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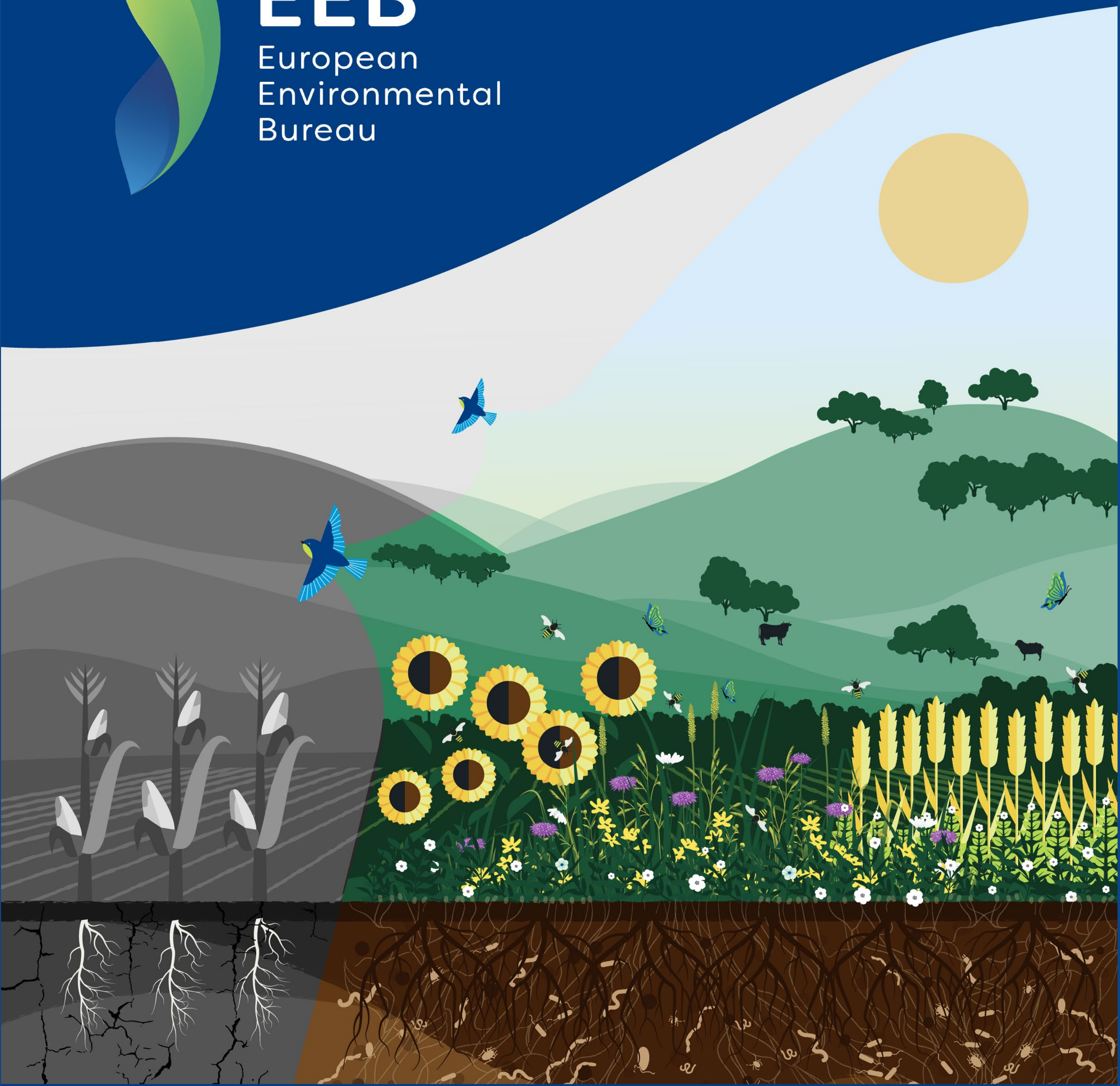

CARBON FARMING FOR CLIMATE, NATURE, AND FARMERS

POLICY RECOMMENDATIONS

We are Europe's largest network of environmental citizens' organisations. We bring together over 170 civil society organisations from more than 35 European countries. Together, we work for a better future where people and nature thrive together.

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Executive summary

Soils at the heart of the climate and nature crises

Climate change and the collapse of biodiversity are intimately connected crises[1]: sharing some root causes and solutions, and interacting through complex feedback loops. Large-scale land use change for agriculture and urbanisation since 1850 and the intensification of agricultural land use in the last 70 years are estimated to have contributed nearly 25% of global anthropogenic greenhouse gas (GHG) emissions[2] and are known to be the most important causes for the collapse of biodiversity[3].

The common denominator is soil degradation, which comes in many forms, including through the loss of Soil Organic Matter (SOM), composed in part of soil organic carbon (further referred to as soil carbon). SOM is the fuel of soil life, which drives the cycling of nutrients and provides crucial ecosystem services. Soil degradation is therefore a major threat. Farmers are at the centre of this challenge, as they manage 40% of the EU's land area, which currently emits around 330 Mt CO_{2e},[4,5] roughly as much as the entire gross emissions of Spain and Estonia combined*.

The new focus on soil carbon in the EU through the "carbon farming" initiative presents opportunities to drive a new positive agenda for soils, with benefits for climate, but also for biodiversity, farm profitability, and resilience, provided the right policy and regulatory framework is in place. This will require, first, to clarify the meaning and scope of carbon farming. The EEB defines carbon farming as land management practices which reduce GHG emissions and increase the sequestration and storage of carbon in soils and vegetation. To do so while also benefitting biodiversity, water, and farmers' livelihoods, carbon farming must adopt a holistic approach towards healthy soils and healthy ecosystems, grounded in the framework of "nature-based solutions".[6]

That means rewetting and restoring drained organic soils (peatlands); managing grasslands in nature-inclusive ways; massively re-integrating trees in agricultural landscapes; and adopting agro-ecological, or regenerative, farming practices on arable land. Deploying these win-win-win solutions could turn agricultural land into a large carbon sink by 2050, while also restoring biodiversity and helping farmers adapt to climate change.

** EU-27 emissions for categories 3.D, 4.B, and 4.C using EEA data for the year 2019, combined with Greifswald Mire Centre calculations for emissions from drained organic soils in agriculture for the year 2016.*

Yet, carbon farming is being introduced in a patchy EU policy context. The lack of an overarching regulatory framework on soils, means the EU has no level playing field for soil protection nor clear and binding targets for improvements. In this vacuum, policy actions are focused on voluntary incentives, with limited impact. Moving forward, the EU must put in place a policy and regulatory framework which will maximise the benefits from action on soil carbon and avoid undesirable trade-offs. To that end, we call on the EU to:

1. Ensure carbon delivers nature-based solutions, benefitting climate, biodiversity, and rural communities.

2. Set legally-binding targets on climate, nature, and soils.

3. Establish mandatory baselines, monitoring systems, and safeguards.

4. Develop a coherent policy mix of effective incentives, mobilising private and public funding strategically.

5. Invest in the enabling factors for behavioural change: knowledge, culture, and infrastructure.

Rebuilding soil carbon for win-win-win benefits

Today's agricultural soils have lost 25 to 75% of their original soil carbon content[7] and continue, on average, to lose soil carbon, although trends vary between soil types, regions, and land use. This staggering historical loss of soil carbon indicates that there may be significant potential to (re) sequester carbon in soils including in agriculture. This is very much what "carbon farming" – climate mitigation through land management practices – is about.

While carbon farming is being promoted as a climate mitigation strategy, soil carbon sequestration has the potential to bring considerable benefits for ecosystems and biodiversity and water protection, as well as to farmers themselves through increased resilience and profitability. This could be a win-win-win scenario.

The EEB defines **carbon farming** as "the management of land-based GHG fluxes, including carbon pools and flows in soils, materials and vegetation, with the purpose of reducing emissions and increasing carbon removal and storage."

This report focuses on carbon farming in the agriculture sector.

The climate mitigation potential of agricultural soils

A distinction must be made between two broad categories of soils: organic and mineral soils. Organic soils are soils with particularly high carbon content in the form of undecomposed organic matter, called peat. Mineral soils contain much less carbon – the boundary is debated, but from a climate point of view should be drawn at 5% carbon content (by dry weight).[8] Organic soils cover only 3% of the EU's agricultural area but are responsible for 25% of emissions from agriculture and related land-use.[9] Mineral soils under croplands are currently a small source of CO_2 and grasslands a small sink[4].

