In collaboration with
Deloitte and NTT Data

Transforming Food Systems with Farmers: A Pathway for the EU

INSIGHT PAPER

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Images: Getty Images

Contents

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Foreword

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Food and agricultural systems are one of the backbones of society, providing the sustenance that is essential to life. They are also central to the global economy, contributing close to 10% of global GDP and over 35% of all jobs. At the time of publishing, the Russia-Ukraine conflict has further underscored the vulnerability of food systems and highlights the critical need to address structural weaknesses affecting the environment and food systems around the world.

The most recent Intergovernmental Panel on Climate Change (IPCC) Assessment Report confirmed that climate change and related biodiversity loss *"have affected the productivity of all agricultural and fishery sectors, with negative consequences for food security and livelihoods"*, especially for the most vulnerable. However, food systems can be a determinant in solving these global crises by addressing their environmental impact and deploying innovative solutions. International frameworks and governance mechanisms are waking up to this fact, with the UN hosting the first ever Food Systems Summit in late 2021 and the Egyptian presidency for COP27 indicating a possible push to incorporate food and agriculture systems into the formal negotiations.

Climate-smart and regenerative agricultural practices and digital innovations already show great promise in helping to mitigate these trends of climate change and biodiversity loss. Yet achieving the adoption of these practices and technology at the scale and speed required demands a new approach. Farmers are the stewards of half of all land on Earth and produce 95% of our food and yet, 65% of the world's poorest people are farmers. We must therefore work with farmers and leverage the innovative capacity of local communities to design, deploy and scale solutions adapted to their varied socio-economic and ecological realities.

This report, developed in collaboration with Deloitte and NTT Data, takes the practical case of the European Union to understand the pathway required for a farmer-centric food systems transition. Its findings show that if just 20% more farmers adopted climate-smart agriculture, by 2030 the EU could reduce its agricultural greenhouse gas emissions by an estimated 6% and improve soil health over an area equivalent to 14% of the EU's agricultural land while improving farmer livelihoods by between €1.9 and €9.3 billion annually by 2030. The feasibility and impact of this transition will depend on the collective ambition and actions of all stakeholders. This report outlines a pathway to address the economic, institutional and technological challenges currently hindering the case for change within the EU. It was developed with the support of the multistakeholder EU Carbon+ Farming coalition in response to a call from the Executive Vice President of the European Commission leading on the EU Green Deal and is part of the broader World Economic Forum's 100 Million Farmers platform.

No region in the world will be spared from the imminent threats to our interconnected food systems, climate and the natural ecosystems upon which they depend. We encourage all food systems stakeholders around the world to take a farmer-centric approach and to harvest and share the evidence on the opportunities and innovations for food systems transformation for climate, nature and people.

> **The EU is waking up to the importance of reshaping its food systems, recognizing the critical role of these systems in achieving the Green Deal and a sustainable future. Working with farmers, especially Europe's next generation of farmers, will be critical to ensure this transition is inclusive and effective. The consultative process behind this report shows what a collaborative effort can achieve when farmers' voices are rightfully recognized as a powerful source of knowledge and innovation.**
>
> Diana Lenzi, President of the European Council of Young Farmers (CEJA)

Executive summary

Better food systems are key to transitioning towards a sustainable economy.

In the European Union (EU), agriculture systems generate 10% of greenhouse gas (GHG) emissions and are a leading cause of biodiversity loss and freshwater consumption. The EU Green Deal's Farm to Fork Strategy aims to transform this impact and spur the transition towards climate, nature and people-friendly food systems. At the centre of this strategy lies a set of proven agriculture approaches, collectively referred to in this report as "climate-smart agriculture".

This report has found that if just an additional 20% of farmers adopted climate-smart agriculture, by 2030, the EU could reduce its annual agricultural GHG emissions by 6% and improve soil health over an area equivalent to 14% of EU's agricultural land while improving farmer livelihoods by between €1.9 and €9.3 billion annually. The feasibility and impact of this transition will depend on the collective ambition and actions of all stakeholders to make the economics work.

Achieving the goals of the Green Deal and the Farm to Fork Strategy will require ambitious, multistakeholder action and farmer ownership. Stepping up to the challenge, a coalition of corporations, NGOs and academics, in consultation with farmer organizations, have convened under the EU Carbon+ Farming Coalition to develop farmer-centric, practical and scalable solutions that support the transition towards climate-smart agriculture.

This report takes a practical look at the farmer and food value-chain landscape in the EU and points to the pathway forward to scale climate-smart agriculture. Key insights uncovered through extensive farmer surveys of and consultations with 1,600 farmers coming from 7 countries, which represent 75% of the EU's farmer base, include:

- **Farm economics**: Farming in the EU is economically challenging, which limits farmers' ability to invest in and adopt climate-smart practices. The average annual family farm income in the EU is nearly 60% lower than that of non-farming families. On average, for every 10% increase in farmers' perceptions of economic benefits, the adoption of that practice increases by 16%.

