduces their capacity to filter and buffer water, nutrients and pollutants, it affects their water storage capacity and also leads to greenhouse gas (GHG) emissions if the depletion takes place through increased carbon mineralisation. The LUCAS[79] dataset of 2015 compared to that of 2008 showed a reduction of 0.5% per year of soil organic carbon on croplands, which was accentuated in areas with already low SOC concentrations[80]. It also showed that SOC in cropland areas is not at an optimum level for agricultural production and healthy functioning soils.

## Decline in biodiversity

Soil biodiversity is considered to be at risk in the majority of agricultural soils in the EU[81]. In these soils, changes in the abundance of certain species or changes in the ratio between species can have important implications for the functioning of ecosystems. The loss of soil biodiversity is one of the key aspects of soil degradation and could have serious long-term effects not only on soil and food security[82],[83] but also on our capacity to develop new antibiotics since less than 1% of antibiotics are thought to have been discovered to this point[84]. Despite being of high importance, it is one of the least studied threats to soil health.

The rate of decline in soil biodiversity, due to changes in both the composition and abundance of soil organisms, is not known since there is no baseline to compare against[85]. And its consequences for the development of soil functions are also not well understood. The impact of a decline of certain soil biota on the whole food web is at the moment difficult to determine. Understanding the role played by the different organisms in soils will be crucial to assess the extent of the damage of their loss or reduced abundance in the coming decades. While there are functions that many organisms can do, others are more specialised and can only be carried out by certain species. If these species are lost, the damage will be harder to remedy. Due to this lack of knowledge, there is no agreement on which species should be preserved to ensure ecosystem functioning and red lists have not been created.

75 Stolte, J., et al., 2015 (see ref 70)

76 Moore, P.D., 2002. *The future of cool temperate bogs*. Environ Conserv, 29, 3-20.

77 Byrne KA, et al. 2004. *EU Peat lands: Current Carbon Stocks and Trace Gas Fluxes*. Carbo-Europe Report, Christensen TR, Friborg T (eds.)

78 Oleszczuk, R., et al., 2008. *Impacts of agricultural utilization of peat soils on the greenhouse gas balance*. In: M. Strack (editor). Peat lands and Climate Change, edited by, published by International Peat Society, 2008, Vapaudenkatu 12, 40100 Jyvaskyla, Finland, pages: 70-97.

79 The LUCAS topsoil survey, covering soil data in 25 EU countries, is a EU-wide attempt to built a consistent database of soil cover allowing the assessment of trends in soil health over time.

80 Hiederer, R., 2018, *Data evaluation of LUCAS soil component laboratory data for soil organic carbon, JRC Technical report. No. JRC1 12711*, Publications Office of the European Union, Luxembourg.

81 Orgiazzi, A., et al., 2016. *A knowledge-based approach to estimating the magnitude and spatial patterns of potential threats to soil biodiversity*. Sci Total Environ 545–546, 11–20.

82 FAO et al. 2020 (see ref 17)

83 McBratney, A., Field, D.J., Koch, A., 2014. *The dimensions of soil security*. Geoderma 213, 203–213.

84 Bérdy, J., 2012. *Thoughts and facts about antibiotics: Where we are now and where we are heading*. J Antibiot 65, 385–395.

85 Guerra, C.A., et al. 2020. *Blind spots in global soil biodiversity and ecosystem function research*. Nat Commun 11, 3870.

A recent literature review[86] grouped threats to soil biodiversity under five categories: climate change, land use change, intensive human exploitation, a general decline in soil health (with particular focus on decline in SOM, soil contamination and soil salinization) and plastics. Most of the research has focused on the impact of climate change on soil biodiversity, followed by that of land use change.

## Other soil threats

**Soil compaction** is the collapse of pore space in soils, threatening air and water circulation and affecting nutrient availability in soil. As a consequence, crop growth and groundwater recharge are negatively affected. Soil compaction occurs as a result of the continuous transit of heavy machinery on soils and is accentuated when heavy machinery operates on wet soil. Tillage facilitates soil compaction by breaking soil structure and leaving it more susceptible to collapse. Overgrazing by livestock in pastures can also contribute to soil compaction. When addressing soil compaction, it is important to differentiate between compaction of the topsoil (easier to deal with) or compaction of the subsoil, which is persistent and considered irreversible leading to high productivity costs[87]. Almost one quarter of EU agricultural soils are affected by a high level of compaction[88], and it is suggested that one third of EU subsoils are susceptible to compaction[89]. In some Member States (MSs) the situation is particularly worrying, such as in the Netherlands, where 43% of subsoils are considered over compacted[90].

**Soil salinisation** is the accumulation of salt in soil. Salts accumulate in agricultural soils mostly as a result of inadequate irrigation practices or poor drainage conditions. There are naturally saline soils in several EU member states such as in Spain, Hungary, Greece and Bulgaria, but poor management is affecting significant parts of agricultural soils across the EU. There is very limited data on the extent to which this happens and trends have not been assessed. Salinisation also occurs due to infiltration of seawater, especially if groundwater levels are dropping due to prolonged droughts or excessive drainage.

**Soil acidification** is the reduction of a soil's pH over time due to the replacement of base cations such as calcium, magnesium, potassium or sodium by acidic elements[91]. It is a natural process that can be accelerated by human management. In many areas in the EU soil acidification was the result of acid rain but in agricultural fields acidification is usually the result of poor fertilisation practices, namely application of high levels of ammonium fertiliser and urea and is exacerbated by the removal of all plant residues from the fields[92]. Soil acidification can impede soil microorganisms to perform their functions, due to nutrient deficiencies in plants and increase their uptake of toxic elements such as heavy metals, cadmium or excessive levels of manganese. This results in a decline in crop yields. In agricultural soils, liming is often used as a solution to counterbalance soil acidity but the long-term solution is to use less acidifying farming practices.

[86] Tibbett, M., Fraser, T.D., Duddigan, S., 2020. Identifying potential threats to soil biodiversity. Peerj 8, e9271

[87] https://www.ecologic.eu/sites/default/files/publication/2018/2730_recare_subsoil-compaction_web.pdf

[88] EEA ETC/ULS. 2021. Soil monitoring in Europe. Indicators and thresholds for soil quality assessments (report under review)

[89] Jones, A., et al., 2012. *The State of Soil in Europe. A contribution of the JRC to the European Environment Agency's Environment State and Outlook Report– SOER 2010.* EUR 25186 EN. doi: 10.2788/77361. Luxembourg: Publications Office of the European Union, 2012.

[90] van den Akker, et al. 2013. *Risico op ondergrond- verdichting in het landelijk gebied in kaart*, Alterra-rapport 2409, Alterra, Wageningen University and Research Centre, Wageningen.

[91] Helyar, K.R., Porter, W.M., 1989. *Soil Acidification, its Measurement and the Processes Involved, in: Soil Acidity and Plant Growth*. Elsevier, pp. 61–101.

[92] Butterly, C.R., Baldock, J.A., Tang, C., 2013. *The contribution of crop residues to changes in soil pH under field conditions*. Plant Soil 366, 185–198.

**Soil contamination** is a major concern not only for soil health but also for human health and biodiversity. Soil contamination or pollution refers to the presence of contaminants in soils. These contaminants are constituted most often of metals, organic contaminants and other chemical substances. It is estimated that 83% of EU soils contain pesticide residues[93], and 21% of agricultural soils have concentrations of cadmium above the safe limits for drinking water[94]. The presence of these substances disrupts the activity of soil organisms which overtime can have negative consequences for nutrient cycling in soils and soil structure[95]. Contaminants can also reach and pollute groundwater and enter plant roots finishing up on our plates. The origin of the contaminants is diverse. These can arrive in soils through atmospheric deposition from industrial or traffic sources or agricultural management practices such as the use of mineral fertilisers, plant protection products and plastic mulches. They can also enter soils through spills, leakage of waste material or extreme events. Little is still known about the combined effect of soil contaminants on biodiversity and human health. It is estimated that 2.8 million ha of land in the EU are contaminated[96] (agriculture and non-agricultural land included). Remediation measures can be used on contaminated soils to remove or reduce contaminant loads, but they are very expensive. Above certain pollution values soil contamination is considered irreversible.

**Soil sealing** is an often overlooked, but highly worrying, soil threat. Soil sealing takes place when soils are covered for housing, building roads or other construction works. It may seem far-fetched from agricultural management but soil sealing has historically taken place on the most fertile soils (the flatter, easier to build upon) and it´s estimated that 78% of current land take (i.e. urbanisation) in the EU is actually taken from agricultural areas[97]. Sealing soil means losing potential agricultural production capability, in addition to increased soil contamination and compaction. Population growth and economic development are the key drivers of soil sealing and land take[98]. Large concentrations of greenhouses for the production of fruits and vegetables in a specific territory can also have a soil sealing effect due to their impermeable plastic covers[99].

**Desertification** is the degradation of land in dryland areas. The causes of the degradation can be found in human activities and climatic variations. In the EU, desertification currently affects 13 countries. It is particularly worrying in Bulgaria, Greece, Spain, Italy, Cyprus, Malta, Portugal and Romania. Most of the above-mentioned soil threats contribute to desertification: soil erosion, loss of SOM, soil contamination and salinisation, soil sealing and compaction and biodiversity loss. A 2018 report by the European Court of Auditors stated that desertification is a growing threat in the EU with important demographic and economic consequences, but that coherence in addressing it is lacking[100].

93 Silva, V., et al., 2019. *Pesticide residues in European agricultural soils – A hidden reality unfolded*. Sci Total Environ 653, 1532–1545.

94 EC and Alliance Environnement., 2021. *Evaluation support study on the impact of the CAP on sustainable management of the soil: executive summary*. Publications Office, LU.

95 EEA ETC/ULS. 2021. Soil monitoring in Europe. Indicators and thresholds for soil quality assessments (report under review)

96 European Commission. 2021. EU Soil Strategy for 2030 (see ref 6)

97 https://www.eea.europa.eu/data-and-maps/indicators/land-take-3/assessment

98 Naumann, S.. Frelih-Larsen, A., Prokop, G., 2018: *Soil Sealing and Land Take*. RECARE Policy Brief. Ecologic Institute, Environment Agency: Berlin, Vienna.

99 Caballero Pedraza, A., Romero Díaz, A., Espinosa Soto, I., 2015. *Cambios paisajísticos y efectos medioambientales debidos a la agricultura intensiva en la Comarca de Campo de Cartagena-Mar Menor (Murcia)*. Estud. geogr. 76, 473–498.

100 European Court of Auditors., 2018. *Combating desertification in the EU: a growing threat in need of more action*. Special report No 33. Publications Office, LU.

**Flooding and landslides**[101] are also threats to healthy soils. They are caused by a combination of factors including land use changes and climatic changes. Their frequency is expected to increase in the EU with climate change. Floods occur when water accumulates in areas that are normally not submerged, due to overflowing of water bodies. Flooding alters soil's physical, chemical and biological properties[102]. It can wash out nutrients and soil organic matter, reducing biological activity, and prolonged flooding clogs pore spaces suffocating plants. Soil compaction can also be increased if heavy machinery circulates on the saturated soil and soils. Flooding can also lead to contaminant deposition on flooded soils. Landslides are defined as the movement of soil, debris or rock down a slope under the direct influence of gravity. Their effects are felt on-site (loss of soil) and off-site (deposition of soil). They are considered to be a local threat, mostly in mountainous regions, and affect human infrastructure and activities. Together, floods and landslides cost millions of EUR in damage every year in the EU.

[101] https://ec.europa.eu/clima/climate-change/climate-change-consequences_en

[102] Stolte, J., et al., 2015. *Soil threats in Europe*. JRC, Publications Office, LU. doi:10.2788/828742 (online).

Chapter 2

# Sustainable soil management (SSM)

## 2.1 An introduction

Soils have been managed by humankind for at least ten thousand years to produce food, fuel and fibre. Since the start of the Neolithic, human populations have been faced with the consequences of managing soils to grow crops. Although difficult to quantify, the land use changes needed to bring soil into cultivation and the practices used to grow better crops with ever increasing efficiency have led to widespread soil degradation and loss. As seen in the previous chapter, some of the key threats are soil erosion, the disturbance of water and nutrient cycles, soil contamination and the loss of soil carbon and biodiversity. With increasing human population, soil sealing and soil contamination in non-agricultural areas have also added pressure to further intensify the remaining agricultural land.

Reversing soil degradation and loss is a slow process. The practices needed to achieve it are not new, they have been known for a long time. In this chapter we present sustainable soil practices and the systems of sustainable agricultural soil management that can be put in place to reduce impacts, maintain, or even restore healthy agricultural soils. The chapter closes with a section on the tools and indicators needed to measure progress in soil health when applying these practices with specific goals.

There are a set of **Sustainable Soil Management (SSM) practices** that can be used to halt and reverse soil degradation in agricultural land. These focus on reducing or eliminating soil threats and/or on improving soil health. It is of course possible, and advisable, to do both at the same time. Guidelines on good practices for soil management are available for farmers, but they're often not mandatory and, even where they are, enforcement is low. While some argue that a pick-and-choose approach amongst a list of sustainable practices is enough to address soil degradation, others claim that such practices must be organised within a broader system that takes into account the combination of practices, wider land management issues and often even wider socio-economic considerations too. Note that while conventional agriculture is not considered a SSM system, many farmers working in conventional agriculture follow some sustainable farming practices that improve and keep soils in good health. Unfortunately, the documented degradation of soils indicates that these are the exceptions and not the norm.

Many farmers working in conventional agriculture follow some sustainable farming practices that improve and keep soils in good health. Unfortunately, the documented degradation of soils indicates that these are the exceptions and not the norm

Over the years, the elements and practices that make up SSM have been grouped into a set of defined **sustainable agricultural systems**, some of which address more than soil. The International Union for Conservation of Nature[103] summarised fourteen such systems under the umbrella of SSM. They are: agroecology, nature-inclusive agriculture, permaculture, biodynamic agriculture, organic farming, conservation agriculture, regenerative agriculture, carbon farming, climate-smart agriculture, high nature value farming, low external input agriculture, circular agriculture, ecological intensification, and sustainable intensification. While not included in their list, agroforestry is also considered a sustainable soil and land management system. Many of these approaches address not only soil degradation but are also intended to contribute to mitigation of and adaptation to climate change, to biodiversity protection and to wider food security. The scope of these approaches is broad. Some address very specific soil threats (e.g. conservation

[103] Oberč, B.P., Arroyo Schnell, A., 2020. *Approaches to sustainable agriculture: exploring the pathways towards the future of farming*. IUCN, International Union for Conservation of Nature.

agriculture vis a vis soil erosion) while others aim to address the root causes of soil degradation focusing on various aspects of soil health[104]. Others include a social dimension (e.g. agroecology, biodynamic agriculture). The next sections review first what is meant by SSM practices, and then sustainable agricultural systems.

## 2.2 Basic soil practices for sustainable soil management

Studies of management practices that increase soil health suggest that they can be grouped under just a few headings[105]. The importance and practical application of each group will differ from one place to another depending mainly on soil type, climate and the crops to be grown. These practices can be classified into five groups (Figure 1): **reducing soil disturbance, keeping soil covered, diversifying** crops and crop rotations, **minimising synthetic inputs and increasing soil organic matter**.


**Figure 1. Sustainable Soil Management (SSM) practices**

It is often suggested that these practices can not only help restore soil health but also reduce farmers' costs by decreasing the use of fuel, fertilisers and plant protection products. Indeed, this combination of practices form the basis of agroecology, and they have been described as the 'innovative practices with the most direct and most positive effect on soil quality'[106]. To achieve the best results, these practices should be combined together since they create synergies (i.e. reducing soil disturbance contributes to the build-up of carbon by reducing its oxidation). Coordinated action at the landscape level can also provide increased benefits for biodiversity[107]. In addition to these five groups of practices structural measures related to water management, i.e. terraces, swales and water harvesting techniques, can also contribute to increasing soil health and successful implementation of SSM practices.

Mixed farming systems with crop-livestock integration and agroforestry systems can also adopt these practices. The animals can make use of some of the break and cover crops in the rotation, they will also require longer rotations to

[104] This is illustrated by the fact that the principal organisation in the UK which pioneered organic farming is the Soil Association.

[105] Montgomery, D.R. 2017. *Growing a Revolution: Bringing Our Soil Back to Life*. New York: W.W. Norton

[106] This is how the assessment of the impact of the CAP on soil management defines agroecological practices. See EC and Alliance Environnement., 2021 (see ref 94)

[107] European Academies Science Advisory Council, 2022. *Regenerative agriculture in Europe. A critical analysis of contributions to European Union Farm to Fork and Biodiversity Strategies*. EASAC policy report 44.

include grass and legumes for grazing, and the animals provide manure whilst grazing and from winter housing. The manure provides both nutrients and carbon input to soil. In agroforestry, trees are combined with annual, perennial crops or livestock in multifunctional landscapes, helping to restore biodiversity and support nutrient cycling and other ecological processes, providing diversified income in more resilient farming systems. Note that in permanent pastures the SSM practices will place the emphasis on the stocking density of grazing animals to avoid soil compaction and biodiversity loss[108].

As described in more detail in Chapter 4, in the EU, cross-compliance under the CAP obliges farmers who receive publicly financed payments to respect good agricultural and environmental condition of land (GAEC). These require minimum soil cover to prevent erosion, maintaining soil organic matter, maintaining permanent grassland, protecting biodiversity and protecting and managing water resources by implementing certain landscape measures and preventing pollution, among others[109]. These conditions have been in place for two decades. However, there is considerable flexibility for farmers when deciding how to implement these requirements and little political control over the results. Globally, the FAO has also established similar global voluntary guidelines[110] that aim at addressing soil threats. It has also produced a definition of SSM, as that which "maintains or enhances" soil functions without impairing any of its services or biodiversity[111]. This leaves a wide range of possible options for soil management, albeit without any form of control. A good example of a network that facilitates global knowledge exchange regarding practical local experiences with sustainable land management practices is the World Overview of Conservation Approaches and Technologies (WOCAT[112]). It also helps to create an enabling environment for their implementation[113]. Their Global Sustainable Land Management Database is the primary recommended database by the United Nations Convention to Combat Desertification (UNCCD) for the reporting of best practices.

### Reduced (physical) soil disturbance

Soils have been tilled for thousands of years. The practice of tillage in agriculture serves the purpose of preparing the soil for planting, aerating the top soil layer, distributing nutrients evenly throughout the soil profile and at the same time destroying weeds therefore reducing competition for crop growth. Cultivation of consistent uniform roots crops (potatoes, sugar beet, carrots) also benefits from deep even tilth. Tillage has also helped farmers to deal with crop residues by burying them in soil. Although tillage facilitates certain farming practices, over the years, and with growing size and power of agricultural machinery, its disadvantages and impacts on long-term soil health have become more apparent. Tillage disrupts soil structure. By doing so, it accelerates the mineralisation of SOC, reducing SOM content and moisture in soils. It affects soil biodiversity directly and through habitat destruction. It also destroys symbiotic relationships such as those held by mycorrhizal fungi which are crucial in soil's nutrient balance. Tillage also contributes to accelerating soil erosion by destroying soil aggregates and laterally displacing soil, but also by leaving the soil bare and exposed. In hilly

108 Buckwell, A. and Nadeu, E. 2018. *What is the Safe Operating Space for EU Livestock?* RISE Foundation, Brussels.

109 https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/cross-compliance_en

110 http://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1043063/

111 Full definition in Principles in the Revised World Soil Charter of the FAO

112 www.wocat.net

113 Liniger, H., & Critchley, W., 2007. *Where the land is greener. Case studies and analysis of soil and water conservation initiatives worldwide* (p. 364). WOCAT, CTA, UNEP, CDE.

areas, tillage can represent up to 70% of total soil erosion[114] (the rest being water and wind erosion).

Over the last decades, soil conservation practices applied in agricultural areas around the world have placed strong emphasis on reducing the intensity and frequency of ploughing, i.e., soil inversion. Reducing the depth at which soil is ploughed and the frequency of ploughing allows soils to recover their structure. No-till farming eliminates ploughing and reduces tillage operations to zero. Farmers implementing no-till plant their seeds through crop residues using machinery that 'cuts' soil to place the seed and closes it back. It greatly reduces soil erosion and maintains soil structure thereby increasing soil's water retention capacity. However, it does come with its own costs: because weeds are not disturbed by ploughing, farmers can sometimes end up applying more herbicides to remove them, with toxic effects on biodiversity[115]. Weed control under conservation farming thus poses some real challenges. Some conservation farmers address this by doing more cultivation, which in turn requires increased machinery and fuel use or they deploy cover cropping. Cover crops such as legumes add nitrogen to the soil, and can protect the soil from weeds and pests. Residues left in soils also make it more difficult for weeds to grow.

Reduced or no-till farming requires specific knowledge and dedicated machinery. It has to be accompanied by other practices to be successful such as cover cropping and crop rotations or adding compost to restore previously lost organic matter. Its success also depends on the soil type and climate. Not all soils are easily managed with no-till and farmers have to find the appropriate balance between no-till and reduced till (reduced depth and frequency) for each type of soil, crop, landscape position and management scheme. Depending on the environmental conditions (e.g. climate and degradation status), the positive effects of no-till or reduced tillage are often only observed after several years, during which crop yields might fall.

### Keeping soil covered

Vegetation plays a central role in protecting soils and enhancing soil health. It reduces erosion by attenuating the impact of rainfall on the soil surface, it also slows the velocity of runoff and keeps soil in place through its roots[116]. Plant roots also contribute to a good pore structure in soil, facilitating water storage and providing food for soil biota, such as for soil microorganisms responsible for organic matter decomposition.

Despite the many benefits of keeping soils covered, agricultural land is often left bare and uncultivated (fallow) at periods of the year, and sometimes for longer. One of these periods takes place after harvest, when the soil is left to 'rest' before planting the new crop. Many soils in the EU 'rest' this way during winter, unless a winter cereal crop is planted. Soils have also traditionally been left uncultivated for one or more crop cycles to allow them to recover their fertility, particularly in semiarid and arid regions. During these fallow periods, crop residues can be left or removed from soils. Ancient Greeks alternated fallow and crops on their fields, in one and two-year rotations, and set the basis for agriculture in the centuries to follow[117]. The benefits of fallow include breaking pest and pathogen cycles, increasing water storage in soil and rebalancing soil nutrients.

[114] https://esdac.jrc.ec.europa.eu/public_path/shared_folder/projects/DIS4ME/indicator_descriptions/tillage_depth.htm

[115] Buckwell, A., et al., 2020. *Crop Protection & the EU Food System. Where are they going?* RISE Foundation, Brussels.

[116] Durán Zuazo, V.H., Rodríguez Pleguezuelo, C.R., 2008. *Soil-erosion and runoff prevention by plant covers. A review.* Agron Sustain Dev 28, 65–86.

[117] Mazoyer, M., Roudart, L., 2002. *Histoire des agricultures du monde: du néolithique à la crise contemporaine,* Histoire. Éditions du Seuil, Paris.

Bare fallow, however, leads to increased rates of soil erosion and has a strong impact on soil biodiversity, reducing its biomass and activity, in particular that of symbiotic organisms which depend on the presence of certain plant roots as a source of energy such as some bacteria and fungi[118].

There are numerous practices that allow soils to remain covered year-round without depleting nutrients and water. The best well-known such practice is the use of cover crops. Soil cover can also be maintained by intercropping and planting perennial crops or varieties rather than annual crops. As their name indicates, cover crops are planted with the objective to cover the soil between the harvest of a crop in the fall and the planting of the following crop in spring. Before the planting of the spring crop, cover crops are either destroyed using chemicals or mechanically ground-up and left on the field or tilled-in to decompose. The latter refers to green manures. Maintaining a crop cover in agricultural fields reduces soil erosion and degradation and can also help fight certain pests and pathogens while adding nutrients to soil, in the case of leguminous crops, as well as increasing organic matter and biodiversity and enhancing water availability. Cover crops have to be carefully selected to avoid adding pest pressure. Examples of cover crops include legumes such as winter peas, clovers and alfalfa, plus other crops such as mustard, radishes, buckwheat and rye. Soil cover can also be achieved with the use of mulches and crop residues. These protect soil from erosion and retain moisture.

## Diversifying cropping

Diversification has many meanings when applied to agriculture and it is not always used consistently[119]. It can apply at the field, farm and landscape scales. In the context of soil management, it generally refers to increasing the number of cultivated crops within crop rotations or intercropping in a field. Growing the same crop continuously exhausts the soil because a crop will always occupy the same soil layers and extract a similar proportion and amount of nutrients. Crop rotations means growing different crops successively on the same piece of land. This is an ancient but effective way to control pests and diseases and maintain good soil structure and health. Fallow periods, which were left every third year to break wheat pest cycle, were replaced around the 17th century with pastures of red clover, sainfoin or a mix of grasses and legumes[120]. The technical revolution starting in the 19th Century and accelerated through the first half of the 20th Century brought about many changes in European agriculture: use of synthetic fertilisers, introduction of plant protection products and an increase in mechanisation. These stimulated a massive transformation in farming encouraging farm and field enlargement, supplying manufactured nutrients, and fighting pest and disease with, it was thought, less need for crop rotation. Farmer focus was on increasing crop yields, losing sight of inherent soil health and related soil biodiversity.

During the first quarter century of the EU's Common Agricultural Policy from the late 1960s to the mid-1990s there was little attention to widening crop rotations. Farmers became increasingly specialised narrowing their number of cultivated crops, under the shelter of the market stabilisation provided by CAP's common market organisation[121]. Following the successive reforms of 1995, 2000

[118] Nielsen, D.C., Calderón, F.J., 2011. *Fallow Effects on Soil*. Publications from USDA-ARS/ UNL Faculty. 1391. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2396&context=usdaarsfacpub

[119] Hufnagel, J., Reckling, M., Ewert, F., 2020. *Diverse approaches to crop diversification in agricultural research. A review*. Agron Sustain Dev 40, 14

[120] Mazoyer, M., Roudart, L., 200. (see ref 117)

[121] This was the era of market intervention, bolstered by variable import levies and export subsidies which raised and stabilised EU commodity markets relative to those in the rest of the world. This era of the CAP changed with the MacSharry reforms in 1995.

and 2004 market support has been replaced with direct payments accompanied by cross compliance conditions. Since 2007 an explicit 'greening' requirement for crop diversification was introduced to encourage more crop diversity and, it was hoped, wider crop rotation. In parallel, evidence has assembled demonstrating that diversified cropping systems can sustain high levels of productivity with lower application of external inputs while improving soil health[122] alleviating biotic and abiotic stress, improving the robustness of agricultural systems[123] and buffering for the weather variability resulting from climate change[124]. Despite the policy encouragement and this evidence, many farmers are still reluctant to enlarge the number of crops grown on their fields[125]. These inhibitions are examined in the next chapter.

The local context (climate, soil type and quality, water availability, farming system) will most likely determine the design of the crop rotation. Typical crop rotations in the EU extend between 3-4 years, while up to 10–12-year rotations can be found in organic agriculture[126]. Optimal crop rotations are represented by a mix of crops with different characteristics and functionalities[127]. The first crop in the rotation (a legume or grass) is generally used to prepare the soil for the following crop which provides a higher income. Crops with longer roots are also rotated with shallower ones, to make use of all nutrients in soil. And the same happens with the need for moisture where a more demanding plant will be followed by a less demanding one. Nitrogen fixing crops (legumes) are included in rotations before high nitrogen consumption crops such as maize. There is also an advised maximum frequency of how often a certain crop should be planted in a field which can range from once every two years to one in eight years, i.e. much longer rotations[128].

Diversity in agricultural systems can also be achieved around crops via the introduction of landscape "structural" elements such as flower strips, beetle banks and hedgerows. Increasing landscape features not only benefits the farmer but also the landscape and region in which the farm is located. The main benefits of implementing landscape structural elements on agricultural land are erosion control (water and wind), pollination and biological control, while at the regional scale such elements can facilitate the movement of species and increase the aesthetic value of the landscape[129].

Increasing genetic diversity in crops is another form of diversification that can help manage pests, disease and adaptation to changes brought about by climate change. Genetic diversity can be achieved through traditional breeding or using new breeding techniques.

### Minimising synthetic inputs

Adoption of the three previous practices can be consistent with this fourth one, which is minimising inputs of synthetic fertilizers and plant protection products. The current agricultural system based on short, narrow rotations and monocultures

[122] Mortensen, D.A., Smith, R.G., 2020. *Confronting Barriers to Cropping System Diversification*. Front Sustain Food Syst 4, 564197.

[123] Li, J., et al., 2019. *Diversifying crop rotation improves system robustness*. Agron Sustain Dev 39, 38.