	Grasslands		Croplands	
	Mineral	Organic	Mineral	Organic
Area	90.5 Mha	4.5 Mha	123.2 Mha	1.5 Mha
Emissions	-38 Mt CO_{2eq}	56 Mt CO_{2eq}	23 Mt CO_{2eq}	36 Mt CO_{2eq}

Table 1: Area and emissions of mineral vs organic grasslands and croplands for the EU, UK, and Iceland for the year 2019. Based on data from the European Commission (2021).

The disproportionately high emissions of organic soils are caused by their draining, which brings the organic matter in contact with oxygen, leading to microbial decomposition of the peat and thereby breakdown of the stored carbon, emitting up to 30 tonnes of CO_2 per hectare per year.[9] Experts estimate that emissions from drained peatlands in the EU are about 151 Mt CO_{2eq},[5] nearly twice as high as reported by countries (Table 1). These emissions can be significantly reduced by raising water levels (rewetting), which leads to net removals of CO_2; an increase in CH_4 emissions; and a decrease in N_2O and dissolved organic carbon losses; overall adding up to lower net greenhouse gas (GHG) emissions.[10] Functional, healthy peatlands are the most space-efficient long-term carbon store and sink. Rewetting all drained peatlands used in agriculture would turn them into a net carbon sink, sequestering about 6 Mt CO_{2eq} per year indefinitely.[11]

The picture is very different for mineral soils. Croplands and grasslands under mineral soils can be carbon emitters or sinks, depending on management practices, soil types and climatic conditions. Many studies have sought to assess the carbon sequestration potential of mineral cropland soils through modelling different changes in management practices. Results vary widely, with the most optimistic technical estimates for the EU+UK as high as 295 Mt CO_{2eq} per year[12] and pessimistic economic estimates as low as 9 Mt CO_{2eq}[13]. An EEB study[14] using the ARISE (AgRIculture and food SystEm interactive) model to simulate a transition to agroecology, including through (but not limited to) the deployment of hedges on cropland and grassland, a shift to no or low tillage, and the widespread use of cover crops, found that agricultural land could sequester 150 Mt CO_{2eq} by 2050.

However, there are several caveats. First, carbon sequestration tends to plateau once soils reach their natural level of soil carbon saturation – generally after around 20 to 35 years[15] depending on soil type, starting level of soil carbon, climate, and management practices[16]. Second, once a high soil carbon stock is achieved, the maintenance of good soil management practices is crucial, as soil carbon accumulated over decades can otherwise be lost in just a few years. Finally, there are considerable uncertainties around the impact of climate change - changes in temperature, precipitations and atmospheric CO_2 concentration - on soil carbon fluxes[17].

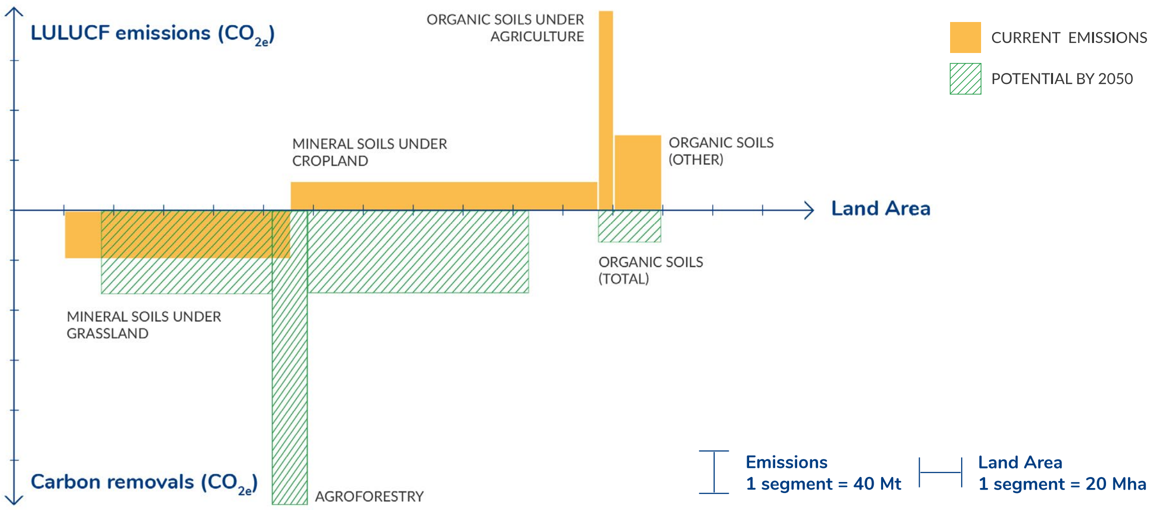

Figure 1: GHG emissions and removals for EU+UK on agricultural land (excluding N_2O emissions reported under agriculture). Current emissions: own calculations based on data from the European Commission[4] and the Greifswald Mire Centre.[5] 2050 potential sequestration: based on EEB pathway,[14] Kay et al.,[44] and data from the Greifswald Mire Centre.[11]

Figure 1 gives an overview of the scale of current CO_2 sinks and sources in agricultural land relative to the land area. This shows clearly that from a climate mitigation perspective, restoring degraded peatlands (organic soils) and protecting healthy ones should be the first priority. Preventing further conversion of grasslands to croplands and ensuring grasslands are managed sustainably is the next highest priority. Soil carbon sequestration on mineral croplands can also contribute to climate mitigation, though the abovementioned uncertainty and caveats have led some researchers to argue that it is more important as a climate adaptation strategy, through the multiple co-benefits of soil carbon for soil functions[18].

The science of soil carbon sequestration

Soils are highly complex ecosystems, where microorganisms interact with each other and with plants in a multitude of ways. Recent advances in soil sciences have found that soil life (from earthworms to microbes) is the primary driver of soil functionalities,[19] including the cycling of carbon and other nutrients.[20] Soil organisms are constantly breaking down organic matter (plant residues, dead roots, etc), releasing nutrients to plants, respiring CO_2, and contributing to the soil carbon pool through their excretions and dead cells. There is no such thing as a “stable carbon pool”, as SOM is made up a continuum of carbon in progressive stages of decomposition, being constantly processed by soil organisms.[21] In soils depleted in organic carbon, organisms are starved, and these processes are slowed down. Healthy soils contain more carbon, but also emit more CO_2 through enhanced microbial activity; carbon sequestration is all about net fluxes. These new insights have been dubbed a “quiet revolution”, as they challenge major assumptions which soil sequestration models were based on.

Traditional climate models ignore the role of soil microbes in C and N cycling. As a consequence, these models tend to overestimate soil carbon sequestration and underestimate soils’ CO_2 emissions,[20] but also overestimate nitrogen scarcity as a limiting factor for carbon sequestration[22]. Such models also struggled to predict the impact of future warming on soils’ carbon fluxes[23].

This new understanding of soil carbon dynamics is leading researchers to the conclusion that nearly all organic matter entering soils will get digested by microbes (and eventually re-emitted), unless it binds to minerals. SOM could therefore be conceptualised as coming in two main forms: particulate organic matter (POM), mostly composed of plant residues, and mineral-associated organic matter (MAOM), mainly consisting of the coating of soil particles derived from dead cells and by-products of

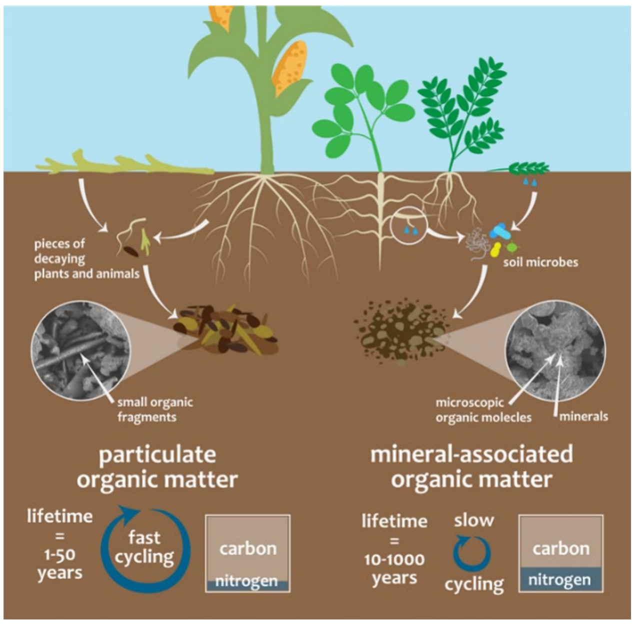

Figure 2: Different forms of soil organic matter. Source: The Conversation. © Jocelyn Lavallee

microorganisms and compounds produced by plant roots (Figure 3).[24] Whereas POM is relatively quickly decomposed by microorganisms and sensitive to environmental changes and agricultural practices[25], MAOM cycles very slowly and is less vulnerable to external changes, making it a good potential long-term store of soil carbon.