- **Awareness and knowledge**: Lack of knowledge or available information was the second most cited barrier to practising adoption after high perceived investment costs. On average, 70% of the farmers surveyed reported having searched for information on climate-smart farming, demonstrating an interest in the area, yet only one out of four reported having a "good" or "very good" knowledge of the subject.

“ The impact of the transition, and its ability to strengthen the security of food systems, will depend on the collective ambition and actions of all stakeholders to make the economics work and maintain yields throughout the transition.

- **Data and technology**: Digital climate-smart practices and digital measurement tools are critical for the transition. They deliver a range of benefits, including improved productivity and crop quality, more efficient operations, reduced fertilizer, pesticide and water use and costs, lower environmental impact and adaptation to climate change. But they also provide the data collection capabilities needed to unlock new revenue streams from results-based schemes (e.g. carbon markets) and innovative, low-cost insurance products. Yet current adoption is low at just 31% on average compared to 44% for other climate-smart practices.

- **Policy and regulation**: The European Commission has reformed its common agricultural policy (CAP) and launched new policy initiatives to promote climate-smart practice adoption, but the fragmentation and flexibility in national implementation might lower overall ambition on climate and nature, drive market distortions and limit the ability for solutions to scale.

- **Diversity**: The EU landscape is regionally diverse. The average German farm is 25 times larger than in Romania. These differences extend over income, ownership structures and agriculture type and in terms of information channel preferences and digital savviness, which might explain why Western European farmers' climate-smart practice adoption rate is twice as high as in Eastern Europe, 45% on average compared to 21%. In addition, the adoption rate is significantly impacted by farmer age, social values and perceptions. Understanding these social, demographic and technological factors will be critical to developing solutions that will be adopted and sustained.

These insights inform a number of coordinated interventions and solutions across four key areas that can help spur and sustain the transformation to reach a tipping point of adoption among farmers:

- **Financing and risk management:** Farmers need innovative forms of upfront capital, guaranteed revenue streams and insurance to help them embark on the climate-smart journey. When brought together, these diverse financial and risk-sharing mechanisms can be deployed in ways that help spread the costs and risks of the transition across value-chain players in a just and transparent manner.

- **Innovation ecosystems:** New technologies can offer a way to support farmers in the challenge to deliver optimal results for business and the planet. It is important to continue developing, improving and reducing the costs of these technologies, which are often prohibitive for smallholder farmers, while acknowledging and fully utilizing the benefits of low-tech climate-smart agronomic practices that have already demonstrated their potential.

- **Education and awareness:** Farmers should be supported in understanding the business case for change with easy access to relevant information for specific farmer segments on the ground which can be disseminated through user-friendly knowledge-sharing platforms, peer-to-peer learning and local on-farm teaching demonstrations that farmers trust. Awareness-raising campaigns are also needed among the broader public and consumers regarding the impact purchasing habits can have.

- **The policy environment:** Farmers and value-chain players should be incentivized by a supportive enabling environment. The EU's policies are only effective when successfully implemented. The flexibility that member states are given in implementation has historically resulted in a general lack of overall action towards sustainable outcomes. This flexibility is also likely to result in a lack of consistency in national frameworks and market-driven schemes in a way that might slow progress, discourage private sector investments at scale, increase market distortions and confuse consumers across the common market.

Based on the insights generated through the farmer survey, the EU Carbon+ Farming Coalition is committed to accelerating the achievement of the EU Green Deal goals and demonstrating the feasibility and impact of solutions across these four key intervention areas through flagship pilots. These pilots will focus on topics such as enhancing knowledge sharing for and among farmers, developing climate-smart procurement guidelines, designing innovative risk-sharing and financing mechanisms, identifying cost-effective measurement, reporting and verification (MRV) solutions to help build a reliable carbon market and implement regenerative farming in specific crop segments, among others. The willingness of the coalition members to jointly design and execute these pilots demonstrates the transformative power of pre-competitive collaboration.

1 Food systems that support climate, nature and people in the EU

Delivering on sustainable food systems: The burning case for multistakeholder action.

1.1 Food systems as a cornerstone of the necessary transition

It is undeniable that human impacts on climate and nature have driven the world towards a planetary emergency.[1] The mutually reinforcing climate and nature crises are now recognized as the biggest global threats to human economies and more importantly, to human survival.[2] While there is still time to avoid worst-case scenarios, this will require urgent and bold action.