[124] Mortensen, D.A., Smith, R.G., 2020 (see ref 122)

[125] Mudgal, S., et al. 2010. *Environmental impacts of different crop rotations in the European Union*. European Commission (DG ENV), Brussels

[126] ibid

[127] ibid

[128] Factsheet Best4Soil project: https://www.best4soil.eu/assets/factsheets/12.pdf

[129] EIP-Agri Focus group. 2016. Benefits of landscape features for arable crop production. https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_fg_ecological-focus-areas_final-report_en.pdf

has been enabled by the use of synthetic inputs applied to the fields. It is estimated that 48% of the global population is fed through the Haber-Bosch process[130], the process which produces synthetic N fertiliser. The use of plant protection products has become a standard and ubiquitous part of conventional agriculture. Nutrient use efficiencies in the EU are relatively high compared to the rest of the world, but nonetheless still involve considerable emissions and leakage to soil, air and water causing important damage to biodiversity. It is estimated that only 20% of the nitrogen and 30% of the phosphorus applied through the food system ends up in our plates[131,132]. It has also been brought to light that the continuous application of synthetic nitrogen fertilisers impacts the composition of the microbial community in soil[133], potentially affecting the performance of their functions.

Synthetic fertilisers have been an important contributor to raising crop yields but are now thought, in the longer term, to weaken crops and render them more vulnerable to pests[134]. This has in turn increased the reliance on plant protection products used to supress weeds, pests and diseases. Plant protection products may leach to surface and groundwater and remain in soils impacting non-targeted species, reducing at the same time populations of beneficial microorganisms in soils. Minimising synthetic inputs can therefore contribute to an increase in water quality and enhanced soil and overall biodiversity.

The reduction in synthetic inputs that a farmer can achieve by implementing SSM practices will largely depend on the choice of crops in the rotation which in turn is conditioned by the farm context. Organic farmers already grow their crops without synthetic fertiliser relying on rotations which include legumes and adding animal manures, green manures and compost. The relative impact of these organic inputs on nitrogen leaching, compared to that of synthetic fertilisers is still not conclusively demonstrated, but there are positive effects on soil biological activity[135].

The theme of reduction in synthetic inputs has been taken up in the EU's Farm to Fork strategy. This is discussed in Chapter 4. Extended crop rotations can contribute to reducing the use of plant protection products; however, pest management will still be needed. Integrated Pest Management (IPM) is the advocated solution of both the FAO and the EU, part of which is to apply longer and wider crop rotations and mixed cropping systems incorporating low-density livestock grazing. The principle of IPM entails the careful consideration of all available plant protection methods keeping the use of synthetic plant protection products to levels that minimise risks to human health and the environment and are economically justified[136]. Use of synthetics should be the last resort having first tried: monitoring and forecasting, cultural control, applying physical or mechanical methods and applying biological methods. The EU Sustainable Use of Pesticides Directive obliges farmers to apply IPM, however its open definition is subject to multiple interpretations. Organic farming represents an example of reduced use

130 Erisman, J.W., et al. 2008. How a century of ammonia synthesis changed the world. Nat Geosci 1, 636–639.

131 van Dijk, K.C., Lesschen, J.P., Oenema, O., 2016. *Phosphorus flows and balances of the European Union Member States*. Sci Total Environ 542, 1078–1093

132 Buckwell, A. Nadeu, E., 2016. *Nutrient Recovery and Reuse (NRR) in European agriculture. A review of the issues, opportunities, and actions*. RISE Foundation, Brussels

133 Geisseler, D., Scow, K.M., 2014. *Long-term effects of mineral fertilizers on soil microorganisms – A review*. Soil Biol Biochem 75, 54–63.

134 Martinez, D.A., et al., 2021. *When the Medicine Feeds the Problem; Do Nitrogen Fertilisers and Pesticides Enhance the Nutritional Quality of Crops for Their Pests and Pathogens?* Front. Sustain. Food Syst. 5, 701310.

135 Lori, M., et al., 2017. *Organic farming enhances soil microbial abundance and activity – A meta-analysis and meta-regression*. PLoS ONE 12, e0180442.

136 Buckwell, A., et al., 2020. (see ref 115)

of plant protection products. Research has shown that organically managed soils contain up to 90% lower concentrations of pesticide residues than conventionally farmed land[137].

In addition to these practices, precision farming can help reduce the use of fertilizer, plant protection products and irrigation by adjusting application rates of these inputs to meet the crop needs given the specific soil and other environmental conditions at the time[138]. However, even the most advanced methods lead to some nutrient leakage and remaining contamination in the soil.

### Increasing soil organic matter

As explained in Chapter 1, soil organic matter (SOM) is crucial for soils to perform all their functions. Maintaining and increasing SOM stocks is key to SSM. This requires higher inputs of carbon than is being lost from the soil. Practices to increase SOM aim at increasing SOM inputs while at the same time reducing losses. To measure SOM changes the focus is usually placed on soil organic carbon (SOC). The list of practices that can contribute to increasing SOC stocks are: reducing soil disturbance, cover cropping, diversifying crop rotations, maintaining grassland and converting arable soils to grassland. SOC can also be increased via residue incorporation, the addition of organic amendments and improved nutrient management. However, organic amendments in soils increase SOC stocks but, in some circumstances, can also lead to a substantial increase in GHG emissions ($CO_2$, $CH_4$ and $N_2O$) depending on the type of soil, climate and management practices used to incorporate them[139]. The IPCC considers in its models that organic amendments to mineral soils release 0.01 kg of $N_2O$-N emissions per kg of N added annually, although in practice, the value differs between different organic amendments[140] and depend on local climate and soil conditions. Increasing SOC stocks through the addition of organic amendments is complex, and correctly assessing the contribution of such practices to GHG mitigation, requires accounting for all GHG fluxes and cannot focus solely on changes in SOC stocks[141]. Other practices that can contribute to increasing SOC stocks in soils are silvopasture, managed grazing, tree intercropping and permanent crops.

While the positive effects of the practices that increase SOC on soils are well-known and relevant, it's their potential contribution to mitigate GHG emissions that is currently attracting most of the attention. In the context of the current efforts to reduce emissions and increase carbon sequestration from the atmosphere, the potential of soils for removing and storing part of this carbon is seen with great interest by policy makers. Some farmers and land owners see that this could possibly even bring new revenue streams to land-based businesses by being paid to store carbon.

The estimated potential to mitigate and offset GHG emissions in soil is surrounded by large uncertainties. Sequestration potential for SOC in mineral soils in the EU ranges between 9 and 58 Mt$CO_2$ eq per year, while for a comparison, emissions from these soils under cropland are estimated to amount to 27 Mt$CO_2$eq

[137] Geissen, V., et al., 2021 (see ref 55)

[138] Balafoutis, A., et al., 2017. *Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics*. Sustainability 9, 1339.

[139] Álvaro-Fuentes, J., et al., 2018. *Pig slurry incorporation with tillage does not reduce short-term soil $CO_2$ fluxes*. Soil Till Res 179, 82–85.

[140] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

[141] Guenet, B., et al., 2021. *Can $N_2O$ emissions offset the benefits from soil organic carbon storage?* Glob Change Biol 27, 237–256.

per year under current practices[142]. Less known is the potential to sequester carbon of introducing agroforestry in arable land and grassland, which could range between 7–234 Mt$CO_2$ eq per year in the EU-27[143]. There is a general perception that potential carbon sequestration rates in soils have been too optimistic[144]. There are also doubts on the long-term significance of SOC storage in soils, not only regarding the stability of the SOC itself, but also vis-à-vis the possibility of a rapid loss of sequestered carbon under changing management practices and changing climate. Farmers and their organisations are only slowly learning that to register in national inventory accounts of GHG emissions and removals they will have to demonstrate permanence and additionality. Although progress is being made, this will not be simple.

All the foregoing said, actions directed at encouraging or obliging the adoption of farming practices that build SOC stocks should be encouraged. Pending the clarification of the issues discussed above regarding the climate contribution, there are strong grounds to believe these practices will lead to an increase in soil biodiversity and also an improvement of many soil functions, including water retention and the control of pests and disease.

## 2.3 Sustainable agricultural systems

There are many agricultural systems which claim to be sustainable, fourteen identified by the IUCN were listed in section 2.1. They are not all well-defined. The main differences and similarities between a selection of them are depicted in Table 2.1. It should be noted that the principal considerations defining these systems are their environmental credentials. There is little consideration of the farm-level or market-level economic impacts of widespread adoption of such practices.

Organic agriculture requires least explanation. It is well established in the EU (and most of the world) with regulations and a certification process, and is well established in the market place. 9% of EU agricultural land is farmed this way[145] and the EGD and its strategies target that this should increase to 25% by 2030 under the new Biodiversity Strategy. The very term organic is widely used as a quality indication denoting 'kind to the environment'. Meanwhile, the terms « regenerative agriculture » and « agroecology » have risen sharply in popularity over recent years. These words mean different things for different groups and whilst there are many definitions offered there is no widely agreed or officially endorsed definition or certification of these systems of sustainable agriculture. All definitions use phrases such as 'close-to-nature' or 'nature-based'. They indicate an overall aim to work with natural processes to restore and enhance soil health and increase resilience, not only of the soil, but also of the farming communities and food value chains that depend on soil for their living[146]. Various agricultural systems can be accommodated under the umbrella of regenerative agriculture and agroecology and many also integrate livestock as part of their operations. Core principles are: keeping soil surface covered, limiting soil disturbance, combining plants to increase soil biodiversity, keeping roots in soil as long as possible and crop-livestock integration[147]. These coincide with the SSM practices outlined in section 2.2.

[142] COWI, Ecologic Institute and IEEP, 2021. *Technical Guidance Handbook - setting up and implementing result-based carbon farming mechanisms in the EU*. Report to the European Commission, DG Climate Action, under Contract No. CLIMA/C.3/ETU/2018/007. COWI, Kongens Lyngby.

[143] ibid

[144] Courvoisier, T.J., European Academies Science Advisory Council, Deutsche Akademie der Naturforscher Leopoldina (Eds.), 2018. *Opportunities for soil sustainability in Europe*, EASAC policy report. EASAC Secretariat, Deutsche Akademie der Naturforscher Leopoldina, Halle (Saale).

[145] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Organic_farming_statistics (accessed 18/5/22)

[146] Electris, C., et al., 2019. *Soil Wealth. Investing in Regenerative Agriculture across Asset Classes.*

[147] https://agricaptureco2.eu/what-is-regenerative-agriculture/

Climate smart agriculture, and high nature value farming have different emphases. The focus is not so much on soil management but on a sought output - food security by contributing to reducing climate change for the first, increased biodiversity and habitats for the second. Circular agriculture takes yet another perspective. Established in the 1990s, it focuses on reducing production of human-edible by products and then recycling the non-edible by-products back into the system. Sustainable intensification defines a goal to maintain agricultural productivity growth, sustainably, whilst limiting food production to existing farmland to avoid bringing additional natural areas into cultivation with damaging impacts on biodiversity[148]. Whilst it does not specify a core set of practices like the other systems, running through sustainable intensification is a strong thread of further capital and/or knowledge intensification[149] of agriculture. Increasing precision, digitisation, robotics and data-based agriculture, urban farming, vertical farming and utilising new technologies such as gene editing could all have a role[150].

The diversity of systems for sustainable agriculture can be seen as a strength. Farmers can pick amongst these systems depending on their farm circumstances and their means, context, knowledge and beliefs. The extent to which any of these systems results in restoration of soil health will depend on how seriously and consistently the prescriptions of the system are followed. Whether it makes a significant difference to group SSM practices together and call them a farming system is not completely clear, although there are indications that combining multiple practices significantly increases the delivery of beneficial impacts. The longest established, and most widely adopted of these systems, organic farming having achieved internationally accepted certification is widely, perhaps universally, recognised in the market place. This certainly confers some commercial benefit to practitioners in the form of an organic premium. The official status of organic farming also enables data collection on the number of registered organic producers, the area they farm and some indication of their output and impacts on the environment. Most of the other systems have broad definitions and no officially recognised certification process. There is consequently very little data on the numbers of participating farmers in these systems – nor their impacts. Practitioners of these systems generally take them up because they believe them to be the right way to farm. There may be market benefits that can be established. These are often based on shortening the distribution chain through local distribution systems. In addition, there may well be fellowship and practical knowledge and experience-sharing value to the protagonists and practitioners of each such system to work together in a common framework. At the same time, there is nothing to preclude farmers working in the 'conventional agriculture' from applying a mix of the practices which make up sustainable systems. They may not feel a need to be represented by the name given to the specific system.

Whether it makes a significant difference to group SSM practices together and call them a farming system is not completely clear, although there are indications that combining multiple practices significantly increases the delivery of beneficial impacts.

[148] Garnett, T., et al., 2013. *Sustainable Intensification in Agriculture: Premises and Policies*. Science 341, 33–34.

[149] Buckwell, A., et al., 2014. *Sustainable Intensification of European Agriculture. A review sponsored by the RISE Foundation*. RISE Foundation, Brussels.

[150] Oberč, B.P., Arroyo Schnell, A., 2020. (see ref 103)

**Table 2.1. Overview of sustainable agriculture systems and their recommended practices (Based on Arroyo and Oberc IUCN 2020)**

| Approach & date of appearance | Defined as | Tree integration/ agroforestry | Reduce synthetic inputs (pesticides, fertilisers) | Soil disturbance |
|---|---|---|---|---|
| **Organic farming**<br>**Early 1900s** | Sustain the health of soils, ecosystems and people | – | No mineral fertilisers, pesticides limited to short list | Minimal tillage, cover crops |
| **Agroecology**<br>**1930s–**<br>**1970s–**<br>**1990s** | Scientific discipline<br>Set of farming practices<br>Social movement | yes | yes | No-till or minimum tillage, compost, cover crops |
| **Nature-inclusive agriculture**<br>**2014** | Agroecological principles | – | yes | Reduced tillage |
| **Permaculture**<br>**1970s** | Working with nature to achieve diversity and resilience of natural ecosystems | yes | yes | No till, s oil covered at all times |
| **Biodynamic agriculture**<br>**1900s** | The farm as a self-contained and self-sustaining organism | – | Use instead biodynamic preparations | – |
| **Conservation agriculture**<br>**1970s** | "keeping soil together" | no | no | No-till, reduced tillage and cover crops |
| **Regenerative agriculture**<br>**1980s** | Practices that regenerate soil | yes | Minimise agrochemicals | Minimise disturbance, permanent cover |
| **Carbon farming**<br>**2010s** | Reduce GHG emissions and sequester C in soils | yes | no | No or minimum till |
| **Low external input agriculture**<br>**1980s** | Focus on closing loops | – | yes | – |
| **Circular agriculture**<br>**1990s** | Ensuring the best possible use of resources | – | yes | – |
| **Ecological intensification**<br>**1986** | Increase productivity reducing environmental impacts | – | yes | Conservation tillage |
| **Sustainable Intensification**<br>**1990s** | Increase yields without adverse environmental impacts | – | yes | – |

**Table 2.1. Overview of sustainable agriculture systems and their recommended practices (Based on Arroyo and Oberc IUCN 2020)**

| Approach & date of appearance | IPM, biological pest management | Crop rotations, diversity, intercropping | Crop-livestock integration | Socio-cultural/ economic/ food chain | Energy & Water | Label |
|---|---|---|---|---|---|---|
| **Organic farming** **Early 1900s** | Resistant breeds and biological control | Crop rotations | Not mandated | no | yes | yes |
| **Agroecology** **1930s–1970s–1990s** | yes | yes | yes | yes | yes | no |
| **Nature-inclusive agriculture** **2014** | yes | Expand diversity of landscape elements | Reduce cattle densities | Integrate ecological aspects & financial results | yes? | no |
| **Permaculture** **1970s** | No pesticides | Layering approach to crops | yes | – | yes | no |
| **Biodynamic agriculture** **1900s** | Holistic approach to pest and diseases | Cultivating biodiversity | yes | yes | yes | yes |
| **Conservation agriculture** **1970s** | – | Crop rotations | no | no | no | no |
| **Regenerative agriculture** **1980s** | Minimise agrochemicals | Crop rotations, intercropping, | possible | – | yes | no |
| **Carbon farming** **2010s** | – | Multi-story cropping | Silvo-pasture | no | no | no |
| **Low external input agriculture** **1980s** | yes | yes | possible | yes | – | no |
| **Circular agriculture** **1990s** | – | yes | yes | yes | – | no |
| **Ecological intensification** **1986** | yes | yes | yes | no | no | no |
| **Sustainable Intensification** **1990s** | – | – | – | – | – | No |

## 2.4 Indicators

A critical element to move forward in achieving SSM is the establishment of indicators to assess soil health and to monitor changes. This would be highly beneficial for results-based programmes which rely on monitoring, reporting and verification of results. To this end, researchers have been developing and using soil parameters for a long time. These have focused on soil properties classified as:

- physical – *bulk density, infiltration capacity, aggregate stability,*
- chemical – *pH, total nitrogen and phosphorus, soil organic carbon content,*
- biological – *soil respiration, microbial activity, presence of earthworms, nematodes, bacteria and fungi*.

By attributing ranges of values to these properties and repeating measurements over time, changes in these parameters provide an indication of the increase or decrease in soil quality and health.

In recent years, it has been acknowledged that indicators should not only reflect soil quality but also its functions to ensure the provision of ecosystem services. There has also been a recognition that indicators should not only have a sound scientific basis but should also be practicable for farmers (and co-developed with farmers) to measure to gain farmers' involvement. Farmers tend to use qualitative over quantitative indicators, which can be easy to assess without sophisticated tools, while scientists rely on their laboratory equipment.

Indicators can help establish whether a specific soil is under certain threats and how well it can perform its functions. However, the linkages between indicators and soil functions are still under discussion as many of them have links to biological soil properties which have been traditionally overlooked. There is also an element of scale, since some soil functions cannot just be linked to a set of specific soil samples but require taking into consideration larger areas or habitat for organisms.

The choice of one indicator over another depends on many criteria including the objective being sought, how easy it is to measure, its sensitivity to changes in that specific environment and the functions or threats that it can be linked to.

For its Soil Mission, the European Commission has identified eight soil indicators which try to cover the soil profile and the landscape and to address threats and functions. Their proposed indicators are (i) presence of soil pollutants, excess nutrients and salts; (ii) soil organic carbon stocks; (iii) soil structure (bulk density, absence of soil sealing and erosion); (iv) soil biodiversity; (v) soil nutrients and acidity (pH); (vi) vegetation cover; (vii) landscape heterogeneity and (viii) forest cover. Each indicator alone or combinations between them are used to track progress towards achieving the Mission's goals. On another note, the UNCCD, with a specific focus on soil degradation and desertification uses three main indicators to track progress towards achieving land degradation neutrality: soil organic carbon content, land use change and net primary productivity[151]. The Sustainable Development Goals 100 indicators contain two indicators with reference to soils for SDG2 and SGD15: soil erosion by water and soil organic carbon[152]. Regarding the monitoring of the impact of the CAP, soil erosion and soil organic carbon are also the soil-relevant indicators used[153].

[151] https://knowledge.unccd.int/knowledge-products-and-pillars/guide-scientific-conceptual-framework-ldn/key-elements-scientific-5

[152] European Commission. Statistical Office of the European Union, 2021. *Sustainable development in the European Union: monitoring report on progress towards the SDGs in an EU context: 2021 edition*. Publications Office, LU.

[153] https://joint-research-centre.ec.europa.eu/eu-soil-observatory-euso/eu-soil-observatory-dashboard-indicators_en

There have been many discussions aimed at developing a single indicator which can provide information on soil health with a unique value. There are two approaches to this. The first is the use of a single measurement as a "proxy" of soil quality and health, while the second is the development of a soil index from a combination of indicators. The attractiveness of providing information of the state of a soil with a single value is tempting but given the multifunctionality of soils and the large differences between different soil types as well as soil profiles this must be done carefully. An example of single digit indicator is Rabobank's "open soil index"[154] which aims to provide information on soil quality and management with a single value ranging between 0-10. This single score is the result of detailed sub-scores focusing on different physical, chemical and biological soil properties, linked to soil functions in addition to soil management and environment functions.

Both from the point of view of policy and of practical farming, the lack of a science-based and officially-endorsed indicators of soil health is a serious deficiency.

In terms of proxies, SOC content has been often used as an indicator of soil quality[155]. It´s easily affected by management and natural disturbances and tends to stabilize over time. Its use as a proxy of soil quality or health offers many advantages: it´s a key indicator for many soil functions, it provides information on the quality of agricultural land for the different EU regions and conditions, it can be used to determine risk of threats such as erosion, it's a basic measurement in carbon farming and it is easily understood when used for communicating results. However, establishing thresholds linking SOC content with functions or monitoring changes in SOC without accounting for changes in the different carbon pools limits the applicability of SOC as a proxy[156]. For the use of soil carbon as an indicator, the EC[157] and FAO[158] have produced guidance documents for its monitoring, reporting and verification.

Both from the point of view of policy and of practical farming, the lack of a science-based and officially-endorsed indicators of soil health is a serious deficiency. Until such indicators are established and are widespread in their use it will not be possible to accumulate the evidence to demonstrate the extent to which, and how, the advocated SSM practices contribute to improvements in soil health. This deficiency has been recognised, and is starting to be addressed, by the EC. The recently launched European Soil Observatory and the enlarged Expert Group on Soil Protection, based on the work done in the Soil Mission, should contribute to defining such indicators in the near future[159].

[154] https://www.nmi-agro.nl/wp-content/uploads/2019/09/Factsheet-Open-Soil-Index-0.3.pdf

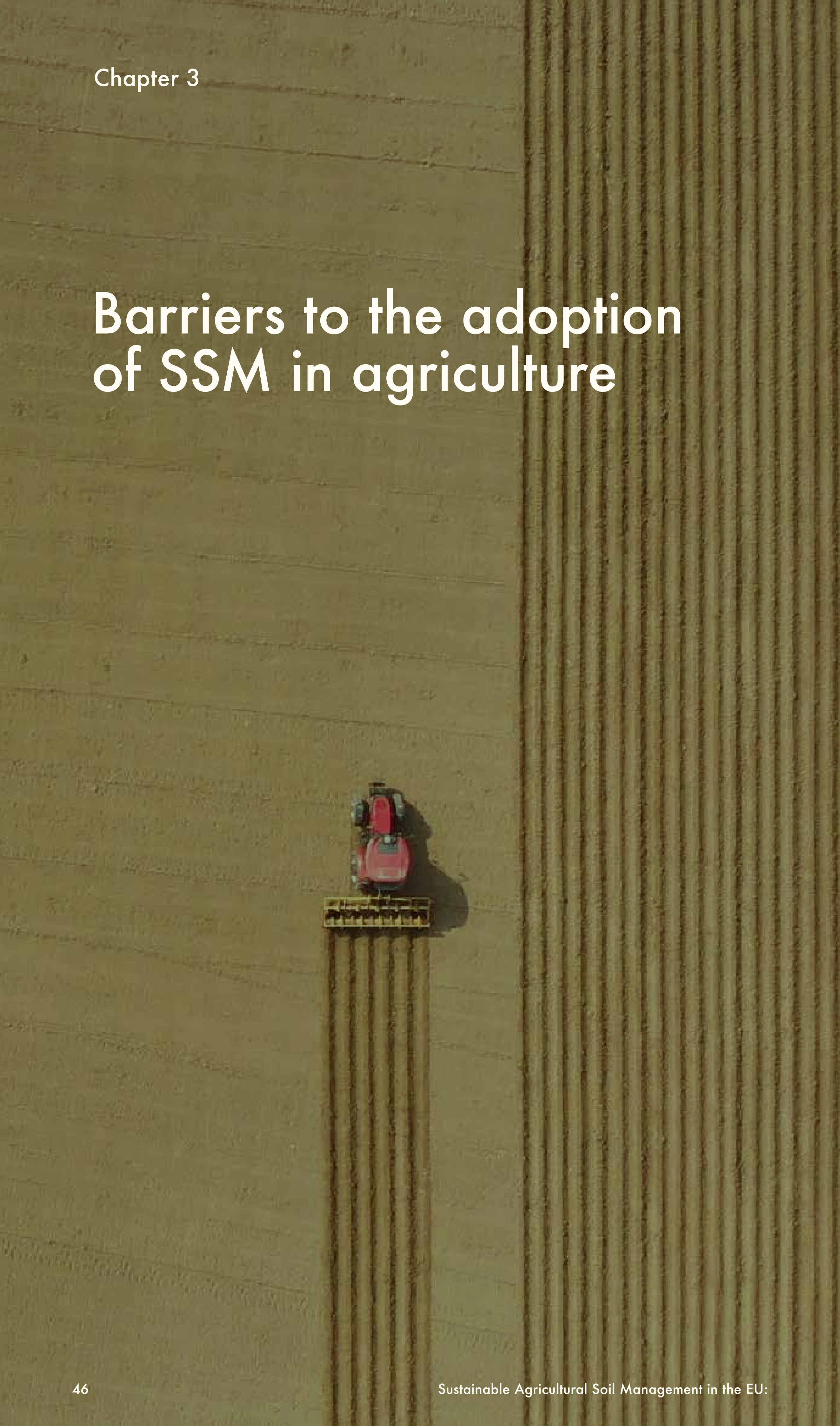
[155] Bünemann, E.K., et al., 2018. *Soil quality – A critical review*. Soil Biol Biochem, 120 (2018), pp. 105-125.

[156] EEA ETC/UL Report. 2021. *Soil monitoring in Europe. Indicators and thresholds for soil quality assessments. Version for review*. https://www.eionet.europa.eu/etcs/etc-uls/products/etc-uls-reports/etc-uls-report-2021-soil-monitoring-in-europe-indicators-and-thresholds-for-soil-quality-assessments/@@download/file/Rep_Soil_Quality_Indicators_v2_13_website.pdf

[157] COWI, Ecologic Institute and IEEP, 2021 (see ref 142)

[158] FAO. 2020. *A protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes – GSOC-MRV Protocol*. Rome.

[159] As mentioned in the 2021 EU Soil Strategy (see section 4.1)



Chapter 3

# Barriers to the adoption of SSM in agriculture

This chapter examines why agricultural land managers have made so little progress in adopting Sustainable Soil Management (henceforth abbreviated to SSM) practices. As described in the previous chapters the dangers of soil degradation and loss have long been exposed and equally the soil management practices and systems which restore and protect soil health have been openly available, evidenced and discussed. There are clearly some deep barriers at work inhibiting the adoption of SSM. A first step must be to better understand these blockages so that strategies can be devised to overcome them.

Adoption of more SSM practices is just one aspect of the broader challenge of improving environmental performance of agriculture. For nearly three decades, agricultural policy in the EU has sought to integrate higher standards of environmental land management into mainstream agricultural practices. Reviews and evaluations conducted during this period show a mostly disappointing lack of progress[160,161,162].

Why is it proving so difficult to achieve widespread implementation of SSM in EU agriculture? This question is first addressed by taking stock of the considerable literature which has tried to learn from psychology and the behavioural sciences how to better understand farmer behaviour and their responses to attempts to induce change in farming practices to better protect the environment.

This review yielded insightful research that looked into the behavioural barriers that are inhibiting farmers from adopting SSM, and how these insights can inform policy work. Section 3.1 outlines some core principles of a multi-layered behavioural framework which identifies first, the willingness, ability and engagement of farmers to change, and then the factors influencing willingness, and third some key learnings about setting choice 'architecture' and how to nudge change in behaviour. Sections 3.2 to 3.4 build on the resulting behavioural framework distilling findings about the barriers which mostly affect the ability of farmers to change and the effectiveness of engagement. These sections are based on a mix of further literature search and the information and views of organisations running a range of private soil initiatives - which are more fully explained in Chapter 4. The barriers investigated in 3.2 to 3.4 are categorised as economic, technical and knowledge, and structural. While public policies have also tried to shape the agricultural system, and sometimes particular policy measures can inhibit adoption of sustainable practices, this aspect is not included as a specific barrier. The role of policy will be taken up in Chapter 4 as attention turns to steering change in the future.

Why is it proving so difficult to achieve widespread implementation of SSM in EU agriculture?

## 3.1 Establishing a behavioural framework to examine the barriers

Given the long history of efforts to integrate improved land management into mainstream agricultural practice it is not surprising that there is now a large literature seeking to explain why these efforts have struggled to bring about significant change. Behavioural researchers have sought to develop a deeper understanding of motivations and behaviour of farmers and their attitudes and actions towards improved land management. From this extensive literature three publications

[160] Alliance Environnement and the Thünen Institute, 2017. *Evaluation study of the payment for agricultural practices beneficial for the climate and the environment: final report*. Publications Office, LU.

[161] Alliance Environnement, 2021. *Evaluation support study on the impact of the CAP on sustainable management of the soil: final report*. Publications Office, LU.