The carbon cycle is closely linked to the nitrogen cycle. SOM contains both C and N, in different proportions for POM and MAOM. This means that different amounts of N are required to sequester a unit of C depending on the share between MAOM and POM, which varies between ecosystems.[26] The relationship also goes the other way: changes in soil C turnover feed back into the N cycle, meaning that soil carbon sequestration could be enhanced or offset by variation in N_2O emissions.[27] Understanding these dynamics is crucial for effective carbon farming strategies. This new knowledge will also need to be integrated in soil carbon sequestration models. First attempts at integrating microbial processes in soil C cycling[23] and vegetation models[22] show promising results, but much more work is needed.

The co-benefits of soil carbon

While science explores these complex systems, one thing is already clear: **the key to soil carbon sequestration lies in the life under our feet; and when soil biodiversity thrives, so do we.** Soil organisms are not only central to the cycling and accumulation of SOM, but also provide crucial ecosystems services: plant nutrition, water regulation and purification, climate regulation, nutrient cycling, and hosting soil life[28] – all very important for sustainable and productive agriculture. For this reason, boosting soil carbon sequestration – especially in degraded soils, which most of the EU's agricultural soils are – can bring many co-benefits for farmers, mostly mediated by soil biodiversity, including improved soil fertility, resistance to pathogens and pests, resilience to extreme weather events, and nutritional quality.

Increased resilience

Soils with good levels of organic matter perform better than those with lower SOM at retaining water and nutrients, achieving efficient drainage and aeration, and minimising topsoil erosion[29]. This in turn reduces nutrients runoff, stabilises yields, and improves resistance to extreme weather events including droughts and floods. These benefits stem primarily from the important role of SOM in maintaining good soil structure. In light of the increasing frequency and intensity of droughts and heavy rains, improving soils' ability to absorb and retain water is crucial.

Higher soil fertility, lower need for fertilisers

Good SOM levels are also a prerequisite for soils' capacity to host biodiversity, including 'decomposers' – organisms which drive the recycling of nutrients. Plants also collaborate with mycorrhizal fungi, to which they provide carbohydrates (exudates) in exchange for nutrients (nitrogen, phosphorus, etc.) and water. These fungi can increase the surface area of the root system by as much as tenfold, doubling or tripling the uptake of nutrients per unit of root length[30]. Research has found that soils with a diversity of fungi species decompose more organic matter and produce more nitrogen compounds in the soil than species-poor soils.[31] These biologically-mediated benefits from SOM can greatly reduce the need for fertilisers.[32] Researchers found that increasing SOM in degraded agricultural soils could supply enough plant-available nutrients to maintain crop yields while cutting N fertiliser inputs by up to 70% in intensive systems.[29]

Restored functional biodiversity, lower need for pesticides

Soil life also plays a central role in the biological control of pests and diseases. Recent discoveries in soil biology found that plants actively produce carbon-based metabolites called 'root exudates' to attract beneficial fungi and bacteria with whom they work in symbiosis for their nutrition and to ward off pathogens.[33] Beneficial bacteria attracted by exudates play a crucial role in plants' "immune system" both below and above ground.[30] Restoring soil life is also an essential first step towards restoring healthy agro-ecosystems, which bring further pest management benefits. Recent research showed that by applying a combination of soil (reduced tillage), crop (diverse rotation) and landscape (small field size) management practices, wheat farmers can achieve high productivity without relying on agrochemical inputs[34]. Similarly, a global meta-analysis found that the simplification of agricultural landscape has negative impacts on crop yields by reducing the species richness of beneficial organisms[35].

Improved nutrition

The large increases in yields over the past century have massively increased the calories available for human nutrition. However, there is evidence that this has come at the cost of a loss in the density of crucial micro-nutrients and that this is partly due to lower SOM levels in most intensively managed agricultural lands. Healthy soils do not only provide macro-nutrients (nitrogen, phosphorus, etc) to plants but also boost plant absorption of micro-nutrients, which are crucial for human nutrition[30,36]. This highlights the need to look beyond yields and calories in the quest to achieve global food security and nutrition, and the importance of rebuilding soil carbon not only for agronomic and environmental purposes, but also for human health.

Soil carbon as a catalyst for the agroecological transition

The intensive management of the majority of the EU's farmland is driving widespread soil degradation.[37] A quarter of EU agricultural soils are compacted; a recent survey found pesticides residues in over 80% of soil samples; and cadmium and copper are also known to accumulate in soils[38]. Scientific understanding of the impact of this pollution on soil life is still limited, though some studies have found a negative impact of certain pesticides on soil microbial density and activity[39], and of heavy metals and nanomaterials pollution on microbial diversity.[38] Severe erosion in the EU is estimated to cost €1.25 billion per year in yield losses (with even higher costs to society as seen during the floods of July 2021 in Belgium and Germany) and soil compaction can reduce yields by up to 15%.[38]

The economic case for preventative and restorative action couldn't be clearer, yet change is slow in coming. The dominant focus on technological solutions which boost the efficiency of production (e.g. precision farming) as a means to reduce environmental pressures from agriculture falls short when it comes to soil and ecosystems protection and restoration[38]. A more fundamental change in farming practices, such as a shift to agroecology or regenerative agriculture, is necessary to achieve soil health and restore biodiversity below and above ground.

As SOM-building management practices are essentially the basics of agroecology (see next section) and farmers are increasingly interested in the potential of soil carbon sequestration to improve their farm profitability and resilience, carbon farming has the potential to become a major catalyst for the agroecological transition of EU agriculture. Rebuilding SOM requires a very different approach to agriculture and strong knowledge of soil biology and ecology. Because soil biodiversity is so central to SOM accumulation processes, agriculture can no longer be seen in purely linear, chemistry-driven terms – looking only at the input of macro-nutrients (nitrogen, phosphorus, potassium) and the output in yields. Biology, ecology, and circularity enter the picture. And once farmers start on the carbon sequestration journey, their new understanding and appreciation of soils as complex ecosystems could become truly transformational.

Agroecology is “the science and practice of applying ecological concepts, principles and knowledge (i.e., the interactions of, and explanations for, the diversity, abundance and activities of organisms) to the study, design and management of sustainable agroecosystems.”

Regenerative agriculture is centred around restoring and revitalising the soil and wider environment to support productive farming. It is based on five core principles:

1. Keeping the soil surface covered as much as possible
2. Limiting the amount of physical and chemical disturbance of the soil
3. Combining a wide diversity of plants to increase soil biodiversity
4. Keeping living roots in the soil for as much of the year as possible
5. Integrating grazing livestock into the system.

Carbon farming as a nature-based solution

While soil carbon is considered a good proxy of soil health, it is important that it remains a means to a bigger end, rather than becoming an end in itself. The soil carbon sequestration drive is largely motivated by climate mitigation intentions. Yet, nature restoration, climate adaptation, nutrition security, and rural livelihoods are equally important concerns. These issues must be fully integrated in the EU's carbon farming agenda to deliver win-win-wins for climate, nature and people.

This is very much what "nature-based solutions" are about – defined by the European Commission[40] as:

> *"Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience [...] through locally adapted, resource-efficient and systemic interventions."*

In what follows, we outline what a nature-based approach to carbon farming should look like.

Protection, rewetting, and restoration of peatlands

As argued above, organic soils (peatlands) should be the EU's top priority for carbon farming. Healthy peatlands should be given strict protection and their sustainable management should be financed adequately including through the CAP. Peat extraction should be phased out by 2027 at the latest and drained peatlands should be rewetted and restored, then either taken out of production and rewilded, or managed through what is known as "paludiculture"[41]: productive land use of wet peatlands, through the cultivation of crops adapted to high water levels, such as reed, cattail, black alder and peat mosses. The products of paludiculture can be processed to

use as insulation and construction materials, growing media, replacement for single use plastics (e.g. disposable bio-based plates or cups), or livestock fodder.[9] Wet peatlands can also be used for grazing by specific breeds adapted to wet conditions. Healthy peatlands are a major ally not just for climate mitigation but also adaptation, as natural "climate buffers", protecting both from droughts and floods.[42] Providing financial support and training to farmers and other land managers is crucial to enable them to shift to this sustainable form of peatland management, though in the medium-term, voluntary incentives should be complemented with more compelling policy measures, including regulation.