As a result of this realization, world leaders are increasingly embarking on green transitions and calling upon producers and consumers to change their habits and processes. However, too often, these calls for change fail to address the importance of food systems in the transition. The role of food and agriculture, for example, is not properly recognized in the governance mechanisms set up by the three Rio conventions nor in the achievement of Sustainable Development Goals.[3] Contributing to nearly a tenth of global GDP, employing 1.2 billion people and nourishing the globe's growing population, food systems are too big to be ignored.[4,5] They are also one of the main contributors to the planetary crisis. Food and land use systems are responsible for up to one-third of global GHG emissions, are the primary driver of biodiversity loss and account for 92% of the global water footprint.[6,7,8]

Furthermore, food systems are inequitable. While 160 million people have been lifted out of undernourishment since 2001,[9] nearly 10% of the global population remain hungry[10] and 65% of the world's poorest work in agriculture.[11] Yet because food systems rely on healthy natural ecosystems, their role in undermining nature puts crop yields and food security at risk. Indeed, 52% of agricultural land is already moderately or severely degraded.[12] By some estimates, in the next 25 years, land degradation could reduce global food productivity by 12% and subsequently increase food prices by over 30%.[13] In this context, and with well over half of the earth's habitable land used for agriculture, the ability to feed a growing population and thrive on a changing planet will depend on reversing these trends and building greater resilience into the planet's food systems.[14]

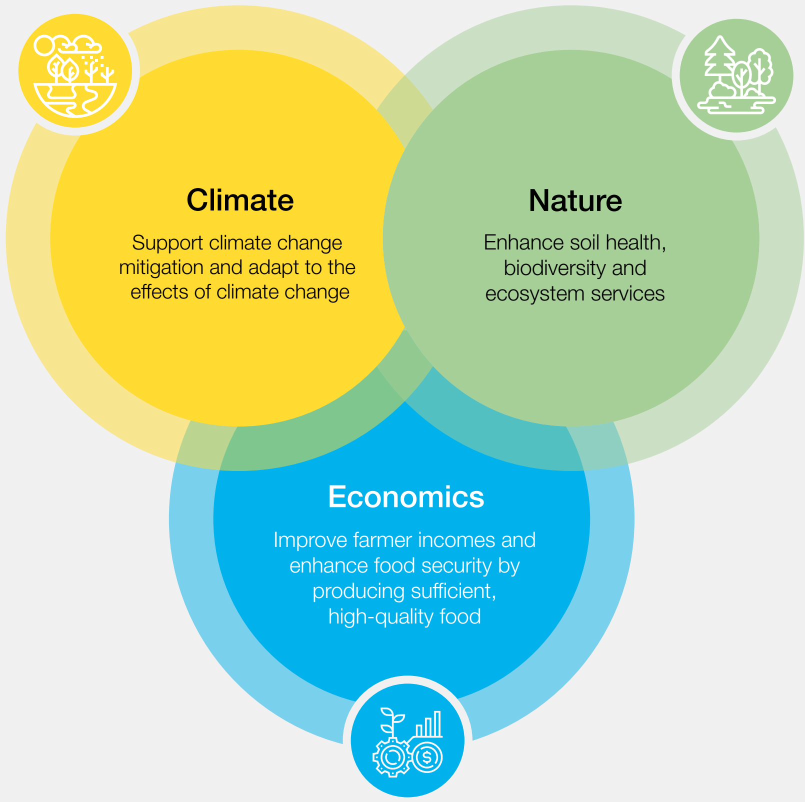
Fortunately, when sustainably managed, food systems can deliver on multiple goals. By deploying proven solutions, farmers can feed the world, restore critical habitats and soil health, mitigate and adapt to climate change, and generate fair livelihoods for their communities.[15] Soil alone hosts more than 25% of all biodiversity on the planet and is the second largest carbon sink on the planet.[16,17] While new technologies and innovations hold the potential to further increase the efficiency of agriculture, a suite of proven and readily-available practices such as no-till, cover crops, precision nutrient management and drip irrigation can already be implemented today.[18] The transition will also need to include broader shifts in production and consumption models, such as eliminating deforestation, dietary shifts and reducing waste. Practices to sustainably manage agriculture production are collectively referred to as "climate-smart", "regenerative", or "carbon farming", among other terms, and their precise definitions have not yet been clearly agreed upon in commonly accepted frameworks. This report is outcome oriented rather than prescriptive in terms of practices and definitions. Practices that can achieve positive outcomes for climate with strong co-benefits for nature and potential for farmer economic outcomes, while never having a negative impact on one of these, are included in the scope, as indicated in Figure 1. The practices included in the survey specifically were selected based on their relevance to the cropping systems included in the scope of the survey sample and hence do not include all practices that are available under the climate-smart, regenerative toolkit. To refer to this suite of practices, this paper will use the term "climate-smart".