[162] European Court of Auditors, 2020. *Biodiversity on farmland: CAP contribution has not halted the decline*, Special report No 13. (European Court of Auditors. Online). Publications Office, LU.

have been selected[163,164,165] to exemplify how ideas from the behavioural sciences contribute to a better understanding of the barriers to change in soil management. These publications themselves distilled lessons from a very wide field of studies over many issues and countries. A fourth selected publication is the book "Nudge"[166].

Combining these elements is a useful framework for examining the barriers to adoption of SSM. The framework can be visualised as three rings of influence on farmers decision making. These impact chiefly on farmers' willingness to adopt new techniques. This then requires that farmers have the **ability** to change and that there is some degree of **engagement** with farmers to stimulate them to change. Another element concerns how the choice architecture adopted by either public policy or private initiatives can successfully engage with farmers to bring about and cement change. These ideas and their relationships are illustrated in Figure 2. The following explanation of these ideas is presented in the order they were published: first the Willingness, ability and engagement approach, second the three rings of influence, and third how the ideas of Nudging behaviour can contribute.

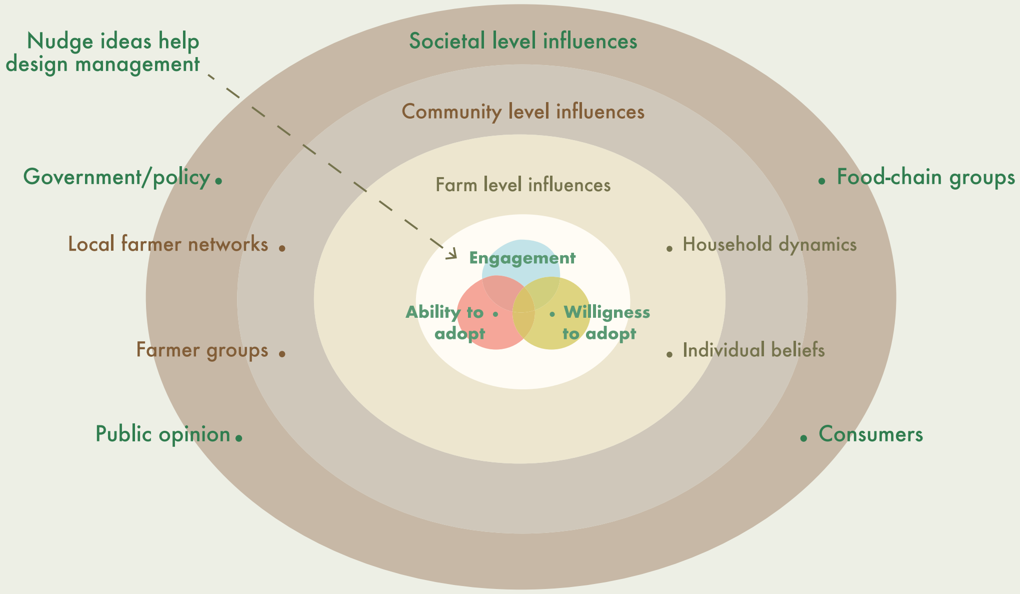



**Figure 2. Behavioural Framework for encouraging farmers' adoption of SSM**
(adapted from Mills et al. 2016 (see ref 164))

## Willingness, ability and engagement

Dwyer et al.[167] provided a comprehensive overview of applications of ideas from the behavioural sciences to farmers' adoption of environmentally sensitive farming practices and agri-environment schemes and, in particular, how to influence this behaviour. This started with a survey of psychological approaches to behaviour change, including the theory of reasoned action and the theory of planned behaviour. The authors then considered how these ideas can help in producing and presenting messages to farmers and how to train and assist extension agents to

[163] Dwyer, J., et al., 2007. *Understanding and influencing positive behaviour change in farmers and land managers – a project for Defra*, CCRI, Univ of Gloucester, and the Macaulay Institute.

[164] Mills, J., et al., 2016. *Engaging farmers in environmental management through a better understanding of behaviour*, Agri Human Values, 34, Springer Science.

[165] Mills, J., et al., 2019. *Barriers to and opportunities for the uptake of soil management practices in European sustainable agricultural production, Agroecology and Sustainable Food Systems*. Based on an EU funded project – SmartSOIL in the 7th Research Framework Programme.

[166] Thaler, R.H., and Sunstein, C.R., 2021 *Nudge*, Penguin, Allen Lane. This book was originally published in 2008, and the authors insist that the 2021 reworked version will be the final edition.

[167] Dwyer, J., et al., 2007 (see ref 163)

interact with farmers. They stressed the importance of understanding the socially constructed nature of messages, the importance of what they called different 'agri-cultures' and farming styles, how to develop solutions *with*, rather than *for*, farmers, and especially how to tune the approaches to the local context. The importance of noting the heterogeneity of farmers and of locality was stressed. Their empirical analysis applied these ideas to examine five case studies or initiatives seeking to improve farmers' environmental performance. What emerged from this study were three principal factors determining farmers behaviour – shown at the centre of Figure 2. They are:

- the **willingness** of farmers to change their behaviour
- the farmers own perceived **ability** to respond to advice and change behaviour
- whether farmers have been **engaged**

These ideas were subsequently developed further[168]. Each individual farmer could be visualised as being located somewhere in the Venn diagram in the centre of Figure 2. Farmers could be engaged and willing, but lack some aspect of the ability to change, or they could be willing and able, but they have not been engaged, or maybe they have the ability but not the willingness and lack engagement, and so on. The authors suggest the zone where all three factors intersect defines those farmers likely to undertake "sustained and durable environmental management". The policy task could thus be visualised as one of trying to enlarge this zone and helping farmers find their way to it to maximise the number of farmers who are willing and able to adopt SSM and are engaged by public policy or private initiatives (or both) to encourage and help them do so.

## Three rings of influence: society, community and personal

Next, the authors took their core willingness, ability, engagement analysis one step further. They noted that "the literature suggests that of these three elements the hardest to influence is farmers' underlying beliefs and therefore their overall willingness to change". They postulated three rings of influence on farmers' beliefs which surround the core ideas as depicted also in Figure 2.

The closest, innermost ring they called 'farm level, individual beliefs and household dynamics'. Around this ring are the 'Community level influences, local farmer networks and farmer groups'. The outermost ring surrounded the other two represents 'societal level influences including food purchasers, consumers, regulators and government and public expectations'. This analytical framework was used by its developers to explore how the three influences affected environmental outcomes by undertaking 60 interviews with UK farmers. A critical finding was that there was "considerable heterogeneity in the levels of farmer commitment to environmental management" and so policy approaches to encourage this management will have to be capable of adapting to the variety of combinations of willingness, ability and engagement. This certainly helps explain why poorly communicated, top-down, prescriptive approaches are not likely to make much headway. There is insightful discussion of how the societal influences can percolate through to the community level and then, over time how farmer to farmer and neighbourly influences can penetrate even strongly held beliefs at the farm level. Sometimes, deeply held values or beliefs by one generation are not susceptible to change, but the next generation may be more open to community and societal pressures for a changed approach. The key lessons for policy from this work is that achieving sustainable

Achieving sustainable and durable environmental activity on farms will require a 'balanced mix of policy measures involving partnership working, incentives and regulation'.

[168] Mills, J., et al., 2016 (see ref 164)

and durable environmental activity on farms will require a 'balanced mix of policy measures involving partnership working, incentives and regulation'. The latter two are needed to signal societal expectations and norms, but the authors suggest that without advice and engagement sustained behavioural change on the ground is unlikely to be achieved.

The empirical analysis in the two studies cited so far in this section related to the UK and was concerned with a range of environmental land management practices beyond, although including, SSM. A more recent study by some of the same authors[169] but including a much wider collaboration under an EU framework research project specifically concerned soil carbon management practices. This work had case studies in regions from five EU Member States (Denmark, Hungary, Italy, Poland and Spain) and the soil management practices analysed were: catch/cover crops, crop rotations, residue management, reduced tillage (or the combination of these in conservation agriculture), plus fertiliser and manure management. The information was gathered through (50) face-to-face or telephone interviews with farm advisers, farmer representatives or decision makers, not directly from farmers themselves. In addition, the ideas were explored through workshops.

Key conclusions drawn were:

- Economic barriers (with respect to profit or gross margin, not just yield) are commonly felt. Also, given the risky nature of the income potential of some practices, the lack of financial incentives is a barrier to uptake.
- Socio-cultural barriers can be as important as technical/economic, one such is resistance to change from 'traditional' practices.
- Land tenure can be a structural barrier. If benefits from soil practices take time to appear short-term tenancies may be incompatible.
- Lack of institutional support in the form of context-specific advice and information was a barrier in all regions.
- The relative advantage of a soil practice compared to existing practices was not always apparent, this is an important information requirement.
- Obtaining locally relevant information about relative advantage is not easy it may best be achieved by bringing together farmers who have adopted these practices over several years with farmers with similar soils and production systems.
- Even when the technical and economic barriers are overcome, institutional and policy support are still required through specific economic incentives, technical skills, and facilitating networks of farmer-to-farmer learning to build confidence.

Whilst there was some consensus across regions, the analysts concluded that there were important regional variations in the barriers and the opportunities seen for the practices. Understanding the context is therefore vital.

## Nudge and choice architecture

In parallel with these studies which applied developments in behavioural science to environmental land management is the contribution of ideas in the book, '*Nudge*'[170]. This book pulls together findings from psychology, behavioural science and economics in an original and insightful way. It offers examples and applications in practically every field of human behaviour. The authors define

[169] Mills et al. 2019 (see ref 165)

[170] Thaler, R.H. and Sunstein, C.R., 2021 (see ref 166)

nudge as "any aspect of choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives". The authors make it clear that nudges have their limits. In their chapter on climate change called 'Saving the planet' they stress "not all problems can be solved with light-touch interventions". The point is that dealing with climate change, and equally SSM, will require a range of regulations and collective interventions, and it is in the design of the 'choice architecture' and the execution of these policies that the key ideas of Nudge can be usefully deployed.

The authors list five aspects that make climate change such a challenge. These ideas can be directly applied to the challenge of shifting mainstream farming into SSM. They are first, *present bias*: the fact that the impacts of loss of soil health and resilience accumulate slowly and are only noticed years later. Second, *salience*: slowly diminishing soil carbon and soil biodiversity are not visible. Third, *no specific villain*: agricultural science, agribusiness, integration and concentration in the food chain, even food consumers as well as soil managers themselves and their farming education, have all contributed to create our narrowly productive, but environmentally harmful, food system. Fourth, *probabilistic harms*: given variability over time and space and biology and in the weather as well as in farmers' actions, it is not clear which crop failures and which environmental damage resulted from which management decisions in the past. Fifth, *loss aversion*: it is well established in behavioural science that decision makers (and there is no obvious reason to exclude farmers) are more negative about anticipated losses than they are positive about making corresponding gains. Therefore, there is no great surprise that we see hesitation in adopting SSM systems which are suspected may reduce short term yields and returns, even if they hold out promise for improved resilience and returns in the future.

If these explanations were not enough, they are compounded by two further features of environmental challenges. First, that farmers in their routine work do not get clear feedback on the environmental consequences of their actions. There have long been public and private efforts to benchmark farm economic performance and to communicate this to farmers, not so for their environmental performance. Work to incorporate environmental factors into the main EU farm business survey, FADN is now underway, but has some catching up to do. Second, that these environmental issues involve free riding. All farmers are contributing to the problem, so there is a strong temptation for an individual to consider their own efforts to do the right thing will be swamped by the inaction of others so why bother?

In summary, the core triad of farmer willingness, ability and engagement to change practices sits within the three rings of influencers. These societal, community and personal influencers primarily act on the decision makers **willingness** to adopt SSM. This is perhaps the hardest aspect to change to bring about a change in the beliefs of the farmer about the necessity to act. It is also the least discussed in the literature and least mentioned by the soil management initiatives interviewed for this study (see next chapter). There is undoubtedly a flow of influence going both from the outermost 'ring' of societal to the innermost 'ring' of family and personal 'influences', and back the other way too. Elements of personal commitment to sustainable production and community-based encouragements do emerge in the discussion of barriers taken up below. Consideration of the critical issue of the top-level societal climate of opinion will be picked up in the policy discussion in the next chapter. The bulk of the considerations which are now explored therefore relate to the **ability** of individual farmers to adopt SSM and the degree to which, and how, attempts have been made to **engage** them in these practices. The barriers are discussed in the following three sections headed: economic, technical and information and structural. The valuable lessons from 'Nudge' about how to design interventions to engage land managers to bring about the desired behaviour change are picked up in the final two chapters.

## 3.2 Economic barriers

The cost of adopting new techniques has been identified as one of the major barriers to the uptake of SSM practices in numerous studies[171, 172, 173, 174, 175, 176]. Although farmers now have a higher level of training in and awareness of environmental concerns than in previous decades, short term economic interests continue to have a greater weight in their decision making regarding SSM practices, than any other factor.[177] This section further considers the economic barriers to adopting SSM based on literature and on the interviews with soil initiatives around Europe. These initiatives are described and discussed in the following chapter. To the extent that there really are new costs and changed benefits brought about by changing soil management practices then these factors can be seen as affecting the *ability* of the farmer to adapt. Whereas if the issue is a *perception* of new costs and different returns and risk and uncertainties surrounding these possibilities then it indicates we are dealing with the willingness to change and attitudes to risk aversion.

The focus will be on the farm level economic barriers and benefits of action for the farmer. However, it is important also to recognise the economic cost of inaction – both to the farmer, and society. It has been estimated that the 12 million hectares of agricultural areas in the EU that suffer from severe erosion lose around 1.43% of their crop productivity annually. This translates to an annual loss to farmers of €1.25 billion, and €155 million in GDP loss[178]. But the costs are not only limited to farmers. SYSTEMIQ looked at the costs related to degraded soils of greenhouse gas emissions, nitrogen leakage into air and water ways and water and biodiversity impacts and calculated the wider cost of soil degradation across the European Union at €97 billion per year, two thirds of which are costs to human health[179]. The social cost of inaction on soil degradation clearly outweighs the cost of action (by a factor of 6, according to one study)[180], but is likely to go far beyond this when the effects of future climate change and food security become more pronounced in the future. So, it is important to stress here that the costs to farmers and society of implementing SSM may be far lower than the costs to society of inaction.

The social cost of inaction on soil degradation clearly outweighs the cost of action.

### Costs and benefits of improved soil management

A study by Tepes et al in 2021[181] carried out a cost and benefit analysis on soil protection, using existing economic information from selected soil protection studies

171 Aznar-Sánchez, J.A., et al., 2020. *Barriers and Facilitators for Adopting Sustainable Soil Management Practices in Mediterranean Olive Groves*. Agronomy 10, 506.

172 Bijttebier, P., et al., 2015. *List of drivers and barriers governing soil management by farmers, including cost aspects.* Catch-C report D4.434

173 Gomes, A., Reidsma, P., 2021. *Time to Transition: Barriers and Opportunities to Farmer Adoption of Soil GHG Mitigation Practices in Dutch Agriculture*. Front Sustain Food Syst 5, 706113.

174 Gütschow, M., Bartkowski, B., Felipe-Lucia, M.R., 2021. *Farmers' action space to adopt sustainable practices: a study of arable farming in Saxony*. Reg Environ Change 21, 103.

175 Piñeiro, V., et al., 2020. *A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes*. Nature Sustainability 3: 809–820.

176 Rodriguez, J., et al., 2009. *Barriers to adoption of sustainable agriculture practices: Change agent perspectives.* Renew Agri Food Sys, 24(1), 60-71.

177 Aznar-Sanchez, J., et al., 2020 (see ref 171)

178 Panagos, P., et al., 2020. *A Soil Erosion Indicator for Supporting Agricultural, Environmental and Climate Policies in the European Union*. Remote Sensing 12, 1365.

179 SYSTEMIQ, 2020. Regenerating Europe's Soils: Making Economics work. https://www.systemiq.earth/wp-content/uploads/2020/01/RegeneratingEuropessoilsFINAL.pdf

180 Nkonya, E., Mirzabaev, A., von Braun, J. (Eds.), 2016. *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*. Springer International Publishing, Cham.

181 Tepes, A., et al., 2021. *Costs and benefits of soil protection and sustainable land management practices in selected European countries: Towards multidisciplinary insights*. Sci Total Environ 756, 143925.

in Europe. The study identified a wide range in costs and benefits of applying SSM techniques and concluded that to date, there is a lack of economic information on SSM techniques, and no comprehensive economic appraisal to effectively guide investment decisions. Part of the reason for the observed variations in costs and benefits is the large number of variables involved. The practices that need to be applied and the potential results will depend on soil type, climatic conditions, the current state of soil health and practices already in use, the farm type and crop. Despite this, a handful of studies over the previous years have attempted to develop a cost-benefit estimation of applying SSM.

The Catch C[182] project endeavoured to understand the costs involved in applying best management practices (crop rotation, reduced tillage, nutrient management, crop residue management, water management and grassland management) to 24 farms across 9 Member States. They found that applying these practices had little effect on cash crop yields and that costs were usually reduced, not increased. The American Farmland Trust, a conservation agriculture movement also took a case study approach to identifying farm costs. Their rational was that while many farmers believe the scientific evidence that soil health practices improve soil and water quality, they are reluctant to change management techniques without knowing how much the soil health practices will cost or benefit them. They therefore carried out a partial budget analysis to test the costs/benefits of investing in soil health practices (no-till or reduced till, cover crops, conservation cropping and rotations, nutrient management, compost) to show farmers what such a change would entail. The nine farms studied also showed a wide degree of variation in the costs. While 4 of the farms saw fertiliser savings of $36/acre/yr, others saw an increase of $60 due to changing the forms of phosphorus and potassium used in order to adopt fertigation practices. Pesticide cost ranged from savings of $200/acre/yr to increases of $8/acre/yr and almost all the farms saw cost savings in machinery use, fuel and labour. However, all the farms saw yield increases from 2-22%, an annual increase in their net income and a positive return on investment[183].

The costs associated with SSM practices can be broadly divided into: operating costs, and capital investment costs. Here we provide an overview of such costs based on a literature review and the information and views of organisations running private soil initiatives which are more fully explained in Chapter 4.

## Operating costs

Operating costs are the ongoing expenses incurred from the normal day-to-day of running a business. The assumption is often made that costs will increase with the adoption of SSM, for example for the additional seeds and perhaps equipment costs for introducing new crops in wider rotations. However, some costs are reported to fall with the application of SSM, particularly in the case of fuel, fertilisers, plant protection products and irrigation. It should also be noted that cost increases or benefits do not remain stable. Farmers may report an initial cost increase, followed by a gradual decline in costs as the results of SSM take effect.

[182] Catch C was an EU funded 7th framework research project to assess the farm-compatibility of 'Best Management Practices' (BMPs) that aim to promote productivity, climate change mitigation, and soil quality. http://www.catch-c.eu/index.php/81-info/80-welcome

[183] The American Farmland Trust. 2021. *Soil Health case study findings*. https://farmland.org/soil-health-case-studies-findings/

Additional operating costs incurred from applying and or changing farm management practices for SSM may include the following:

- Seeds – for cover crops and flower strips
- Labour – for planting an extra crop (winter soil cover),
- Organic amendments – the addition of manure/ biochar/digestate
- Specific operating costs of new technology – smart agriculture platforms
- Additional farm contractor time for harvesting/ processing new crops
- Information and expert advice
- Soil testing
- Maintenance of newly established field boundaries (e.g. walls and hedges)

Whilst almost all soil initiatives interviewed (see Annexes 2 and 3 for the full list and main characteristics of initiatives) agreed that some additional operating costs were involved in applying SSM, none of those interviewed suggested that the operating costs were an insurmountable barrier to the uptake of SSM. The exception to this was the price of organic amendments, such as compost or biochar, which were considered to be expensive in some regions. Rather it was considered that with time the application of SSM would lower overall operating costs as farmers were able to reduce fertiliser and/ or pesticide use, reduce irrigation, labour and fuel. Initiatives also reported that farmers were able to stabilise income through greater crop resilience during periods of erratic weather (drought and excessive unseasonal rainfall). And increased resistance to pests and disease in some cases led to higher quality and quantity of crops, thus providing a higher sales price.

Unfortunately, it was not possible to obtain data from the initiatives interviewed to quantify these claimed cost savings and benefits, yet nineteen of the twenty initiatives that commented on costs suggested that the economic benefits would outweigh costs in the long run. This mirrors the conclusions of the SYSTEMIQ study in 2020 which looked into regenerating soils on two farming types and regions and concluded that 'farmers can improve the profitability and resilience of their business by 'a well-managed gradual transition to regenerative agriculture'[184].

Perceived financial benefits were found to be one of the main factors driving the adoption of climate mitigation practices among Australian farmers[185] and similarly, the main mitigation practice favoured amongst Scottish farmers were those related to the reduction of mineral N fertiliser leading to cost reductions[186].

While the initiatives interviewed did not highlight operating costs as a major barrier to the uptake of SSM (based on the gradual implementation of SSM), the perceived cost was mentioned to be a potentially important barrier to farmers adopting SSM. Indeed, the Catch C study compared the *perceived* costs and time estimations for Best Management Practices given by non-adopters as compared to the cost and time difference given by adopters and found that the non-adopters tended to provide more pessimistic answers, predicting far higher levels of costs and time that would need to be invested to apply best management practices[187].

[184] SYSTEMIQ, 2020 (see ref 179)

[185] Morgan, M. I. et al. 2015. *Landholder adoption of low emission agricultural practices: A profiling Approach.* J Environ Psychology, 41, 35-44.

[186] Wreford, A., Ignaciuk, A., Gruère, G., 2017. *Overcoming barriers to the adoption of climate-friendly practices in agriculture* (OECD Food, Agriculture and Fisheries Papers No. 101), OECD Food, Agriculture and Fisheries Papers.

[187] Tepes, A., et al., 2021 (see ref 181)

A number of studies also noted that farmers were reluctant to change practices that implied a cost, but for which there was no direct monetarised market to provide income and highlighted the lack of financial incentives for taking the risk on behalf of society[188, 189, 190].

This suggests the potential to reframe the cost discussion and refocus on the cost savings that can be made. In turn this requires a more concerted effort across a range of soil and farm types to provide evidence of the potential cost and benefits of SSM practices and to take into consideration possible lead in times before farmers can start to see cost reductions. This is a process to which the current soil initiatives ongoing throughout Europe can make an important contribution. There is also perhaps an element of disbelief amongst farmers about the benefits of some SSM practices which manifests in their perceptions of higher costs. If so, it may take more than simply providing more empirical evidence of costs and returns but bringing about a more fundamental shift in values and beliefs.

## Capital costs

Capital costs, or fixed costs, *are* the lumpy or one-time expenses incurred on the purchase of land, buildings, construction, and equipment used in the production of goods or in the rendering of services. Some are one-time costs such as time spent learning and trialling new systems, or the costs of dealing with previous compaction. The main capital costs referred to in the interviews of the soil initiatives were machinery related especially in connection with no-till or reduced-till farming requiring no-till seeders (costing typically ~€20k - €25k), mowers or Eco ploughs (~€10K - €15k). Other machinery costs related to precision agriculture spraying (sprays, nozzles, ICT), and to any specialist cultivation, harvesting, handling or drying equipment needed for new crops. Capital costs for materials and machinery could also be incurred if landscape structures were required such as dry-stone walls, and hedge planting.

Only one of the initiatives saw capital costs a major barrier to the uptake of SSM. This is perhaps because all of the initiatives advocated a gradual incremental approach to changing their farming methods (except conversion to organic production – although even here farmers can convert part of their farm). It was mentioned by several interviewees that farmers are more likely to invest in new machinery/ technology when they had already been working towards SSM for a time, and were convinced by the benefits, or they had in any case to invest in new machinery, such as replacing their standard plough. However, the implementation of landscape structures such as dry-stone walls and hedges were considered to need financial support as the private return on such investment would be low.

Investing in new equipment requires access to funds, this may be a problem in some cases. For example, adopting precision agriculture technologies may require a large initial investment in time and capital from farmers, this may explain the lower-than-expected rate of adoption in Europe[191]. The high costs of precision agriculture can make it prohibitive for small-scale and lower-income producers[192]. However, machinery sharing and other collaborative working arrangements can help reduce such obstacles.

[188] Gomes, A., Reidsma, P., 2021 (see ref 173)

[189] Demenois, J., et al., 2020. *Barriers and Strategies to Boost Soil Carbon Sequestration in Agriculture*. Front. Sustain. Food Syst. 4, 37.

[190] CIRCASA, 2019. Deliverable D1.1: *Assessing barriers and solutions to the implementation of SOC sequestration options*. EU Horizon 2020 research and innovation programme grant agreement No 774378 - Coordination of International Research Cooperation on soil Carbon Sequestration in Agriculture.

[191] Reichardt, M., et al., 2009. Dissemination of precision farming in Germany: acceptance, adoption, obstacles, knowledge transfer and training activities. Precision Agric 10, 525–545.

[192] Higgins, V., et al., 2017. Ordering adoption: Materiality, knowledge and farmer engagement with precision agriculture technologies. Journal of Rural Studies 55, 193–202.

## Risks and uncertainties

Risk is considered by many farmers as perhaps the greatest economic barrier to adoption of SSM. It will affect willingness to undertake change. While there is now a wealth of scientific information that shows that the greatest long-run risk to farmers is disregarding the health of their soils, many farmers still seem to believe that the sustainable soil management practices advocated are accompanied by a risk of reduced crop yield, crop quality and perhaps financial returns. The perception of risk in part comes through the uncertainties of changing farm practice. Most of the practices and approaches proposed require farmers to move away from the system of farming that they, and their predecessors, have followed for the previous 50-60 years. For farmers, the adoption of mineral nutrients, plant protection products, increased mechanisation and simplified rotations was precisely to gain what was seen as more control over crop production in order to reduce the variability and risks of farming. The slow but remorseless, cumulative, unintended impacts of these techniques on soil, structure and health, farm biodiversity loss, and indeed the consequences of climate change, were not noticed until considerable damage had been done.

Risk is considered by many farmers as perhaps the greatest economic barrier to adoption of SSM.

One of the more specific risks expounded by those interviewed who were not farming organically, was the risk of moving entirely away from, or dramatically reducing the use of synthetic pesticides and fertilisers. There was a concern regarding erratic harvests and loss of quality. These uncertainties of the short run impacts are feared. This identifies the challenge of how to factor into farmers' decision process the longer-term effects of soil management practices. It requires a whole farm, multi-year approach. Given the variety of soil types, climatic conditions and crops, conversion to SSM systems require experimentation, and often several years of trial and error. Furthermore, it takes time before changes in soil management make measurable improvements in the soil condition. The behavioural analyses reviewed above help explain the challenges of over-coming long-held, but possibly mis-informed, beliefs, and the roles of peer-to peer learning and influence, and how to manage risk. This raises questions of how to provide farmers the most helpful assurance and support in the transition to sustainable systems which will be picked up in later chapters.

Production risk is thus a barrier mentioned in numerous interviews - the lack of room for error. Many farmers are managing high levels of debt. This is combined with an industry characterised by low margins where there is considerable pressure on farmers to deliver their crops in a certain form, at a certain time to upstream processors and retailers who hold a high proportion of the value added in the food chain[193]. Therefore, whilst improving soil may future-proof farming businesses in the long term, the low margins and high level of debts will often focus priorities on the short-term viability of the business making many farmers risk adverse.

Farmers also argue that risk and uncertainties impact their access to credit. In a study conducted in the US, farmers expressed concern that potential reductions in yields may affect their relationships with lenders[194]. And in two initiatives interviewed, the uncertain and long run-in time to obtain financial benefits was cited as a barrier to credit when loans are often given on a 5-year payback period.

[193] While the largest number of businesses [in the food chain] is involved in agriculture, the share of value-added belonging to agriculture in the whole food chain remains at about 25%. DG AGRI, 2017. The Food Supply Chain. https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/farming/documents/food-supply-chain_en.pdf

[194] Stuart, D. et al., 2014. Reducing nitrogen fertilizer application as a climate change mitigation strategy: Understanding farmer decision-making and potential barriers to change in the US. Land Use Policy, Vol 36: 210-218.

Consistent outcome measurement remains a stumbling block to the broad scale investment in regenerative agriculture as investors seek proof of the efficiency of capital deployed[195].

The need to reduce the risk of transition to SSM was considered by almost all the initiatives interviewed. A common way of reducing risk was for the group of farmers involved in an initiative themselves to run pilot trials in the local region using commonly grown crops. This allowed them to reduce some of the uncertainties and variability for the farmers. Also, the majority of the initiatives which held results-based contracts with farmers signed multiyear contracts which allowed for year-to-year variations.

## Land tenancy

Land ownership has a particular impact on economic decision making at the farm level vis a vis SSM. Farmers who own their own land face different incentives to those who rent the land. Many SSM practices will only start to make a real impact on reducing farmers operating costs and production after several years. There is a wide variety of farm business structures in EU agriculture: wholly owned, wholly rented and mixtures of the two are the most common structures; and many variations: corporate or institutional ownership, collective or public ownership at one scale, and contract farming at the other. Rental agreements can range from one-season grazing or cropping licences, through short term, 1-to-5 -year tenancies to succession tenancies which can last generations.