Re-integration of trees on farmland

Agroforestry, the integration of trees into productive agricultural landscapes, offers ecosystemic, resilience and productivity benefits to farming systems.[43] Agroforestry comes in three major varieties: silvo-arable systems (tree and shrub alleys, hedges, and windbreaks in cropland), silvo-pastoral systems (grazing in parklands such as the Iberian *dehesas* and *montados*, mountain pastures, and forest grazing), and polycultures (horticultural systems and homesteads). Incorporating trees in agricultural landscapes increases carbon sequestration per hectare through the carbon sequestered in the tree biomass, the inputs of leaves and branches on the soil, and the incorporation of roots into the deeper layers of the soil. Applying agroforestry systems to just 9% of agricultural land in Europe identified as "priority areas"[44] could sequester up to 235Mt CO_2 (17 t CO_2/ha) per year, nearly half of current emissions from agriculture and related land use. Because agroforestry systems pump carbon into much deeper soil layers than grasses or crops, they bring better guarantees of permanence than other soil carbon sequestration solutions.

In addition to its huge climate mitigation potential, agroforestry brings major benefits for farmers and the wider environment, including through by buffering of storms and droughts,[45] boosting soil fertility,[46] capturing excess nitrogen,[47] helping with pest control,[48] reducing wind and water erosion,[49] limiting the risk of large wildfires,[50] boosting dairy and meat production in grazing systems,[51] and offering new income streams for farmers (e.g. production of fruits, nuts, or timber). Most importantly, agroforestry systems raise the full system productivity of a plot (i.e. the total biomass produced by the land) by up to 100%.[52] Yet, farmers face major administrative and financial hurdles when trying to establish trees in their farms. The European Agroforestry Federation has proposed 15 recommendations to encourage farmers to add trees to their systems with a minimum of bureaucracy.[53]

Nature-inclusive management of grasslands

Grasslands are a crucial part of the climate and biodiversity puzzle: when managed sustainably, they are both a major carbon sink and an important habitat for biodiversity.[54] Converting as little as 5% of grasslands to arable land would lead to losses of more than 300 Mt CO_{2eq} over the next 50 years,[55] whereas restoring diversity to intensive grasslands could deliver significant carbon removals.[56] Yet, semi-natural grasslands are threatened by both abandonment and management intensification. Protecting remaining biodiversity-rich grasslands, preventing the conversion of grassland to arable land, promoting additional conversion from arable to grassland (e.g. permanent buffer strips), and mainstreaming more nature- and climate-friendly management of grasslands are key priorities for protecting and enhancing carbon sinks.[57]

While ruminants have a key role to play in the maintenance of grasslands, fundamental changes to how most farm animals are reared in Europe are required to achieve climate, biodiversity, circularity, and zero-pollution objectives. Farmed animals currently consume almost 60% of cereals and 70% of oilseeds available in Europe, driving high demand for arable land for feed production, with disastrous impacts on biodiversity, soils, water and air quality, and climate.[58] There is strong scientific consensus that the high levels at which animals are farmed in much of Europe are unsustainable, and experts have estimated that to bring animal farming within planetary boundaries, Europe should reduce its livestock herd by half.[59] This would allow to move to primarily grass-fed dairy and beef production, with nature-friendly grazing systems such as extensive, rotational, or holistic grazing. This would be highly beneficial also in terms of carbon sequestration, as shown by Table 2.

Mean soil organic carbon content in topsoil	
High Nature Value mires and heathlands	132 g kg^{-1}
High Nature Value natural grasslands	68 g kg^{-1}
Pastures in intensive agricultural areas	59 g kg^{-1}

Table 2: Mean soil organic carbon content in topsoil of different types of grasslands, from Burrascano et al. (2016).

Re-integrating farm animals in arable farming systems (mixed farming) is also crucial for nutrient and soil health management. This contrasts strongly with approaches focused on efficiency improvements to maintain production levels while reducing environmental impacts, which fail to address the fundamental unsustainability of intensive animal farming in terms of biogeochemical cycles, biodiversity, and food-feed competition for land in the context of a growing world population.

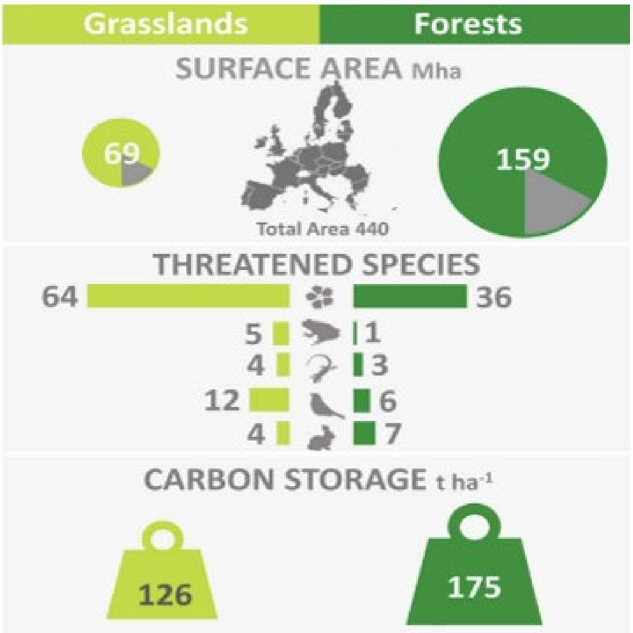

Figure 3: Biodiversity conservation and carbon sequestration in European grasslands and forests. Adapted from Burrascano et al. (2016)

Boosting the conversion of grasslands to forest could be highly misguided, both from a climate and biodiversity perspective. While afforestation increases carbon stocks in living biomass, studies have shown that, in pastures, this may be offset by a decrease in soil carbon, especially in moist regions and if conifer trees are planted.[54] In addition, as semi-natural grasslands are an extremely important habitat for biodiversity, with many grasslands species threatened by extinction, further afforestation of such areas would have very negative impacts on biodiversity. Figure 3 summarises key climate and biodiversity indicators of grasslands and forests, highlighting the importance of grasslands on both counts.

Agroecological management of croplands

Finally, maintaining and enhancing soil carbon levels on arable land is also an important avenue for climate mitigation and adaptation, and as a first step towards the restoration of agro-ecosystems. As current trends show a continuous loss of soil carbon due to intensive agricultural management, and future climate change is expected to increase the mineralisation of organic matter[57], this will be a key challenge.

Soil carbon sequestration requires to boost soil carbon flows by creating a positive balance of C inputs to soils (from plant growth and organic amendments) compared to losses of C from soils (through harvest and emissions). The key land management practices[55,60] to achieve this include include cover cropping, wide crop rotations including nitrogen fixing crops, and ley cropping (integration of temporary grasslands in the crop rotation). Reduced- or no tillage tends to improve soil carbon too, but is particularly important to reduce the detrimental impacts of ploughing on soil biology and structure. Adding organic matter to the soil by leaving crop residue on the field, applying mulch or composted biowaste, or integrating livestock in the rotation are also important ways to increase soil carbon levels and to substitute energy-intensive synthetic fertilisers. However, the application of additional biomass does not necessarily lead to net sequestration benefits as it may cause 'carbon leakage', so a holistic approach is crucial.

Unsurprisingly, it appears that the practices and systems which hold the highest potential for soil carbon improvement are those which form the basis of agroecology. This explains why organic farming tends to lead to higher soil carbon in topsoil than conventional farming.[12] In contrast, very intensive conventional production systems tend to perform worst in terms of soil carbon and GHG balance due to the high extraction of biomass and increased machinery use.[61] In a study of 15 European crop sites, researchers found that emissions from the use of machinery, the manufacturing, transport and storage of pesticides and fertiliser, and the use of irrigation accounted on average for 15,6% of the field's net GHG budget, while N_2O emissions from fertilisers and crops residues represented another 16.4%.[61] This highlights the importance of considering the whole farm GHG budget when assessing sequestration benefits under carbon farming schemes.

Closing the nutrient cycle

A technological solution proposed by some to sequester carbon in agricultural soils is the use of biochar (biomass pyrolised into a coal-like substance). Biochar seems promising: studies have shown positive impacts on soil health,[62] N_2O emissions reductions,[63] and crop productivity,[64] and it appears highly stable in soils.[65,66] However, research also shows that the environmental impacts of biochar are highly variable, depending on soil properties and biochar production methods and feedstock.[67,68] Similarly, life-cycle assessment studies showed that the total GHG balance of biochar is not always a net sequestration benefit.[69] While some studies have found very optimistic climate mitigation potential,[70] others did not.[71] There is also very limited knowledge of potential contamination risks.[72] Pyrolysis can produce carcinogenic polycyclic aromatic hydrocarbons, which could be emitted during production or released to soils by biochar. These risks require robust rules to ensure clean and controlled processes, yet only a private standard exists to date. Finally, the question of feedstocks is crucial, and this links to the wider question of biomass use hierarchy and circularity.

