

SOIL HORIZONS: UNEARTHING PERSPECTIVES ON THE FUTURE OF SOIL CARBON GOVERNANCE

Part 2: Digging Deeper

The background image is a close-up photograph of dark, rich soil with a small green plant sprout on the left. The soil is uneven and textured, with some roots visible. The lighting is warm, suggesting a sunset or sunrise, with a bright light source in the upper right corner creating a lens flare effect. The image is split into two main sections: a blue header on the left and a blue footer on the right, both containing text.

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RESEARCH METHODS

The goal of this research was to gather incisive perspectives on the following themes:

- issues facing European farmers,
- the role of farmers in mitigating climate change,
- the state of EU soil data,
- the technical readiness of various soil carbon MRV methods,
- and how to implement a climate-friendly farming transition in Europe.

To this end, we applied qualitative research methods to interviews of a range of soil stakeholders. We conducted one-to-one interviews lasting between 30 and 60 minutes which we transcribed and analysed, with personal anonymity respected to elicit candid views. Our methodology was based on an interview guide comprising a comprehensive list of questions across all themes, but we preferred a semi-structured approach to cater to interviewees' specific areas of expertise. We used transcription services such as Otter.ai and the in-built function on Microsoft Teams and recorded interviews to ensure accuracy. Due to technical faults, four interviews were not recorded, though transcripts were recovered in three of these instances. One interview was neither transcribed nor recorded and we relied upon notetaking during the interview, buttressed by organisational literature. We applied thematic analysis techniques to the transcripts to compare interviewees' views across key topics. We then manually coded the transcripts for the key themes and sub-themes. This semi-structured approach to expert interviews coupled with thematic analysis has been used in multiple studies to identify key suggestions and themes.

Fourteen soil stakeholders agreed to be interviewed, collectively possessing expertise across the scientific, political and business realities related to soil carbon in Europe. The composition of the sample is detailed in Table 1.

Based on time constraints, Carbon Gap could not obtain a large sample that would elicit generalisable results. Rather, we optimised for a diversity of viewpoints from which to identify areas of convergence and disagreement among soil stakeholders. In the results write up, we have shown convergence of opinion by listing the number of interviewees who agreed with a sentiment in brackets at the end of a sentence. For example, (6) means that six interviewees made the same point. By unearthing arguments on both sides of contentious debates, Carbon Gap has been able to derive a set of guiding principles for future soil carbon governance.

Table 1: Stakeholder Mapping: Who we interviewed

Category	Quantity	Organisation
MRV developers	5	Yard Stick PBC Our Sci LLC GENESIS – landscore Silicate Soil Watch
Civil Society	3	Carbon Market Watch European Environmental Bureau Institute for European Environmental Policy
Farmer Payment Schemes	2	Sward (dissolved) Soil Capital
Researchers	2	Oxford University Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)
Farmer Representative	1	European Coordination via Campesina
Landowner Representative	1	European Landowners Organisation



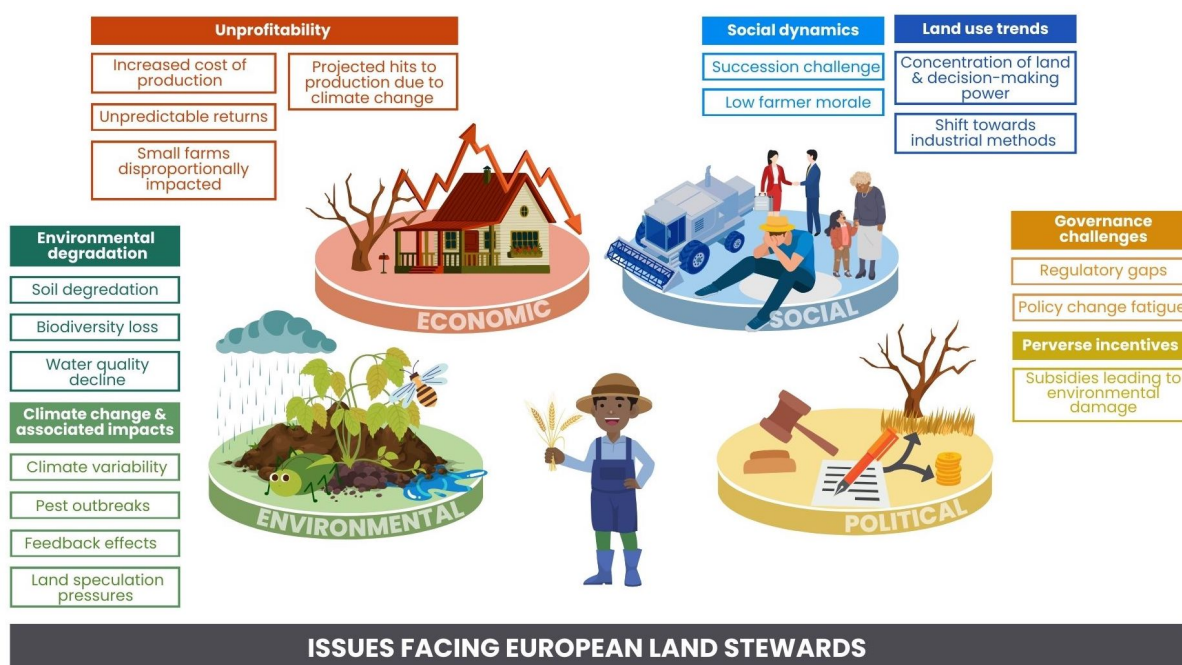
THEMATIC RESULTS

ISSUES FACING EUROPEAN LAND STEWARDS

Eight interviewees across all stakeholder types explored the theme of issues facing EU land stewards, with farmer representatives, landowner representatives, and civil society groups providing the most extensive input.

Results show that European farmers face challenges across environmental, economic, social and political dimensions (see Figure 1). Interviewees explored the links between these dimensions, highlighting how economic and political conditions drive social, land use and environmental trends, which can, in turn, set off destructive feedback effects.

Figure 1: Issues facing European land stewards



Environmental dimension

Six interviewees highlighted climate change, water management, extensive environmental degradation and soil degradation therein. Climate change and its associated weather impacts was the most often cited issue (4). Interviewees emphasised the differential impact of climate change across EU territory, the compounding effect of feedback loops unleashed by climate change, and the fact that farming plays a causative role in anthropogenic global warming. Additionally, concerns were raised about changing water trends (2), extensive soil degradation and an array of environmental degradation types.

Climate change and associated weather impacts

Interviewees highlighted these negative effects of climate change on farmers:

- **Climate variability**, such as more frequent and longer droughts and increased rainfall over shorter periods (2). In the words of one interviewee, “farmers are experiencing much more weather volatility. [There is] both too much and too little water”. This variability can lower production.
- **Pest outbreaks**, such as bark beetle attacks on forests.
- **Feedback effects**, such as how climatic impacts could increase overall agricultural GHG emissions compared to a baseline scenario without global warming. One interviewee specified that “it’s definitely a feedback effect system that if you keep this system going, it’s just going to continue to make a very bad situation worse. I would be mostly concerned about the feedback effects from the impacts of climate change”.
- **Land speculation pressures**, such as those driven by EU bio-energy policy. The EU’s Bioenergy Strategy and Renewable Energy Directive have been linked to a rise in energy crops, processes of farmland concentration, and increased land prices. “We are seeing lots of pressure regarding the use of land for non-agricultural purposes and a movement of speculation around the prices of land, like for the production of renewable energies”.

One interviewee pointed out that climate change impacts are felt most acutely on overseas territories that are in a similar position to (or are physically located in) the Global South.

Environmental degradation

Interviewees raised that farmers contribute to and are affected by extensive soil and environmental degradation (2). “Most of our agricultural and forest soil are degraded... 60% of soils are degraded in Europe”. This trend, along with biodiversity loss and water quality decline, were linked to intensive agricultural practices. The more damage wrought on ecosystems, the greater the competition for scarce land to be used for restoration versus production.

Economic dimension

Four interviewees discussed the economic pressures facing EU farmers. The overall picture painted was one of unprofitability due to increased production costs (2), over-reliance on public subsidies, and unpredictable returns due to market volatility (2). Additionally, the negative economic impact of climate change was addressed (2).

Unprofitability

Profitability challenges depend on type and scale of farming. Broadly speaking, it entails production costs versus returns. Interviewees explored how farmers are squeezed from both ends, navigating higher costs and unpredictable returns. This bind makes surviving as a business very difficult for some farmers.