“ Food and land use systems are responsible for up to one-third of global GHG emissions, are the primary driver of biodiversity loss and account for 92% of the global water footprint.

The climate-smart transition will require significant investments and policy changes to transform current economic systems and the food value chain. Action will include efforts from across the food value chain, from farmers to retailers, to investors and consumers. Fortunately, demand for sustainable agriculture is increasing. For example, recent consumer surveys have found that over 70% of consumers would be willing to pay a premium for brands that provide traceability and for organic ingredients.[19]

FIGURE 1 **28 climate-smart practices that can help improve outcomes for climate, nature and farmer economics have been considered in the scope of the farmer survey**

Climate-smart agriculture practices



Climate-smart inputs

- Organic inputs (organic fertilizers; harvest and pruning residues)
- Energy-efficient tools and machinery
- Low-carbon mineral fertilizers
- Biostimulants
- Improved crop varieties (e.g. drought resistant, more nutrients or water efficient, or higher yielding)
- Biological crop protection products
- Biodegradable plastic ground cover (prevents weeds and improves water retention)
- Nitrification inhibitor for fertilizers (slow fertilizer decomposition, increasing nitrgoen uptake by plants and reducing overall application need)

Agro-ecological practices

- No-till farming and direct seeding
- Soil coverage or permanent cover (with crop residue or pruning residues)
- Buffer strips or permanent vegetation
- Cover crops
- Rotational grazing

Efficient irrigation technology

- Use of water efficient irrigation technology such as drip irrigation
- Fertigation (applying fertilizer through irrigation systems to increase fertilizer use efficiency)
- Dynamic irrigation based on soil moisture sensing and digital decision support tools

Precision farming techniques

- Nutrient management planning tools (using farmland analyses to optimize or reduce overall fertilizer use)
- Irrigation management planning tools
- Variable rate fertilizer application (different rates and/or types of fertilizers within a field according to a pre-set field map)
- Remote sensing (e.g. satellite, drone)
- Farm management software
- Decision support apps for crop protection (optimizing or reducing pesticide use)
- Private weather station
- Soil nutrient cartography
- Soil analysis modelling
- Variable rate seeding
- Dynamic fertilizer application according to crop growth
- Targeted application of herbicides enabled by cameras and sensors

Digital practices

1.2 The economic case for EU food systems that support climate, nature and people

Food systems and the natural ecosystems on which they depend, such as soil, climate and water, are unique and diverse. Accordingly, successful food systems transitions will need to be nuanced to the specific environmental, economic and social factors in which they are embedded.

Food and agriculture systems are a fundamental sector of the European economy. Together, they provide almost 44 million jobs, including regular work for 22 million people within the agricultural sector itself on the region's 10.3 million farms.[20,21] The EU is also the world's largest agri-food exporter and one of the leading importers, putting the region's activities and actions at the helm of global trade.[22] Yet growth in the EU's agricultural sector has come at the expense of the region's environmental health. Occupying nearly 40% of the region's land-mass, agriculture is currently responsible for 10% of the EU's GHG emissions and is a leading driver of environmental degradation.[23,24] Since the 1950s, traditional farm management has been replaced by heavily industrialized and intensive agriculture. Intensive practices have allowed global agricultural output to increase by 60% over the past 40 years, yet they have also led to many environmental and social externalities.[25] Recent studies show that the EU loses 970 million tonnes of soil annually, equal to an area the size of Berlin at one metre deep, and has already lost 50% to 70% of the carbon stocks held in these soils.[26,27]

This degradation has already begun to impact the EU's productivity, farmer income and resilience to climate shocks, species abundance and habitat integrity.[28,29] Soil degradation is estimated to cost the EU €97 billion per year, more than a quarter of the EU's total agricultural output and much more than the subsidy bill given to agriculture through the CAP.[30] Some estimates predict that by 2050, climate-change-related temperature increases could reduce crop yields by 20%.[31] Such predictions are dire.

> **"In Europe, farmers' incomes are 40% lower than the average wage in the EU27 economy.**

In 2021, the EU launched its Farm to Fork Strategy under the European Green Deal to support the development of sustainable food systems that help mitigate climate change and adapt to its impact, reverse the loss of biodiversity, produce sufficient, safe, nutritious, sustainable food and generate fairer economic returns for farmers.[32] This strategy is complemented by a binding commitment for each member state to achieve climate neutrality in the land-use sector by 2035 (i.e. all emissions from land use are compensated by at least equivalent removals in the sector).[33] At the centre of the strategy lies climate-smart farming, with targets such as halving nutrient losses and the overall use and risk of chemical pesticides by 2030, which could help improve the EU's environmental impact while enhancing farmer livelihoods and resilience.