The EU agri-food system is currently largely linear, with high inputs of nutrients (mostly as manufactured fertilisers and livestock feed imports) and high waste and pollution. The continuous loss of soil carbon on much of the EU's land is a logical outcome of an extractive bioeconomy, where biomass is exploited unsustainably and biowaste is not sufficiently brought back into the system. To restore sustainable nutrients cycles (C, N, P), policymakers must recognise that biomass can only be used sustainably within the limits of ecosystems' biocapacity and according to a hierarchy of use:

1. Providing sustainable and healthy food to local populations,
2. Feeding farm animals (treated food waste, grass, some crop residues),
3. Returning nutrients to the land to maintain the fertility of agriculture and forest soils,
4. Producing bio-based materials to replace less sustainable materials (eg. bioplastics or in construction),
5. Producing energy, respecting strict sustainability criteria.

Cycling nutrients back to the land is currently the missing link in conventional farming, as synthetic fertilisers are easier and cheaper to use. Yet, improving the recycling of biowaste through composting can contribute to climate mitigation[73] and circularity objectives[74] by replacing GHG-intensive N fertilisers, boosting soil carbon sequestration, substituting peat in horticulture, and producing biogas. While biochar partially returns biomass to the land, it does so after a highly energy-intensive pyrolysis process, and in a form not available to soil organisms or plants – as "dead coal". As a consequence, additional fertilisation can be required to avoid N and P deficiencies in crops after biochar application.[75] The additional benefits from this transformation compared with using the raw biomass as soil improver directly or after composting are therefore unclear. In sum, given these risks and uncertainties, further research into the pros and cons of biochar is necessary, but in any case, whether from a climate mitigation or soil conservation perspective, biochar should only be considered as part of a holistic approach to biomass and soil health management.[72]

Policy context

The current policy and legislative landscape surrounding soils is strikingly underdeveloped. A patchwork of EU and national environmental and sectoral laws and policies touches on soil matters, but there is no overarching, coherent legal framework. In the absence of European legislation focused on soil, many soil threats remain unregulated and many soil functions unmonitored, leading the European Environmental Agency (and many others) to conclude that "the absence of suitable soil legislation at the European level contributes to the continuous degradation of many soils within Europe"[38].

The baseline of mandatory practices and standards to protect soils is very weak, while policy action is focused on voluntary incentives, with limited impact. The new EU Soil Strategy will likely not change this. In sum, this gives the picture of inverted pyramid (Figure 8), precariously balancing on its pointy end.

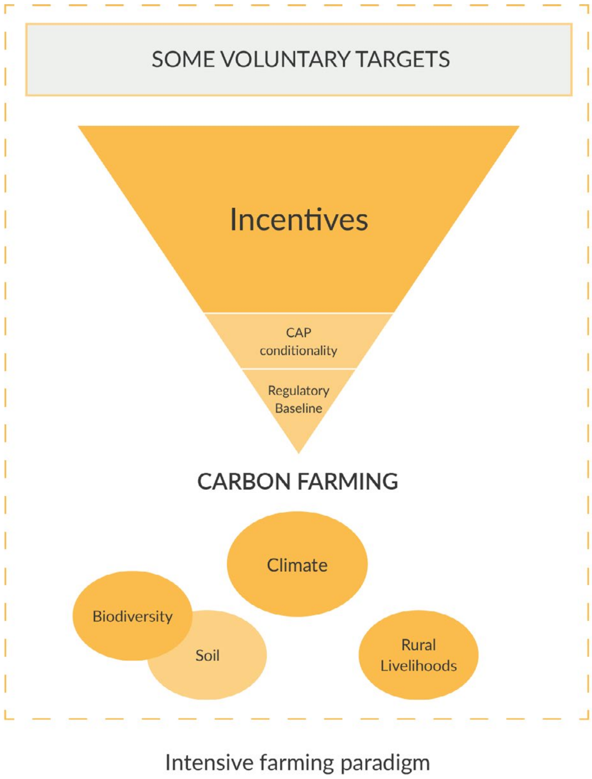

Figure 4: Current policy landscape

Wobbly foundations

No binding targets

EU governments have made a plethora of voluntary commitments around soils in the past decade, for example 'no further degradation of soils' under the Soil Thematic Strategy or 'restoration of 15% of degraded ecosystems' under the Biodiversity Strategy to 2020. However, these aspirational targets have so far largely failed to materialise and mandatory targets are scarce. EU climate legislation imposes a "no-debit" rule on land use and forestry emissions, but accounting tricks allow net losses in GHG removals and the absence of a specific target for agricultural land means there is no obligation to address the continued decline of soil carbon on farmland. EU environmental laws such as the Birds & Habitats Directives or Water Framework Directive contain some binding mechanisms to protect and restore certain ecosystems, but this is not leading to large-scale restoration of key carbon sinks due to their limited scope and weak enforcement.

Weak mandatory protection

The lack of overarching soil legislation would not be such a problem if sectoral policies and laws ensured effective protection of soils within their scope. However, when it comes to agricultural soils, the most relevant policy, the Common Agricultural Policy (CAP), falls direly short. The effectiveness of CAP rules depends on national or regional implementation choices. Consequently, there is no level playing field amongst Member States and soil protection rules are generally very unambitious and disconnected from the level of local threats to soil health. The official evaluation study of the CAP's impacts on soils found that soil-related mandatory standards under cross-compliance did not deliver significant impacts, with only some positive impacts from the biodiversity- and water-related standards, while major soil threats such as compaction and salinisation are not addressed at all.[76] Outside the CAP, some EU laws provide indirect, but very limited, protection to soils, e.g. by regulating air pollution or nitrates leaching.

Poor data collection and monitoring

EU countries are not legally required to monitor key soil threats (erosion, compaction, etc) or attributes (pH, nutrient content, etc), and the EU does not have common indicators and methodologies to monitor soil health. The resulting lack of high-quality and high-resolution data is a major obstacle in tackling soil degradation and in monitoring the impact of relevant policies such as the CAP[76]. The Land Use and Coverage Area frame Survey (LUCAS), gathering data from over 250,000 sample points, which started in 2009 and has gradually expanded since, is a major step in the right direction, but remains too little.

Even under the climate reporting framework, rules for land use emissions reporting are lax and many EU Member States (MS) still use very inaccurate emissions factors, or do not report at all on certain aspects. In the 2021 GHG inventory report[4], 7 MS did not report on changes in soil carbon in mineral soils under croplands, including Germany and Italy, and 17 MS did not report on changes in soil carbon in mineral soils under grasslands, including France, Denmark, and the Netherlands. This is despite accounting for cropland and managed grassland having become mandatory for all MS from 2021. Emissions from drained organic soils used in agriculture are also inadequately accounted, as several countries underestimate the area of organic soils under cropland or grassland, and some fail to report on CH_4 emissions from these soils.[8] Accounting of GHG from managed wetlands (outside agriculture) will only become mandatory in 2026.

Patchy incentives

The primary focus of EU policy action for carbon farming is in providing incentives and "business models" for farmers to sequester carbon in their soils. Yet, current measures in the CAP have been found to have very limited impacts, while the new drive for carbon markets comes with many potential issues.

Untargeted and ineffective CAP schemes

Greening has been largely found to be ineffective, including for soil protection, as MS implemented it so as to ensure farmers would have to change as little as possible to meet the criteria. Instead, MS have relied on voluntary agri-environment-climate measures (AECMs) to address soil issues. Here, evaluators found positive impacts, though only very locally and with poor targeting of where the needs were highest.[76] On the other hand, they also found negative impacts from some CAP measures, such as investment support for heavy machinery contributing to soil compaction, and a possible link between income subsidies and the intensification of land use. Finally, they concluded that the CAP has failed to provide a safety net for farmers wanting to take risks and switch to regenerative farming practices.

A free for all rush to carbon credits

In light of the failure of the CAP to meaningfully drive climate action in agriculture, policy-makers are turning to alternative financing opportunities. At the same time, businesses across the world are eyeing the potential of agricultural soils to sequester carbon as a source of carbon offsets to deliver on their climate neutrality pledges. This gold rush to soil carbon credits in a regulatory vacuum raises many issues.