One interviewee, speaking exclusively to arable farmers' experience, summarised this problem as the "increased cost of inputs – fertilizer in particular – and very strong volatility on the prices of their crops [means] you have huge challenges just about... making the business work". It is suggested that these unfavourable market dynamics are driven by the war against Ukraine and enforced structurally through over-reliance on public subsidies.

Another interviewee highlighted the disproportionate impact on smallholder farmers. "In the last one to two years, we have seen a sharp rise in production costs (on the order of 50 percent of increases) that have expressions like 100 to 200 percent in some products... It puts a huge pressure on agricultural income and of course, once again, especially small and medium scale farmers."

Economic knock of climate change

Beyond war and policy, climate change was identified as an economic threat to land users. Many of its effects jeopardise production, from pest outbreaks to droughts. One interviewee claimed that "[farming and forestry] will be the most susceptible, economically speaking, to the negative impacts of climate change... There's a whole bunch of natural disasters that could negatively impact [it]".

Social dimension and land use trends

Economic and environmental dynamics are driving social and land use changes. These trends affect who farms, what is produced and how, public opinion on farmers, and farmer psychological wellbeing.

In the first instance, interviewees claimed that unprofitability was causally linked to the "succession challenge" and the concentration of decision-making power across EU farms. "The average age of a European farmer is north of 60, and so there's a generational succession challenge here, which is that if farming is structurally unprofitable, it's hard to get younger generations motivated. So, what you actually see on a trend basis is more and more farms being bought up to make bigger and bigger farms by fewer and fewer farmers, as a consequence of not being able to hand over to the next generation. So, you have roughly the same area of land being farmed, but by fewer and fewer decision-makers".

With the decline of smallholder farms comes a shift in agricultural practices away from "peasant" agroecological methods towards industrialisation. One interviewee explained

“small-scale farms are actually the huge majority of farms in the EU... But the projection in terms of [the] amount of farms in the EU is decreasing really swiftly... This is especially concerning for small scale farms.” The interviewee said that smallholders are more likely to practice a “peasant approach” to the land, “transmitted from generation to generation”. If current trends continue, and the EU does lose a projected 6.4 million farms by 2040 (a 62% decrease as compared to 2016), then smallholder practices will be jeopardised.

Farmer wellbeing is also in decline, with political and economic conditions sometimes compounding to fatal effect. This observation echoes articles reporting on the farmer suicide crisis in Europe, which has led to members of the European Parliament’s agriculture committee to call for mental health support for EU farmers. Land stewards are also subject to social pressure and unfavourable public opinion; “farmers are very aware that they are typically painted as ‘part of the problem’. There are different reactions to that, you know, one is resentment that the good work that they do isn’t appreciated. Other reactions are about recognising where there are valid critiques and needs for improvement”.

Political dimension

European farmers face uniquely policy-related challenges. Interviewees raised concern about CAP provisions, perverse incentives, policy change fatigue, and international trade agreements. Not all interviewees agreed with the characterisation of these issues as negative, for example of industrial farming or incentives for it.

The key political challenges facing EU farmers were identified as:

1. A shifting regulatory landscape that can leave farmers uncertain and confused: “We have just introduced a new common agricultural policy... And I think farmers are still trying to wrap their heads around what that means in practice. How different is it? There’s greater devolution of power to nation states and then regions and so that is... making it harder to understand exactly what is being done because there are more layers of decision-making introduced”.
2. An agricultural policy framework that creates bias towards industrial agriculture and leads to abandonment of land: “Absence of market regulation... puts small and medium scale farmers under huge pressure from the industrial agriculture spreading all over Europe... It leads to abandonment in several regions of Europe, especially the most economically and socially depressed ones, leading to a series of very serious territorial, social and economic problems”.
3. A system of subsidies that curb farmer autonomy and drives perverse outcomes, though these outcomes differ according to farmer activity. Subsidies are often conditional upon implementing specific practices that limit farmers’ autonomy. When these payments are linked to negative environmental outcomes, they were considered perverse: “We’re really over subsidising our farmers to do the bad thing

– intensive large-scale agriculture – and that’s really pushing people into a path dependency that only leads one way and that’s soil degradation”.

4. EU International trade agreements that reinforce the trend toward industrialisation across EU farmland.

Debating the role of land stewards in EU climate action

Nine interviewees explicitly explored the role of land stewards in the climate crisis. Findings show that farmers and land managers are perceived both as part of the problem and the solution. Interviewees broadly agreed that land stewards have a sizable role to play in mitigating this crisis (5), but interviewees’ opinions diverged as to what that role should be. Interviewees also acknowledged that, when it comes to exacerbating climate change, not all farmers are equal, highlighting the outsized negative impact of industrial agriculturalists (2).

Size and significance of land stewards’ role in addressing climate change

Interviewees generally expressed support for the view that land stewards have a prominent role to play tackling climate change. Collectively, interviewees used the terms “big impact”, “massive part of the solution”, and “key role” to describe land stewards’ potential contribution. Two interviewees went a step further to suggest the role is not only sizable, but critical; “these sectors [farming and forestry] will play a key role in getting us to net zero. If we reach these objectives that the EU has, and also the Paris agreement objectives, you won’t get there without these sectors making a huge contribution when it comes to mitigation.” Another interviewee argued that land stewards’ decisions are the decisive factor in climate outcomes. “Farmers are the ones between things getting worse and things getting better. If we don’t change practices on the farm, then all of the doomsday apocalypse-like scenarios that we talked about will probably happen. We’ll cut down the whole Amazon, warming will go well above two degrees... Obviously, fossil fuels in the energy sector also play a part. But those industries don’t have an impact on land use and the surface of the Earth the way that farmers and foresters do”.

Debating land use & management in an era of climate change

Interviewees conceptualised land steward climate action under the dual banner of “mitigation” and “adaptation”. Mitigation activities covered carbon removal and emissions reductions, many of which were expected to have adaptive co-benefits. Due to Carbon Gap’s focus on carbon removal, mitigation took precedence in the interviews and was primarily explored in the context of which activities should (or should not) be supported at the EU-level.

Interviewees starkly diverged in opinion on how land stewards can best contribute to climate efforts. Variation stemmed from their different interests, appraisals of the science on

regenerative agriculture, and prioritisation across land use needs. Notably, there was a tension between those advocating for regenerative agriculture (4) and those who caution against deploying it at scale (2). Another key divergence was interviewees' views on industrial farming, with some strongly opposed to it and others optimising for maximally efficient food production.

Opinion differences were rooted in interviewees' commitments to solving different problems through land – i.e., which problem interviewees believed was most pressing to help solve through land use and management choices. Eight underlying priorities were identified across the transcripts, each associated with distinct problem statements and solutions (see figure 2). Sometimes solutions are mutually exclusive; other times they are reinforcing. The degree to which these priorities were in conflict was, within itself, debated as interviewees differed in opinion on whether trade-offs between environmental safeguards and food production were real or perceived. Where interviewees did perceive a trade-off, they caveated that it was geographically contingent – i.e. it need not be a trade off in regions where yield suffers due to soil degradation and improvements to soil health would also boost production.

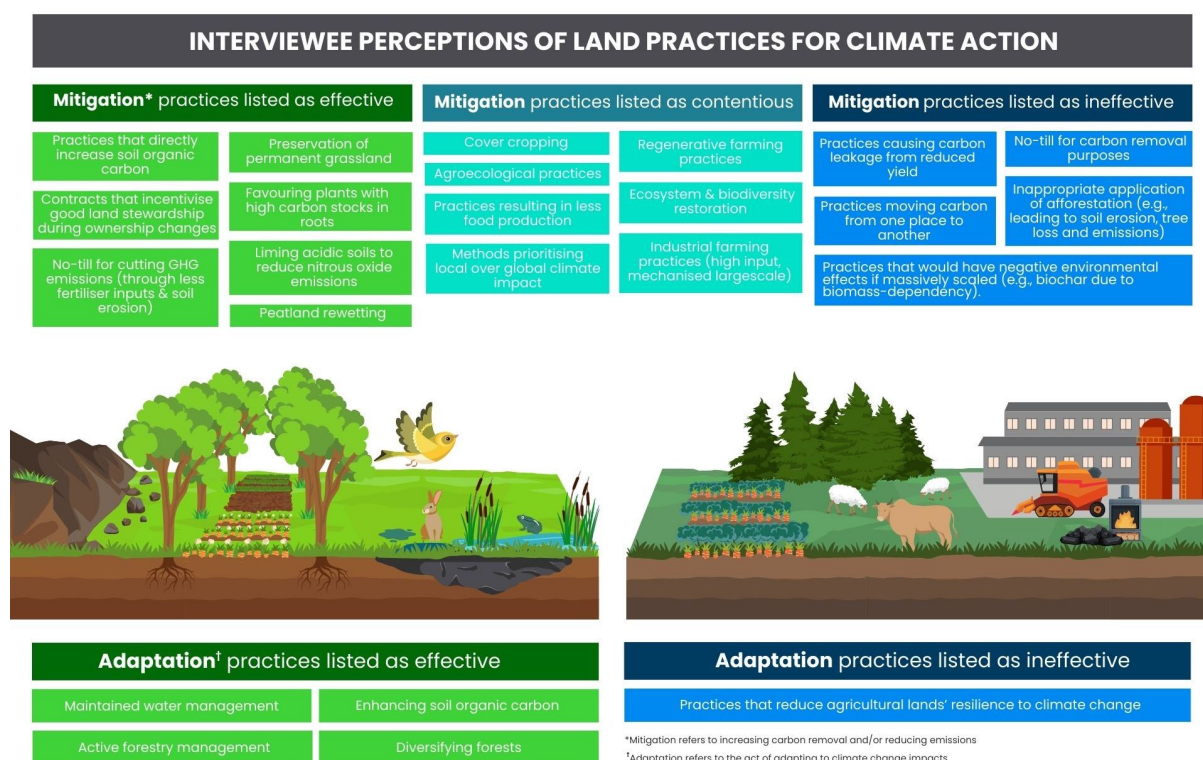
Figure 2: Eight varieties of European land stewardship priorities