The 22 million farmers who manage nearly half of the EU's land must buy into any solution that is designed.[34] Farmers hold a wealth of historical agricultural knowledge which, in conjunction with modern agricultural techniques, is crucial for solving the complex, multifaceted challenges of food and agriculture systems today.[35] Yet farmers have often been left out of the decision-making process, meaning that policy, innovation and value-chain decisions have not always been farmer friendly. As a result, in Europe, farmers' incomes are 40% lower than the average wage in the EU27 economy.[36] These trends, combined with concerns over policy structures, have led to the recent waves of farmer protests and general discontent, notably in Ireland, Germany, France, the Netherlands and Belgium, among other countries.[37,38] Working closely with diverse farmers is therefore a critical pillar to enable a successful transition that will work and be sustained on the ground.

EU agriculture by numbers

10 milllion farms in the EU

22 milllion people work in agriculture in the EU

38% of total EU land dedicated to agriculture

€97 billion in lost value from soil degradation in the EU

10% of total EU GHG emissions

1.3 Moving from ambition to impact: A multistakeholder, farmer-centric approach

With less than ten years to go before the EU's goal of climate neutrality in the land-use sector, action and impact are needed now.[39] Both private and public sectors must embrace net-zero, nature-positive strategies and support farmers in the transition. Early movers still have an opportunity to seize competitive advantages, while those who lag may struggle to adapt as delivering broader societal value quickly becomes the expected norm for business practice.

While climate-smart practices have been recognized as key to achieving sustainable food systems, they have yet to be adopted at scale. Too often, farmers that want to implement climate- and nature-positive strategies are not supported or incentivized with an enabling environment. Without the appropriate policy, value-chain and consumer mechanisms to bring farmers on board, such practices will not become commonplace. Given the complexity of food and agriculture systems, developing these mechanisms will require a systemic approach that is greater than what any single actor can bring.[40] Any change that occurs at the farm level is unlikely to last if it is not supported by demand signals and financing for more sustainably produced products. This systemic approach is also important to balance the multiple, sometimes conflicting, goals of food systems actors, such as high production, nutrition, health, inclusive livelihoods for farmers and environmental sustainability. By working together, stakeholders can create and scale coherent action and cost-effective innovations in a way that may be impossible to reach if attempted by the individual organization alone.

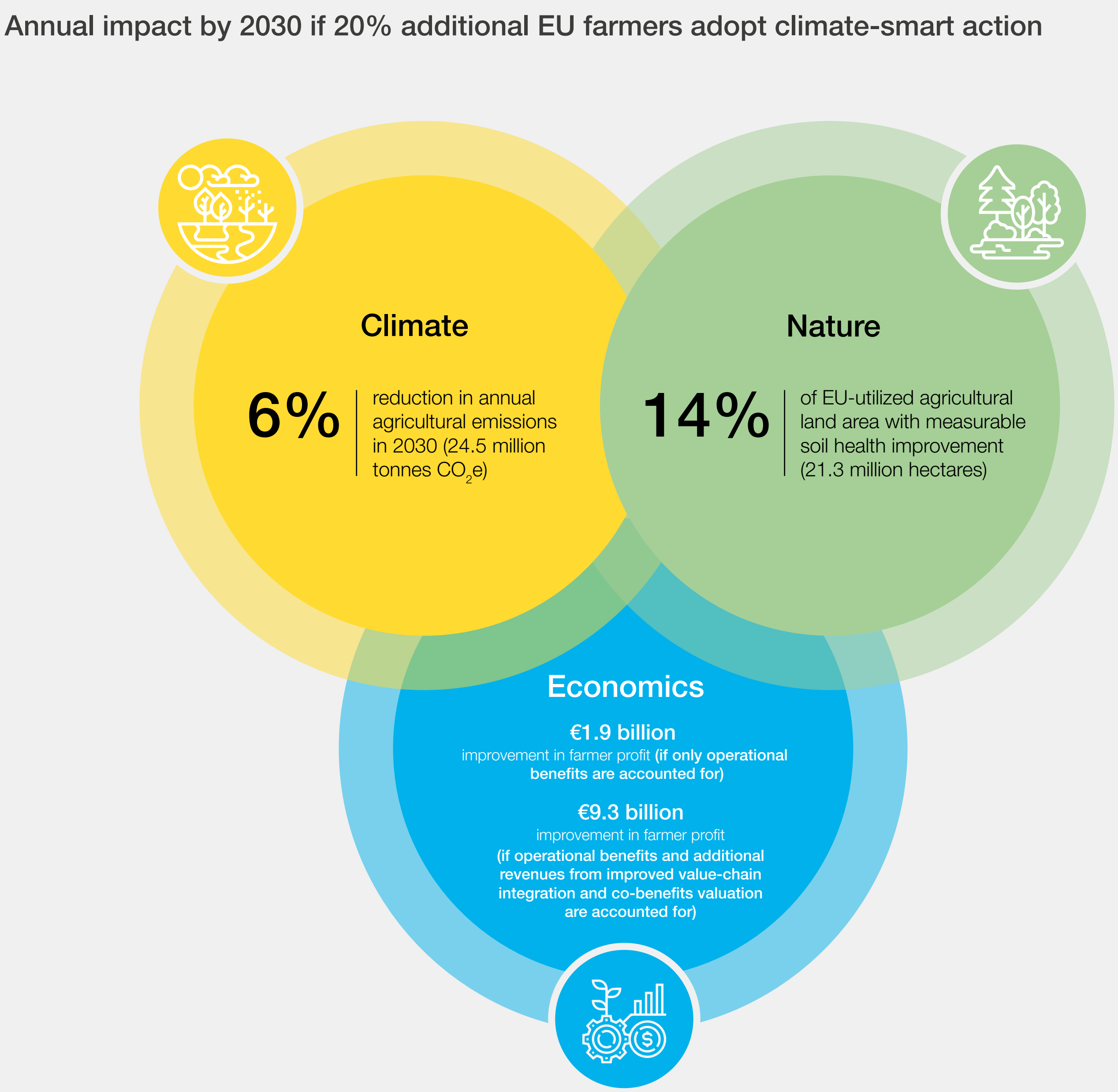
To address this gap, organizations from across the food and value chain have come together under the EU Carbon+ Farming Coalition to work with farmers to scale and mainstream the adoption of climate-smart practices that are better for climate, nature and farmers, and ultimately accelerate the Farm to Fork Strategy's goals.