Compliance markets are created and regulated by mandatory regional, national, or international GHG emissions reduction regimes, *i.e.* tied to legal emissions reduction targets. The European Union's Emissions Trading Scheme (EU ETS) is a compliance carbon market.

Voluntary markets function outside of the compliance markets and enable companies and individuals to purchase carbon offsets on a voluntary basis. Such carbon credits cannot be used to meet legally-binding emissions reduction targets.

There is the inherent contradiction that offset-based funding mechanisms boost carbon sequestration as a replacement for emissions reductions. However, climate models tell us that to stay well under 2°C global warming as per the Paris Agreement, we must *both* increase carbon sequestration *and* cut emissions as fast as possible.[77,78] In addition, the different timescales of fossil and biogenic carbon fluxes mean that emissions from the burning of fossil fuels are not fungible with nature-based removals[79]. For these reasons, allowing companies to buy land-based carbon credits to meet their legal emissions reduction targets would be extremely problematic. Yet, the European Commission's "Fit for 55" package hinted at the integration of land-based removals in the EU's carbon market after 2035.

Voluntary carbon markets are a different matter – voluntary carbon credits are meant to complement legally-binding climate action – but raise many issues. Some concerns are linked to the design of carbon credit projects:

- **Accurate Monitoring, Reporting and Verification** (MRV) is very costly, which can greatly reduce the appeal for farmers.
- There is still **high uncertainty** in soil carbon models and soil carbon measurements can vary significantly within a parcel and across depth levels. There is a strong trade-off between accuracy and cost in estimating soil carbon sequestration.
- Carbon sequestration **can be reversed** if the right management practices are abandoned, or due to natural disasters such as fires. Future climate changes may also negatively impact soil carbon.
- The question of **liability in case soil carbon is re-emitted** after a credit is sold is crucial and highly complex. It should not be placed solely on farmers, which would be unfair when carbon sequestration is reversed for reasons outside of their control and may deter their participation in schemes; but if the carbon is lost due to intentional management changes or negligence, farmers must be held accountable.

- **Fake offsets** could be generated when carbon credits can be gained from "avoided emissions" (e.g. avoiding deforestation) or if the emissions linked to the practice generating the offset fail to be accounted fully.

- There is a **risk of carbon leakage** within a farm if the carbon credit project does not cover the entire farm, or across regions, for example if cropland converted to grassland for carbon credits leads to the creation of new cropland elsewhere. Additionally, some carbon farming practices might lead to higher N_2O emissions from soil or CO_2 from machinery, so the entire farm GHG balance must be considered.

- Weak transparency and oversight can lead to **double claiming of credits or double monetisation** of sequestration efforts (double counting).[80]

- **Cheap carbon credits** can disincentivise emissions abatement and provide too little compensation to farmers, especially those with less economy of scale, making more ambitious management changes (e.g. agroforestry or peatland rewilding) unattractive. In an unregulated market where farmers are price takers, this is highly problematic.

There are also wider challenges inherent to a quantitative market-based approach:

- **The narrow focus on greenhouse gases** can make it hard to integrate biodiversity and wider soil health criteria, which can lead to perverse incentives (e.g. afforestation of high nature value grasslands).

- Robust carbon credits require environmental, f**inancial and regulatory additionality**[57] which can be burdensome to prove and could disincentivise alternative policy action (financial additionality may be harder to prove if public funding is available for carbon farming, and the setting of mandatory standards could hinder regulatory additionality). On the other hand, existing carbon offsetting projects often lack additionality due to leeway built into the way additionality is demonstrated[81].

- A purely quantitative approach to carbon farming would provide very **unequal incentives to farmers**, as soils' potential to sequester carbon vary greatly across regions and soil types, and past management practices. Farmers in temperate climates who have lost most soil carbon through past intensive management would be favoured; while farmers with already good SOM levels or in dry climates (where soils have lower C sequestration potential but increases in SOM would be very beneficial for climate adaptation) would have very limited access to financing from carbon credits. This could channel considerable funds to very intensive farms and distort competition.

- This links to the **risk of capitalisation in land prices**, which would further hinder access to land for new entrants and could worsen foreign or corporate land grabbing at the cost of rural communities.

These issues must be very carefully considered by policy-makers as they design a policy toolbox to foster carbon farming. While global standards have been developed, they offer only partial responses to the challenges listed above.[82] Furthermore, many voluntary carbon credit projects take place outside these frameworks, and there is currently no public oversight on this booming market.[83,84] In the following section, we make recommendations for EU policymakers to mitigate these risks.

Policy recommendations

Carbon farming has the potential to drive positive action for soils, climate, biodiversity, water, and farmers. However, in the absence of an adequate policy and legislative framework, this opportunity could also be squandered, if easy fixes and inappropriate solutions are allowed to take precedence. The central challenge for policy-makers will be to balance rules and incentives into a coherent and ambitious policy mix, and to drive political and private sector action in the right direction, at the pace required by the urgency of the climate and environmental crises. This requires, first and foremost to tip the pyramid back on its base to underpin effective incentives with robust regulatory foundations in a dedicated legal framework for soil protection and to give policy a clear direction through ambitious legally-binding targets on climate and nature (Figure 5). In what follows, we lay out five key recommendations to build this stronger pyramid and harness the full win-win-win potential of carbon farming.

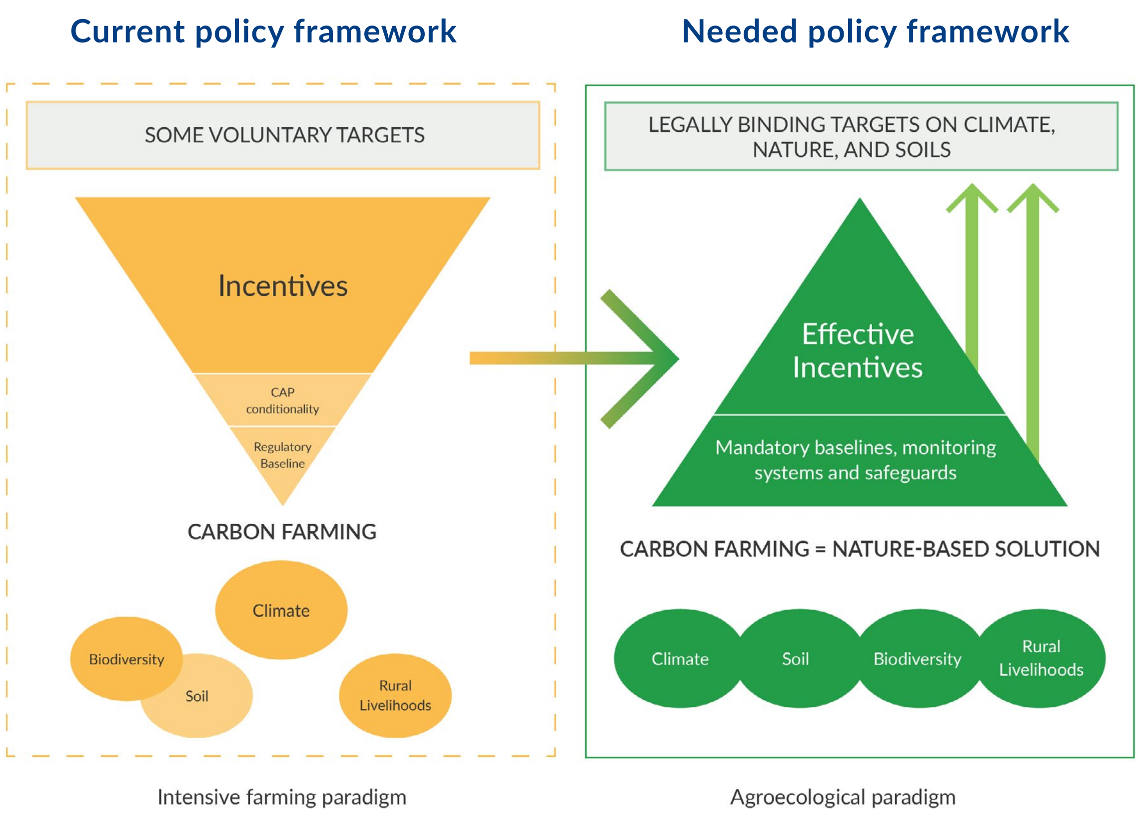

Figure 5: EEB's recommendations for an overhaul of the policy and legal framework surrounding carbon farming

1. Ensure carbon farming delivers nature-based solutions

The EU and its Member States have committed to limit global warming to 1.5°C, to put biodiversity on a path to recovery by 2030, to achieve zero pollution, and to deliver a just transition. Placing 'carbon farming' squarely in the context of 'nature-based solutions' (in line with the IUCN agreed definition and global standards[6]) and steering clear of false 'easy fixes' is essential to deliver on these multiple objectives simultaneously. Concretely, this means:

The IUCN definition of Nature-based Solutions:

"Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

- Developing and applying methodologies for the calculation of benefits beyond climate mitigation (biodiversity, soil health, water quality, farm resilience,...), based on the 8 criteria of the IUCN Global Standard for Nature-based Solutions.[6]

- Carbon farming schemes must take a holistic approach by enrolling the whole farm, accounting for all GHG fluxes linked to land management practices, and also quantifying benefits for other environmental dimensions (e.g. soil health, biodiversity, water), as well as socio-economic objectives (e.g. impacts on rural livelihoods, farm resilience).