These structures can certainly impact the motivation of farm operators and their attitude to the mostly long-run benefits of SSM practices. Tenant farmers who rent land on short term contracts are therefore incentivised to prioritise current production at the expense of future production whereas owner operators are more incentivised to consider their soil's future productive capacity when making current year decisions[196]. In these situations, there may be longer term impacts on soil quality, land value and ultimately the rent chargeable. The landlord – tenant system could benefit from mediation and support to deal with this issue to ensure that tenants are not denied the opportunity to adopt SSM. The length of the contract for tenant farmers will also inevitably have an impact on access to credit for investing in SSM due to the length of the contract versus payback time on any loans. With 43% of land in the EU-28 currently farmed under tenancy agreements (and as much an 80% in France and Malta)[197], it is imperative that the structure of ownership is taken into consideration in the design of incentives.

It is imperative that the structure of ownership is taken into consideration in the design of incentives.

Whether the person making decisions about farm practices is the owner, or the tenant will have an important influence on the decision-making processes. For example, year to year tenant farmers have the incentive to prioritise current production at the expense of future production, whereas economically rational owner-operators may be better incentivised to consider their soil's future productive capacity when making current year decisions.[198] This was an issue highlighted several times during the course of interviewing the initiatives for this project. The investment in soil is by its very nature a long-term investment with a delayed return. Farmers who are on short term leases therefore may judge that the return on

[195] The Conservation Finance Network, 2020. *The State of Regenerative Agriculture: Growing With Room to Grow More.* https://www.conservationfinancenetwork.org/2020/03/24/the-state-of-regenerative-agriculture-growing-with-room-to-grow-more

[196] Stevens, A. 2022. *The economics of land tenure and soil health*. Soil Security Vol. 6.

[197] European Commission, 2018. Farm Structures. DG Agriculture and Rural Development, Unit Farm Economics.

[198] Stevens, A. (see ref 196)

their investments in their soils would only materialise beyond their tenancy period and thus not feel incentivised to make such investments. However, tenancy arrangements are varied and complex. Rent security, long term tenancies and preferable rights for new leases can have significant effects on how farmers consider their soil conservation priorities[199] and should be taken into account.

## 3.3 Technical and knowledge barriers

### Technical and agronomic barriers

An intrinsic characteristic of many of the SSM practices is that they must be adapted to local conditions to maximise their benefits for soil health. Not all SSM practices fit all soil, environmental or climatic conditions in the same way. Climate, soil type, soil properties such as pH, and texture can have a strong influence on the success of SSM practices. For example, drought and extreme temperatures, together with high pH and calcium carbonates in soils can potentially have a negative effect on legume nodule formation, and on plant development and decomposition processes after plant residue incorporation, jeopardizing the potential benefits of green manures in South Eastern Spain[200]. The adoption of no-till is often reported to cause difficulties for weed control, particularly when no herbicide is used.

An intrinsic characteristic of many of the SSM practices is that they must be adapted to local conditions to maximise their benefits for soil health.

Below are a few examples reported in the literature[201] which explain why SSM practices have to be adapted to the local conditions and a universal set of practices cannot be imposed.

In Denmark, perennial weed problems and lack of appropriate existing technology to control weeds in organic farms were reported to be major technical barriers for the adoption of no-till. In Italy, competition between crops and weeds for water and nutrients were reported where minimum and no-till were applied, along with the inability of applying these techniques to all areas in the region due to soil type, lack of adequate machinery and adequate skills to implement these practices. They also mention that difficulties can also arise when replacing mineral fertilisers. Access to and incorporation of manure can prove difficult in some regions. Growing legumes to fix nitrogen is not a universal solution. And in some regions the soil type can be considered unsuitable to grow legumes such as the Central Region of Hungary, with predominantly sandy soils.

### Information and knowledge barriers

Lack of information is often cited as one of the primary barriers for farmers to move towards SSM. This is partly to ensure that farmers have the ability to adapt, although as will be explained, the way knowledge is created and communicated can also make a difference to the capacity to engage farmers. Getting clear, accessible, science-based information to farmers has been the topic of multiple studies and discussions over the years. Much of this literature concludes with the need for better peer to peer learning, demonstration farms and well-funded, and trusted, independent farm advisory services. Soil science has a rich history of

[199] Daedlow, K., Lemke, N., Helming, K., 2018. *Arable Land Tenancy and Soil Quality in Germany: Contesting Theory with Empirics*. Sustainability 10, 2880.

[200] Luján Soto, R., et al., 2021. *Restoring soil quality of woody agroecosystems in Mediterranean drylands through regenerative agriculture*. Agr Ecosyst Environ 306, 107191.

[201] See here a few examples for some EU countries: Ingram, J., Mills, J., 2014. Overview of socio-economic influences oncrop and soil management systems. SMartSOIL deliverable.

sharing information and knowledge building with researchers working closely with farmers and land users. However, the type of knowledge being produced and the way that it is developed and communicated have features which can be seen as hindering the development and adoption of SSM.

## The type of knowledge produced

What is known today about soils and soil management has been built from centuries of observations and experiments. It was not until the 19th century that soil science became a discipline, and the acknowledgement of the role of soils beyond agriculture did not materialise until the 20th century[202]. The green revolution in the mid-20th, with its focus on new crop varieties, introduction of synthetic fertilizers and plant protection products, along with the further developments in mechanisation and technologies, shaped the course of agronomic research over the following decades. The deeper comprehension of soil systems and crop growth was enabled by knowledge compartmentalization in highly specialized fields of study, for instance soil science in its sub-disciplines (pedology, physics, chemistry, biology). However, it is now acknowledged that there are limitations to this approach, and that attention should be paid to the complex interactions of soils, agroecosystems, nature and society for our agricultural systems to be sustainable over time. The compartmentalisation of disciplines can be viewed as a barrier to the adoption of SSM practices[203]. Furthermore, the way the knowledge production process of the current academic system is focused on academic outputs, publications and citation scores, makes the outputs of research less accessible to farmers, and so making it harder to increase the implementation of SSM. Short-term thinking is also a barrier to the development of SSM, as the multiple benefits and advantages of multifunctional and diversified farming systems can take from years to decades to be perceived. However, policy, research, and business approaches are bounded by short-term cycles, pushing short term solutions to fix problems immediately, which may be insufficient and unable to address underlying causes[204].

## And the way knowledge is developed

Multiple studies have demonstrated the effectiveness of SSM and land restoration practices[205,206,207]. However, the high level of disconnection between researchers and farmers entails a challenge for farmers to access information, leading to a serious lack of knowledge among these on the existence of SSM practices, their implementation and benefits[208,209,210]. One of the reasons for this disconnect is that knowledge is generally developed from a scientific perspective and tends to overlook the empirical knowledge of farmers. This is sometimes called a top-down

[202] Brevik. *A brief history of soil science* http://www.eolss.net/sample-chapters/c19/e1-05-07-01.pdf (accessed 12/4/22)

[203] Bouma, J., 2019. *How to communicate soil expertise more effectively in the information age when aiming at the UN Sustainable Development Goals*. Soil Use Manage 35, 32–38.

[204] IPES-Food, 2016. *From Uniformity to Diversity - A paradigm shift from industrial agriculture to diversified agroecological systems*.

[205] Kassam, A., Friedrich, T., Derpsch, R., 2019. *Global spread of Conservation Agriculture*. Int J Environ Stud 76, 29–51.

[206] Palm, C., et al., 2014. Conservation agriculture and ecosystem services: An overview. Agr Ecosyst Environ 187, 87–105.

[207] Morugán-Coronado, A., et al., 2020. *The impact of intercropping, tillage and fertilizer type on soil and crop yield in fruit orchards under Mediterranean conditions: A meta-analysis of field studies*. Agr Syst 178, 102736.

[208] Aznar-Sanchez, J., et al., 2020 (see ref 171)

[209] Long, T.B., Blok, V., Coninx, I., 2016. *Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy*. J Clean Prod 112, 9–21.

[210] Wreford, A., Ignaciuk, A., Gruère, G., 2017. *Overcoming barriers to the adoption of climate-friendly practices in agriculture* (OECD Food, Agriculture and Fisheries Papers No. 101), OECD Food, Agriculture and Fisheries Papers.

> Top-down approaches have been reported to be of low effectiveness to overcome barriers to the adoption of SSM and to support change on the ground through knowledge exchange.

approach in contrast to participatory and integrated approaches where farmers and scientists work together to find solutions. Top-down approaches have been reported to be of low effectiveness to overcome barriers to the adoption of SSM and to support change on the ground through knowledge exchange. Top-down approaches commonly neglect existing local knowledge on traditional soil management, farming experiences, farmers´ needs and objectives, resources and capacities, and promote solutions that are neither adapted to local contexts nor apposite for intended users. Researchers face the challenge to shift from the condescending vision of solving others´ problems, into a procedure where the problem is considered to be a mutual challenge requiring social learning processes where all voices are valid. This provides a constraint to the transition towards long-term sustainable systems that requires training for cooperating in multidisciplinary teams involving multiple stakeholders (researchers, farmers, politicians, consumers, retailers, NGO´s) in transdisciplinary approaches, using holistic perspectives to address soil related issues and connect different spatial scales (plot, farm, landscape, region). These approaches would also benefit by focussing more attention on involving local farming communities to develop and experiment with SSM practices[211] and seeing farmers as a source of knowledge rather than as research objects and sinks of information[212].

## The way knowledge is communicated

When lack of information is cited as a barrier to the implementation of SSM, this is often due to poor communication with the farmers and land managers who need to apply SSM. The lack of awareness and specific knowledge of SSM and climate friendly practices, and of locally tested practices vis a vis different soil types, crop types, weather conditions and local environments, and skills and how to implement them, have all been widely cited as barriers to farmer uptake of SSM practices[213]. Many of these knowledge barriers keeping farmers from implementing SSM could be solved with better education and training and strong advisory services. The role of peer-to-peer communication is important and has been shown to be highly successful in the diffusion of knowledge among farmers and the potential adoption of SSM[214].

## Education and training

The way in which information is translated to farmers along with who gives the message are often mentioned as an important factor for the adoption of SSM[215]. Positive approaches focusing on empowering farmers to take action are generally more successful at engaging people in SSM adoption[216]. Participatory methods and tools for knowledge co-creation between farmers and researcher such as workshops, focus groups, participatory rural appraisal, have shown great potential to involve local farming communities in the planning and sustainable

211 Bouma, 2019 (see ref 203)

212 Luján Soto, R., et al., 2021. *Participatory monitoring and evaluation to enable social learning, adoption, and out-scaling of regenerative agriculture*. E&S 26, art29

213 See for example: Ingram et al., 2014 (see ref 97), Aznar-Sánchez et al., 2020 (see ref 171), Wreford et al., 2017 (see ref 209)

214 Luján Soto, R., et al., 2021 (see ref 212).

215 Ingram, J., Mills, J., 2019. *Are advisory services "fit for purpose" to support sustainable soil management? An assessment of advice in Europe*. Soil Use Manage 35, 21–31.

216 See Bouma, 2019 (see ref 203), Wreford et al., 2017 (see ref 210)

management of their agroecosystems[217]. However, technical language with scientific jargon, and unidirectional knowledge transfer from researchers to farmers still predominate as communication methods. The person who shares the information on SSM is also a key factor for SSM adoption since farmers may have some information sources they trust more than others, and indeed some information sources may be less impartial than others[218].

Participatory methods and tools for knowledge co-creation between farmers and researcher such as workshops, focus groups, participatory rural appraisal, have shown great potential to involve local farming communities in the planning and sustainable management of their agroecosystems

### The role of advisory services

Farm advisory services are expected to play a crucial role in the agricultural sector providing farmers with tailored knowledge along several dimensions (economic, technical/ agronomic, environmental, organisational, legal and social) to help them thrive. While traditionally the advice has focused on technical aspects (and many young farmers still seek primarily this type of advice[219]), advisors are increasingly expected to help farmers address a broader set of issues including sustainability.

Advisors can play different roles with farmers. They can work as capacity builders helping farmers develop their own knowledge and skills or help them achieve a particular result[220]. Both of these dimensions are important in the case of SSM practices. Implementing SSM requires a broad knowledge of agriculture and soil management, as well as ecosystem functioning, which many farmers have not been taught. Shifting from focusing entirely on crop yields to providing a wide array of ecosystem services requires new knowledge and demands from farmers, advisors and other stakeholders[221]. This reinforces the need for appropriate knowledge, information, and advice to support farmers´ and advisors´ capacity building for SSM[222]. There is no single message or set of advice that is relevant to all contexts and advisors are challenged with a multiplicity of factors and frameworks to consider when providing advice (i.e. farming approaches, SSM practices, choice of indicators, trade-offs and synergies). The traditional role of the farm advisor "linking practice and research" has gradually been replaced by a diversity of services, including financial advisors, and guidance on policy supports available. The diverse EU farming population together with the multi-scale character of SSM creates a complex arena in which to provide advice to the farming community.

Few studies have analysed the state-of-the-art of advisory services regarding SSM in Europe. Building on the literature and lessons learned from three EU funded projects (SmartSOIL, RECARE and SoilCare). In an in-depth study on the appropriateness of existing advisory services to support SSM in Europe, Ingram and Mills[223] emphasized the need for, and the lack of, advisers able to deliver credible and balanced advice at the farm level with specialist soil knowledge; an understanding of trades-off and synergies between soil functions, and the ability to accommodate different styles of farmer learning. The study summarised the failure

[217] Luján Soto, R., et al., 2021 (see ref 212)

[218] de Vente, J., et al., 2016. *How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands*. E&S 21, art24.

[219] Pilot project on Exchanges Schemes for Young Farmers, see slides 23-28 on https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/field_event_attachments/sem-knowledge-20151203-pres02-inge_van_oost.pdf

[220] Dockès, A.-C., et al., 2019. *Advice and advisory roles about work on farms. A review*. Agron. Sustain. Dev. 39, 2.

[221] Ingram, J. and Mills, J., 2019 (see ref 215)

[222] Bouma, 2019 (see ref 203)

[223] Ingram, J. and Mills, J., 2019 (see ref 215)

to achieve SSM in the EU in relation to advisory services in four points: poor integration tending to focus on single soil functions; low priority given to SSM in advisory services; ineffective linking of research and practice (e.g., through demonstration farms); and over-focus of private advisory services on commercial highly productive farming which tends to exclude SSM.

The assessment of advisory services in Europe concluded that capacity building in advisory services is crucial for SSM. This is required to formulate credible, practical and tailored advice with respect to the co-benefits and trade-offs of soil management options under varying scenarios. For this to work access to evidence and tools from research, integration with practitioner knowledge, and capacity building in facilitating farmer-centred networks should be encouraged, backed up with capacity building in the farming community itself[224]. These are important lessons about the meaning and importance of **engagement** with farmers.

## 3.4 Structural barriers in farming and the food chain

Farmers may also encounter that even when they are determined to change, have the knowledge of what to do, and ways of absorbing the costs and risks, they may still find themselves facing structural barriers that seem to freeze them into a certain system of agriculture. They feel 'locked-in' to the status quo. These structural aspects of the food chain in which farmers find themselves sandwiched between more powerful operators upstream selling them their inputs, and downstream processing and distributing their produce, and consequently the way this system operates, are often referred to as 'lock ins'[225]. The focus in this section is on features of the operating and business environment for farmers which constitute physical, financial, legal or operational barriers to change even when a farmer is ready to adopt some new practices or whole farm system. Some examples can be the contracts that farmers sign with input suppliers or buyers of their produce. The barrier could be the lack of market support to cultivate and sell minority crops. Such lock-ins can make it difficult for farmers to implement even simple agronomic practices such as cover cropping or extending their crop rotation with a minority crop. Another example is that farmers following precision agriculture may encounter restrictions on which specific technology or data management providers they have to use. This can be a discouragement to adoption of further change.

How important are these barriers and what is needed to overcome them? Can SSM be mainstreamed under the current agricultural system within the current food industry structures? For instance, is it possible for farmers to extend their crop rotations and introduce cover crops without changing their commercial relationships and the actors with whom they are involved? The barriers discussed in this section relate to technologies, data management and the structure of the food chain.

Can SSM be mainstreamed under the current agricultural system within the current food industry structures?

These barriers clearly fit into the *ability* to change box. They represent inertial factors which impede or prohibit change beyond the immediate capacity of the individual farmer to overcome. To remove them may therefore require a stimulus or shock, through societal action or policy interventions.

[224] Ingram, J. and Mills, J., 2019 (see ref 215)

[225] These lock-ins are described in great detail for the case of Britain in Chapter 4 of: Lang, 2000. *Feeding Britain: Our food Problems and How to Fix Them*, Pelican Books, UK.

## Technological lock-ins

The EU agricultural sector has developed towards increased specialisation, providing farmers with the means to achieve high yields for a narrowing range of crops. The main developments have been in the form of improved seeds, chemical fertilisers, crop protection products, mechanisation and management services. In this process farmers have become highly dependent on the inputs, services and advice of the agricultural supply sector, many parts of which are highly concentrated with global companies with significant market power. If a farmer wants to adopt new practices that include widening the variety of crops they plant, or making a less intensive use of inputs, they may find that their current provider cannot, or may not be inclined, to give them support. Switching providers may be costly or even legally impossible in the short-term if contracts have been signed locking the farmer into specific input use. For many farmers, the choice of vendor of inputs may lead to an "investment path dependency" meaning that they invest over the years to farm a certain way. This situation is referred to as a "technological lock-in", or "vendor-lock in" if it links farmers to a single provider. The word "technological" can refer to the techniques of production or to specific inputs and services supplied to farmers by the agroindustry such as genetics and crop protection and animal health products. A study in France carried out by INRAE[226] showed that one of the main obstacles for crop diversification was precisely the organisational structure of agro-industrial production systems, with mechanisms that tended to be self-reinforcing over time.

One of the key issues highlighted in the literature is that the introduction of cover crops and diversification of rotations requires the cultivation of minority crops. Because less research and investments have gone into minority varieties, there are fewer seed and crop protection options available. This requires farmers to find alternative suppliers and advisors to help them grow these crops. This is not always straightforward. Farmers have to become aware of knowledge networks that help them find the right advisors and providers. Lack of knowledge from both farmers and advisors may prove to be a barrier in this case.

## Data management and digital systems

A second type of structural barrier at the farm level is related to data management. The introduction of smart-farming, precision farming or digital agriculture ("Agriculture 4.0[227]") tends to make farmers highly dependent on external assessment and technology providers. While it may be seen that digital tools can help farmers gain independence, the more technology is used, data is recorded and management advice provided by machine learning, the more farmers may find themselves losing some of their ability to make their own decisions, assess trade-offs and even to repair their own equipment. Contractual agreements may tie them to a specific provider for these functions. This may be discouraging for some.

Precision farming requires that farmers use sensors to collect data that is interpreted by machine-based applications often managed and owned by the machine manufacturers or the agronomic services. Because large amounts of data and many participants are needed to create the network effect which make these systems work optimally, the data collected by a single farmer has a very low value compared to the aggregated data of large numbers of farmers. Therefore, farmers need these companies to translate sensor readings into management recommendations. If switching providers, they may fall into issues of inter-operability

[226] Meynard, et al., 2013. *Crop diversification: obstacles and levers Study of farms and supply chains*. Synopsis of the study report, INRA, 59 p.

[227] Rose, D.C., Chilvers, J., 2018. *Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming. Front.* Sustain Food Syst 2, 87

between machines, some of which may become obsolete and the investment lost. It has been mentioned that the lack of clear rules in this developing area do not help farmers and there is still much debate about the ownership of agricultural data. Machine learning and artificial intelligence widens the gap between the farmer and the technology provider, although this has been a process underway now for a long time. Investment in agricultural technology has grown greatly over the last ten years. These developments are not only made by the main agroindustry players like traditional mechanisation and agrochemical companies but also by large information technology companies (Microsoft, Google) who are interested in the data that they can acquire. One solution proposed to deal with this is the use of "neutral third-party data intermediaries". They will generally be more neutral regarding the products and services used by the farmer to collect and use data. Such intermediaries do not store data in their system, but simply communicate the data, and advise how it may be used to advantage.

Precision farming or digital agriculture is generally used in large arable areas, intensive livestock farming and vegetable production[228.] The use of satellite images for instance will not be suitable for all crops grown in all circumstances. It works best to detect yields and pests in large and homogeneous fields, rather than smaller fields with more than one crop. So, while precision farming or digital agriculture can be used in principle in all types of agriculture, it offers greatest possibilities in more specialised, larger scale and intensive agriculture. The sustainability of these systems has still to be assessed. Precision nutrient and pesticide application, and robotic weeding may significantly reduce pollution and collateral damage to non-target species. Yet, these technologies will tend to lock farmers into continued dependence on ever more remote technology suppliers.

## Structures and power in the food chain

As already mentioned a very specific farm business structural issue which can affect both the willingness and ability of farmers to move to SSM are the tenurial relations between farm operators and land owners[229]. In addition to this, a wider structural issue which is also likely to impact on both farmers' **willingness** and **ability** to move towards SSM concerns the balance of market power in the food supply chain. When harvested, most crops are substantially processed, packaged and stored before distribution either to the retailers or food service companies. Farmers do not act alone when choosing the crops and varieties to plant. Even the cultivation methods and harvest dates can be fixed beforehand. All these are joint decisions between several actors, in which profitability through the chain is a key driver. The food chain is a complex network of actors with highly uneven power relationships between them. Between farmers, and consumers, there exists a wide range of actors including food manufacturers, suppliers, purchasing companies and supermarkets, wholesalers, restaurants and food service companies each of which plays a specific role. Not all actors hold the same power. While there are millions of farmers in the EU, the number of input providers, retailers and purchasing companies is much smaller, concentrating the power in fewer hands[230].

This imbalance in market power in the food chain is frequently raised by farmers' organisations and over the years there have been many studies of whether concentrated sectors in the food chain were extracting abnormal profits to the detriment of farmers. These studies have generally concluded that whilst there is a high degree of concentration amongst retailers downstream of farmers there is

[228] JRC, 2014. Precision agriculture: an opportunity for EU farmers – potential support with the CAP 2014-2020. Brussels. https://www.europarl.europa.eu/RegData/etudes/note/join/2014/529049/IPOL-AGRI_NT(2014)529049_EN.pdf

[229] Stevens, A.W., 2022. The economics of land tenure and soil health. Soil Security 6, 100047

[230] IPES-Food, 2016. *From Uniformity to Diversity - A paradigm shift from industrial agriculture to diversified agroecological systems.*

strong competition amongst these operators and little evidence has been found that they systematically abuse their market position at the expense of farmers[231]. In parallel to such studies there has been a drive in the EU to regulate the use of what came to be called unfair trading practices in the food chain. Following reviews of such practices and the creation of an Agricultural Markets Task Force to advise the Commission, finally a directive on unfair trading practices in business-to-business relationships in the agricultural and food supply chain was adopted in 2019[232]. It will no doubt take time for this directive to be implemented and as far as the issue of farmers adoption of sustainable soil management is concerned what matters is not the specific measures on unfair trading practices but rather whether this regulatory move changes the general tone of relations in the food chain to a more collaborative balanced approach.

This is required because the regulatory drive to internalise the pervasive environmental externalities that the current farming practices have on soil health and other aspects of the environment and human health is weak. At the same time, the incentive for other key actors in the value chain to pull farmers into switching towards SSM has been low[233], although this may be changing as discussed in the next chapter. There are also specific barriers to the implementation of certain SSM practices that arise from the current structure of the food chain. One such example is crop diversification. Diversification is one of the key practices of SSM systems, implying increasing the number of crops that a farmer grows, either in the form of cover and catch crops, or through extended crop rotations or polycultures. This means often the introduction of minority crops next to the most common ones. This poses several challenges. On the one hand, logistic issues can result from dealing with a larger diversity of farm outputs, making farmers reorganise their supply chains. On the other hand, because the current agricultural system has been optimised for specialised farms with simplified rotations involving much reduced crop diversity, farmers may encounter difficulties in terms of finding inputs and knowledge to grow these crops as well as lack of buyers when selling them. Profitability is linked to the volumes collected and the market prices, therefore opting for the cultivation of minority crops is not a straightforward decision[234]. There is also a lack of final products made with minority crops, and for many decades now consumers have moved away from certain vegetable and root crops. Consumer preferences themselves have been conditioned by food manufacturers and retailers who have driven the food system down a route in which ultra-processed 'junk food' leading to chronic human health problems has become a high-level societal challenge. The EGD and Farm to Fork Strategy highlight these trends. These issues and how regulators and the food industry itself responds to them are important, societal factors that condition the attitude of farmers towards their willingness to adopt SSM.

231 See for example the OECD review of the issue in https://www.oecd-ilibrary.org/agriculture-and-food/concentration-and-market-power-in-the-food-chain_3151e4ca-en

232 European Commission, 2019. Directive (EU) 2019/633 on unfair trading practices in business to business relationships in the agricultural and food supply chain. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0633&from=EN

233 Sukhdev, P., May, P., Müller, A., 2016. Fix food metrics. Nature 540, 33–34.

234 Meynard, et al., 2013 (see ref 226)

Chapter 4

# Overcoming the barriers: drivers of change

This report aims to highlight how the need to shift EU agriculture, and particularly its soil management, could be achieved by a combination of ambitious policy intentions harnessing the enthusiasm and energy of many private soil initiatives. The lack of progress to SSM to date is certainly not through an absence of motivation and desire at the highest societal level as expressed in EU policy. The first part of this chapter summarises the efforts that have been made through aspects of European agricultural policy to encourage farmers in this direction. Neither can it be claimed that there is a complete absence of desire at the farm-family level to adopt sustainable practices. The second part of this chapter reviews the approaches and operations of private initiatives that are seeking routes to SSM. Key ingredients are therefore in place. Having reviewed the efforts made through public policy actions and through private initiatives we then bring together some conclusions about their effectiveness and adequacy with the behavioural framework described in Chapter 3 to try to understand what further steps could be taken to bring about a wider transformation of soil management, in the final chapter.

The need to shift European agriculture, and particularly its soil management, could be achieved by a combination of ambitious policy intentions harnessing the enthusiasm and energy of many private soil initiatives.

## 4.1 Support and encouragement for SSM through public policy

Agricultural and environmental policies are core competences of the EU. This is justified because of the strong transboundary interactions of land and environmental management activities and the need to approach these issues in a harmonised way in the EU single market. There are several policies in the EU which for several decades have been directly and indirectly steering and supporting farmers in their soil management, although not always in a positive direction. The most generously funded and potentially most influential of these is the Common Agricultural Policy (CAP). Looking to the next two or three decades the most striking development has been the launch of the European Green Deal (EGD) with its Biodiversity, Farm to Fork and Soil Strategies, the Communication on Sustainable Carbon Cycles as well as the Soil Mission. These strategies and actions make many specific proposals for soil management aiming to raise the ambition and contribute to SSM. Additional support for farmers and other stakeholders also comes from the Cohesion Policy and the Research and Innovation programmes. All of these policies are intended to contribute to the long-established objectives of environmental policies especially the Nature Directives, the Nitrate and Water Framework Directives. Indeed, agricultural policy has been the principal policy tool which directly interfaces with land managers. The CAP has had substantial public financial resources at its disposal to intervene on behalf of environmental protection and make its contribution towards adoption of sustainable soil practices. How well has this worked?

### The Common Agricultural Policy (CAP)

From the founding of the European Economic Community, it was regarded essential that agriculture should be part of the common market and this necessitated a Common Agricultural Policy. From the 1960s to the mid-1990s this policy was a commodity-based support system characterised by high and stable support prices and strong border protection. This policy did not cause the technical and structural changes seen in agriculture in the last four decades of the 20th Century, the same changes were seen in agricultural systems across the developed world under widely different policy regimes, and they also occurred in EU sectors not supported by the CAP (such as horticulture). However, the CAP certainly provided European farmers with relatively stable, predictable and remunerative market conditions under which agriculture was transformed. This transformation involved generally more specialised, larger farms operating at higher intensity of inputs helped by developments in crop breeding, nutrients, crop protection, mechanisation and business management. This in turn lead to higher intensity outputs – yields per hectare and per animal. However, side effects of this transformation turned out to be gradual and cumulative damage to soil health documented in Chapter 1, loss of habitat and biodiversity in soil, in and around fields, and pollution of water, air and atmosphere.