If just an additional 20% of farmers adopted five climate-smart agriculture practices, by 2030 the EU could reduce its annual agricultural GHG emissions by 6%, improve the soil health of 14% of EU's agricultural land and improve farmer profits by between €1.9 and €9.3 billion annually.

Our analysis suggests that if just an additional 20% of farmers adopted five climate-smart agriculture practices, by 2030 the EU could reduce its annual agricultural GHG emissions by 6%, improve the soil health of 14% of EU's agricultural land and improve farmer profits by between €1.9 and €9.3 billion annually. The impact and feasibility of this transition will depend on the collective ambition of stakeholders to make the economics work. Indeed, the economic benefits for farmers following the adoption of climate-smart practices could be increased by more than fivefold if operational on-farm improvements are complemented by broader market-based incentives that are inclusive of societal benefits, such as carbon credits and price premiums, along with public subsidies. These additional sources of value would formally recognize and reward farmer contributions to the global goals regarding human and planetary health, incentivizing change and minimizing the burden and risk put on farmers. The coalition aims to support efforts seeking to unlock the potential for these market-based incentives.

It is important to recognize that several additional positive outcomes from applying these climate-smart practices are not captured by this analysis, such as avoided pollution, restored biodiversity and climate adaptation. Despite not being quantified, these additional benefits are essential to consider when making the case for the transition. Furthermore, the impact of some of these practices could be underestimated. For instance, with the rise in energy prices, the economic case for farmers to reduce fertilizer use through precision techniques is likely to be significantly enhanced.

FIGURE 2 **The impact of scaling climate-smart agriculture across the EU could support the region in meeting part of its Farm to Fork objectives**