Interviewees varied in the level of precision with which they identified effective and ineffective land practices for climate action. Although specific examples of effective practices were offered (5), other interviewees lamented the vagueness and misconceptions that pervade discussion, such as “regenerative agriculture” which “can mean literally anything”; “the problem is... people have equated these regenerative practices with increased soil carbon”.

The efficacy of regenerative agriculture was hotly debated, with some arguing that low input agriculture is best for food quality, social rights, ecosystem health and climate change mitigation (2), whereas others claimed that “the science is basically saying it doesn’t even work”, adding that it is “really problematic for the world, encouraging things that don’t work”. In figure 3, areas of contention are highlighted, with interviewees categorising “cover cropping”, “no-till” and “enhanced rock weathering” as both effective and ineffective practices to incentivise at the EU-level.

Figure 3: Interviewee perceptions of land practices for climate action



Differentiating between farmers' mindset, capabilities, and responsibilities

Four interviewees explored the drivers behind farmer action and inaction on climate change, identifying personal attributes, physical constraints, and policy effects as key factors. Farmer “mindset”, “openness to innovation” and “willingness to... take risk” were thought to play a big role. Risk was highlighted as “the absolutely central point” because “changing how you farm is littered with risk in a context where, obviously, farmers face huge risk all the time”. On the flipside, farmers’ conscience played a part in their not wanting to be “the guilty part of the system” by abetting greenwashing efforts from industry. The physical conditions of farmland were also thought to impact farmer decisions, such as “soil type” and “local climate”, constraining possibilities for implementing soil carbon building practices.

Interviewees also highlight the perverse impact of European policies – particularly the CAP – driving farmer exacerbation of climate change. Interviewees thought the farmer-climate relationship was mediated through policies pressurising or incentivising farmers to perform practices inconducive to climate change mitigation. For example, interview participants thought CAP favoured industrial farming methods that “are responsible for most of the environmental and climate related problems”. Interviewees noted that European farmers and stakeholder groups were not solely subject to such policies, but active participants in safeguarding them. As an example, “industrial farms... only go for... [environmental and climate] supports if they feel that their profitability will not be harmed by those instruments”. One interviewee claimed that vested interests made progress impossible, saying “agricultural ministries and agricultural stakeholders – Copa Cogeca here in Brussels – they all have their fingers in the pie... the reason why we can’t green the CAP is because it’s just politically impossible. Policy-makers give up because they fear farmers”.

Interviewees explored the idea that farmer responsibility for mitigating climate change should correlate, in some way, with their differential impact on the crisis. Loosely, a divide between small-scale, low-input farms versus industrial operations emerged, with the former allegedly stewards and the latter systematically exacerbating the problem.

Soil carbon MRV: State of play and future potential in Europe

In addition to learning about the issues facing European farmers and the role they should play in mitigating climate change, a key aim of this research was to understand the state of EU soil data; and the potential of various soil carbon MRV methods. Policy-makers partly base decisions on how to measure and grow soil carbon on the technological readiness of MRV methods, as well as the gaps that exist across EU soil databases.

Assessing the state of EU soil data

The five interviewees developing MRV methods went into most depth on this topic. Three interviewees collectively painted a picture of the state of EU soil data (see Box 1), comprising EU- and member state-level systems. Overall, interviewees agreed that Europe had achieved a good level of soil data (3), but improvements were possible. Interviewees highlighted quality discrepancies across national soil databases (3), as well as lack of public access to high-resolution, proprietary soil maps. Harmonisation of national databases and standardisation of MRV protocols were suggested as solutions.

Box 1: Glossary of European soil data initiatives discussed by interviewees

EU-LEVEL

The European Soil Data Centre (ESDAC) Hosted under the Joint Research Centre, ESDAC is the soil data hub in Europe. It coordinates five databases, including the European Soil Database & Soil Properties, as well as various atlases and maps, such as the European Soil Database Maps and the pan-European Soil Data Maps. These maps were made user-friendly through the ESDAC Map Viewer, which integrated many layers of data (including information about soil threats), but this service was suspended in 2020. It is also the hub for soil knowledge, hosting numerous soil-specific networks and projects.

EU Soil Observatory (EUSO). The EUSO was launched in 2020 under ESDAC and prompted by the European Green Deal. Its mission is to support EU policymakers to meet Union-wide soil-related objectives by providing integrated data flows and knowledge. Currently under development, the EUSO aims to fulfil this goal by implementing a harmonised soil monitoring system for the EU, improving ESDAC's capacity, and launching a novel EU Soil Dashboard that reports on soil health trends across Europe.

MEMBER STATE-LEVEL

Basic soil data is captured by every member state, though not all maintain a soil information system (SIS) and soil monitoring system. Nations vary in the rigour of their methodologies, resolution of results, up-to-dateness of data inputs and in criteria monitored. National level data collection is yet to be systematically harmonised into a

EUROPE-WIDE DATABASE.

CAP Farmer Identification System The CAP is also a useful repository of data as it tracks farm-level information. The EU manages payments to farmers through an integrated administration and control system (IACS), which includes systems for land parcel identification (to identify all agricultural plots in EU countries) and a farm accountancy data network that reports farms' income and business activities. This data is useful for any organisation that wants to track the climate impact of activities at the farm-level.

Comparing types of soil carbon MRV

Interviewees discussed three types of soil carbon MRV: lab-based, in-situ, and modelling. Collectively, their expertise spanned spectroscopy, enhanced rock weathering, hybrid lab-based testing and modelling, and empirical versus process-based modelling.

Interviewees examined the merits, pitfalls and types of lab-based MRV (5). This methodology was viewed as effective and accurate, but very costly (2). It was also viewed as human resource intensive and difficult to scale with regular monitoring intervals. Interviewees highlight the dry combustion method as conventional best practice and list the types of insights gleaned from lab-based tests, such as the active carbon component of a soil sample.

Interview participants explored various uses of lab-based MRV. For example, lab-based (and in situ) methods are necessary for the development of modelling. As one interviewee said, “if you don’t have direct observation of your soil, you’re using vegetation covered surfaces as data input for your model. Then, you basically use vegetation as a proxy for how much soil carbon there is, which... very often... the correlation between the two is really not... evident, especially in cropping systems because there’s a lot of fertiliser inputs”. Accordingly, the question becomes less how to scale lab-based MRV and more how best to use the data obtained from it for optimal insight – i.e. to train empirical models or to calibrate process-based models. Lab-based tests are also necessary to verify the efficacy of novel CDR methods. For example, an interviewee developing MRV methodology for enhanced rock weathering explained that lab-based testing is needed to measure whether carbon removal is truly taking place on land where their product is applied.