During this process the CAP has not been static. It has been reformed periodically, and since 1985 there has been growing recognition in each successive reform that an agricultural policy has an important role to play in environmental management of Europe's rural land. The earliest environmental measure in the CAP was an article in Regulation 797/85 on "Improving the efficiency of agricultural structures" which authorised Member States to introduce national schemes to provide assistance in Environmentally Sensitive Areas[235]. Next, the Agri-environmental regulation 2078/92 was a more substantive recognition of the need to pay attention to the negative and positive externalities of agriculture. It was one of three 'accompanying measures' to the MacSharry reforms that started reining-back the over-generous price supports which had led the European Economic Community into embarrassing commodity surpluses. The 1992 MacSharry reform of the CAP introduced for the first time some direct payments to farmers as compensation for reducing the (intervention) price supports which had been a key part of the CAP since its origin. Linked to these direct payments, which initially only applied to the principal arable crops (cereals, oilseeds) and beef production, Member States had the option of requiring recipients of the payments to respect some environmental cross-compliance conditions.

## The two-Pillar CAP: Pillar 1 and cross compliance

In the successive, Fischler, reforms of 2000 and 2004 the price intervention system for all commodities was displaced by a comprehensive single farm payment system becoming the core of Pillar 1 of the CAP and using about three-quarters of the CAP budget. In modified form this is still largely the case today and will continue through to 2027. In the Fischler reforms cross-compliance conditions became mandatory for all farmers receiving direct payments. The Agenda 2000 reform created the second Pillar of the CAP, the Rural Development Regulation, which included and expanded the pre-existing accompanying measures. As many of the schemes in the second pillar involved incentive payments, receipt of these payments also required farmers to respect the cross-compliance conditions.

The concept of cross-compliance was a way of laying down explicitly what is meant by Good Farming Practice, or Good Agricultural Practice. This is turn is seen as defining management activities which provide minimum protection for natural resources (energy, soil, water, air, plants and animals), cultural resources, farm animals, farm labour and the general public[236]. These ideas became more codified as they were attached to the receipt by farmers of considerable sums of public financial support.

The current CAP has an annual budget 55.71 billion EUR, representing 33% of the annual EU budget, one of the largest policies funded by the EU. The first

[235] See Lowe, P. and Whitby, M., 1997. *Chapter 13. The CAP and the European Environment, in The Common Agricultural Policy*, by Ritson and Harvey (Eds), CABI.

[236] IEEP, 2000. The development and scope of cross compliance. IEEP, London.

Pillar accounts for 70% of this budget[237]. Farmers receiving payments must comply with the EU's environmental policies and implement a set of mandatory practices which indirectly contribute to SSM. The CAP also offers additional funding and support for farmers wanting to implement environmentally friendly practices, most of which do not target soil health directly but have the potential to contribute to it.

The following summarises the main elements of the cross-compliance regime and how they relate to SSM practices. Cross compliance is made up of two sets of requirements on farmers. The first are the Statutory Management Requirements (SMRs), the second are termed the Good Agricultural and Environmental Conditions (GAECs) a term which signifies how good agricultural practice must also encompass environmental considerations.

The SMRs are the EU environmental regulations which are relevant to rural land management. The ones which relate to soil management are the regulations on plant protection products (EU Regulation 1107/2009 concerning the placing on the market of Plant Protection Products, and the Sustainable Use of Pesticides Directive 2009/128/EC), the Directive on the use of nitrates (Council Directive 91/676/EEC), the Directive on the conservation of wild birds (Directive 2009/147/EC) and the Directive on the conservation of natural habitats and of wild fauna and flora (Council Directive 92/43/EEC).

The GAEC measures which are relevant for soil in the current CAP are: minimum soil cover (GAEC 4), minimum land management to limit erosion (GAEC 5) and maintenance of soil organic matter (GAEC 6).

Cross-compliance conditions apply to all farmers receiving supports from the CAP whether the direct payments in Pillar 1 or through the agri-environment schemes in Pillar 2. Although it is not compulsory for farmers to apply for direct payments, practically all farmers do receive them and are thus subject to cross compliance. However, a much smaller number engage in the voluntary agri-environmental schemes under Pillar 2 of the CAP. These are designed and operated by the Member States. The interaction of cross-compliance conditions and agri-environment schemes, not surprisingly, is complex, and is further considered below after the actions for soil management available under Agri-environment schemes are outlined.

### The Rural Development Regulation, CAP's second Pillar

The first Rural Development Regulation (RDR) 1257/1999 offered a menu of measures for rural economic development and agri-environment structured around four axes. These are listed below showing the total expenditures for each axis in billion Euro over the first programming period (2000-2006). Also shown for each axis are the three biggest measures in terms of their expenditures over the period [238].

- Axis 1 (€20): Modernisation of farms (€4), Improving marketing (€3), Forestry (€2)
- Axis 2 (€26): Agri-environment (€15), Less favoured Areas (€8), First afforestation of farmland (€2)
- Axis 3 (€5): Village renewal (€2), Rural Infrastructure (€0.6), Diversification of agriculture (€0.6)
- Axis 4 (€1.4): management of local strategies (€0.8), LEADER local action groups (€0.3)

[237] https://www.europarl.europa.eu/factsheets/en/sheet/106/financing-of-the-cap#:~:text=The%20EU%20budget%20for%202021,budget%20(EUR%2055.71%20billion)

[238] Dwyer et al., 2008. *Review of Rural Development instruments, for the European Commission DG Agri,* Final Report.

The total EU funded expenditure under the RDR amounted to €52 billion for the seven-year programme. Adding-in the Member State co-financing of these measures, the total expenditure was €88 billion, (€12.6 b per year). It can be seen that the agri-environment measures in Axis 2 accounted for the largest expenditures.

There have been many changes to the details of the RDR in the three succeeding programmes for 2007-13, 2014-20 and for the current period 2021-27, the axes were dropped, some new measures added and unused ones discarded, but the essential structure and operation continue.

The MSs devise their own agri-environment measures to suit the environmental challenges and farming structures in their territory, but all should only pay farmers for actions above and beyond the base level requirements. Payment rates may only cover income forgone by farming in a less intensive way, and direct additional costs. There can be some capital cost payments in these schemes for environmental purposes. The measures available under agri-environment include a large collection of SSM practices. The MSs select the measures for which funding is available to their farmers. In practice they have tended to address biodiversity and water issues, rather than soil, so the impact on soil health remains limited[239]. The current RDR establishes that 30% of the Pillar 2 funds must be dedicated to climate and environment. For the next period, whose delayed start commences in 2023, this will rise to 35%. The increased focus on climate is reflected in the name change so these schemes and their measures are called Agri-Environment-Climate Measures (AECMs). The intention is to avoid double-funding i.e. to avoid paying farmers more than once for any particular action, thus environmental actions in Pillar 1 (cross compliance and greening, explained below) cannot be further supported in Pillar 2. In principle, agri-environment schemes should only pay farmers for actions which go above and beyond the obligatory requirements of cross compliance on their Pillar 1 payments. In practice there was, and probably remains, a good deal of overlap between these two.

In principle, agri-environment schemes should only pay farmers for actions which go above and beyond the obligatory requirements of cross compliance on their Pillar 1 payments. In practice there was, and probably remains, a good deal of overlap between these two. A paper by the Institute for European Environmental Policy written during the early development of cross compliance and agri-environment schemes analysed this relationship for the elements of cross compliance and agri-environment which deal with soil management. They found that reduction of soil erosion (five measures), the preservation of soil organic matter (through four measures) and the preservation of soil structure (two measures) were explicitly focussed on from the outset of the development of the cross-compliance tool. Of these eleven measures only one (preservation of field border features) was the main preserve of agri-environment, the other ten are either mainly cross-compliance and therefore apply to practically all farmers, or they were shared between compliance and agri-environment.

In the current version of agri-environment schemes, measures relating to soil management include:

- measures to support organic farming help to safeguard soil health and biodiversity,
- measures to support forestry development that are effective against soil erosion,

[239] EC and Alliance Environnement, 2021 (see ref 94)

- investment measures to finance machinery for conservation tillage – to minimise breaking-up of the soil and to maintain a high level of soil cover in autumn and winter, thus potentially limiting GHG emissions, reducing erosion and building up soil organic matter,
- measures to support knowledge transfer, advisory services and cooperation to help farmers address various soil threats - like erosion, acidification or loss organic matter – and foster the adoption of SSM practices adapted to local agro-ecological and farming conditions.

## Two further developments in the greening of the CAP

The two-pillar system was developed through the two programming periods, 2000-2006 and 2007-2013, but the improvement in environmental performance that it brought was judged as insufficient. This led, in the reform of CAP for the 2013-2020 period under Commissioner Cioloș, to the introduction of additional environmental requirements for farmers to receive direct payments. This was done through so-called direct "greening payments" as part of Pillar 1. This reform also explicitly sought to widen the reach of agri-environment schemes in Pillar 2 to include explicit measures for climate protection. For farmers to receive the greening payments they had to respect whichever of the following three greening requirements was relevant to their farm system:

- **Crop diversification**: to encourage farmers to widen and lengthen their crop rotations. Farms with more than 10 ha of arable land have to grow at least two crops, while at least three crops are required on farms with more than 30 ha. The main crop may not cover more than 75% of the land. There are exemptions to the rules, depending on the individual situation; for instance, farmers with a large proportion of grassland, which is in itself environmentally beneficial.
- **Maintenance of permanent grassland**: intended primarily as a climate measure to minimise oxidation of soil carbon if permanent grassland is ploughed. The ratio of permanent grassland to agricultural land is set by EU countries at national or regional level (with a 5% margin of flexibility). Moreover, EU countries designate areas of environmentally sensitive permanent grassland. Farmers cannot plough or convert permanent grassland in these areas.
- **Ecological focus areas (EFA)**: to safeguard and improve biodiversity on farms. Farmers with arable land exceeding 15 ha must ensure that at least 5% of their land is an EFA.

These measures were not well received by farmers and the impact of the "greening" payments is considered to have been extremely limited[240]. The requirements are minimal. In the case of crop diversification, the measure has not in practice expanded or diversified crop rotations since most farmers already grow two or three crops, or they cultivate less than 10 ha and are not affected by the requirement[241]. Its impact was therefore also minimal. Also, MSs may allow farmers to meet one or more greening requirements through equivalent practices based on AECMs even though farmers are not supposed to be paid twice for the same action from both Pillars. In the rules for greening payments, organic farmers directly receive their greening payment without further actions since their requirements are considered to go beyond greening[242].

[240] Alan Mathews http://capreform.eu/the-ciolos-cap-reform/

[241] EC and Alliance Environnement, 2021 (see ref 94)

[242] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/greening_en

The next period of operation of the CAP will follow the reform launched by Commissioner Hogan in 2018 and completed under Commissioner Wojciechowski in 2021. In this policy, which will operate from 2023-2030, the Greening Payments will disappear, their provisions will partly be placed under so-called 'enhanced conditionality' for Pillar 1 payments, with the aim of increasing its level of ambition. The GAECs under this enhanced conditionality are listed in Table 4.1. It can be seen that all of these requirements can contribute to more SSM.

The remaining greening provisions plus new ones will be taken up in a new Pillar 1 structure called 'eco-schemes'. These schemes will receive 25% of the funds of Pillar 1 and will include climate and environment "friendly" farming practices (such as organic farming, agro-ecology and carbon farming), as well as animal welfare improvements. Consistent with the New Delivery Model in which the mix of CAP measures adopted and how they are specified and implemented will be the responsibility of the MSs rather than laid down by Brussels. The design of the eco-schemes will also be devolved to the MSs. To do all this each MS has to draw up and get EC approval for a CAP Strategic Plan for their territory based on their own needs assessment[243]. The EC offers guidance with examples on how the eco-schemes might be designed and put together[244].

**Table 4.1. Good Agricultural and Environmental Conditions in the post-2023 CAP[245]**

| GAEC | DESCRIPTION |
|---|---|
| GAEC 1 | Maintenance of permanent grassland based on a ratio of permanent grassland in relation to agricultural area |
| GAEC 2 | Appropriate protection of wetland and peatland |
| GAEC 3 | Ban on burning arable stubble, except for plant health reasons |
| GAEC 4 | Establishment of buffer strips along water courses |
| GAEC 5 | Use of Farm Sustainability Tool for Nutrients (FaST) |
| GAEC 6 | Tillage management reducing the risk of soil degradation, including slope consideration |
| GAEC 7 | No bare soil in most sensitive periods |
| GAEC 8 | Crop rotation |
| GAEC 9 | Minimum share of agricultural area devoted to non-productive features or areas; Retention of landscape features; Ban on cutting hedges and trees during the bird breeding and rearing season; As an option, measures for avoiding invasive plant species |
| GAEC 10 | Ban on converting or ploughing permanent grassland in Natura 2000 sites |

Table 4.2 pulls together a list of practices included in Pillar 1 of the CAP (current and post-2023). The table indicates which of these practices are included under cross-compliance or greening/eco-schemes. The table also indicates under which of the five SSM categories established in Chapter 2 they fall. Currently, Pillar 1 only includes five of these practices. The guidance given for the eco-schemes, to replace greening in the coming programming period for the CAP,

243 The CAP Strategic Plans for each Member State were supposed to be submitted to the Commission by the end of January 2022. The Commission has to review them, discuss amendments with the Member States if required, to enable them to enter into force in 2023.

244 https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/factsheet-agri-apractices-under-ecoscheme_en.pdf

245 https://guidehouse.com/-/media/www/site/downloads/energy/2018/3climatefriendly-design-of-the-eu-common-agricultu.pdf?la=en

has the potential to ensure that a larger number of practices becomes more easily implemented being part of direct payments, whereas many of them were previously funded under Pillar 2. However, the experience with these programmes since 2000 suggests caution. The measures available under the regulation, the ones that are picked up by the MSs in their scheme design, and then the measures adopted by farmers are three different things. It is, none-the-less an advance that these SSM practices have been acknowledged.

**Table 4.2. CAP supported measures for five groups of SSM practices identified in Chapter 2. (Brown colour in columns 2-4 refers to the 2023-2027 CAP).**

| MEASURES | CAP PILLAR 1 | | | SUSTAINABLE SOIL MANAGEMENT PRACTICES (according to Chapter 2 classification) | | | | |
|---|---|---|---|---|---|---|---|---|
| | cross-compliance (conditionality) | Greening | Eco-schemes (suggested) | Keeping soil covered | Reducing soil disturbance | Diversifying crops and rotations | Organic matter management | Minimising synthetic inputs |
| Minimum soil cover | X, X | | | X | | | X | |
| Minimum land management to limit erosion | X, X | | | | X | | X | |
| Maintenance of soil organic carbon | X, X | | | | | | X | |
| Maintenance of permanent grassland | X | X | X | | X | | X | |
| Crop diversification | X | X | | | | X | | |
| No bare soil in most sensitive periods | X | | | X | X | | | |
| Cover crop between tree rows on permanent crops (above conditionality) | | | X | X | X | | | |
| Winter soil cover and catch crops (above conditionality) | | | X | X | | X | X | |
| Ban on converting or ploughing permanent grassland in Natura 2000 | X | | | | X | | | |
| Erosion prevention strips and wind breaks | | | X | | | | | |
| Establishment of buffer strips along water courses | X | | | | X | | | |
| Establishment or maintenance of terraces and strip cropping | | | X | | X | | | |
| Conservation agriculture | | | X | | X | | X | |
| Extensive use of permanent grassland | | | X | | | | | |
| Crop rotation | X | | | | | X | | |
| Mixed cropping-multi-cropping | | | X | | | X | X | |
| Crop rotation with leguminous crops | | | X | | | X | | X |
| Mixed species/diverse sward of permanent grassland for biodiversity purposes | | | X | | | X | | |
| Low intensity grass-based livestock system | | | X | | | | X | |
| Rewetting wetlands/peatlands | | | X | | | | X | |
| Appropriate protection of wetland and peatland | X | | | | | | X | |
| Appropriate management of residues | | | X | | | | | |
| Practices and standards as set under organic farming rules | | | X | | | | | X |
| Use of Farm Sustainability Tool for Nutrients (FaST) | X | | | | | | | X |

## The impact of the CAP on SSM

The above summary of a wide range of measures under the two Pillars of the CAP to which farmers have had access and funding for many years should have helped transition towards many SSM practices. However, evaluations of the environmental performance of the CAP generally conclude that the supports have not produced substantial environmental results[246,247]. The reasons are many. While there is some support, the level of ambition is low. Member States have not prioritised SSM management. And farmers when offered choice of measures to adopt they tend to take the easiest options, i.e. those least disturbing of the status quo. Payment rates appear not to motivate farmers to engage in the implementation of more demanding SSM practices and farmers often lack the technical knowledge required to effectively implement them[248]. Another aspect which diminishes the effectiveness of the CAP's measures is that the control rates are low. They are low for cross-compliance (around 1%) although higher for voluntary environmental schemes[249]. The ratio of payments to benefits is also considered low. There is no monitoring for many of the environmental issues that CAP measures aim to tackle, such as soil biodiversity, soil pollution, soil salinisation or soil compaction, and in the case of soil organic matter observing positive changes requires long-term observations, often beyond the seven-year cycle of each iteration of the CAP. The time frame needed to apply certain practices can also be problematic. In the case of long crop rotations, national authorities should track the management in a specific field and inform future farmers in the case where arable land is leased under short-term contracts[250]. This is also the case for nutrient management, conversion to grassland or carbon farming practices under the new CAP.

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The absence of baselines against which to compare progress, and the lack of agreed metrics for measuring some aspects including soil organic matter and biodiversity, make it difficult to provide comprehensive evidence of the effectiveness of CAP instruments in assisting SSM. The general conclusion of most studies is that they have not been very effective. It should be acknowledged, however, that agricultural practices are performed by farmers often operating in economically marginal businesses, in the open air subject to all the vagaries of biological variation, weather and climate change with extreme events such as drought, fires and floods pushing them off-course. Improving soil management is not a simple mechanical matter of changing business practices with predictable results. Furthermore, when extreme events occur MSs authorities may allow farmers to relax the environmental obligations, even for cross-compliance, rather than encouraging a transition to sustainable farming which is needed to mitigate and adapt to climate change. Since climate change is expected to increase the frequency of these events a more deep-seated understanding of the precariousness of agricultural systems is vital – and apparently absent.

[246] European Court of Auditors, 2017. *Greening: a more complex income support scheme, not yet environmentally effective*. Special report No 21. Publications Office, LU.

[247] See also: EC and Alliance Environnement, 2021 (see ref 94), European Court of Auditors, 2020 (see ref 162)

[248] EC and Alliance Environnement, 2021 (see ref 94)

[249] ibid

[250] http://capreform.eu/eco-schemes-a-work-in-progress/

## The European Green Deal (EGD)

In autumn 2019, the new European Commission under President von der Leyen judged that the public mood was ready to launch an ambitious strategic 'Green Deal'. This followed the build-up of publicity over what came to be described as the twin crises of climate change and loss of nature from late 2017. Significant events around that time were the broadcasting of Blue Planet II[251], the 2019 IPBES report on biodiversity and ecosystem services[252] and UNEP's Global Resources Outlook report[253] analysing the impacts of growing use of natural resources, including soil.

The EGD explained that strategic changes would be necessary across a wide range of activities to meet the climate and biodiversity crises. Food, agriculture, and wider land and resource management were all foreseen to require changes in direction. These were subsequently spelled out in a series of Strategies for Biodiversity, for the food system called the Farm to Fork Strategy (F2F), and for Forestry and Soils. This certainly indicated a clarity of understanding at the very top of the political structures in the EU. It was widely welcomed publicly and by European Councils. However, and regrettably, the F2F and Biodiversity strategies were received with resistance from a large part of the farming sector.

Unfortunately, the global Covid19 pandemic and subsequently the Russian invasion of Ukraine have swept these issues off the headlines. The sheer scale of the economic costs of responding to the pandemic complicated if not blunted the political drive to implement the EGD strategies. The language of the EGD adapted to this reality by talking about the Green Recovery (from the pandemic), and the funds pledged were increased. But it is now possible that the impacts of the war in Ukraine on markets for energy, food and fertilisers, may further derail the Commission's clear-sighted view of how farming and soil management has to change as focus inevitably switches to shorter-term food availability.

Soils are directly and indirectly an important component of the EGD. They are explicitly addressed in the Farm to Fork Strategy, the Zero-Pollution action plan, the Biodiversity Strategy, the new organic action plan and indirectly contribute to the ambitions for climate change mitigation and adaptation. The focus here will be on the recently adopted Soil Strategy, and parts of the Biodiversity and Farm to Fork Strategies. In line with the objectives of the EGD the Communication on Sustainable Carbon Cycles is another relevant element of the EU-level policy mix.

The organic action plan can play an important role in the deployment of SSM practices in the EU. The three axes of this plan focus on stimulating consumer demand, stimulating production and reinforcing the organic value chain and improving the contribution of organic farming to sustainability. The plan is likely to play an important role in delivering the EGD goals on organic farming.

## Soil Strategy

This strategy was adopted in November 2021. The main aim of the Soil Strategy is "to ensure that by 2050:

- all EU soil ecosystems are healthy and more resilient and can therefore continue to provide their crucial services

[251] BBC Natural History Unit (2017) Blue Planet II, first broadcast 29 October 2017 https://en.wikipedia.org/wiki/Blue_Planet_II

[252] IPBES, 2019. *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.*

[253] Oberle, B., et al., 2019. *Global resources outlook 2019 natural resources for the future we want.* A Report of the International Resource Panel. United Nations Environment Programme. Nairobi, Kenya.

- there is no net land take and soil pollution is reduced to levels that are no longer harmful to people's health or ecosystems
- protecting soils, managing them sustainably and restoring degraded soils is a common standard"

The soil strategy describes one of the key actions as "making SSM the new normal". It acknowledges that there is no one-size-fits-all recipe for SSM. The actions listed under the strategy include both defining what SSM practices are, and are not, and working in cooperation with Member States to promote dissemination through advisory services and the Agricultural Knowledge and Information System (AKIS)[254]. A parallel initiative is the Soil Mission[255] which will promote a network of practitioners in combination with the idea of 'Living Labs' and 'Lighthouses' to discover and encourage better practice. Notably, the Soil Strategy leaves it to the MSs to ensure that the CAP contributes to "maintaining and enhancing soil health" through their CAP Strategic Plans. It remains to be seen if the MSs have the will and determination to take up this challenge and use the opportunity to drive towards SSM. This will only become apparent when the CAP Strategic Plans have been approved and put into place, and then much will depend on the **engagement** and **willingness** of farmers to move their soil management in the indicated directions. This timing is unfortunate because if it is judged that the Soil Strategy came too late to meaningfully influence the CAP Strategic Plans of the Member States the next opportunity to change the regulatory basis of the CAP will not arise until the next programming period running from 2028.

Another key action listed in the Soil Strategy is to produce in 2023 a dedicated legislative proposal on soils a "Soil Health Law". This will include defining what is soil health and it will establish soil monitoring and reporting among other measures. The creation of a legislative framework for soil has been a request of the European Parliament[256], the Committee of the Regions[257] and has also been recently recommended by the European Court of Auditors[258], the European Environment Agency[259] as well as European Stakeholder's views on the need to protect soil[260].

In relation to climate change, the Soil Strategy proposes legally binding targets to limit peatland and wetland drainage and for rewetting peat soils which have been drained for agricultural use and thus dried. These soils have become sources of GHG emissions as their carbon stocks are oxidised, rewetting them is designed to turn them back into carbon sinks. Finally, the strategy aims to set a common framework for addressing soil degradation, soil sealing and increasing soil monitoring and research.

### Farm to Fork Strategy (F2F)

The aim of the Farm to Fork strategy is to "accelerate the transition to a sustainable food system". It proposes to reduce the overall use and risk of synthetic pesticides by 50% by 2030, reduce nutrient losses by 50% by 2030 (reducing fertiliser use by 20% at least) and ensure that at least 25% of EU agricultural land is under organic farming by 2030. The principal objective of setting such targets seems to have been to reduce dependency on pesticides and antimicrobials, reduce excess fertilisation,

[254] AKIS: Agricultural Knowledge and Innovation System set up in each Member State

[255] see page 78 on Research and Innovation

[256] https://www.europarl.europa.eu/doceo/document/TA-9-2021-0143_EN.html

[257] https://cor.europa.eu/EN/our-work/Pages/OpinionTimeline.aspx?opId=CDR-3137-2020

[258] European Court of Auditors, 2018 (see ref 100)

[259] EEA., 2019 (see ref 49)

[260] European Commission. 2021 (see ref 6)

increase organic farming and help reverse biodiversity loss. The F2F strategy does acknowledge the need to improve soil management and water quality but does not directly refer to SSM, this came later with the Soils Strategy.

The F2F aims were not well received by farming organisations. They fear that this proposed de-intensification of agriculture, together with plans to increase forest area, reduce extensive grazing on peat lands, and increase space for nature, will both reduce the agricultural area, and reduce the intensity of EU production, drawing in imports (produced to lower standards) and potentially raising food prices. They repeatedly asked for impact assessments which analyse and confront these concerns. Consequently, attempts by the EC to have the F2F targets formally adopted in the CAP reform were resisted by the EU Council and EU Parliament. The text of the F2F strategy mentions the new 'eco-schemes' as an instrument to fund sustainable practices (including precision agriculture, agro-ecology, carbon farming and agroforestry) that help to achieve the F2F goals. It therefore expects the EC to ensure that MSs prepare their CAP strategic plans with these targets in mind. The outcome of this process will only emerge in coming years.

## Sustainable carbon cycles communication

The Commission's communication on Sustainable Carbon Cycles[261] builds on the 2021 European Climate law which set the EU target of Net Zero Green House Gas emissions by 2050, and on the climate related elements of the EGD Strategies. Its third key action is to: "*upscale carbon removal solutions that capture $CO_2$ from the atmosphere and store it for the long term, either in ecosystems through nature protection and carbon farming solutions or in other storage forms through industrial solutions while ensuring no negative impact on biodiversity or ecosystem deterioration in line with the precautionary and Do No Significant Harm principles*". It goes on to explain Carbon farming – "*by 2028 every land manager should have access to verified emission and removal data, and carbon farming should support the achievement of the proposed 2030 net removal target of 310 Mt $CO_2$ eq in the land sector, as presented in the July 2021 package on delivering the EGD*".

Carbon farming is presented as a new business model for land managers. "*Improved land management practices resulting in carbon sequestration in ecosystems and reducing release of carbon in the atmosphere*". It is hoped that this will increase carbon removals, increase biodiversity, increase climate resilience of farm and forest land and in the process provide additional income for land managers.

The proposed practices include: afforestation and reforestation; use of conservation tillage, catch crops and cover crops; restoration, rewetting and conservation of peatlands and wetlands; targeted conversion of cropland to fallow, or of set-aside areas to permanent grassland; agroforestry and other forms of mixed farming[262]. The EC has promoted the inclusion of carbon farming practices in MS' CAP Strategic Plans and produced a document guiding the implementation of carbon farming schemes in peatlands, agroforestry, mineral soils, grasslands and the livestock sector[263]. The EC also mentions that funding opportunities under the CAP for the implementation of these measures fall under: eco-schemes and rural development AECMS, the European Innovation Partnership and the Advisory Services. The next legislative step is to provide a regulatory framework for carbon removals, this is expected to be published at the end of 2022.

[261] Communication on Sustainable Carbon Cycles, 15/12/2021 https://ec.europa.eu/clima/system/files/2021-12/com_2021_800_en_0.pdf

[262] https://ec.europa.eu/commission/presscorner/api/files/attachment/870610/Factsheet%20-%20Sustainable%20Carbon%20Cycles%20_EN.pdf

[263] COWI, Ecologic Institute and IEEP, 2021 (see ref 142)

Carbon farming should certainly be regarded as an approach to make it attractive to restore soil health, but the objective sought should go beyond climate change mitigation to improve soil health and functions.

While the Communication is a further step in shifting towards SSM, there are still a large number of outstanding issues to be addressed before carbon farming – especially the soil carbon storage aspect – can be operationalised. There are many reports prepared and in process on this subject. Among them, the EJP-Soil programme has identified important gaps in our understanding of SOC dynamics which it aims to respond to by funding dedicated research projects with strong emphasis on implementation[264]. These knowledge gaps are: the saturation of carbon sequestration in organic matter of different soil forms, understanding the mechanism of SOC persistence in soil and subsoil, the dynamic interactions between SOC and GHG emissions and the management practices that allow minimising GHG emission from soils. In addition to these gaps in understanding, questions remain on the practical measurement issues for carbon such as the depth at which SOC should be measured and the methods used for the monitoring, reporting and verification of SOC stocks.

These practical issues show that it may be some time before there are large scale operational and certified ways for using SOC sequestration to be sold as offsets to other sectors which have difficulties to reduce GHG emissions. Many NGOs question whether carbon farming should be allowed to offset emissions from other sectors whilst the land, especially agricultural, sector is still responsible for around 10% of GHG emissions in the EU and the sector is struggling to reduce its own contribution.

All the foregoing said, carbon farming should certainly be regarded as an approach to make it attractive to restore soil health, but the objective sought should go beyond climate change mitigation to improve soil health and functions.