- Practices eligible under carbon farming schemes should be defined based on unequivocal scientific evidence of their climate and environmental benefits and in respect of the precautionary principle. Additional safeguards should be put in place to prevent potential harmful impacts (e.g. rules on the use of agro-chemicals or on nitrogen load).

2. Set legally binding targets on climate, nature and soils

If implemented properly, targets can galvanise action by the public and private sectors. The urgent need to deliver large-scale protection and enhancement of carbon sinks, as well as to improve the health of agricultural soils calls for ambitious and cross-cutting targets. While soil carbon is a reasonably good proxy for these issues, a single target on soil carbon would not be sufficient given the complexity of the task ahead. Instead, the EU should set a range of legally-binding targets in relevant pieces of legislation:

- The upcoming **Nature Restoration Law** should include ambitious targets for the restoration of carbon-rich ecosystems such as peatlands, semi-natural grasslands, and traditional agroforestry systems such as the montado or dehesa based on the definitions of the Birds and Habitats Directives. (more information: Restoring Europe's nature – NGO position paper)

- A new **EU Soil Law** is urgently needed and should enshrine in law existing voluntary targets related to soil (e.g. land degradation neutrality) as well as establish new ones, such as improving the ecological status of cultivated soils and reducing the EU's external land footprint. (more information: Halting and Reversing Soil Degradation in Europe - NGO position paper)

- The revised **Land Use and Land Use Change (LULUCF) regulation** should set a specific target to achieve net-zero emissions from agricultural land use by 2030. (more information: Beyond net-zero emission in agriculture – EEB policy brief)

  - **No credits on the compliance market**: Removals in the LULUCF sector should only complement and never replace legally-binding emissions reductions under other climate instruments.

  - **Only additional credits on the voluntary market**: To guarantee that voluntary carbon markets complement regulatory action and to avoid double claiming, voluntary credits issued in the EU and claimed by non-state actors or non-EU countries should lead to a commensurate adjustment to EU LULUCF targets (i.e. if 50Mt CO_{2e} are bought by private companies on the voluntary market, LULUCF targets should be increased by 50Mt CO_{2e}).

- The revised **Effort Sharing Regulation** should set a specific target to reduce agricultural emissions by 20% by 2030 compared to a 2005 baseline. Some flexibility could be envisioned between this target and the target for agricultural land use emissions under the LULUCF regulation, but agriculture should not be able to rely on the large forest sink to compensate for its emissions. (more information: Beyond net-zero emission in agriculture – EEB policy brief)

3. Establish mandatory baselines, monitoring and safeguards

Carbon farming, like all environmental action in the EU, needs strong foundations: common definitions, data collection and monitoring systems, and guiding legal principles. The European Commission should develop a robust regulatory framework for carbon farming through climate, soil, and nature restoration legislation including at least the following elements.

Improve the monitoring systems for soils and land-use emissions

As the EU moves to net emissions reduction targets, the need for much more precise land use emissions monitoring methodologies[85] becomes even more acute.

- Public funding should be dedicated to upgrading climate and soil sequestration models based on the latest scientific knowledge on soil biology.

- Member States should be required to use the latest IPCC guidance and emissions factors immediately, and tier 3 emissions accounting methodologies for LULUCF and agriculture by 2025.

- A new Soil Law should set common definitions for soil health and other soil-related issues as well as establish mandatory monitoring systems to be implemented by European and national agencies.

- Stronger monitoring requirements should be triggered through the relevant source control and media protection legislations (e.g. the Industrial Emissions Directive, the Regulation on the European Pollutant Release and Transfer Register, or the Water Re-Use Regulation).

- Require and publicly fund independent scientific monitoring and evaluation of carbon farming projects.

Establish and enforce regulatory safeguards

The EU acquis contain several legal principles which are highly relevant to carbon farming, and should guide its implementation, such as the precautionary, pollution prevention at source, and the do no harm principles. The polluter-pays principle should also be applied: while policy action could be more focused on voluntary incentives in a first instance, in the medium-term, fiscal instruments should be used to apply carbon pricing across the board, including for land-based GHG emissions. In addition, the 'no deterioration' obligation established in the Water Framework Directive (WFD), which is being considered for the upcoming Nature Restoration Law, should also apply to carbon farming.

- A 'no deterioration' obligation should apply to protect remaining C stocks and to provide guarantees of permanence to new carbon sequestered, at least within the bounds of the land manager's control and with certain buffers to allow for natural variation in C fluxes.

- Existing environmental law must be fully implemented and enforced (WFD, Nitrates Directive, Birds and Habitats Directives, Environmental Quality Standards Directive, etc)

Mandatory baseline

In line with the do no harm and no deterioration principles, basic land management practices which are necessary to maintain soil functionality should be mandatory for all land managers. These practices largely overlap with basic Integrated Pest Management (IPM) practices and are mostly included in the conditionality of the post-2022 CAP.

- The Sustainable Use of Pesticides Directive should be strengthened to clearly define IPM and the implementation and enforcement of mandatory IPM should be stepped up.

- CAP conditionality standards on the protection of peatlands, soil cover, tillage management, and crop rotation must be implemented ambitiously.

4. Develop a coherent policy mix of effective incentives

The economic signals guiding land managers' decisions are currently stacked against soil protection, biodiversity conservation, and climate mitigation objectives, favouring instead short-term production maximisation. Mainstreaming sustainable soil management practices requires to create the right economic incentives for farmers, but also to make financial support available to help farmers cover the extra costs of their transition. Public and private funding should therefore be mobilised strategically.

Different private financing models have been tried and tested or are emerging, such as environmental assurance schemes (e.g. organic label); 'supply chain financing' whereby a retailer or food brand provides support to its own primary producers to adopt carbon farming; and voluntary carbon credit projects at different scales and with different constellations of actors involved. A key distinction can be made in these models in whether they are based on 'collaboration' or 'commodification'.

The former involve actors across supply chains or in regional partnerships, tend to be longer-term and to combine monetary reward and knowledge exchange. In contrast, financing models based on commodification take the shape of a pure market-based mechanism, where carbon credits are traded on an international market like any other commodity, with the many caveats identified above. Several collaboration-based models were reviewed in a European Commission's carbon farming study[57] and showed broad and long-lasting benefits.

The focus should therefore be put on public funding and private non-market-based financing, with voluntary carbon markets only making up the tip of the iceberg, for the most 'secure' carbon farming options (Figure 6). While voluntary carbon credits could finance some new (or "additional") carbon farming projects, it is also crucial to provide continued support for the maintenance of good practices, which could be achieved through environmental assurance schemes, supply chain financing, or public funding. Policy-makers must consider all options, to build a coherent and comprehensive approach.