Interviewees also discussed the merits, pitfalls, mechanisms and conditions of use for in situ spectroscopy MRV. Spectroscopy was deemed cheaper than lab-based methods (2) and capable of providing the same type of insights. In the words of one interviewee, “I’m doing the exact same thing that conventional sampling does. I give you organic carbon as a percentage, but I do it way cheaper because I’m not removing soil from the ground, I’m not mailing it to a lab, and most importantly, I’m not using a very expensive piece of equipment at the lab to do the analysis”. One interviewee tempered their enthusiasm by noting the high uncertainty levels of results obtained using their in situ technology – “we’re not sure yet that we could get the accuracy of our carbon predictions within a range that would be acceptable to a carbon market... If we said you had 1.3% carbon, what we’re really saying is we think you’re between 1% and 1.6% carbon”. Another interviewee insisted that “lower per sample site accuracy [is] compensated for with greater sampling density”, which means that more samples are taken to adjust for low certainty per sample. Debate on this matter may stem from the interviewees’ different device designs, but one raised a concern regarding lack of transparency and “willing[ness] to share” information. Accordingly, MRV methodologies could become open source to ensure the integrity of any credits sold off the back of these methodologies in carbon markets.

Spectroscopy-based MRV can account for the heterogeneity of soils. “When we take a spectral collection, our probe evaluates that soil, and it basically says have I seen this soil before?... We evaluate spectral distance to determine whether we need more training data [to incorporate into our model]”. However, while there are ways to account for differences in soils over space, there are hard rules to measuring changes to the same soil body over time. For example, in situ soil analysis only works well if the soil is not waterlogged or frozen because “moisture will increase the amount of light that’s absorbed, which will give the appearance of additional carbon, so you’ll end up overestimating carbon”. Although there are ways of adjusting for moisture content, these fixes are limited.

There is another way of collecting data on soil that does not entail directly sampling the land. Interviewees weighed up the pros and cons of obtaining data through remote sensing (RS), such as from satellite imagery. On the one hand, RS data is readily available, easily

accessible and its resolution is improving. If improvements are made, it could allow for low-cost monitoring of soil carbon at regular intervals. In turn, this would enable researchers to generalise across time and space, contextualising data points in terms of seasonal trends: “what allows you to generalise the results is the satellite image, or at least the time series of satellite images, because you use a full year of data to make this estimate... you want to make sure that seasonality doesn’t impact your results”.

On the other hand, RS has limited reach when it comes to tracking below ground phenomena: “The problem is soil carbon is underground; satellites can’t see underground. It is really that basic. The most advanced satellite technology for subsurface monitoring in the world is synthetic aperture radar, [which] can see maybe five centimetres underground in bone-dry desert conditions... It’s totally insufficient for the soil carbon market”. Another interviewee estimated the penetration depth to be 10–30cm but emphasised that it is necessary to obtain data on the “full top metre in order to actually understand what’s going on in the soil profile”. The result of this limitation is relatively high levels of uncertainty of results (2). Furthermore, the quality or “ratio of pixel size to field size” of RS data varies across datasets and no socioeconomic or land tenure information is captured.

RS data has many uses; it is especially helpful for identifying areas to restore and points across a field to sample. The latter use can help farmers increase profits from carbon payment schemes, as pointed site selection can decrease the number of samples needed while maintaining levels of uncertainty. “[We] get public soil data from publicly available soil layers... push that together and tell you... these are the places where you should put your soil probe to best sample for the variability of conditions in that field with the idea of... tak[ing] fewer samples but still maintain[ing] that level of uncertainty that you need to qualify for the credits. Most carbon credits will say they’re going to dock you a certain amount for the uncertainty of whatever the quantifications are. So, if they’re highly uncertain... your credits are worth 20 bucks, but we’re actually going to pay you 10 because of all this uncertainty”. RS is also useful for analysing aboveground biomass density, and it could be used to verify farmer claims regarding land use changes if their practices are evident aboveground.

Interviewees highlighted that it is not only a matter of RS data quality but also how the data is used. Most interviewees appraised models in sweeping terms, warning of inaccuracies and highly technical obstacles. One interviewee explained that “the models have huge errors, are incredibly unpredictable, and people are saying they want to use satellite images... to track soil carbon but the calibration alone for that kind of thing is incredibly difficult to do”. Others noted that models are “great if they are describing something they have seen before” but only a “very narrow set of management practices... have been studied”. In other words, the model is only as good as the data it is trained on. “It’s always a risk when you start saying, now I want to take this prediction that we built in Malawi and I’m going to go down to Zimbabwe and I’m going to run the same prediction model because no soils from that region were in the training set”. Models are reliant on ground truth data for calibration (3), and although associated costs are expected to decline over time, analysts are “never done building their training data set”.

Box 2: Remote sensing and modelling techniques discussed by interviewees**REMOTE SENSING DATA INPUTS**

Type: Synthetic Aperture Radar (SAR) As opposed to passive optical images, this data collection method directs energy towards the earth and then records how much energy is reflected. Sensor wavelength determines penetration depth into forests and soil. SAR can retrieve higher resolution data than RS using visible light for subsurface and densely vegetated areas because it picks up surface details such as structure and moisture. Regarding carbon, it has been used to estimate the total carbon stocks of forest ecosystems. For soil ecosystems, SAR is mostly used to detect soil moisture content, and there are efforts underway to use it for monitoring SOC. Thanks to the European Space Agency and other developers, many SAR datasets are freely accessible. Limitations include extensive pre-processing steps and technical expertise/special software to process SAR data. Depending on soil type and sensor properties (i.e., wavelength and incident angle), penetration depth varies between 0–25cm.

Type: Normalised Difference Vegetation Index (NDVI) NDVI is used to quantify the density of plant growth. This formula is used for almost all satellite Vegetation Indices, and it results in a number per pixel ranging from –1 to +1, with –1 associated with water bodies, 0 associated with no green vegetation, and +1 representing maximally dense vegetation. Scientists have used RS dependent upon the NDVI to estimate SOC. The NDVI formula is as follows: $NDVI = (NIR - VIS) / (NIR + VIS)$ * Near-infrared radiation minus visible radiation divided by near-infrared radiation plus visible radiation.

Empirical Models (EMs) Types: Machine learning; Statistical regression EMs are based on observed data and statistical correlative relationships. Compared to PbMs, they are generally simpler to build, less comprehensive, have lower uncertainty and larger data requirements. EMs, which have been used by scientists to model various aspects of soils, tend to be strongly biased toward the particularities of the soil samples upon which they were developed or calibrated.

PROCESS-BASED MODELS (PBMS)

PbMs simulate a system of interest based on equations and algorithms, although they too rely on empirical information to an extent. Compared to EMs, PbMs are generally more comprehensive, complex, have higher uncertainty and smaller data requirements. Higher uncertainty may exist due to the extensive model parameters and data inputs. But these characteristics also help to make PbMs better for generalising across regional and global scales. For example, global-scale simulations (at a coarse spatial resolution of $\sim >50\text{km}^2$) have generated accurate estimates of SOC stocks. As local-level soil data improves, so too can PbMs become more accurate at finer scales of analysis.

One interviewee differentiated between two types of models used to process data: empirical and process-based (see table 3). Empirical models require direct observation and are, therefore, limited when it comes to soil carbon MRV (as opposed to biomass carbon, which is more readily available by virtue of it being aboveground). It is possible to obtain direct observations from soil using RS, for example, but only when the land is exposed (as in after tilling on an annual cropping system). On this basis, the interviewee thought process-based models would be more suitable than empirical models in the long-run in anticipation of a shift toward regenerative practices that require less tilling.

Although both approaches need ground truth reference data “to train a model that you then generalise to the whole landscape”, empirical and process-based models vary in data input type. For process-based models, “you don’t actually [have to] have a direct observation of the soil... What we monitor is the carbon input into the system. So, how much does photosynthesis bring carbon into the system? That becomes the driver of that model”. The result of a process-based approach is a more rigorously derived uncertainty, as it takes into account all potential sources of error and propagates them appropriately into the final reported uncertainty, while empirical approaches just report the root mean squared error (RMSE) and other error metrics from an (empirical) validation. To be calibrated properly, these models require a lot of a priori beliefs, which are often context- and region-specific. “You need to be able to map the probability distribution of each of your assumptions... using a Bayesian framework to do all the necessary computations to characterise the uncertainty of these models”.

Efforts are underway to improve data availability across remote sensing and in situ methods, which would consequently increase the efficacy of models. For example, in situ monitoring of SOC for farmer payment schemes produces data that can be fed back into predictive models to improve their calibration. However, despite a growing global training library, one interviewee predicted that “for the next ten years, we don’t have MRV that is affordable” given the “extremely expensive” and “complicated” options available today.