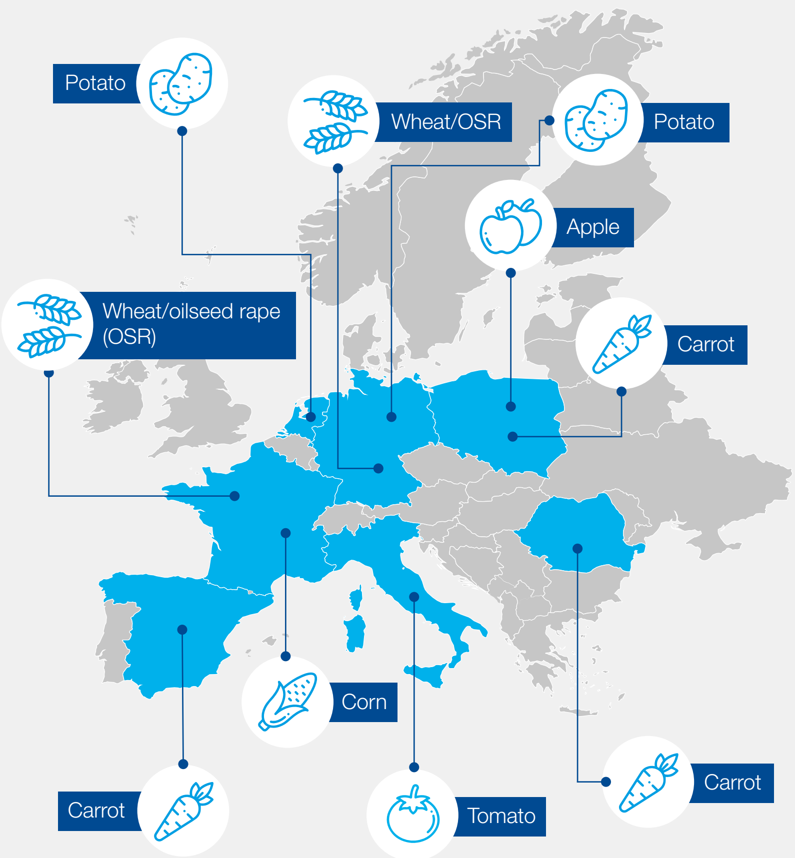
2

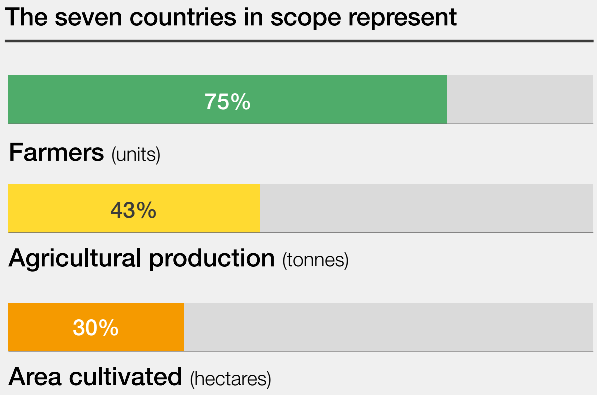
The state of climate-smart agriculture in the EU today

Helping farmers adopt climate-smart agriculture will also help make farming rewarding and attractive again.

To understand the current EU agricultural landscape, approximately 1,600 farmers across ten different country-crop combinations (covering seven countries and six crops) were surveyed to share the pain points they encounter in their activities, their level of understanding of climate-smart practices and the barriers they perceive to the adoption and scaling of these practices. The ten country-crop combinations were selected based on their representativeness for the EU agricultural landscape in terms of volume, farmer base, value-chain importance and consumer appeal (Figure 3).

FIGURE 3 **The ten country-crop combinations in the scope of the survey offer a good representation of the EU agricultural landscape**





EU total number

Farmers	10.3 million
Agricultural production (tonnes)	1,197 million
Area cultivated (hectares)	263 million