## Research and Innovation

Another aspect of support, including financial support, for the implementation of SSM can also come through research programmes of the EC. Horizon Europe (2021-2027) is the current research and innovation programme with a budget of 95.5 billion EUR. The programme has introduced the concept of EU Missions, focusing on key challenges, which support the EC's priorities with ambitious goals and tangible results to be achieved by 2030. One of these missions, "A Soil Deal for Europe"[265], aims to establish a network of 100 living labs ("*places to experiment on the ground*") and lighthouses ("*single sites which showcase good practices*") to help transition towards healthy soils by 2030[266]. In addition, the mission aims to establish a harmonised framework for soil monitoring and raise citizen awareness of the value of soil. The mission already incorporates the F2F's objectives on reduction in nutrient losses and pesticide use but does not bind itself to the objective of achieving 75% healthy soils in the EU, as mentioned in the EGD, which had been proposed by the mission's board[267].

The Horizon Europe mission to achieve healthy soils has a substantial budget and its initial focus is on Carbon farming. For 2021, the Soil Mission is offering

[264] For information: https://ejpsoil.eu/about-ejp-soil/news-events/item/artikel/new-ejp-soil-projects-to-bridge-identified-research-gaps

[265] https://ec.europa.eu/info/sites/default/files/research_and_innovation/funding/documents/soil_mission_implementation_plan_final_for_publication.pdf

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

[267] https://ec.europa.eu/info/publications/caring-soil-caring-life_en

support for actions on eight topics:

- National engagement sessions and support to the establishment of soil health living labs
- Linking soil health to nutritional and safe food
- Next generation soil advisors
- Engage with and activate municipalities and regions to protect and restore soil health
- Validating and further developing indicators for soil health and functions
- Social, economic and cultural factors driving land management and land degradation
- Incentives and business models for soil health
- From knowledge gaps to roadmaps on soil mission objectives

The establishment of the EU Soil Observatory[268] to develop soil indicators for the CAP and the F2F, should also contribute to providing the necessary data and monitoring to achieve the objectives set in the EGD.

Particular mention is also given to the EJP Soil[269], a European Joint Programme Cofounded on Agricultural Soil management. Its objectives are to develop the knowledge and tools leading to sustainable food production, supporting biodiversity and sustaining soil functions.

## The "4 per 1000 initiative"

In 2015, after the Paris COP21 of the United Nations Framework Convention on Climate Change (UNFCCC), the French Minister of Agriculture launched the "4 per 1000" initiative[270]. This is one of the best-known large-scale efforts to increase SOC stocks globally. Its objective is to increase SOC stocks by 0.4% annually in the top 30-40 cm of soil by encouraging the implementation of agricultural practices such as agroecology and conservation agriculture which promote SOC stocks and restore soil health. Since its launch, the declaration has been signed by more than 300 parties including tens of countries and several international organisations such as the FAO, the UNFCCC, research institutions, producer organisations and many NGOs among others. "4 per 1000" aims to promote actions oriented at SSM with the objective to turn soils into C sinks rather than sources while limiting trade-offs[271]. Although the main focus is placed on carbon, the Strategic Plan of the initiative reiterates the importance of soil health and the social dimension of soil management including increasing food security. The international multi-actor platform fosters exchanges, the creation of partnerships and overall collaborative work to share best practices, project and policy design.

Globally, this initiative is contributing to creating awareness of soil health and changing discourses, but it has received criticism in terms of the feasibility of achieving the 4 per 1000 carbon sequestration rates. While they were based on sequestration reported rates around the world and, therefore suggested to be

[268] https://joint-research-centre.ec.europa.eu/eu-soil-observatory-euso_en

[269] https://ejpsoil.eu/

[270] For more information visit https://4p1000.org/

[271] Rumpel, C., et al., 2020. The 4p1000 initiative: *Opportunities, limitations and challenges for implementing soil organic carbon sequestration as a sustainable development strategy*. Ambio 49, 350–360.

achievable[272], their feasibility has been contested[273,274,275,276]. It was later clarified that the target was meant to be inspirational[277], like those of the UNFCCC and the Sustainable Development Goals.

## A broad conclusion on the public policy drive for SSM

Manifestly, the considerable efforts and resources over three decades since the early 1990s under the CAP to stimulate better soil management through an elaborate web of regulations and implementing rules for cross compliance, agri-environment, and greening have certainly raised awareness, including amongst farmers, that all is not well, but palpably they have not been sufficient. If they had been producing the desired results it would not have been necessary to invent an equally elaborate new set of strategies and measures. Indeed, the Commission's justification for the proposed Soil Health Law and the EGD targets for land management provide a stark assessment of the state of Europe's soils indicating how far short the previous soil protection regime has fallen.

However, whilst the proposed Soil Health Law contains important proposals for new measures to control the take of the most fertile agricultural land for development, soil sealing, and to better deal with contaminated land, the key actions to 'make SSM the new normal' are devolved to the CAP with its new delivery model. It is perfectly understandable that, of course, soil management has to be a core part of agricultural policy, but it does prompt the question: why should the policy which has failed since the late 1960s to protect Europe's soils be expected to do significantly better in the next, and critical, three decades? Discussion of this question is postponed to the next chapter.

> Why should the policy which has failed since the late 1960s to protect Europe's soils be expected to do significantly better in the next, and critical, three decades?

In dealing with market failures public policy leverage is necessary, indeed essential. It can take many forms beyond agricultural policy. An understandable aspect of farmers' organisations reluctance to accept what they see as restrictions on their farming not applied to farmers in large exporting countries is the loss of competitiveness this might entail and the risk of simply exporting environmental damage as domestic products are displaced by a rise in imports. This concern is currently being addressed for climate change by proposals for a Carbon Border Adjustment Mechanism which would impose a tax on imports produced in countries with lower climate ambitions and restrictions than the EU. However, this is not expected to extend to the agricultural sector. A more recent idea which was flagged in the EGD and is being investigated currently is to subject agri-food imports into the EU to the same environmental and animal welfare standards as are deployed domestically[278]. Meanwhile there are many private initiatives which seek to distinguish and label farm produce which have been grown under conditions of SSM extolling their environmental qualities. There is always scope

[272] Minasny, B., et al., 2017. *Soil carbon 4 per mille*. Geoderma 292, 59–86.

[273] Chopin, P., Sierra, J., 2021. *Potential and constraints for applying the "4 per 1000 Initiative" in the Caribbean: the case of Guadeloupe*. Reg Environ Change 21, 13.

[274] Wiesmeier, M., et al., 2020. *Feasibility of the 4 per 1000 initiative in Bavaria: A reality check of agricultural soil management and carbon sequestration scenarios*. Geoderma 369, 114333.

[275] de Vries, W., 2018. *Soil carbon 4 per mille: a good initiative but let's manage not only the soil but also the expectations*. Geoderma 309, 111–112.

[276] VandenBygaart, A.J., 2018. *Comments on soil carbon 4 per mille by Minasny et al. 2017*. Geoderma 309, 113–114.

[277] Rumpel, C., et al., 2020 (see ref 271)

[278] A Commission paper on what are referred to as 'mirror clauses' to reflect onto imports the same standards as apply to domestic production is in preparation in spring 2022. Meanwhile Tulip Consulting and IEEP are also finalising a paper for WWF on the concept of Core Environmental Standards to apply equal treatment to domestic products and imports.

to extend such activities, and some public support to help this could be justified. These policy actions are not the only route to changed soil management.

Private initiatives have long been a very important aspect of how some groups in European rural society have recognised the importance of soil health. There are many examples of groups of farmers who have spontaneously come together recognising that the preservation of soil health may require different approaches to farming. The next section therefore turns to such initiatives.

## 4.2 Support and encouragement for SSM through private initiatives

Over the past decades, a large number of mostly private, but also public, initiatives[279] have emerged within and outside the EU working with farmers to implement SSM practices and improve the sustainability of the food chain. Soil is an aspect of land management which has fired the concerns, imagination and energy of farmers, municipalities, food companies and NGOs alike to the extent that they felt the need to create organisations of like-minded stakeholders to find out and share how better to manage this vital resource.

Such initiatives are not confined to soil and most simultaneously address concerns about the climate, biodiversity, water and human health. Many are locally based, in a municipality, district, valley or region. Others are product based, e.g., dairy farmers, or wine growers. In all, soil is seen as a fundamental aspect of farming and therefore an integrating and common factor for all farmers[280].

The idea of looking more closely at private initiatives was partly sparked by the reviews of public policy attempts to induce behaviour change which concluded that that they have not been resoundingly successful. This prompted a question of the contribution the private sector is making and whether it could play a stronger role. Discussions with farming and environmental stakeholders revealed that the issue of soil management has been enthusiastically taken up by numerous private initiatives. This was followed through three public webinars in March 2021 (RISE webinar: A conversation on the future of European Soil), in May 2021 (RISE-EPP Webinar – Soil Protection and building up organic humus) and a workshop in March 2022 (RISE webinar: Less talk more action, turning the soil story around). Each of these webinars brought policy makers and experts together with people involved in a range of current soil initiatives to hear how they are addressing the current challenges in soil health, and how these initiatives can link to and be supported by policy. These events indicated the existence of strong motivations within the agricultural sector itself to recognise the challenge of improved soil management and practical ideas about how to bring it about. It became apparent that such initiatives existed in many if not all MSs.

These ideas were therefore followed-up by selecting and interviewing as many of these private sector organisations as resources permitted. Interviews were conducted throughout 2021. The methodology followed and interview template can be found in Annex 1 and a summary table of the soil initiatives interviewed is contained in Annex 2. The organisations investigated were creating or running initiatives to engage farmers in sustainable agricultural management which included soil management even if that was not the prime or only focus. This was an exploratory effort to discover what initiatives are in operation, their objectives and the way

[279] The existence of these initiatives has also been recognised by the EC in the text of the Soil Mission, although an exhaustive list/mapping with all of them or does not exist

[280] Of course, it is acknowledged that intensive livestock farmers may not be directly engaged in much soil management – although someone else has to be to dispose of their manures! Also, there is a growing highly specialised branch of contained, vertical farming based on hydroponics or growing in media other than soil.

they were operating. They were asked if their activity could be generalised and expanded and what they thought was the attraction to farmers who had joined. These positive aspects and the lessons about the future scope private initiatives could play in mainstreaming SSM are the subject of this section.

In total 30 initiatives were investigated (of which 28 were interviewed) operating in 15 countries. They ranged from those run by certification schemes, food and other companies, farmer led initiatives, regional initiatives, and private non-profit organisations. Some were privately funded, such as in the case of the food company soil initiatives, some relied on carbon credit payments, some were paid for by the farmers themselves and most had a combination of private and public or charitable funding. All of them had the objective of improving the sustainability of the farming system in which they were engaged – and whether soil was the core focus, or the initiative's objective was organic certification, or whole farm system change, soil was at the core of all the initiatives we engaged with.

The initiatives were identified through the team's own research and networks. No claim is made that this is a statistically representative sample of the much larger total number of such initiatives around Europe. For each initiative a representative of the organisation behind it was interviewed for one hour. These were semi-structured conversations to understand the origins and motives behind the initiative, their main activities, and especially to understand how and why farmers joined, the commitments they made and the benefits they gained. It was neither desirable nor possible to obtain answers to every question on the questionnaire so there are gaps in the Annex 2 table. It is also stressed that there will be omissions where an activity of an initiative was not recorded and not mentioned simply because time precluded covering that facet of their work. However, the survey gives an indication of the sheer variety of approaches that are currently ongoing to improve soils and the key drivers behind them.

## Type of initiatives

The 30 initiatives studied covered a cross section of EU Member States plus one from the US and five from the UK. They covered France, Spain, Austria, the Netherlands, Belgium, Germany, Ireland, Italy, Portugal, Cyprus, Denmark, Finland and Sweden and six of the initiatives have projects in numerous EU, and in some cases, non-European countries. The initiatives were highly individual having arisen from particular national or regional circumstances. Each had its own specific funding model, objectives, structure and activities. They were chosen and interviewed in relation to their work on soil management. Some were entirely focused on soil and others saw soil as part of wider sustainability. All had soil as a primary or secondary focus. Almost half (12) of the initiatives have been launched since 2015. Based on the initiatives' objectives, funding models and mode of practice they have been categorised into three groups as depicted in Figure 3.

**1** *Certification-Label based* (5). This is a group of organisations where the participating farmers adopt a specified set of practices and standards in exchange for which they acquire the certification for a label, or a certain 'mark' that demonstrates their sustainability. The longest established such label is of course organic farming. Two of this group are the principal organisations in the UK which certify organic products, the tellingly named Soil Association and Organic Farmers and Growers. In these two initiatives, farmers pay annual fees to be registered and certified as organic. This pays for the organisational costs and the independent inspection. There are corresponding Organic Farming organisations in all EU MSs. These are long-established initiatives. The UK Soil Association was created in 1946 as motorised farm mechanisation and 'artificial' nitrogen were spreading rapidly. The founders were concerned about the health consequences of intensively produced food and the dangers of soil loss through erosion and depletion.

They explicitly make the one-health connection between the health of the soil, of plants, animals and of humans. As a generalisation, farmers convert to organic production because they have become convinced that this is the right way to treat soil and farm the land. It requires time, knowledge and indeed some risk-taking to convert from conventional farming. It is generally, but not necessarily, done on a whole farm basis rather than piecemeal. The organic label offers the potential to secure access to a higher price segment of the market, and there are incentives and help for the conversion process offered under the CAP.

<table>
<tr><td>CERTIFICATION/<br>LABEL-BASED</td><td colspan="3">LEAF UK<br>Organic farmers and growers<br>Rabobank/ASR/Vitens<br>UK Soil Association<br>WASP</td></tr>
<tr><td>FOOD<br>COMPANY<br>LINKED</td><td colspan="3">Arla<br>Barilla<br>McCains<br>Nestle<br>Tesco</td></tr>
<tr><td>OTHER<br>PRIVATE INITIATIVES<br>(generally smaller<br>and more local)</td><td>Knowledge<br>brokers<br>Alpine Soil Platform<br>FRDK<br>KES Research<br>Odling i Balans</td><td>More holistic, SSM<br>Alejab<br>AlVelAl<br>Better soils, better world<br>Burren Programme<br>Carbon Action Prog. (BSAG)<br>Climate Farmers<br>Commonland<br>Gentle Farmers<br>Okoregion<br>Soil and water outcomes<br>Soil Heroes<br>TerraPrima<br>Wij.land</td><td>Focus on specific<br>form of farming<br>ELOI<br>Graines d'Avenir<br>M. Paysanne Laude</td></tr>
</table>

**Figure 3. Overview of thirty initiatives interviewed classified into three main groups and by alphabetical order**

The other three initiatives in this group share the feature that participating farmers sign up to a well-defined certification scheme, involving verification. In the case of WASP, the Wines of Alentejo Sustainability Programme, the certification scheme was set up by the Alentejo Regional Wine Growing Commission. In return for respecting the sustainability criteria jointly agreed by this farmer-based organisation the producers benefit from the territorial brand 'Alentejo'. The Rabobank/ASR/Vitens initiative is a joint venture by a bank, an insurance company ASR, and a water company (Vitens). They commissioned the creation of a sophisticated, but simple to use, Open Soil Index (OBI) by an independent group of scientists. Farmers who agree to apply the index to their farming activities and then follow advice on how to improve the index over time may then benefit from favourable terms when seeking investment and may in the future be able to link to carbon schemes. LEAF (Linking Environment And Farming) was initially a UK initiative, set up in 1991, to define and promote Integrated Farm Management. It now operates the LEAF Mark which is recognised as a quality mark for sustainable food by major, UK food retailers. Participating farmers therefore get access to these outlets for their produce. The organisations running these initiatives are generally not-for-profit charities.

**2** *Food company linked* (5). These initiatives each centre round a food company and their principal farmer suppliers. There are many of these across Europe. The five in this sample are one supermarket, Tesco, three food processors /

manufacturers Barilla, McCains and Nestle, and one farmer-owned cooperative milk supplier and dairy processor Arla. These large companies may have several initiatives in action, the focus here was on their environmental work and of course soil management. Each company saw this as part of their drive to improving the sustainability of the supply chain. They were all strongly focussed on net zero GHG emission reduction targets and therefore efforts to help their farmer suppliers to reduce carbon emissions as well as other environmental impact of the company's supply chain. This was seen as part of reducing the risk for both the farmer and the food company and increasing supply chain resilience. For the farmers involved part of the motivation to engage with the programmes was to secure a buyer for their produce, whilst having guided, often paid-for support and information. Some, e.g. Barilla and Arla, involve the farmer in record keeping and even paying for the analysis and feedback on the data supplied. For the company, especially those dealing with minority and / or crops that were more sensitive to changing growing conditions, the relationship helps to guarantee and future proof their supply chains.

**3** *Other private initiatives*. The other 20 initiatives are distinguished by the fact that they are neither certification based nor associated with a specific company as a key element of the initiative. They are generally spontaneous, bottom-up groups of motivated individuals and farmers, sometimes along with researchers, who have been inspired to come together to develop some aspects of improved soil management. Three sub-groups can be distinguished amongst the 20, although this categorisation is suggestive and not water-tight.

*3.1 Knowledge brokers* (4) – This includes a group of initiatives whose main focus is the development or translation of knowledge to and for farmers. Whilst all the soil initiatives including those in groups 1 and 2 also offer this service, for these initiatives this is their principal purpose. They do not support the marketing of products, certification, access to financing, monitoring or any of the other activities covered by the other categories of soil initiatives. They are either primarily publicly funded initiatives (FRDK, KES Research and the Alpine Soil Platform), or privately funded (Odling i Balans). They all put stress on farmer-to-farmer demonstration activities and work with advisors and local organisations to develop knowledge and translate it for local farmers to implement. Some pursue a specific farming system, e.g. FRDK is a conservation agriculture association, others promote a wider range of SSM practices or holistic management.

*3.2 Broader, more holistic sustainable soil management initiatives* (13) – These organisations all take a broad 'holistic' approach to SSM in some cases going beyond soil management techniques and into wider support such as identifying value added markets, attracting tourism and providing local awareness raising at the community level. They support farmers in the initial planning for change, provide locally adapted information through a wide range of channels e.g. farmer-2-farmer, conferences, training events, workshops, provision of written material. Two-thirds offer some kind of financial incentives to the farmers and all provide some form of monitoring of results. Financial incentives are offered in the form of carbon payments ranging from €22 – €45 per tonne of $CO_2$ equivalent sequestered, to payments for practices that reduce water pollution, results-based payments for biodiversity, low interest loans, the free provision of green manure seeds or hedging plants, and co-funded contributions for landscape structures. The funding structure for the organisations varies greatly, but most have a mix of public and private funding (charitable and companies). Many of the initiatives were set up due to concern regarding the wider impact of agriculture on our landscapes, soils and climate (Gentle Farmers. Better Soils – Better World, Climate Farmers, Commonland) or in response to a local issue such as desertification and fire risk (Alejab, AlVelAl, KES Research), biodiversity loss (Burren programme), water pollution (BSAG and Soil and Water Outcomes Fund), local soil deterioration such as loss or compaction (Alpine Soil Platform, Wijland, Soil Heroes, FRDK).

*3.3 Initiatives with narrower focus on particular forms of farming* (3) – These were set up to advocate a specific social agricultural model. All three organisations are focused on supporting small scale 'peasant' agroecological famers. The initiatives support farmers who are themselves already motivated to pursue the specific farming model. Land access is an important element in all three initiatives, as is information targeted for the specific model of farming, or access to finance. A strong component of all three of these initiatives was the development of networks of likeminded farmers to support and learn from one another.

## Analysis of the initiatives

The interviewed initiatives were involving farmers in fourteen separate SSM practices[281]. Each initiative had a different focus on what combination of these measures they advocated depending on their objectives. Despite this, there were broad similarities across all the initiatives. Of the thirty interviewed, it was possible to identify the principal practices for twenty-five of them. The most common practices advocated were: reduced till (18), cover crops (16), crop diversification (11) and extended crop rotations (10). Nine of the initiatives also encouraged organic additions but this was considered by some of the non-organic initiatives as a high-cost practice. All of the initiatives except the organic certification bodies advocated a gradual upscaling approach to improving soil management over a period of years to enable farmers to manage both the cost and the risk of changing farming practices. In contrast the organisations based around organic certification schemes generally require a sharp switch-over to adopt the full range of prescribed practices including an immediate end to the use of synthetic inputs. The transition is expected to be completed in two years, during which organic transition payments are available.

An activity that was central to all the initiatives was supporting the farmers with practical information. All but one of the initiatives carried out intensive research and brought together experts to translate current knowledge on the practical application of SSM for farmers. Ten supplemented this information with their own local farm trials which doubled as pilot farms or 'lighthouses' for the projects. Eight initiatives provided individual farmers the assistance of expert agronomists for at least the initial entry phase to develop a plan. In all but two cases this cost was either covered by the farmer or deducted from the payment received by the farmer. Two initiatives considered farmers would require initial intensive training and provided free access to holistic training modules. All the initiatives provided a combination of short training sessions (workshops, lectures), farmer to farmer learning and networking, farm visits, written material, conferences and online support.

Payments to farmers was not a predominant theme amongst the initiatives. Nine of the thirty initiatives provided some form of payment, six were carbon payments, and three combined carbon payments with results-based biodiversity and water indicators. All used a results-based system to monitor changes. However, the potential to access carbon markets in the future had been taken into consideration by many of the initiatives involved who were currently taking steps to ensure that their own system of monitoring would enable farmers to provide proof of carbon sequestration to access potential carbon funds.

[281] These were: reduced tillage, organic additions, cover crops, crop diversification, extended crop rotations, livestock integration, sustainable grazing, biodiversity strips, agroforestry, nutrient use efficiency, no fertiliser, no pesticides, reduced fertiliser, reduced pesticides.

None of the interviewees expressed problems with recruiting farmers, and many were oversubscribed. The food companies often had contractual arrangements with their farmers, as did the initiatives that were supporting the farmers with results-based payments. In such arrangements, if the farmer did not manage to adhere to all the requirements of the scheme and were not able to take the suggested corrective actions they risked being dropped from the programme in all cases, and returning funds in the case of carbon payments.

The monitoring of results varied greatly between the initiatives. The certification schemes all require good farm recording and record keeping and had independent monitoring and inspection. Those using carbon payments took soil carbon measurements, but others (2) used self-assessment, and some went much further, measuring multiple indicators including soil biology, structure, erosion, water retention, GHG emissions, biodiversity and soil coverage.

Picking up the ideas of rings of influence introduced in Chapter 3, the soil initiatives exemplify the use of the inner two rings of influence – farm families, and communities to encourage and recruit farmers into the schemes. For example, 12 of the schemes were essentially working at the community level in reaction to a localised problems relating to soil, water or biodiversity and therefore farmers were encouraged to join the schemes as a result of local pressure and awareness. As one interviewee put it, many farmers have felt so blamed for so long for many of the environmental problems we face today, that having a plaque indicating their membership of their sustainability scheme at their farm gate and talking publicly in their locality about their involvement in the scheme helps them restore pride and self-confidence about their profession. Those in the company-linked initiatives were motivated to join because of the influence of the food processors and retailers – the buyers of their products – who were encouraged to effect change due to societal and regulation pressures. Equally growing consumer awareness and self-awareness concerning how our food is produced is encouraging growth in farmers seeking to acquire organic or other sustainability certification and their labels.

Farmer to farmer learning, farm visits, farmer workshops and developing farmer networks were prevalent in all but three of the initiatives.

Almost all of the initiatives interviewed operated at the **community level** of influence. Farmer to farmer learning, farm visits, farmer workshops and developing farmer networks were prevalent in all but 3 the initiatives and were considered a crucial element in supporting farmers to transform their soil management and in recruiting and persuading neighbouring farmers to take up SSM.

All bar 3 initiatives focused on the gradual upscaling of practices; some initiatives went further than others with regard to what they deemed necessary. For example, for some reducing synthetic inputs + flower strips + extended rotations were felt to be enough, while for others reduced till and cover crops were paramount and sufficient. There was great variety in the nature and extent of monitoring between the initiatives, and whether they collected base level performance of famers as they join, so there is little evidence available about the achievements of each initiative and how they compare with each other. It is also difficult to judge if what they are asking from farmers is enough. The variety of the initiatives is a strength in that it reflects the diversity of farming and environmental challenges and the variety of motivations of groups of people and organisations to rise to these challenges. At the same time, this variety and individuality of private initiatives makes it hard measure and pool evidence of their effectiveness in improving soil health.

In summary, just as each farmer has a set of individual beliefs, and there is not just one farm type, soil type or environment, the process of interviewing the soil initiatives for this project has shown that each soil initiative is unique. Each initiative represents a different structure, ideology and approach for dealing with local challenges or specific crops. These correspond to farmers' own motivations, and each goes about addressing the challenge of soil health in a different way. Yet patterns do exist: the importance placed on developing locally applicable information, a flexible and undogmatic approach to which methods should be applied, the importance of monitoring and knowledge exchange, and the consideration that payments, such as carbon payments, have the potential to be a significant hook to engage farmers in SSM that will inevitably and eventually bring them financial benefits.

### A broad conclusion on the role of private initiatives

There is no doubt that the 30 private initiatives presented here are a small sample of the total population of such organisations around the EU. There are organic farming organisations in every MS, and Integrated Farm Management exists in many EU Member States. Likewise, a great many food companies, and not just the big supermarkets, food processors and food service companies are linking back to primary production on farms to ensure sustainable sourcing and in particular to pay attention to the net emissions in the part of the food chain in which they are operating. The third category are harder to define because they have come together for a wide variety of reasons and with an equally wide variety of activities, some with quite specialised and narrow objectives others extremely broad seeking to build and maintain natural, financial and social capital.

All have in common a clear recognition that more should be done to protect soils. Every farmer participating in every one of these initiatives already had access to the public policy measures described in section 4.1, no doubt most are drawing on CAP support payments, and many are enrolled in environment schemes. Yet the very existence of these initiatives, plus the expectation that more will be coming into existence and participation growing, can be interpreted as signs that many farmers feel that public policy alone is insufficient to the task of improving soil management. Coming from the opposite direction, there is little recognition in the Soil Strategy of the existence of this stratum of activity. This seems a missed opportunity. It does mention the Land and Soil Award[282] as an initiative on sustainable soil management that can increase cooperation with the farming community, but forgets about a myriad of other initiatives across the EU. Are there ways in which synergies could be found between these private initiatives and public policies which could extend the reach of the former and the effectiveness of the latter? There are signs that Carbon Farming which offers the prospect of financial gain could also lead to the development of opportunist initiatives. These might put financial gain over soil health and could, if not effectively monitored, lead to a deterioration in some instances of soil health. The management and monitoring of carbon farming will therefore be critical to ensure that this new activity supports carbon sequestration for the long term and soil health. This matter is taken up in the concluding chapter.

## 4.3 Drawing the threads together

This section draws together and discusses the ideas of the preceding sections using the framework of the behavioural model outlined in section 3.1. The framework comprises the three rings of influencers - society, communities and farm families, within which sit three circles of – willingness and ability of farmers to adopt SSM and engagement to help them to do so, utilising nudge principles where appropriate.

[282] Awarded annually by the European Landowners Organisation (europeanlandowners.org)

## The influences of society, communities and farm families

### Society

The discussion starts with the three sets of influencers. At the outermost level, in the EU context, the societal influencers can be thought of having three sub-strata: (i) a top-level stratum of EU opinion and policy within which are (ii) Member State national policies and (iii) the principal national thought leaders and mood setters in the media, amongst intellectuals and scientists, and the national actors in the food industry, farmer organisations and NGOs. While this report focuses mostly on the societal, and particularly top-level, influencers, we also discuss community and family influence and drivers of change.

**EU policy**. The EU has clearly recognised the necessity to integrate environmental considerations including soil management into its major relevant policy the CAP. EU policy has been working on this for more than three decades by seeking to increasingly integrate environmental management into the CAP. These efforts were outlined in section 4.1. In these developments soil management was not overlooked – but neither was it elevated as a strategic priority. Despite these efforts, and the considerable sums of public funds devoted to the measures, evaluations of the outcomes of environmental schemes have been disappointing. Progress has been small, and the cost-effectiveness of many of the measures low[283]. Soil degradation, amongst other environmental indicators, has not been halted far less reversed[284].

Therefore, if soil has been introduced into agricultural policy for so long, it is important to understand why so little progress has been made. No doubt a variety of factors are at work. Despite the efforts of environmental organisations and many groups in society, the *zeitgeist* of the 1990s and even first decade this century, had not accepted the language of 'climate and nature emergencies'. These came later. Sustainability was a common concern, but with limited strategic top-level political backing[285]. The fact that CAP direct payments, with their embedded language of entitlements, and their initial link to commodity production, came to dominate CAP expenditures, also sent the message that the environmental measures were somehow less important. This structural imbalance in the CAP persists, and unfortunately will continue to do so for much of the present decade.