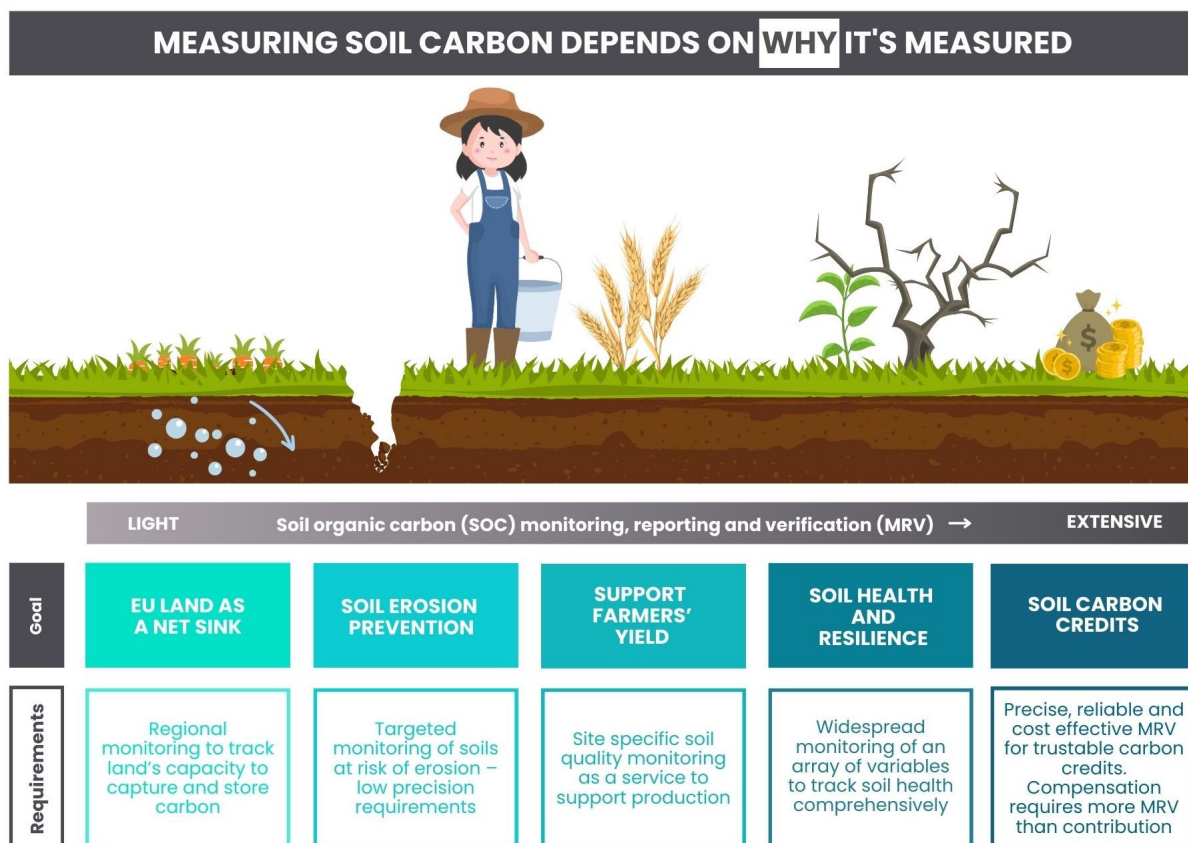
Debating the need for soil carbon MRV

Beyond evaluating MRV types, interviewees debated the extent to which a robust, EU-wide SOC MRV program was necessary. Interviewees’ assessments varied depending on which end purpose they had in mind for the MRV system (see figure 4). Generally, they thought that SOC should be measured, but for reasons besides climate change mitigation; “don’t do it for the soil carbon. Do it for the soil health. Do it because it increases your yields, or do it because it saves your farm from turning into dust”. Accordingly, the extent to which SOC monitoring is needed is based on the initial state of the soil and how useful measurements would be to the farmer (2). One interviewee suggested advice be given to land stewards alongside SOC results to turn information into action, recommending regenerative practices if SOC levels are low or else ways to optimise fertiliser application if SOC levels are high. These suggestions

reflect interviewees’ desire to avoid carbon “tunnel vision”, which could result in practices that harm nature or produce less food.

Regarding climate change mitigation, some interviewees accepted the premise of soil carbon credits sold on a market (2), whereas others argued against it (3). From a market-oriented perspective, soil carbon was thought to be the most commodifiable aspect of soil health; “[it] is relatively easier to quantify at scale [compared to other soil health indicators] – not without its challenges, of course – [and] relatively easier to... put a value on the market... If you think about... biodiversity and water retention and so on, these can be much harder to quantify at scale, mobilise whole markets and much harder to put a value on at scale”. A non-market based, climate-oriented approach could be to monitor the EU land sink just enough to ensure it is a net remover and not a net emitter.

Figure 4: Measuring soil carbon depends on why it’s measured



Imagining the EU's climate-friendly farming transition

Given the issues facing EU land stewards today, interviewees agreed that a transition was necessary, but differed in their conception of what such a shift entailed. Interviewees were asked how the EU should incentivise desired changes in the LULUCF sector. All interviewees, except for one MRV developer, contributed answers to this question in terms of what is incentivised – i.e., which activities or outcomes – who is incentivised – i.e., farmers or SOC MRV developers, by whom is it incentivised – i.e., private versus public sector), what do funders get in return – i.e., information, a claim – and who is liable in the scenario in which SOC is commodified.

What should (or should not) be supported through EU intervention?

Interviewees identified multiple metrics to optimise for when it comes to EU intervention: soil health/broader soil quality outcomes (4), food production, ecosystem services, SOC MRV (2), creating a high-resolution EU soil map, reduction in farm-level GHG balance and soil carbon itself.

On the topic of SOC, three interviewees explicitly argued against incentivising gains through commodification/offsets given the unpredictability of the soil carbon cycle, high risk of reversal, and difficulty in accounting for soil-sequestered carbon. Rather, it was thought that soil health is intrinsically valuable and need not be additionally incentivised through SOC-oriented policies. By contrast, a subset of interviewees thought public funding for national or regional SOC measurement programs would be a potent intervention that could increase scientific knowledge, evaluate predictions and verify the accuracy of any payments to farmers for soil carbon fluxes. “From a taxpayer perspective, I’d say it’s well worth it... you would end up crowding in so much more private sector finance if you took this risk out that it would be completely worth it from a taxpayer perspective in the long term, in terms of subsidizing the agricultural sector”.

Beyond desired outcomes, interviewees explored upon which basis should support be given. Three suggestions were made: activity-based payments (2), results-based payments (3), and a hybrid of the two (2). However, one interviewee made the point that a polluter-pays model could be an appropriate “way of charging the person who is producing a negative externality to pay for the consequences of that negative externality in the hopes that they would be incentivised to stop”. This statement points to the idea of some farmers as “polluters” to be punished or dissuaded, rather than rewarded and persuaded to act.