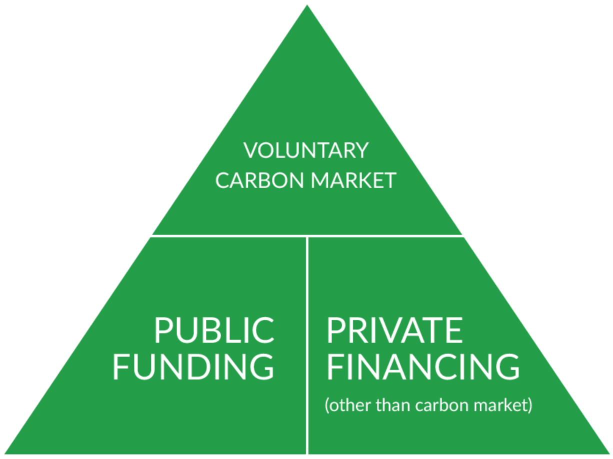

Figure 6: Strategic hierarchy of funding models for carbon farming

Engage with all food system actors to promote best practice

The first priority for harnessing private financing for carbon farming should be to boost the development of collaboration-based financing models. For this, policy-makers should explore policy options to:

- Incentivise private companies (in the agri-food sector or beyond, e.g. insurance companies) to set up collaborative carbon farming schemes that support farmers through upskilling and financial support (e.g. an Extended Producer Responsibility-type mechanism or other fiscal instruments).
- Mainstream the use of performance benchmarks set out in the EU Eco-Management and Audit Scheme's Best Environmental Management Practice (BEMP) for Agriculture.[86]

Establish basic rules for carbon farming schemes

To ensure all result-based carbon farming schemes (whether privately or publicly funded) deliver the required holistic change, clear rules should be set at EU level, in addition to the safeguards listed above:

- All result-based carbon farming schemes must enrol the whole farm and account for all GHG fluxes linked to land management practices (including emissions from machinery and embedded in inputs).

- The scope of carbon farming must be clearly defined, to focus on nature-based solutions for the management of land-based emissions and removals. Hence, livestock rearing should only be considered within carbon farming schemes in relation to land management.
- Ensure permanence via long-term contractual commitments (e.g. 10 years) and an obligation to ensure no deterioration after the end of the project.
- Record all result-based carbon farming projects in a publicly available and easily searchable database, including information on the emitters and buyers of credits when relevant.

Ensure high ambition in CAP Strategic Plans

The post-2022 CAP contains several policy measures which could be used to promote nature-based carbon farming: eco-schemes, agri-environment-climate measures, coupled support (e.g. for extensively managed semi-natural grasslands), investment support, farm advisory services, etc. While the tools are there (and largely were there in the current CAP), what has been missing is the political will to use them to drive large-scale change. However, our soils, biodiversity, climate, and farmers cannot afford to waste another 5 years of inaction. The European Commission must use its national plans approval powers to ensure EU public money is mobilised in the new CAP to deliver on the EU's environmental commitments.

Regulate voluntary carbon markets

There is large evidence that under global voluntary and compliance market standards, projects with very low environmental integrity and even with negative impacts on the environment or farming communities have been carried out, especially in the Global South.[81] To avoid replicating this in the EU, a comprehensive regulatory framework for land-based voluntary carbon credits is required. In addition to the rules and safeguards listed above, at least the following elements should be included in the framework:

- Stringent requirements for Monitoring, Reporting and Verification (including soil testing at the start and throughout the project and a ban on land use change for five years before project start). The costs of MRV should be (mostly) covered by the credit buyer;
- A robust system to ensure permanence, mitigate the uncertainty of measurements and risks of reversal, for example through the use of buffer accounts for reversal, time weighting of credits, and precision buffers;
- Rules for transparency and oversight of project design and implementation, including mandatory separation of the verification and approval processes[82];
- An automatic "commensurate adjustment" mechanism to prevent double counting between voluntary credits bought by private actors and mandatory national targets;
- Alignment with EU-wide carbon pricing mechanisms, adjusted to the national cost of living index;
- Geographical scope limited to the EU: companies based in the EU can only buy credits registered in the EU or meeting the same criteria as listed here (to avoid double counting, ensure quality, and control price);

- Eligibility for carbon credits restricted to the most effective, secure and no-regret practices, such as peatland rewetting and restoration, and establishment and restoration of agroforestry systems. Other practices, such soil carbon sequestration on croplands and grasslands, should only become eligible for voluntary credits once adequate MRV and co-benefit indicators are operational;

- Only genuine net removals should give rise to carbon credits. "Avoided emissions" (e.g. non conversion of grassland to cropland) or reduced emissions should not be compensated through tradeable carbon credits.

Set strict rules on corporate climate claims

Even if all those conditions are respected and carbon credits have the highest environmental integrity, companies (or public bodies) buying credits to offset their emissions should not be allowed to claim "climate neutrality" or "zero emission", as this would be misleading to the public and could lead to a rebound effect slowing down the necessary lifestyle shifts away from GHG-intensive goods and services. Companies should instead communicate separately about their emissions and offsets and offer full traceability and transparency about the origin of their offsets.

Leave no one behind

A major issue with carbon credit schemes is the unequal support they can provide to farmers based on their starting soil carbon levels, soil type and climatic context. Policymakers must ensure support is available for pioneers and long-term practitioners (who could otherwise be tempted to undo past achievements to meet the additionality test) and other farmers who do not have large carbon sequestration potential.

- Public funding must finance the maintenance of good soil management practices, e.g payments for organic farming or extensive grassland management.

- Public funding must support farmers in dry climates or very small farms, who have limited carbon sequestration potential but for whom good soil management practices are key for climate adaptation.

- Special access rules may also be needed to facilitate the participation of small farms in result-based carbon farming schemes, for example by simplifying the administrative burden or providing higher rewards for the first tonnes of sequestered carbon or minimum base payments for participants.

Finally, concerns around capitalisation of soil carbon value in land prices (and possible ensuing land grabbing) must be given serious considerations by national governments, including strict protection of the land rights of rural communities and action to ensure access to land for new entrants.

5. Enabling factors: knowledge, culture, and infrastructure

Insights from behavioural change theories point to three key levels where enabling factors are crucial to enable change: the individual, social, and material level. Based on this model, we draw particular attention to three key enabling factors.

Invest in farmers' knowledge

Adopting agroecological or regenerative farming practices to build up soil carbon is highly knowledge-intensive, and will therefore require farmers to acquire new skills and knowledge. Concerted efforts should be made to enable knowledge transfer from researchers and experienced farmers. Farm advisors should be independent from economic interests, and adequately trained and able to upskill farmers in soil health practices and field assessment methods. The latest knowledge on soil science and practices for soil health must also be central to formal agricultural education.

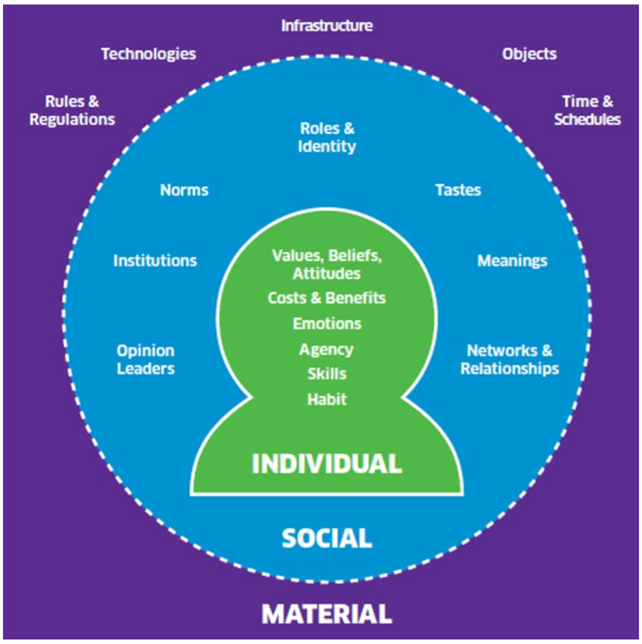

Figure 7: ISM Model. Source: Scottish Government (2013).

While existing structures and funding (e.g. in the CAP and Horizon Europe), can significantly contribute to these objectives, additional resources will be needed, both for upgrading advisory services and for their day-to-day running. A survey of farmers in the United States found that most were open to raising fertiliser fees or a carbon tax as a source of funding for soil health training programs.[87]

Steer a cultural revolution

While the green revolution was largely chemistry based, agriculture now needs a soil care revolution, underpinned by renewed interest in ecology and biology. Long-term, widespread change will require changing the cultural norms of farmers, policy-makers and wider society about what is a healthy agricultural landscape, as well as fostering genuine understanding of how soil life underpins all life.

Develop infrastructure for accessible soil testing

Serious investments will be necessary to facilitate the large-scale adoption of carbon farming. First, farmers will need to shift to machinery adapted to SOM-building practices. Public authorities should support these changes, while also bearing in mind the need to limit raw resources footprints – e.g. by facilitating retrofitting or repurposing of existing machinery, where that is not possible, ensuring recycling, and where new machinery is needed, group purchasing could be considered. In addition, soil testing is currently seen as a significant expense by farmers, yet it is a crucial step towards better soil management. As farmers are asked to do more for climate mitigation, and result-based carbon farming schemes are rolled out, affordable soil testing facilities must be made available to all farmers.

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