However, the radical new top-level EU societal drive for the Green Deal was launched in autumn 2019 with the new EC. The ambitious EGD and its succession of strategies which focus directly on food, agriculture and land-using sectors indicate a strong top-level influence. The need to act on soils is abundantly clear and this is at the heart of the four strategies for the land-based sector: Biodiversity, Farm to Fork, Forests and Soils. The latter promises a Soil Health Law to come.

**Member State reactions**. Is the new-found ambition at EU level to push strongly for a sustainable food system, which includes a push for SSM echoed by the Member States? How do they view the EGD with its strategies and targets? Do they show a positive determination to have them implemented on the ground? Will the EGD make the necessary strides needed to turn around soil management in the EU?

It is not clear that the MSs do have the same degree of conviction as the EC of the need to elevate SSM high in the agenda. The EGD was well received

**283** EC and Alliance Environnement, 2021 (see ref 94)

**284** EEA, 2019 (see ref 49)

**285** A DG Envi official at RISE Webinar 14/3/22 asked about the failure of 1992 – 2022 policy efforts to stimulate sustainable soil management suggested: The EU rules of the game were not clear, there was no clearly designed concept of soil health and who had to do what to improve it. Nor was it as well understood as now how interconnected soil management is to water quality, biodiversity and climate.

politically at European Council level. But the key political leadership on food and land management at MS level has not so far engaged enthusiastically and constructively with the EGD strategies. It is unfortunate that the latest CAP reform was launched in 2018 by the previous Commission and its negotiation was well underway before the EGD was published over a year later. The result is that that the policy targets proposed in the EGD's strategies for practices that will affect soil management - on nutrients, pesticide and antibiotic use, and for organic farming and protected areas – are not formally built into the CAP reform as binding commitments.

This resulted from the not unfamiliar rather negative approach of the co-legislators, the Agriculture Council and the Agriculture Committee of the European Parliament COMAGRI, to many of the Commission's proposed reforms of the CAP to steer agriculture onto a more sustainable path. In taking this stance the political reaction of the Agriculture Council mirrors the response to the EGD strategies of the principal, conventional, farming organisations[286]. The main argument against the EGD by the farming lobby concerned the lack of impact assessment to determine if the political targets in the EGD were economically viable or indeed, would have the wished-for environmental impact[287]. This leaves a gap in perceptions amongst the actors in this top-level influencing ring. The widely accepted societal discourse mostly outside farming circles accepts the evidence that there is now an imperative to change in the way we farm. There is some general agreement amongst this group that the norm for the future for the food system should be founded on nature-based approaches variously described as agro-ecology or regenerative farming (see section 2.3). But this encounters substantial push-back from the main farmers' organisations who have not been convinced that their conventional farming 'norm' is environmentally unsustainable or that de-intensified approaches such as agro-ecology or regenerative farming are economically sustainable. Their perspective has developed from decades of arguing that food security for a growing global population combined with diet changes which accompany economic development (including an increase in consumption of livestock products) drive the need for constant expansion of agricultural productivity (conventionally measured) and total agricultural output.

The production-oriented viewpoint struggles with the quite different perspective offered by the F2F Strategy and numerous other analyses which point out that the current food system from consumption to production in the developed world is fundamentally environmentally unsustainable. This perspective maintains that it is the current system of environmentally damaging production coupled with unhealthy and equally unsustainable consumption and food waste that pose the real threat to food security. It was for this reason that the EC's food strategy puts sustainable food consumption, food loss and waste prevention, and sustainable food processing and distribution on a par with sustainable agricultural production. From the production side, it proposes a transition path towards sustainable production which "reduces dependency on pesticides and antimicrobials, reduces excess fertilisation, increases organic farming, improves animal welfare, and reverses biodiversity loss". But at the same time argues that "the transition will not happen without a shift in people's diets", suggesting that "while about 20% of the

[286] This refers mostly to COPA-COGECA. Organic farming organisations and Campesina took a very different view.

[287] The subsequent publication of assessments by the US Department of Agriculture (Beckman, J., et al., 2020. *Economic and Food Security Impacts of agricultural input reduction under the European Union Green Deal's Farm to Fork and Biodiversity Strategies*. https://www.ers.usda.gov/publications/pub-details/?pubid=99740) and later in a report for the European Parliament (Guyomard, H., et al., 2020). *The Green Deal and the CAP: policy implications to adapt farming practices and to preserve the EU's natural resources*. European Parliament, Policy Department for Structural and Cohesion Policies, Brussels) served to raise the issue of the food production and price effects of the efforts to de-intensify agricultural production. These were not calmed by an assessment sponsored by the Joint Research Centre which was published later (Barreiro Hurle, J., et al., 2021. *Modelling environmental and climate ambition in the agricultural sector with the CAPRI model*).

food produced is wasted, obesity is also rising. If European diets were in line with dietary recommendations, the environmental footprint of food systems would "be significantly reduced"[288].

Herein lies a mismatch between policy ambition and credible operational policy measures which leads to the clash of views at the outer strategic level of influencers on farmers' ultimate behaviour. It is necessary to unpick this discrepancy to understand if the EGD and its strategies will really be able to make the traction needed on soil health.

The objectives and targets for sustainable agricultural production systems are clear. These are spelled out over five pages in the F2F strategy.

To explain: the objectives and targets for sustainable agricultural production systems are clear. These are spelled out over five pages in the F2F strategy. The overall indicated direction of change is strongly towards less intensive production as enshrined in the quantified targets for: reducing nutrient excess, pesticides and antibiotics, and increasing organic production and protected areas, the deployment of more technology, reallocating some agricultural area to afforestation to create carbon sinks, and removal from production of some other areas in agriculture which are based on peaty soils. In short, the EGD requires some reduction in agricultural area[289] and some reduction in the intensity of use of part of the remaining land.

How does this balance out with the EGD proposals for food consumption? The F2F Strategy has just 1½ pages of suggestions for sustainable consumption and waste reduction. These sections contain fewer proposals that are far less concretely expressed. Three headings are offered on diets and consumption: clearer information to empower consumer food choices; providing minimum mandatory criteria for sustainable food procurement to help regions, cities and public authorities to source sustainable foods; and examination of targeted variable VAT rates to guide consumption of organic fruit and vegetables.

It is recognised that the food industry has a large responsibility for providing healthy products and guiding healthy dietary choice. But in contrast to what are seen (at least by farmers) as strong and concrete proposals on sustainable farm production, the principal proposal aimed at the food industry is the "future development of a voluntary EU Code of conduct for responsible business and marketing practice accompanied with a monitoring framework"[290]. The Code will be developed by the EC with all relevant stakeholders. However, given the reluctance of the food industry to acknowledge its role in encouraging and facilitating extremely unhealthy diets, which have resulted in dramatic societal health costs there appears to be very little confidence that this voluntary and co-developed code of conduct will have meaningful impact.

Simultaneously, the F2F Strategy claims that it seeks to "preserve the affordability of food, while generating fairer economic returns in the supply chain, so that ultimately the most sustainable food also becomes the most affordable". Highly desirable as this is, the combination of proposals to reach sustainable production and consumption lack credibility. The targets on the production side are clear – and if the will in MS exists the apparatus of the CAP could certainly be used to drive through the changes. In contrast, there are no targets on the consumption side and the policy measures are rudimentary.

[288] Quotations from European Commission's 2020 Farm to Fork Strategy, for a fair, healthy and environmentally-friendly food system. https://ec.europa.eu/food/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf

[289] In addition to land switched from agriculture to forestry and rewetted peat, it is expected that making more space for nature on farms also removes some land that has been in cultivation for restoring biodiversity.

[290] EC 2020. *A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system* COM/2020/381 final. (page 13)

There are several aspects to the dissonance this creates. First, the economics of the proposed transition. Internalising environmental externalities by moving to less intensive production systems with lower yields, and doing this over a smaller total agricultural area suggests that the total volume of output is likely to fall – and the total value too unless there is an offsetting rise in unit values, i.e. farm gate prices. From a normative perspective, it would seem reasonable that food prices should rise. The social value of sustainable production would be expected to be higher, the social costs of producing to the higher standards are certainly likely to be higher. In addition, a higher real price of food might also encourage some economising consumption behaviour which could have desired health benefits too. Few organisations advocating the move to agro-ecology, including the EC, confront this issue head on[291]. Empirical support that nature-based food production is likely to be associated with higher prices is shown by the existence of the real (though highly variable) price premia for organic products. But this is a disputed area.

As mentioned by the initiatives interviewed for this report, many claim that implementing SSM is not only environmentally beneficial and better for health but is economically more rewarding too as they claim the savings in expensive input costs, and greater resilience, outweigh the lower average yields. However, the evidence on production costs and margins is mixed and bedevilled by getting sufficient data on agro-ecological system performance and comparable farm systems to compare with, especially if there was a large-scale switch in farm system. Better quantification of the benefits of sustainable farming for the farmer, but also for society measured, for example, as biodiversity protection, reduction in the severity of floods and the associated damage to infrastructure, could contribute to making the case even stronger.

A second concern is that if European farmers follow the path towards agro-ecology and output falls, and if consumption and reduction in food waste adjustments do not come about to the same extent, then EU food imports will rise with the result that more EU food consumption will have been produced to lower standards of soil, climate and biodiversity protection. This defeats the strategic objective of the EGD – and diminishes the EU's domestic agricultural production base in the process.

Real food prices are therefore the core concern, but one that the political process is reluctant to openly discuss. Higher food prices are strongly regressive – just as high energy prices are too. Transition to sustainable energy and food might be expected to raise prices, at very least for the transition period until a new equilibrium is ultimately reached. Without meaningful and substantial adjustments in welfare systems it is very difficult to see how public support can be maintained for strategies which are likely to raise these basic prices which impact most heavily on the poorest in society on a daily basis. Yet welfare policy is out of reach of the EU.

The early 2022 combination of pandemic-induced disruption followed by the Russian invasion of Ukraine precipitated sharp rises in energy and food prices for which all societies will have to device coping strategies for their most vulnerable citizens. It would be intelligent if these welfare mechanisms are designed to include a long-term perspective of helping society adapt to paying the real cost of sustainable food (and energy) production. However, rather than seizing this opportunity to increase uptake of SSM practices, farming organisations are

It would be intelligent if these welfare mechanisms are designed to include a long-term perspective of helping society adapt to paying the real cost of sustainable food (and energy) production.

[291] IDDRI's Ten Yaears to Agro-ecology is a notable exception. This advocates a wholesale transition of European food production to agro-ecology over a ten year period and explicitly acknowledges that this necessitates a significant change in consumption. Unfortunately their analysis is based on biophysical modelling with little reference to the farm and market-level econòmics of the transition. https://www.iddri.org/en/publications-and-events/presentation/ten-years-agroecology-uk

responding by calling to intensify production in Europe to counter reduction in exports from Ukraine and increased production costs. Of course, immediate attention must be given to what are hoped to be relatively short-term (one or two year) supply and price shocks. But this need for emergency action highlights the urgency to make the agriculture system more resilient against future crisis, including the climate crisis. Short termism at this stage, only make the European food system less resilient to growing shocks in the medium and longer term.

It was flagged in section 3.2 that the perceived cost of a transition in soil management is seen as a major barrier to farmers who have little leeway to take on the potential risk associated with changing their system of production. A possible way to reduce the share of increase in prices to the consumer, is to rely on the collective responsibility and contribution of the whole food chain to the transition. This inevitably encourages scrutiny of how value in the food chain is shared between the input suppliers, the primary producers and the downstream processors, retailers and food service businesses. Structurally, farmers are in the least concentrated and weakest position in the chain and returns on total capital involved are lowest. Some farmers can improve their market position by pursuing local markets with local produce. Those adopting SSM may be able to command a better price by labelling this fact. But the mass of the population is inescapably served through the mainstream food chain. The F2F Strategy shows awareness of the weak position of farmers in the food chain but no new remedies for this issue are identified. The F2F Strategy (in its section 2.1) mentions help to: "strengthen their [farmers] position in the supply chain and to capture a fair share of the added value of sustainable production by encouraging the possibilities for cooperation", "monitor the implementation of the Unfair Trading Practices Directive by Member States" and "improve agricultural rules that strengthen the position of farmers (e.g. producers of products with geographical indications), their cooperatives and producer organisations in the food supply chain". All of these approaches have been reviewed many times over. The practical measures are invariably voluntary codes and farmers' perceptions is that little changes on the ground.

**In summary**, the outer ring of political influence ultimately manifests itself in policies. At the top-level the EC, with support from the EU Council, has taken the lead in building from strong general public support for transitions in energy and food (amongst others) to confront the climate and nature crises. This manifests itself in the EGD based *inter alia* on renewable energy and more nature-based food production. However, this strategy seems not to have convinced agriculture ministers and the principal farming organisations essentially around the economic feasibility of the strategy. Until this is resolved it is likely to negatively influence the **willingness** of farmers to throw themselves wholeheartedly into all aspects of SSM.

Before leaving this influencer level it is worth noting the nuanced stance of many, especially large established, companies in the food chain, both upstream and downstream of farming. There are many signs that these organisations are now systematically taking the twin-crises of climate and nature on board. These commercial influencers respond both to the scientific consensus on the crises and public opinion, i.e. their customers, who demand action. Many of these companies are developing their own sustainable sourcing strategies and contracting with their suppliers to adapt their farming methods including soil management. Companies provide information and advice and encourage and facilitate soil testing. These efforts are often sharply focused on climate, i.e. net zero emission targets within their own businesses and those of their suppliers and customers. This could potentially offer a strong route to practically influence soil management amongst the mainstream farming community who supply these companies. However, this is an area where more rigorous monitoring and reporting is necessary to ensure that progress is real across the supply chain, trade-offs are assessed, and that the costs of meeting sustainability requirements are reasonably shared in the food chain.

## Community

Naturally, organisations operating at regional, local and neighbourhood level are themselves influenced by the wider national and international debates just reviewed. These organisations and the people who run them and participate in their activities will display the full range of opinions about those big-picture debates. But what characterises this level is the desire and willingness of participants to get involved and make things happen on the ground to the best of their ability irrespective of the decisions taken at the outer level over which they feel they have little direct influence. Indeed, many of the initiatives interviewed while preparing this report were taken by groups of mostly entrepreneurs, researchers and farmers at this level who are trying to do 'the right thing' almost regardless of what was going on in their capital city or in Brussels. The influence of such initiatives is growing. Some of these may in the future seek support from the EU Soil Mission which has the ambition to establish a large number of lighthouses and living labs to foster the creation and spread of improved soil management. Pooling these public and private efforts could be beneficial to both.

Because agriculture is spatially diffuse, distributed over the whole territory, and operates in fragmented small mostly family units, farmers have always been active in creating social capital. This shows up in farmers networks and discussion groups, research projects, farming shows, and events both professional and social, as well as in the formation of cooperatives, machinery sharing rings and selling groups with more commercial objectives. The newer soil initiatives such as those interviewed created to encourage SSM have swelled the ranks of these farmer-to-farmer groups. The big national farming and land-owning organisations will also typically have their base branch organisation at the community level.

It is at this community level that interaction occurs between farming organisations and the officials from national and regional government, the ministries of agriculture and environment and their agencies, local authorities and also with universities, research institutes and colleges and with the range of professionals advising farmers – agronomists, accountants, land agents. What often matters at this level is who is the trusted 'expert' in the locality – who commands respect? The trusted voices could come from any of these private or public organisations. This in turn will influence the predominant accepted production norm of the locality. And amongst different sectors – livestock, arable, horticulture - there can be quite different dominant views ranging across the spectrum from strict, narrowly defined production efficiency to nature-based regenerative farming and agro-ecology.

## Farming family influences

This is the ultimate decision level at which soil management practices are decided on the ground, year-in year-out. European soil management is mostly in the hands of individual private owners and occupiers of the land, and there is no Europe-wide demand to collectivise land ownership. It is interesting to note that despite the apparent failure of one or two generations of private land managers to do what they often say is their ambition for their period of stewardship – to leave their soils in as good or better condition than they received them - there is no appetite to change the fundamental structure based on private individual land ownership. In addition, a large part of farms in the EU are under tenancy and there are limited incentives to encourage tenant farmers to invest in long term soil health beyond the length of their tenancy contracts. Farming family businesses are highly diverse especially in size and degree of economic dependence on farming. Their family and business objectives are equally diverse, so their reactions to policies and incentives will differ too. Nevertheless, generational differences are significant, and farm system change is much more likely at the point of generation turnover.

Given the influences which surround land managers described above, for the farms producing a large portion of total farm output in the EU, the norm with the perceived 'certainties' offered by the technological comfort blanket developed over the last half-century is still conventional farming. Whilst this norm survives, peer pressure is strongly to stick with it. It takes courage, or perhaps a new incomer to step outside the norm and become the one talked about at the market. Yet the new norm – organic / agro-ecological / regenerative agriculture is out there on the kitchen table and being argued about. Attitudes are different amongst the younger generation of farmers. There is a sense that the farming world has been poised on the cusp of seeking to move-off in the new nature-based direction. This seemed especially so in 2019 as the twin emergencies climbed the political agenda, but risks being pushed away by the Covid-19 pandemic in 2020, and in early 2022 the invasion of Ukraine.

### Implementing SSM: willingness and ability to adopt new practices and engagement

**Willingness of farmers to adopt SSM** – The above influencers together shape the willingness of farmers to adopt SSM practices. It has been seen that there are strong messages now coming from the top policy level, from the voluntary initiatives and from some commercial food companies to move in this direction. To date there is a growing but still minority of farmers who are adopting farm systems which embrace SSM, and, although this is not well documented, there is probably an even larger number of farmers who are adopting some of the practices of SSM but falling short of full system change. However, a tipping point for the farmers producing the majority of farm output to make this shift has not been reached.

Apart from farmers' own beliefs and trust that they are doing the right thing as seen in the society within which they operate, the next requirement for change is that farmers have the confidence that the change is possible on their farms, that it has a real benefit for their farms, and they can find out how to do it. This concerns the ability to adjust.

**Ability to adopt SSM** – at the farm level. The practical constraints to changing farm practices are real. The necessary knowledge of how to manage new soil management practices and fit them into the farm system, any necessary advice and hands-on guidance, any new technology, skills, finance and risk management arrangements will all be aspects whose absence would be likely to inhibit change and adoption of farming practices which are novel to the particular farmer. Chapter 3 drew out the many economic, technical, knowledge, and structural barriers to change. Farmers are well aware of the debates raging round them, but they are even more aware of their own production costs and margins and also how most of their neighbours are reacting to these pressures. The risks of departing from their tried and tested routines are real. There are tangible costs of switching farming system and costs even for adopting individual practices. For many farmers the evidence on the resilience of nature-based systems and how they can reduce long term production costs is 'interesting' but not persuasive enough. It is not simple to switch a farm system. Learning how to grow, manage and profitably sell additional crops in a widened rotation is a big step and takes time and determination to master. Whilst there may well be knowledge and advice available it requires the farmer to be able to overcome a hump of indecision and lack of real conviction that it can work on this farm. For this, it is important that knowledge is co-developed with farmers to ensure that it is not only scientifically sound but also tailored to their conditions and feasible to implement. The structural lock-ins of contractual arrangements, and tenancy agreements are further impediments to change which should be taken into account.

Many of these aspects affecting the ability of farmers to adjust have long been identified and there are many efforts to surmount them and avenues down which farmers can secure help. The soil initiatives interviewed here present sources of real practical, contextualised and tested solutions to this. The largest of these are the established organic certification schemes who are a strong fund of practical information and advice. Knowledge, advice and also financial assistance can also be provided through policy supports. The challenge with public support schemes is to disentangle the positive inducements they can offer for change towards sustainable farming from the long-running and unresolved disputes about the scale and purpose of the (much larger) 'basic' agricultural support payments. These disputes have unfortunately soured the attitude of farmers towards 'government schemes'. The F2F Strategy is alert to the need for "objective, tailored advisory services on sustainable management choices". The Commission is therefore promoting "effective Agricultural Knowledge and Innovation Systems (AKIS), involving all food chain actors"[292] and is hopeful that this aspect will be specifically addressed in the CAP Strategic plans the Member States have submitted. If the Member States CAP Strategic Plans rise to this challenge and take the set-up of AKIS seriously, this has the potential to make a considerable difference to farmers seeking applicable knowledge.

The economic, technical, knowledge and structural barriers are surmountable. Some, like the tenancy arrangements and relations in the food chain, may require collective, even legislative, action but if the will amongst farmers and policy makers was that these impediments to progress should be unblocked, then they could be resolved. If the farmers are able to access (and develop) practical, locally applicable knowledge, had the necessary adjustment assistance to invest in system change, and were unhindered by structural or technical barriers, then the remaining obstacle would lie with the conviction of farmers that the changes could work on their farm and the fundamental farm level economics can stack-up. This takes the story back to the food prices issue and fairness in the food chain.

Even when the **willingness** to adopt SSM in principle is there and the land manager is reasonably sure he has the **ability** to change, the transformation generally will still not happen unless the farmer is constructively engaged with all those he has to link with. Is the engagement process working sufficiently well?

The means for farmer **engagement**, broadly speaking, do seem to be structurally in place. Farmers *are* being reached-out to. It is coming from four directions: public policy schemes at several levels, certification schemes such as organic farming and integrated farm management, company contracts and numerous private initiatives. Perhaps this multiplicity of approaches in itself could represent a challenge. Which approach should a farmer select? Is it possibly confusing that there are so many partners willing to engage and help the farmer adjust? This seems unlikely. There is such diversity in farmer motivations, farm structures and natural conditions that it must be a strength that there is a multiplicity of avenues for help. How the engagement works does matter. Enthusiasm to change can easily be damped by burdensome paperwork, delays and bureaucracy. For which schemes or initiatives is the farmer eligible? This is where the farmer's community level influencers and trusted facilitators play a vital role, as well as farmer's engagement in the decision-making processes regarding the practices to implement.

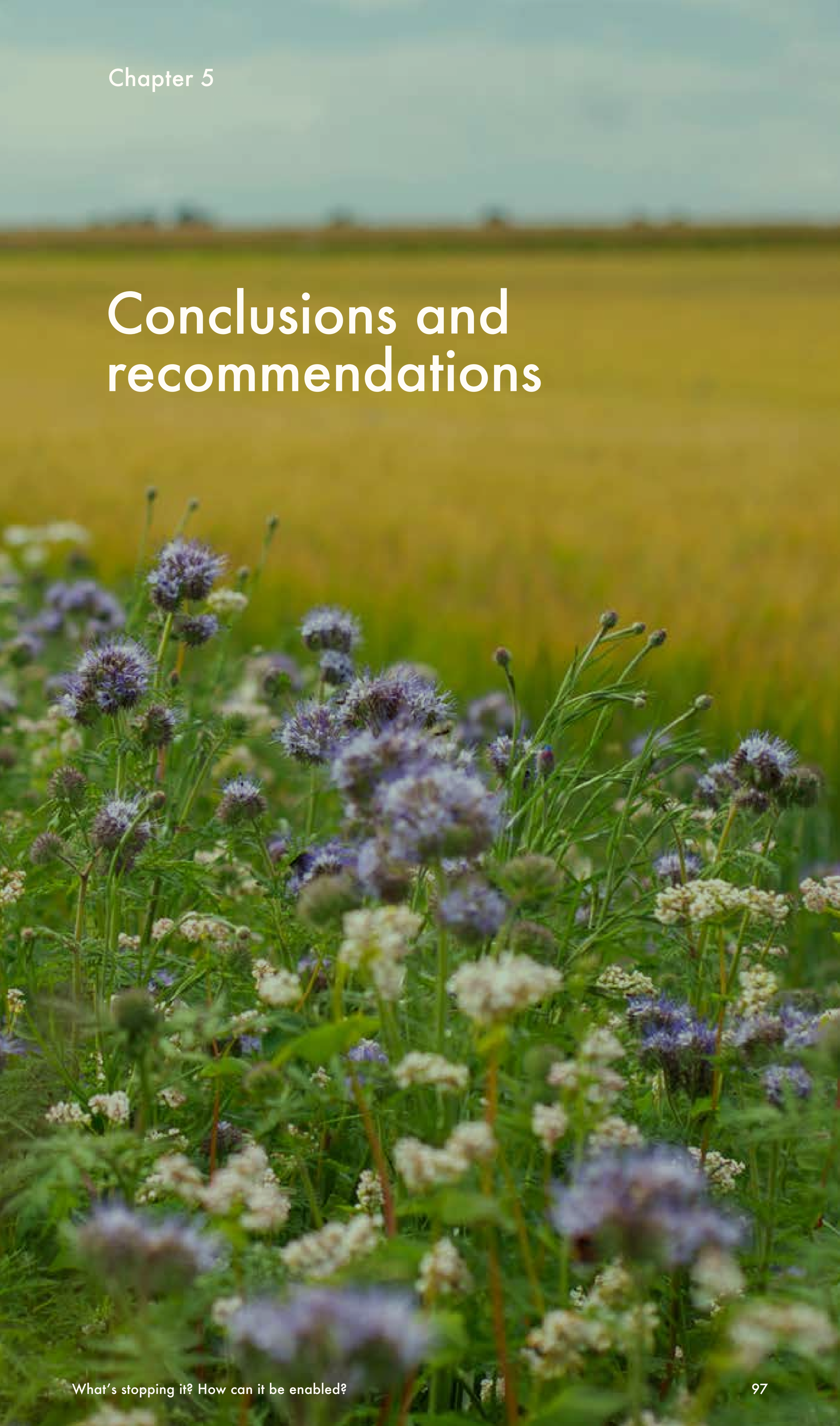
A specific example of where land managers could be paralysed into inaction concerns the attempts to induce farmers to sell their carbon. This area is badly in need of clarity of acceptable practice especially in relation to soil carbon. There are many unsettled questions to resolve: developing the criteria of permanence and additionality, defining and establishing the metrics of carbon sequestration

[292] EC, 2020. *A Farm to Fork Strategy* (see ref 288) p17.

and the verification systems, bringing trade-offs into consideration to avoid a harmful impact on soil health and biodiversity, and defining the way in which public and private payments can be stacked. These can only come from the appropriate competent authority and for the global concern of climate protection this has to be harmonised internationally.

The publicly financed schemes are widening out. Supports from the CAP to adopt sustainable soil practices can be found through cross compliance, the eco-schemes and agri-environment and climate measures. The ideas and practices which make up sustainable farming are becoming understood and accepted part of the agricultural policy scene. Over the 2022-23 period as the new CAP arrangements are designed and implemented, the willingness of the MSs to rise to the challenge and opportunity the Commission has offered them will become clear. Much will depend on the attitudes of farmers and the skills in choice architecture developed by the MS authorities who now have the responsibility to design the policy measures and roll them out. In doing this there is much that could usefully be learned about that from some of the key ideas of Nudge. Two of the most obvious are: make it easy to do the right thing, make the green option the default option; encourage or consider disclosure e.g. of soil related emissions or erosion rates to encourage social pressures; and exploit loss aversion by framing the challenge around what is lost through inaction.

Make it easy to do the right thing, make the green option the default option; encourage or consider disclosure e.g. of soil related emissions or erosion rates to encourage social pressures; and exploit loss aversion by framing the challenge around what is lost through inaction



Chapter 5

# Conclusions and recommendations

This report has laid out in Chapter 1 the threats to soil health. It followed this in Chapter 2 by explaining the already known practices and systems which could reduce or even eliminate the threats. The third Chapter sought to explain what has been learned in the last decade or so about farmer behaviour towards these issues and to understand better each of the main categories of inhibitions to change at farm level. Chapter 4 then provided an overview first of how public policy has tried to influence the adoption of SSM but with rather modest results, and then it illustrated how three broad types of private initiatives are working to bring about change, albeit still at a relatively small scale. These were, first, certification schemes especially organic farming, second private food companies through their efforts to sustainably source food, and third a heterogeneous group of private initiatives, from local to international, which set out to help farmers shift to some aspect of SSM or more holistic landscape management, and to act as knowledge hubs.

The focus of this report is on agricultural soil management. This is a big enough, and independent enough subject to require its own treatment. All analyses of sustainable farming systems devote space to soil management as a critical and indispensable component to get right. However, it is well recognised that although soil is agreed to be fundamental to the production of a very high proportion of food output[293], the way it is managed is just one aspect of a much larger set of considerations which make up a sustainable food system including all actors of the value chain. How these big-picture considerations are addressed will strongly influence the progress made towards SSM.