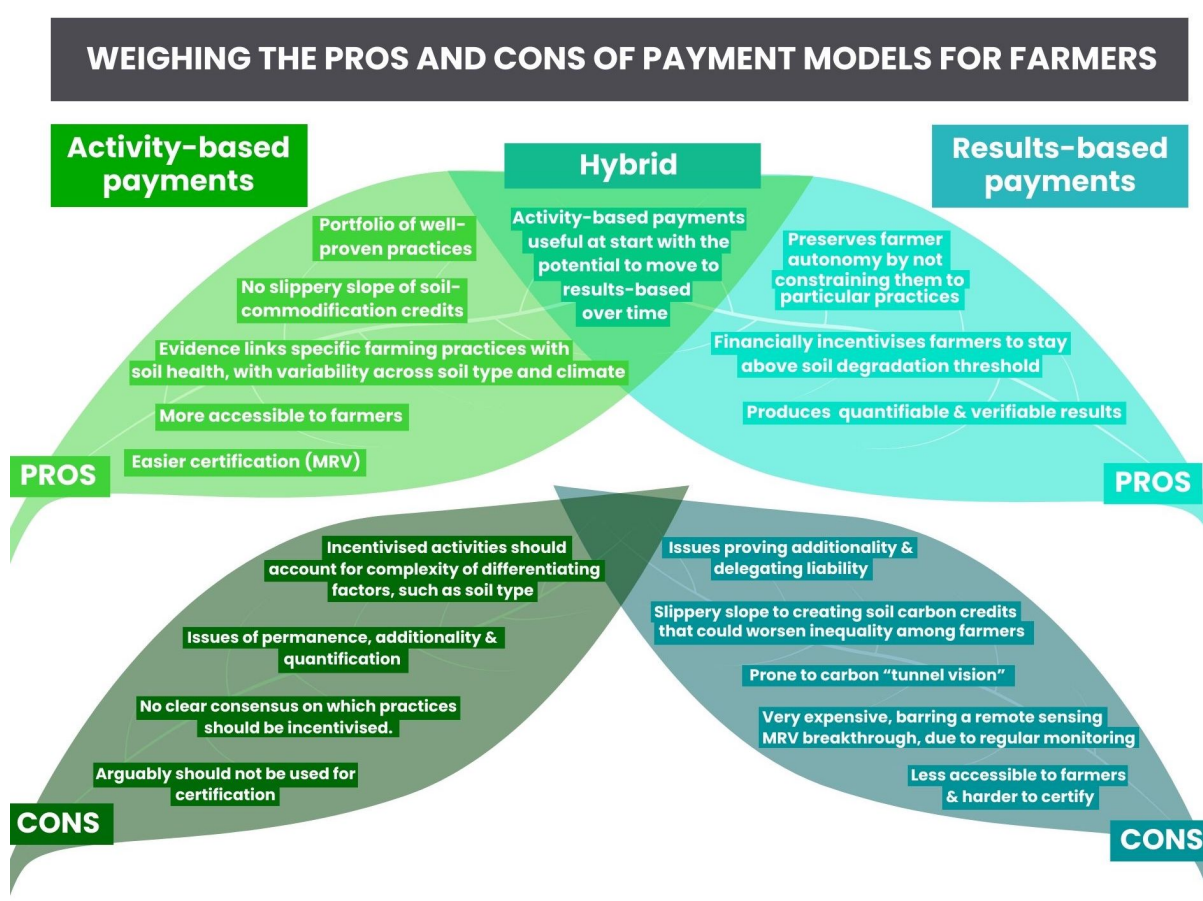
Activity-based payments are granted on the application of activities, as opposed to results-based payments which are conditional on the outcomes achieved. Purely activity-based approaches are granted independent of “ends”, and purely results-based schemes are granted independent of “means”. However, it should be noted that activities must still be monitored, even if payments are not conditional on results. “Being action-based doesn’t mean that you don’t test and check... We still need to be taking samples”. Likewise, it was

thought that activity-based models can be used to underpin a results-based approach or that a results-based approach could be applied to specific farming practices with reliable MRV systems that are not tied to SOC measurements.

Hybrid approaches might be temporally sequential, starting off with activity-based payments and shifting toward results-based once more data and technological advances have been made. Or, they might be simultaneous, with some incentives geared towards specific practices and others towards outcomes.

Overall, interviewees were divided as to which basis should underpin payments to farmers, if such a scheme were to be refined by the EU (see figure 5 for a list of the pros and cons per approach). The overall leaning was against results-based payments for SOC outcomes, but there was appetite for payments that would incentivise a wider array of impacts and practices.

Figure 5: Weighing the pros and cons of payment models for farmers



The results-based approach also spurs difficult questions regarding liability for soil carbon. If SOC is commodified or its increase is codified in a contract between buyer and seller, then who should be liable if the increase is not delivered, or reversed: the buyer or the purchaser, the farmer, or the landowner? Interviewees interpreted this question from ethical (2) and risk

management angles. Given the “should”-based nature of liability, the ethical question is: upon which basis should liability be ascribed? Two models of liability were put forward based on who benefits – “if you’re going to benefit from the carbon payment in any way, you’ve got to be liable for the carbon” – or based on ownership – “who owns the carbon and therefore who is liable?... The carbon basically comes with the land”. However, even this distinction does not cover the intergenerational angle. If liability is attached to the land, then debt could be passed on to future generations of farmers. This injustice becomes particularly unpalatable given increasing climate volatility. Drawing up short-term contracts, as opposed to long-term, could help address this issue.

Another approach optimises for pragmatic risk management. To ensure no single actor shoulders too much risk or costs, a shared liability model could be agreed across a range of interested parties and allowed to evolve over time.

Shared liability models could have an underlying benefit-based logic in so far as those who shoulder the liability also share in the benefits. Ultimately, it would be a question of how much more buyers are willing to pay and how much less sellers are willing to sell for to create a buffer. “If you’re buying natural carbon storages, you’ve got to accept that with a certain amount of risk of, let’s say $\pm 20\%$, it won’t be there, and that reduces the liability on everybody, because you’ve all agreed up front that it may be $\pm 20\%$... This would probably be incorporated into the ultimate price... [the private sector is] probably going to pay a bit less, but then the farmer would say, OK, I’m prepared to take a bit less for the tonnage because I’m not going to be afraid that if I don’t make the full 100% in five years’ time, you’re going to ask me to pay something back”.

Who should be supported to implement change?

Although interviewees disagreed on what should be supported, they generally agreed that farmers, land managers, foresters and those who do the work should be privy to rewards (7). One interviewee, for example, highlighted the danger of support flowing only to landowners and not tenants. “If it’s the person who owns the land who’s receiving the payments, you’re creating a whole host of economic problems [for]... semi-subsistence farmers and also farmers who don’t have a lot of income who are leasing the land that they’re working on”. Interviewees further drew distinctions among land stewards based on vulnerability and scale of operation (2), arguing that “more vulnerable, small-scale farmers deserve more support”.

Ultimately, this question cannot be divorced from what is paid for. For example, if it is SOC measurements and monitoring, then MRV developers or servicers would be the appropriate recipient of funds. What is paid for also determines how much support recipients gain. If SOC gains are used as the basis for payments, support could be limited to “a behavioural nudge at current prices rather than a financial silver bullet to fix farm finances,” given the limited contribution of carbon payments to a farm’s balance sheet. Furthermore, the more “middlemen” helping to mediate the incentive system, the less funding reaches the land stewards.

Who should provide the support to catalyse change?

Interviewees identified three major stakeholder groups to help provide support: government (9), private companies (7), and the agricultural sector (2). Most thought that it should be funded jointly by the public and private sector (7), though in different ways and for distinct reasons. Types of support include investment, capital or literal tools.

Interviewees considered government funding a powerful lever. They remarked that there are mechanisms already in place that could help drive this transition, such as CAP funding (5). Other relevant regulatory or funding mechanisms comprise the Soil Monitoring Law, Nature Restoration Law, and the CRCF. The three strongest arguments put forward in support of public funds were:

- soil is a public good and its degradation is a “national security risk”;
- vast sums have been earmarked for such change in the CAP budget;
- over-reliance on private finance may lead to greenwashing.

On the other hand, governments can be slow to act and should not be solely relied upon to achieve what needs to be done given the crunched timeline (2). Moreover, environmental initiatives under CAP were deemed of limited efficacy (2).

Many interviewees thought the private sector should play a key role in supporting change. Increasingly, companies are required to report their scope three emissions, which can drive soil health MRV given that many businesses are “linked to the soil”; companies “sourcing from nature... [need] really precise data on the impact... It could be a bank, it could be insurance, the cosmetic industry, food industry, biofuel”. Ultimately, one interviewee argued that companies “must buy the product at the right price and the right price includes the measure of the footprint”. However, interviewees cautioned that private sector engagement must be scrutinised and limited to avoid mitigation deterrence and greenwashing (2). For example, claims could be limited to contribution only.

Lastly, two interviewees suggested that the agricultural sector partially foot the bill. For example, large fertiliser companies and food processing firms could be subject to a polluter pays model. Another line of reasoning goes that farmer expenses would soon be outweighed by profitability gains from improved soil health.

What should “payers” or “donors” receive in return?

When it comes to the private sector, interviewees focused on which safeguards to put in place to protect the efficacy of transactions from a climate impact standpoint. Many thought that compensation claims or soil carbon “offsets” should be banned (5), such that they “can’t be as part of your net zero trajectory if you’re a corporate”. As one interviewee summarised, “the writing on the wall from regulation, from voluntary sector standards and from many, many NGOs... is that compensation should only be allowed once extremely deep cut in scope 1, 2 and 3 have been made”. Contribution claims were generally deemed

permissible (2), as was the “broader ESG desire to just do good”. Indeed, simply learning information on how soil carbon stocks change over time could be sufficient gains.

In addition to compensation claims, one interviewee considered direct land investment to be a negative private sector approach given that “if not done well, farmers can be deeply resentful of absentee institutional investment taking ownership of farmland... It’s control over farmland moving to people that don’t farm, and it has inflationary pressures on land values which potentially squeezes normal farmers out from the opportunity to own farmland”.

When it comes to government, the question of returns is simplified. The public sector is not, and need not be, incentivised in the same way as the private sector. Protection of a crucial common resource and increased soil data and knowledge would suffice. See table 2 for a summary of stakeholders and actions to enact the transition to climate-friendly farming.

Table 2: Climate-friendly farming: who should pay and how

CLIMATE-FRIENDLY FARMING: WHO SHOULD PAY AND HOW	
Actor	Mechanism
 GOVERNMENT	CAP 40% of the Common Agricultural Policy's €-155 billion budget is expected to go towards climate spending between 2023-2027. Member states have autonomy over how to spend their budget and meet their climate goals.
	SML The Soil Monitoring Law could set legal requirements to stay above “soil health thresholds” creating financial stakes if member states fall short of Union-wide target
	NRL The Nature Restoration Law could be used to set legal requirements to restore degraded soil ecosystems, creating financial consequences for those member states that fall short
	CRCF The Carbon Removal Certification Framework could set the standards necessary to bring in private finance, but associated use of certificates must be heavily regulated.
 PRIVATE SECTOR	Voluntary Carbon Markets Voluntary carbon markets could boost funding for soil carbon removal, but claims must be heavily regulated and double counting must be avoided
	MRV Providers Direct payments to MRV providers as middlemen between the private sector and farmers could help companies expediently receive information on soils.
	Farmers Direct payments to farmers could empower the private sector to reduce scope 3 emissions and, depending on MRV and regulatory constraints, provide supporting evidence for soil carbon claims.
 AGRICULTURAL SECTOR	Products Internalise the cost of environmental impact of farm products into their price. Doing so would disincentivise environmental depletion across the supply chain as all players would want to reduce costs. It would also allow farmers to become less dependent on public subsidies.
	Ag-ETS An EU agriculture-specific Emissions Trading Scheme could drive polluters to counterbalance residual biogenic emissions with certified soil carbon removals

Soil transition in practice: interviewees' policy propositions

For each of the dimensions explored in this research, interviewees were invited to go beyond characterising the challenges and propose measures or policy ideas to overcome them. In this section, we compile their propositions and document how consensual or controversial they were.

EU soil governance must balance priorities across contexts and scales. Simply put, EU policy does not exist in a vacuum. Soil measures affect Europeans at a local and national scale, as well as the international community with whom the EU trades or donates food aid. Soil policies should reflect and respect the many needs societies have of soils, and not sacrifice any of the sustainability criteria to optimise for a single function. To this end, interviewees made the following recommendations:

1. EU policymakers should consider soil through a multi-dimensional lens, whereby its primary roles of regulating water and air quality, ensuring food production, and supporting biodiversity are viewed as the main benefits of soil governance, and positive climate outcomes are co-benefits. This perspective echoes that of some scientists who refer to soil carbon storage as an “ancillary benefit” secondary to food production.
2. The Soil Monitoring Law, Nature Restoration Law, and the LULUCF Regulation should be the centrepieces of soil governance, as opposed to climate legislation. However, there was support for the EU to instrumentalise some climate measures on behalf of soil, such as removing fertilisers from the free allocation list under the ETS or regulating scope 3 emissions.
3. Given high scientific uncertainty on the efficacy of soil carbon storage as a mitigation tool, EU policymakers should restrict the role of soil carbon storage in meeting its climate neutrality goal based on conservative estimates on soil's carbon removal capacity and durability. This restriction can help minimise the risk of over-relying on the biosphere for geospheric (fossil) emissions. This position reflects recent scientific findings indicating that traditional soil science theories and subsequent models underestimated soil carbon's risk of reversal and vulnerability to climate change.
4. EU imports and exports should be redressed for better climate outcomes at the global level. Imports can decrease through improved EU food productivity where possible (without sacrificing soil health) and with diet changes. In places with high food imports, increasing food productivity per hectare is paramount, “otherwise you're just offshoring your land costs and your emissions”. The call for EU imports to become more environmental is shared by ENGOs noting that the EU is “the second-largest importer of products linked to tropical deforestation”. Regarding exports, interviewees predicted that Europe could become increasingly relied upon by

countries struggling to meet their domestic food demand, thus efforts should be made to meet this demand. If Europe does not meet this demand, other countries might, but in a less environmental way, thereby driving land clearance and deforestation.

5. EU soil policies should not lead to negative soil impacts beyond its borders. For example, policies that incentivise extensification could lead to deforestation and carbon leakage if the supply gap is filled through more carbon-intensive, land-degrading ways. Scientists warn possible carbon leakage is a barrier to adopting “carbon farming”, noting it could lead to yield reductions compensated for by “growing crops in other regions not already cultivated”. Note, scientists report that some carbon sequestering practices (under specific conditions) would not compromise yield.

In the first instance, the EU should implement measures to reduce the pressures on soil, which would entail using soils more efficiently, shifting dietary preferences and reducing demand for soil-based products by cutting food waste. To this end, interviewees suggested the following:

1. EU policy should optimise food production by reducing Europe’s food waste. Currently, almost 60 million tonnes of food waste are produced in the EU each year, costing an estimated loss of €132 billion, and amounting to as much as 40% of the food produced in the EU. This waste leads to inefficient use of land and substantial carbon emissions; “[if food waste were a member state, it would be the fifth largest emitter of GHG emissions]”. Researchers have found that zero food loss and waste across a range of crops can “significantly reduce the burden on land resources”, although others argue that this outcome is overblown and instead highlight the importance of European efforts cohering with global food waste reduction policies for the sake of global food security. An extensive set of recommendations has been put forward by the EU Platform on Food Losses and Food Waste, helping Europe advance food loss prevention.
2. EU policy should help farmers produce more food on less land by shifting Europeans’ diets towards more sustainable choices. For example, research suggests that a worldwide shift towards plant-based diets would reduce global land use for agriculture by 75%, freeing up soils previously used for growing animal feed and grazing.
3. EU measures should balance the need for productivity with the need to respect social and cultural values, as well as the non-human world. One expression of this demand can be seen in La Via Campesina’s advocacy for the rights of peasants and those working in rural areas, and in the broader food sovereignty movement, as articulated in the Declaration of Nyéléni, which demands “all peoples, nations and states are able to determine their own food producing systems and policies that provide every

one of us with good quality, adequate, affordable, healthy, and culturally appropriate food”.

4. The EU should prioritise climate solutions that have a low land-footprint but that achieve the same impact a land-based approach would. For example, where technology can be deployed to the same effect as land use but with a lower land-footprint, technology should be used. In this way, spared land can be put toward other ends besides climate change mitigation. This recommendation aligns with the biodiversity mitigation hierarchy and related approaches that aim to minimise or avoid negative environmental effects.
5. The EU should support research on how to boost soil health and yield on already productive land, “because even the most high-yielding farmland in the world still has to increase production”. This view is reflected in scientific discourse raising alarm that yield growth rate is outpaced by global population growth rate, arguing that increased agricultural productivity is the only way to meet higher food demands. By supporting research, the EU could pioneer ways to lift the socio-ecological ceiling (see figure 6), lessening the trade-off between productivity and soil health. Relatedly, the EU could support research on how the land sector could best adapt to climate change, developing new breeding, biocontrol, regenerative farming, and water management techniques.

Alongside measures to reduce pressures on soil, the EU should drive positive soil outcomes through reforming its soil governance matrix. Interviewees primarily highlighted the following for reform:

1. The EU should reform the CAP so that small farms are no longer biased against, fair prices for agricultural products are set, and the CAP budget is spent in a more democratic way that is not “shackled to our cultural practices that are based on massive fertilisation use... that we know devastate our soils”. Enforcing these measures could entail ending perverse subsidies and establishing new ones. According to critics, the CAP has a history of driving unsustainable agricultural practices, including encouraging use of synthetic additives harmful to human health and entrenching inequalities among farmers through payments linked to historical production levels. Despite CAP reforms that have helped funnel funds to smaller farms, critics argue that “unacceptable inequalities in the distribution of direct CAP support remain,” citing the European Commission’s estimate that 20% of CAP beneficiaries receive 80% of the payments. However, it should be noted that the biggest beneficiaries are mainly medium-sized farms (20-100ha), and not very large farms. Proposed new CAP legislation for the period 2021-2027 does show ambition to redress inequalities but has been criticised for not going far enough to protect climate and biodiversity security.