## 5.1 Key conclusions

- Unless we rapidly reverse the current degradation of our soils, our food production systems will become less productive and increasingly vulnerable to the changing climate and reliant on resource intensive external inputs. This is the key threat to food security and human well-being.
- Agricultural soils in Europe are degrading at an unacceptable rate. 60-70% of all soils in the EU are considered to be unhealthy, and agricultural soils are no exception. One fifth of agricultural land is affected by moderate to severe erosion rates, and 80% are classified as erosion prone. Cropland soils are losing carbon at a rate of 0.5% per year, 50% of peatlands are drained and emitting GHG, 83% of EU soils contain residual pesticides. The impacts of intensive land management on soil biodiversity and the vital ecosystem services it supplies are insufficiently quantified, because the complexity of soil biology and functioning is not well understood, but the impacts are considered strongly negative. Overall, the total costs of soil degradation are estimated to exceed 50 billion EUR/year[294].
- Systemic transformation is required – a holistic whole farm approach, that will require us to consider the whole food system including diets and consumption behaviour as well as structural relations in the food chain. Action on the farm-level production system alone will not be sufficient.

[293] An important part of production of some horticultural, especially salad, soft fruit and other such crops are produced in contained circumstances on coir and other non-soil media. There could well be much expansion of such systems which can very efficiently use artificial light and energy, water and nutrient cycling and biological pest control. Furthermore, they could be significant developments in insect, algal, fungal and cultured protein none of which are directly dependent on soil (although it is not yet known on what media these will be cultivated and the soil dependency of the cultivation of such nutrients). These non-soil dependent developments are unlikely to displace the majority of out door, soil-based, farming in the foreseeable future.

[294] All references can be found in section 1.4

- The soil management practices which can halt and reverse this degradation are sufficiently known to act with confidence. These are keeping soil covered, reducing soil disturbance, diversifying crops and rotations, minimising synthetic inputs and increasing soil organic matter. Locally adapted forms and strategies for implementation need to be developed and tested in close collaboration with all actors of the food system. Coordination at the landscape scale can provide increased benefits for biodiversity.
- These practices can be adopted through whole farm system change to sustainable agricultural systems such as organic farming, regenerative farming or agro-ecology.
- Substantive improvement can be made by adopting combinations of soil management practices short of complete whole farm system change. This gives farmers flexibility and can create synergistic effects. However, only the measurement of the evolution of the soil health will determine if the chosen combination of measures go far enough.
- If we know what needs to be changed, why is this not happening? There are a set of technological, knowledge, economic and structural barriers that need to be overcome at the farmer, food system and consumer levels.
- There is sound, well-evidenced framework explaining influences on farmer behaviour, farmers **willingness** to adopt SSM, the factors affecting their **ability** to adopt these practices and what is needed to **engage** them to consider it.
- A critical inhibitor in **willingness** to contemplate SSM is the lack of conviction that society is prepared to pay for it and to put in place the necessary welfare supports and trade policies to support a sustainable food system.
- Important blockages in farmers' perceived **ability** to adopt SSM are: the economics and risks of sustainable systems, knowledge of how to do it in the local context, and structural features in farmer-buyer contracts, tenancy arrangements and of the food chain itself.
- EU agricultural policy has tried for over 30 years to encourage more SSM but these efforts have been insufficient by mis-directed CAP payments.
- Multiple private initiatives have stepped in to encourage farmers to adopt SSM practices – these are:
    - Certification schemes especially for organic farming and Integrated farm management.
    - Food company sustainable sourcing schemes contracting with farmers to improve environmental management, including soil management.
    - Bottom-up initiatives: ranging from support for conservation (low-till) farming to global schemes to restore degraded lands. Key features of these initiatives are that they are voluntary and provide access to trusted, tailored information and knowledge.
- These decentralised spontaneous initiatives are harnessing energy and enthusiasm and many are successfully working with farmers and achieving positive results. However, their impact currently remains limited, and in most cases, localised. These initiatives are not sufficient on their own. The more successful they are, and especially perhaps the commercially based sustainability initiatives, the more important their transparency and the need for scrutiny to guard against trade-offs and greenwashing.
- With the advent of carbon farming, there is also a risk of unregulated practices (e.g. certain soil amendments) causing greater harm to soils as some farmers may prioritise carbon additions to soil to receive payments, without considering the possible trade off effect on their overall soil health.

- Neither public policy alone, not private initiatives have yet sparked the required transition in production and especially SSM. It is important that both work together to create synergies.
- The European Green Deal (EGD) and its key land-management strategies: Farm to Fork, Biodiversity, Forest and Soil, provide a strong top-level steer and clear targets for the desired direction of change which is to de-intensify some production systems making them less dependent on external inputs.
- There is recognition that food consumption has to be part of the system transformation yet the measures on consumption are unclear and have no targets.
    - In order to internalise externalities society must credibly demonstrate to farmers how the costs will be paid, if necessary, with appropriate cost sharing in the food chain. The EGD could do more to show how this could be done.
    - Just as for energy, a just transition in the food sector will require meaningful adjustments to social welfare policy to ensure the most vulnerable are assisted.
    - Action to drive the changes in dietary habits which result in chronic ill health at large public cost are a further dimension of the necessary package of food system transformation. Reducing food waste is another necessary aspect of moving to sustainable consumption.
- The legal framework for bringing about change in soil management is now set by the 2023-28 version of the CAP with its New Delivery Model. Whilst this offers the necessary tools to transform soil management the responsibility to take this opportunity now lies predominantly with the MSs and their farmers. The signs are not encouraging because MSs Agriculture Ministries, encouraged by mainstream farming organisations, have not enthusiastically embraced the EGD targets.
- The next opportunity for a renewed drive led by the CAP towards a new norm for sustainable production will be in the preparations for the post 2028 CAP, it is not too soon to commence the thinking on this.
- Meanwhile it is possible, and everything should be done, to make significant progress on the adoption of SSM practices through the existing CAP mechanisms such as the eco-schemes.
- A combination of public money through the CAP, if effectively applied, combined with carbon farming payments should be sufficient to cover the costs of the transition to SSM for farmers. However, it should be clearly recognised the continuity of such a transition will only be sustained when the food prices reflect the full social and environmental costs of food production. Governments must recognise and communicate this message and lead the debate on how to make it happen.

## 5.2 Suggested actions to encourage SSM

**Within the mechanisms of the CAP, support and upscale what is already being done on the ground to achieve SSM**

**Provide farmers with locally specific and crop specific information** that has been tried, and scientifically tested at research farms in cooperation with farmers. By already narrowing down what practices will have the most effect and how they should be applied in a context specific situation, the risk to the farmers can be reduced and their motivation to engage increased. Start with universal SSM practices adapted to their local context: keep soils covered, reduce synthetic inputs (fertilisers and pesticides) and increase diversity (in crops and rotations). The information could be compiled by the EIP-Agri groups and distributed through the advisory services.

**Support existing initiatives that contribute to SSM** and the development of local pilot farms and projects – at the regional and MSs level as well as through the EU Soil Mission's lighthouses/living labs. Investigate further the full range of private food sustainability initiatives across Europe which include soil management to discover how they are succeeding or not, how they are measuring soil health improvement, and what if any assistance and coordination of their efforts could multiply their effects.

**Quantify the benefits of sustainable farming and soil health**, for the farmer and for society. This is now limited mostly to carbon sequestration, but the benefits are much broader (reduction in soil erosion, biodiversity protection, reduction in the severity of floods, reduction in damage to infrastructure, to mention a few). Whilst benefits will vary greatly between farms, and regions, the willingness of farmers to take up SSM will be helped greatly by giving them access to concrete examples of real-life farm cost savings, and yield impacts of transiting to SSM in order that they may relate the possible benefits to their own farms.

**Allow the transition to be gradual** and don't be dogmatic about the practices or farming system a farmer should implement, seek to focus on outcomes of healthier soils. Thus, it is unwise to require farmers to immediately and fully adopt no-till farming or complete cessation of using synthetic inputs – allow trial and error.

**Use carbon farming and carbon sequestration initiatives as a motivating force**. But assess trade-offs to ensure that the practices encouraged to improve soil health do not lead to further soil degradation. Farmers are interested in their soil carbon and how much they can sequester. There is a strong research, education and communication task to help land managers understand the complex issue of permanence.

**Work to create an enabling framework and align incentives to mainstream SSM**

**Clarify the sustainable food system model Europe is working towards**: be open and bold about the consumption, food price and welfare changes which will be necessary to bring this about. Integrate policies to make this happen.

**Complete the work of definitions of soil health and metrics**: What is healthy soil and how do we measure it at each scale? Substantive efforts are now underway to resolve this, such work should be given high priority. It should include thorough examination of the numerous indices, and indicators of SSM devised by the private initiatives including certification organisations and food companies. Robust systems to monitor changes should be developed to assess soil health at the local and regional scale. Develop tools to predict how these indicators will change under future management and climate conditions to support planning.

**Ensure the whole food system is onboard**. Farmers are under great pressure from downstream companies to deliver their crops in a certain form, at a certain time, and are reliant on buying in certain products to manage their crops. This is often in detriment to soil health. Adding new crops into rotations will also require opening new markets. The right alignment from markets can also help increase the speed of the transition. Help achieve transparency amongst food industry sustainable sourcing schemes and work towards harmonised and transparent reporting and verification of their outcomes.

**Ensure SSM is a core component of education, advisory and farmer training**. Some initiatives focus already on training advisors that go out in the fields and help farmers implement SSM practices. The CAP offers the possibility to fund this. Include and update soil science courses in higher education, teach about the importance of soils and SSM soil as early as primary schools. Make it mandatory for farmers-to-be to take courses in SSM and natural resource management to understand the links between soils, water, air and biodiversity and the interactions between farms and other ecosystems. Include environmental sustainability courses at business schools to promote the involvement of the whole value chain in developing sustainable business models.

**Get clearer on the mix of incentives in agricultural and environmental policy**. More has to be done to clarify the respective roles of: CAP basic payments with cross-compliance, eco-schemes, agri-environment and climate schemes, private and public C-farming payments, incentives for change of land use (for forestry and peat restoration), and biodiversity offsetting payments by developers. Don't underestimate the challenge of getting the policy signals right and avoiding a muddle which paralyses progress. These are not trivial issues, and many land managers may hold off making what may turn out to be irreversible, permanent, land use changes locking-in the room for manoeuvre for their successors. Consider how to adapt support to ensure both tenants and land owners are equally motivated to improve soil health for the long term.

**Research and resolve the international trade issue**. This is another issue which has the potential to undermine the credibility of EU policy in the eyes of land managers. High domestic standards which effectively diminish EU production in favour of imports from regions operating at lower standards are feared by farmers organisations and inhibit them in engaging in sustainable production. This issue is now on the table through the 'mirroring' ideas of the French Presidency, it requires thorough investigation.

**Increase citizens' awareness on the importance of soils** by sharing success stories and reporting about progress in soil health and its crucial role in relation to human health. Work together with food retailers and food service providers to achieve this.

# Annexes

## ANNEX 1. INTERVIEWS: METHODOLOGY AND QUESTIONNAIRE

### 1 Selecting the initiatives

A selection of initiatives was conducted by making use of our own network, suggestions from the Advisory Committee, suggestions from the contacted initiatives and through internet searches.

### 2 Contact and interview

Each of the initiatives was approached with an email explaining the goal of the study and their specific contribution before an interview date was set. The interviews were semi-formal, 1h conversations based on the questionnaire presented below.

| **S.I.1 Soil Initiative: [name]** | | | |
|---|---|---|---|
| **S.I.2 Sector:** | Private | Civil society | Public |
| | (Food industry, retailer, machinery business) | (NGO´s, non-profit, farming associations/ syndicates) | (Municipality, universities-research institutes, governments) |
| **Date of Interview:** | | | |
| **Interview/Research by:** | | | |

| GENERAL INFO |
|---|
| **G.1 Contact details**<br>1.1 Name<br>1.2 Website<br>1.3 Phone number<br>1.4 Email |
| **G.2 Information source** (website, interview (dates, by whom?...) |
| **G.3 Launch date** |
| **G.4 Managed by** |
| **G.5 Type of initiative** (loan/payment for ecosystem services/food chain incentives/ $CO^2$ compensation/sponsorship/donations...) |
| **G.6 How is it funded** |
| **G.7 Objective** |
| **G.8 Sustainable approach promoted**<br>Regenerative Agriculture, agroecology, conservation agriculture... |
| **G.9 Soil management practices promoted and which, if any are compulsory.**<br>9.1 Farm level (no tillage, reduced tillage, organic amendments, green manure, crop rotations, cover crops, crop diversification...)<br>9.2 Landscape level (keyline design, hedgerows, terraces...)<br>9.3 Others |
| **G.10 ha covered** |
| **G.11 #farmers** |
| **G.12 Does the initiative address social-cultural-informational aspects** to support the adoption of soil sustainable management? How? |
| **G.13 Summary of the project**<br>Why it was set up, to a specific challenge? And how it works |
| **G.14 Do the farmers receive financial incentives?**<br>If so, how are they calculated, how are they paid, over what timeline, are there conditions that need to be met? |
| **G.15 Other incentives** (land value, access to lower interest loans, buyer contracts, higher crop prices, etc.)? |
| **G.16 What is the timeline?** Is there an end date? |

| |
|---|
| **G.17 If there is an end date or objective met**<br>What is the interaction with the farmer after this time? |
| **G.18 What results are monitored?** |
| **G.19 How?** e.g. soil testing, what type, or other aspects (public and private goods) |
| **G.20 Who does the monitoring?** |
| **G.21 Who covers monitoring costs?** |
| **G.22 Perspectives of scaling up/across** |

| COSTS |
|---|
| **C.1 Have they calculated how much it costs the farmer to carry out the required changes in practices? Is there a detailed breakdown?** |
| **C.2 Do they see different timelines for different costs** (short and long term costs)? |
| **C.3 Are there capital costs, how much and for what?** |
| **C.4 If they don't have a detailed breakdown, perhaps they can identify the main cost areas?** And give a ballpark figure |
| **C.5 Are these costs easily covered by the farmer, or is financial support required in their view** (*short v long term/capital v running costs*) n.b. cost can include yield loss |
| **C.6 Risk** actual or perceived risk by farmer<br>6.1 In either case, how do they overcome it in the project? |
| **C.7 Private Benefits.** Have they calculated financial benefits?<br>Do financial benefits overcome costs (long/short term) |
| **C.8 Public Benefits.** Do they see public benefits? What?<br>And to what extent, do they measure these (if not answered above) |

| INFORMATION |
|---|
| **I.1 How to they manage information in the project**<br>(i.e. A manual, expert agronomists working with farmers, demo farms etc.) |
| **I.2 How did they get information to the farmer to join?** |
| **I.3 Do they work to target the consumer? How?**<br>How do they communicate about their work outside their network? |
| **I.4 Do farmers have knowledge/informational needs related to soil sustainable practices and management?**<br>4.1 Do you provide support for capacity building?<br>4.2 If yes, how? |
| **I.5 What are the main information requests they receive from farmers/stakeholders?** |
| **I.6 Do they find the "lighthouse" and "living-lab" approach useful for them?** |

| ARCHITECTURE |
|---|
| **A.1 Are there issues that farmers struggle with due to the "system" of agriculture that may stop them from joining** (machinery, suppliers, buyers, advisors, market infrastructures, peers/family etc.) |

| MOTIVATION |
|---|
| **M.1 How easy has it been to recruit farmers?** |
| **M.2 What is the drop-out rate?** |
| **M.3 What do they think are the key elements of their project that motivate farmers to join and stay with the program?** |
| **M.4 Do they think (or have information on) the number of farmers that continue to apply the practices prescribed in the project even after the payments/incentives/program/initiative have stopped?** |

| POLICY & OTHER BARRIERS |
|---|
| **P.1 Are there policy barriers that need to be addressed?** |
| **P.2 Are there other barriers that:** • Stop farmers joining their scheme or • Make it difficult for those in the scheme to continue applying the practices prescribed? |
| **P.3 What do they think needs to be changed at the European level?** |
| **M.4 Do they think (or have information on) the number of farmers that continue to apply the practices prescribed in the project even after the payments/incentives/ program/initiative have stopped?** |

| OTHER |
|---|
| **O.1 Why do you think farmers stay conventional/do not adopt sustainable soil management?** |
| **O.2** In your opinion, **which other changes not mentioned before should be made to motivate/support farmers to engage in sustainable soil management?** |
| **O.3 Do you know any other European Soil initiative** (private/civil society/public) operating in your country or other EU country **that is worth knowing?** |

## 3 Analysing the data

The information obtained through the interviews was introduced into the questionnaire. When all interviews were finalised, the information in the various boxes was summarised into a document to extract the learnings and establish comparisons and differences between them whenever possible. The results are presented in Chapter 4 in the report.

# ANNEX 2. SUMMARY TABLE OF THE INTERVIEWED INITIATIVES

| TYPE OF INITIATIVE | COUNTRY | START DATE | FUNDING SOURCE | ENTRY PRE-REQUIREMENT | TEST FARM/RESEARCH? | SSM PRACTICES | | | | | | | | | | | | | | | PAYMENT | OTHER BENEFITS (OTHER THAN COST SAVINGS AND PUBLIC GOODS) | | | | | | | | | MONITORING | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Undefined | Reduced tillage | Organic additions | Cover crops | Crop diversification | Ext crop rotation | Livestock integration | sustinable grazing | Biodiversity strips | Agroforestry | Nutrient Use Efficiency | No fertiliser | No Pesticide | Red. Fertiliser | Red. Pesticide | | | Direct support | Training - intensive | Training- short | Farmer to farmer | Farm visits | writen material | Conferencees | Online support | What | Does initiative pay? |
| CERTIFICATION/LABEL-BASED | UK | 1973 | Fees for certification support for organic farming and multiple other labels | Organic conversion+ | No | | | | | | | | | | | | | | | | No | Added value sales | | | | | | | | | Annual inspections including soil testing and verification of practices. | No |
| | UK | 1976 | Charitable + public + membership | Organic conversion+ | No | | | | | | | | | | | | | | | | No | No | | | | | | | | | Annual inspections | No |
| | UK | 1991 | subscription | No – but apply certain measures to achieve certification | n/a | | | | | | | | | | | | | | | | No | Added value sales | | | | | | | | | Self assessment | No |
| | NL | 2019 | Private companies (bank, insurance, water) | No | No | | | | | | | | | | | | | | | | No | Access to impact investors, future access to carbon and biodiversity credit schemes | | | | | | | | | Score system that considers soil health indicators + mngt techniques | No |
| | PT | n/a | Subscription | No | n/a | | | | | | | | | | | | | | | | No | Added value sales | | | | | | | | | Results based. For soil there are 10 criteria | No |
| FOOD COMPANY LINKED | EUR | n/a | Own funding | Grower for company | Yes | | | | | | | | | | | | | | | | No | Contracts 3-5 yrs | | | | | | | | | Not at present | No |
| | UK | n/a | Own funding | No | No | | | | | | | | | | | | | | | | No | Contract | | | | | | | | | Via third party - self assessment and third party visits | No |
| | EUR | n/a | Own funding | Grower for company | | | | | | | | | | | | | | | | | No | | | | | | | | | | n/a | No |
| | IT | 2009 | Own funding | Grower for company | Yes | | | | | | | | | | | | | | | | No | Contract 3 years | | | | | | | | | Cost, $CO_2$ emissions, inputs, yeilds | Yes |
| | NL | 2016 | Public + private companies | No | Yes | | | | | | | | | | | | | | | | Yes | No | | | | | | | | | Soil carbon | Yes |
| | EUR | 1881 | Private | No | Yes | | | | | | | | | | | | | | | | Yes | No | | X | | X | | X | | X | n/a | No |
| OTHER PRIVATE INITIATIVES | UK | 2021 | Carbon credits | No or reduced tillage (under 10cm) | No | | | | | | | | | | | | | | | | Yes - Carbon certificate payments | No | | | | | | | | | GHG reductions and removals at the field level | No |
| | ES | 2015 | Foundations, charitable giving | No | Yes | | | | | | | | | | | | | | | | No | Added value sales, cover crop sales | | | | | | | | | Self assessment results and practices | No |
| | DK | 1999 | Farmers | n/a | n/a | | | | | | | | | | | | | | | | No | No | | | | | | | | | n/a | n/a |
| | DE | 2019 | Private-public | No | n/a | | | | | | | | | | | | | | | | Yes | No | | | | | | | | | Carbon. To be expanded | No |
| | CY | 2019 | EU funds | No | Yes | | | | | | | | | | | | | | | | No | No | | | | | | | | | C storage; water retention; soil activity; biodiversity | Yes |
| | PT | n/a | n/a | No | Yes | | | | | | | | | | | | | | | | No | Added value sales | | | | | | | | | Soil coverage, vegetation, biodiversity. | yes |
| | SE | 1991 | Food business + farmers | No | n/a | | | | | | | | | | | | | | | | No | No | | | | | | | | | Large scale data alalysis | Yes |
| | EUR | 2017 | Institutional (EC) | No | Yes | | | | | | | | | | | | | | | | No | No | | | | | | | | | n/a | n/a |
| | BE | 2018 | n/a | No | No | | | | | | | | | | | | | | | | No | No | | | | | | | | | n/a | n/a |
| | FR | 2005 | Public + suscription fee | Peasant project + contribute to collective working | | | | | | | | | | | | | | | | | No | Access to land | | | | | | | | | System management | No |
| | FR | | Private companies-individuals- public | Follow organic/agroecological farming approach | No | | | | | | | | | | | | | | | | No | Access land and development of local network of like minded farmers | | | | | | | | | No | No |
| | EUR | 2013 | Private-public | No | YES | | | | | | | | | | | | | | | | No | No | | | | | | | | | Social capital, natural capital (soil health, biodiversity, water), financial capital (business dev, profitability, farmer income, return to investors). Indicators adapted to local context | Yes |
| | PT | 2009 | Carbon fund | No | Yes | | | | | | | | | | | | | | | | Yes | No | | | | | | | | | No | No |
| | IE | 2018 | Public- charitable | No | Yes | | | | | | | | | | | | | | | | Yes | No | | | | | | | | | Soil coverage, vegetation, biodiversity. | No |
| | INT | 2019 | Farmers buying soil 'plans' | No | Yes | | | | | | | | | | | | | | | | No | No | | | | | | | | | Voluntary. Limited to # farmers engaged etc. | No |
| | AT | 2007 | Private companies | No | No | | | | | | | | | | | | | | | | Yes | No | | | | | | | | | Soil carbon | No |
| | US | n/a | Public + private companies | No | No | | | | | | | | | | | | | | | | Yes | No | | | | | | | | | Soil carbon, water quality | Yes |
| | FI | 2017 | Grants | No | Yes | | | | | | | | | | | | | | | | No | No | | | | | | | | | Soil carbon and nutrients | Yes |
| | EUR | 2020 | Private companies, public research funds | No | Yes | | | | | | | | | | | | | | | | Yes | No | | | | | | | | | Soil carbon and water retention (to be expanded) | Yes |

## ANNEX 3. INTERVIEWED SOIL INITIATIVES (IN ALPHABETICAL ORDER)

| | NAME OF INITIATIVE | CONTACT FOR INTERVIEW | WEBSITE |
|---|---|---|---|
| 1 | **Alejab** | Manuel Die | www.manejoholistico.net |
| 2 | **Alpine Soil Platform** | Borut Vrscaj | www.alpinesoils.eu |
| 3 | **AlVeLAL** | Alfonso Chico de Guzmán & Elvira Marin | www.alvelal.net |
| 4 | **Arla** | George Morrison | https://www.arlafoods.co.uk |
| 5 | **Barilla** | Ciati Roberto, Leonardo Mirone | www.barillagroup.com/en/purpose/sustainable-sourcing |
| 6 | **Better Soils, Better World** | Azadeh Farajpour Javazmi | www.bettersoil.info |
| 7 | **Burren Programme – Farming for Nature** | Brendan Dunford | www.burrenprogramme.com |
| 8 | **Carbon Action Platform (Baltic Sea Action Group)** | Laura Hojier & Elisa Vainio | www.bsag.fi |
| 9 | **Climate Farmers** | Fabio Volkmann | www.climatefarmers.org |
| 10 | **Commonland** | Victoria Gutierrez & Simon Moolenaar | www.commonland.com |
| 11 | **ELOI** | (not interviewed) | www.eloi.eu |
| 12 | **FRDK – Conservation Agriculture Denmark** | Hans Henrik Pedersen | www.conservationagriculture.dk/frdk |
| 13 | **Gentle Farmers** | Thomas Gent | www.gentle-farming.co.uk |
| 14 | **Graines d'Avenir** | François Wiaux | www.facebook.com/FormationsAgroecologie |
| 15 | **KES Research** | Dimitrios Sarris | www.kesrc.org.cy |
| 16 | **Leaf** | Dawn Terverson | www.leaf.eco |
| 17 | **Maison Paysanne de l'Aude – ADEAR de L'Aude** | Cecile Senegas | www.maisonpaysanneaude.fr |
| 18 | **McCains** | Gerard Dupeto & Niek Engbers | www.mccain.com/sustainability/smart-sustainable-farming |
| 19 | **Nestle** | Olivera Medugorac | www.nestle.com/sustainability/nature-environment/regenerative-agriculture |
| 20 | **Odling i Balans** | Lena Holm & Hakan Wahlstedt | www.odlingibalans.com |
| 21 | **Okoregion Kraindorf Association** | Jochen Buchmaier | www.oekoregion-kaindorf.at/home.html |
| 22 | **Organic Growers and Farmers** | Steven Jacobs | www.ofgorganic.org |
| 23 | **Rabobank** | Harry Smit | www.rabobank.com/en/raboworld/articles/soil-health-for-stronger-farms-we-can-measure-that.html |
| 24 | **Soil and Water Outcomes Fund** | n/a | www.theoutcomesfund.com |
| 25 | **Soil Heroes** | Mellany Klompe & Gina Pattisson | www.soilheroes.com<br>www.soilheroes.com/the-foundation |
| 26 | **Terraprima** | Tiago Domingos | www.terraprima.pt |
| 27 | **Tesco** | Alice Ritchie | www.tescoplc.com/sustainability/taking-action/farming-and-sustainable-agriculture |
| 28 | **UK Soil Association** | Gareth Morgan & Liz Bowles | www.soilassociation.org |
| 29 | **Wijland** | Vincent de Leijster | www.wij.land |
| 30 | **Wines of Alentejo Sustainability Programme (WASP) from the Alentejo Regional Wine Growing Commission (CVRA)** | José Muñoz Rojas | www.sustentabilidade.vinhosdoalentejo.pt |

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Readers should note that the views and opinions expressed in this RISE report are solely those of the RISE Foundation and do not necessarily represent the views of the sponsors, those we thank below, or the soil initiatives interviewed.

## The Advisory Committee

Claire CHENU, Research Director – INRAE (French National Research Institute for Agriculture, Food and the Environment), France

Franz FISCHLER, Former EU Commissioner for Agriculture, Rural Development and Fisheries (1995–2004)

Ana FRELIH-LARSEN, Senior Fellow – The Ecologic Institute, Germany

Luca MONTANARELLA, Senior Expert – The Joint Research Centre, Ispra, Italy

Joris DE VENTE, Tenured Scientist – CEBAS-CSIC, Spain

## The Soil Initiatives (see Annex 3)

## Everyone else

Laurence BRAURE, Origins Programme in France & Belgium – Kellogg's

Per ESPEN STOKNES, Assistant Professor BI – Norwegian Business School

Azadeh FARAJPOUR, Research Institute for Applied Knowledge Processing, Ulm – *Better Soil for a Better World*

Victoria GUTIERREZ, Head of Global Policy – Commonland

Peter HOLLAND, EU Market and Trade Policy Advisor & Government Relations – Cargill

Julie INGRAM, Professor of Innovation for Sustainable Agriculture, Countryside & Community Research Institute – University of Gloucestershire

Jozsef IVAN, Unit D.4. Environment, climate change, forestry and bio-economy, DG Agriculture & Rural Development – European Commission

Gottfried KIRCHENGAST, Professor at the Wegener Centre for Climate and Global Change – University of Graz

Mellany KLOMPE, Director – Soil Heroes Foundation

Professor Dame Theresa MARTEAU, Director, Behaviour and Health Research Unit, Cambridge University

Jane MILLS, Associate Professor in Agri-Environmental Behaviours, Countryside & Community Research Institute - University of Gloucestershire

Gareth MORGAN, Head of Farming and Land Use Policy, Soil Association, UK

Leonardo MIRONE, Group Purchasing Director, Sustainable Sourcing Coordination – Barilla

Claudia OLAZABAL, Head of Unit – Land Use and Management, ENV.D.1, DG Environment – European Commission

Kerstin ROSENOW, Head of Unit Research and Innovation, DG Agriculture and Rural Development – European Commission

Franz RÖSL, Interessensgemeinschaft gesunder Boden e.V

Harry SMIT, Senior Analyst, Farm Inputs and Farming – RaboResearch food and agribusiness, Rabobank

Tiffanie STEPHANI, Director of European Government Relations and External Communications – Yara International