To improve the likelihood of success on Europe's soil goals, the EU could introduce new governance measures. To this end, interviewees suggested:

1. The EU could set a new legally binding target to improve soil health, including an obligation on member states to track soil carbon. As soil carbon MRV improves, member states could be required to incorporate quantitative targets for soil carbon into the Nationally Determined Contributions.
2. The EU could create regulations obliging Big Ag companies to curb their pollution through a polluter-pays model. However, it should be noted that a polluter-pays approach may not be well suited to the EU agricultural sector given the “high levels of economic concentration downstream from farming, especially in the processing and retail stages”, indicating that the polluters (farmers) would not be the actors capturing most of the added value.
3. Regarding the CRCF, the use of soil carbon removal must be heavily regulated. Due to the high risk of reversal and accounting complexities, it may be best for certified soil carbon removal not to qualify as offsets, but only count towards claims such as contributions. Interviewees further suggested that certification should only be granted for results-verified “carbon farming”, though the EU could seek to incentivise activity-based payments through other means.
4. All soil governance measures, especially those intersecting with climate outcomes, should be reviewed at regular intervals to gauge if change is needed and whether transitional measures can be phased out.

To incentivise land users to work towards better soil outcomes, the EU could consider many possible routes. Collectively, interviewees recommended:

1. Farmers be paid to pass ecosystem health “degradation thresholds”. For soil carbon, that means paying farmers based on the amount of carbon their soils store above a stated threshold, incentivising them to go above the average. In doing so, payments would not rest on additionality or permanence, a range of ecosystem services could be optimised for, and first adopter farmers would not be disincentivised to continue their good work.
2. To help drive climate outcomes and improve economic stability for farmers, payments to farmers could be granted for emissions avoidance, emissions reductions and carbon removal in the initial phase of an EU agricultural transition. However, payments for soil carbon removal should not be over-relied upon as an incentive, given that it will likely not be highly profitable.
3. Specific practices known to be positive for soil carbon and soil health could be incentivised through additional funding. Practices should be differentiated

according to the environmental conditions conducive to success. Suggested practices include rewetting drained peatlands (which initially counts as emissions avoidance), agroforestry, sustainable management of grassland, conversion of less productive arable land to buffer strips, and agroecological practices. However, there was debate around the efficacy of some of these practices, and the trade-offs they present. An activity-based approach would reduce pressure on farmers to deliver results, while maintaining a high likelihood of positive impact.

4. Alternatively, or in tandem with an activity-based approach, the EU could consider a results-based model, whereby farmers are financially incentivised to make verifiable carbon sequestration in a way that does not tie them to specific practices. This model would promote flexibility, farmer autonomy and innovation.
5. The EU should consider a differential approach to account for inequalities across the EU farming sector. For example, it may be appropriate to pay smallholder farmers to make necessary changes but oblige larger farmers to transition their operations toward sustainability. Another example would be to prioritise funding for farmers based on their respective vulnerability to climate change (not how degraded their land is) so as not to punish first adopters.
6. The EU should avoid market mechanisms to drive carbon gains in its LULUCF sector. Interviewees generally thought that market approaches would lead to more harm than good or would be unnecessary given Europe's high governance proficiency and economic development, which means it has many policy alternatives at its disposal. This position is in keeping with academic literature that denounce carbon markets as "driving familiar processes of uneven and crisis-prone development... exacerbating uneven development within the Global South, as elites in emerging economies leverage carbon market financing to pursue new strategies of sub-imperial expansion". There is debate as to the impact of market mechanisms on farmers, with some representatives strongly advocating for the remuneration and trading of soil carbon certificates, while others highlight "the convoluted, burdensome and unpredictable nature of receiving offset credits". However, it should be noted that there was disagreement on this point, with some interviewees advocating for the role of government to de-risk carbon markets for farmers and the private sector.

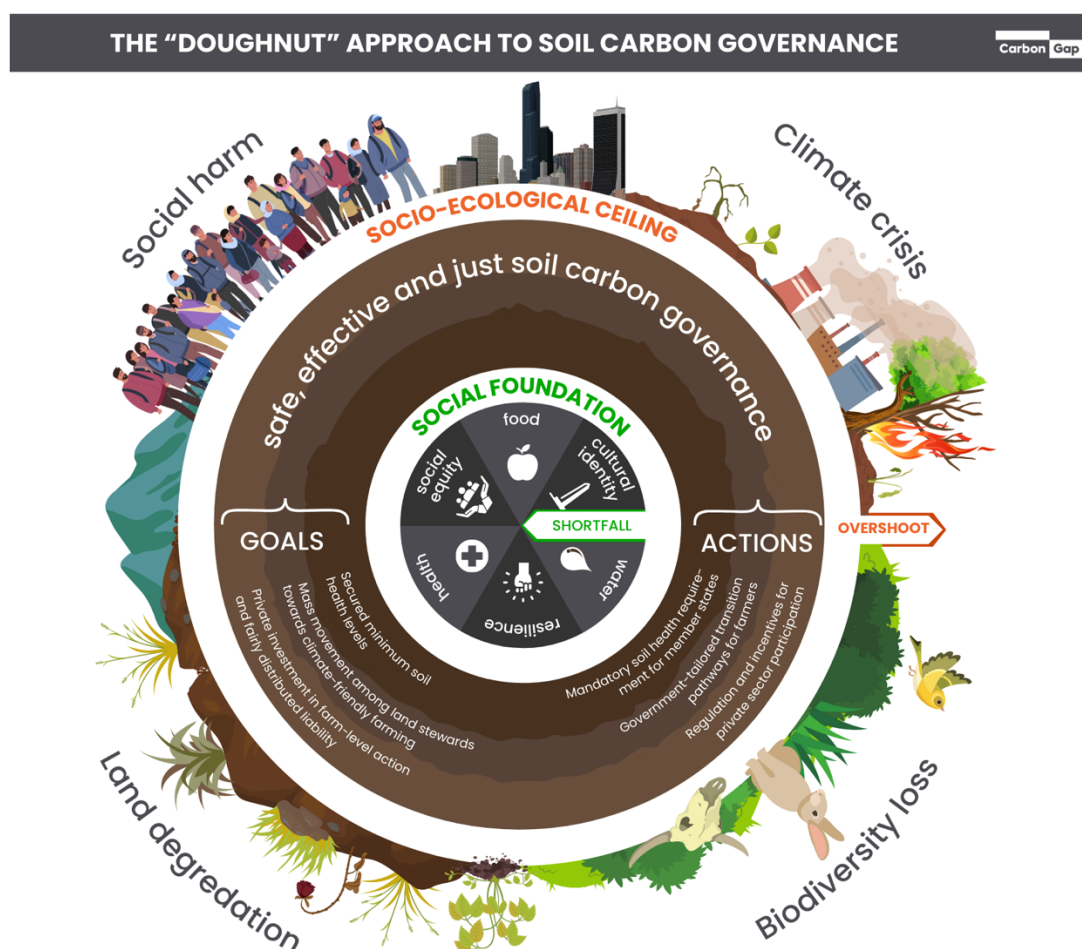
The EU should develop a robust soil health MRV system to ensure that bridging the soil carbon gap is trackable, and stakeholders are unilaterally working towards achieving this goal. The SML proposal already achieves much of what interviewees recommended – a harmonized methodology for measuring soil health across member states that robustly defines health indicators, including soil carbon. Further considerations include:

1. Depending on the EU's overall soil goal, an appropriate level of granularity for soil carbon MRV should be identified and not exceeded. For example, National Soil Inventories should be able to capture detailed soil carbon fluxes at the member state

level, but not at the farm level. At the farm level, efforts could focus on identifying and monitoring farmer practices to incentivise adoption of sustainable soil practices. Alternatively, if the EU deprioritised member state granularity to merely determine whether Europe's land was a net sink, a less ambitious MRV approach is needed. The granularity of MRV matters because of public spending implications. The more detail, the more costly, and although it was generally agreed that soil health MRV should be government funded given it is a public good, interviewees felt that public spending on MRV should not outweigh the public benefit derived. Once the EU has succeeded in the mammoth task of collecting reliable baseline data across EU soils, further granularity could be funded by private sector efforts. Note, even if the EU favours activity-based funding, MRV will still be necessary to monitor progress.

2. The EU should strategically collect specific data types to expedite progress on soil carbon MRV. For example, collecting data on farming practices could help improve crop modelling efficacy.

Figure 6: The doughnut approach to soil carbon governance



LIST OF ABBREVIATIONS

CAP – Common Agricultural Policy
CRCF – Carbon Removal Certification Framework
EM – Empirical Models
ESG – Environmental, Social and Governance
ETS – Emissions Trading Scheme
GHG – Greenhouse gas
LULUCF – Land Use, Land Use Change and Forestry
MRV – Monitoring, Reporting and Verification
NDVI – Normalised Difference Vegetation Index
NRL – Nature Restoration Law
PbM – Process-based Models
RS – Remote Sensing
SAR – Synthetic Aperture Radar
SML – Soil Monitoring Law
SOC – Soil Organic Content

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