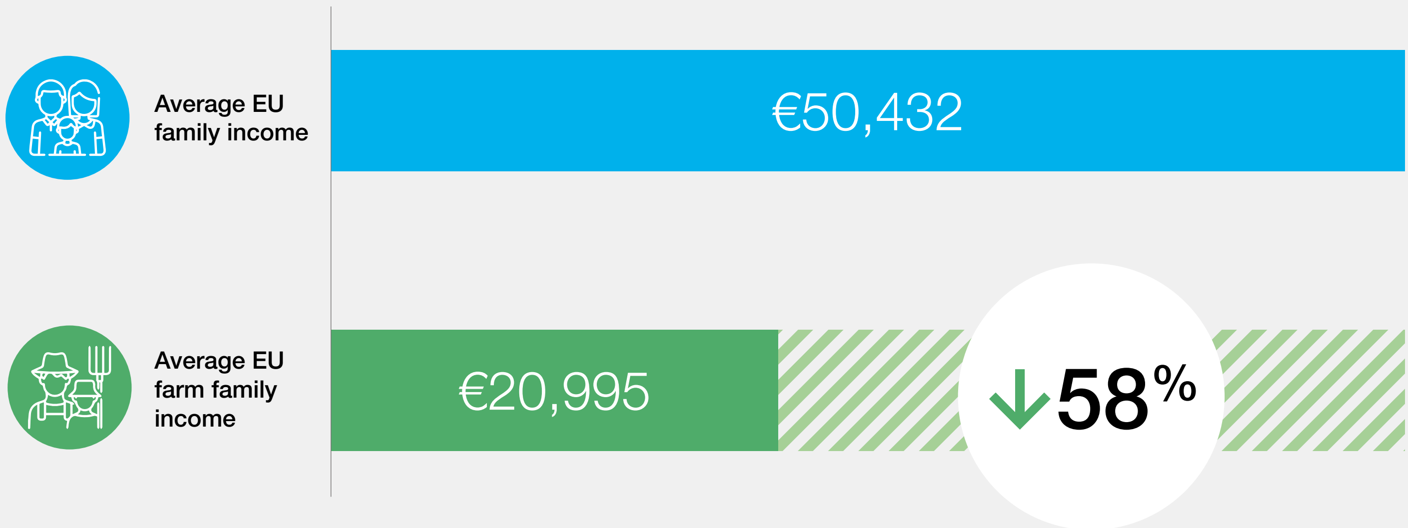
Source: FAOSTAT

2.1 Farm economics

Being a farmer in the EU is economically challenging. An average farming family in the EU earns just €20,995 per year, well below the average EU family wage of €50,432 (Figure 4), and over two-thirds of farms in the EU earn €8,000 or less.[41,42,43] Translated into hourly rates, farmers make less than the obligatory minimum wage in some of the EU27 member countries.[44] As price takers in a commodity market with declining prices, farmers capture a small portion of the total profit from food relative to other actors in the food value chain, such as consumer-facing brands.[45] The size of EU farms partly drives low farm wages. Most EU farms are relatively small, with over two-thirds spanning less than five hectares, and 96% are family owned.[46] Smaller land sizes inhibit economies of scale, which in turn disincentivizes "professionalization" through larger investments that could drive long-term profitability.[47] In addition, current policy schemes lack the support for smallholder farmers, with about 80% of the CAP direct payment subsidies going to just 20% of farmers and over 30% going to just 2% of EU farms.[48,49] These difficult conditions led the number of farms in the EU to drop by nearly 30% between 2005 and 2016, with over 4 million farms disappearing as farming became less and less attractive.[50]

FIGURE 4 **An average farming family in the EU earns nearly 60% less than the average non-farming family.**

Average yearly EU family income vs. income of family farms in 2019



Source: Farm Accountancy Data Network, Eurostat

In addition to being relatively low, farmer incomes are highly volatile and vulnerable to environmental and market swings, with crop prices sometimes fluctuating by as much as 50% over a single year. In 2014, for example, optimal growing conditions for German potato production led to above-average yields and production volume increased by 20%, resulting in a 48% drop in potato prices.[51,52] In 2015, severe droughts cut the harvest volume of carrots in Poland by 18%, causing prices to surge by 51%.[53,54] Farm input prices also fluctuate significantly, with fertilizer price, for instance, having increased by as much as 95% between 2010 and 2021.[55,56] Weather-related challenges, which were rated by surveyed farmers as some of the most challenging pain points in their operations, are only set to increase due to climate change, which makes unpredictable weather events more extreme and frequent.[57]

> **If a farmer wants to survive, he needs to be economically viable. Only then can he start thinking about the environment.**
>
> Spanish cereal farmer

A meta-analysis found that farmers implementing just three climate-smart practices could increase their profit by more than 11% and reduce the cost per hectare by 37% compared to conventional practices.

Still, many farms do not have the appropriate tools to cope with extreme weather events. Among farmers from across three country-crop combinations (Poland-carrot, Romania-corn and Italy-tomato), 86% mentioned that extreme weather resulted in events not appropriately covered by available insurance schemes and 69% said the available insurance plans were unaffordable. The importance of finding a solution to effectively insure against weather risks cannot be underestimated, especially with the growing impacts of climate change. Agriculture insurance can have long-lasting impacts on farmers' livelihoods by mitigating the loss of income and the risk of new investments in their farms without the risk of suffering losses or slipping into debt.[58] This is particularly important as many farmers are not appropriately equipped with the technologies to deal with climate events. For instance, just 12% of Romanian farmers felt that they had sufficient access to water-efficient irrigation to cope with droughts, which have become widespread across the region.

Farmers' top stated motivations for adopting practices were to increase yields and reduce costs. While some farmers value improving the impact of their operations on the environment, most will need a strong business case to change their practices. Many farmers are discouraged by the initial investments required for some of the climate-smart practices and because the potential initial yield drops while the soil regenerates and adjusts to the new conditions. However, an increasing amount of academic literature indicates that the business case for climate-smart agriculture is positive.[59] After two to four years on average, many climate-smart practices have demonstrated a positive return on investment.[60,61,62] Economic benefits can be delivered through increased yields, better crop quality and nutritional value, reduced water usage, decreased input costs and energy usage, and greater resilience to (or lower variability of) environmental changes.[63] Recent evidence from the US, for example, shows that corn farms using practices such as reduced tillage and lower application of fertilizers and pesticides earned 78% higher profits than traditional farms despite yield reductions in corn, thanks to the reduction in input costs and revenue stream diversification, and experienced fewer than one-tenth of the pests due to increased biodiversity and resilience.[64] A meta-analysis found that farmers implementing just three climate-smart practices (no-till, cover crops and diversified crop rotations) could increase their profit by more than 11% and reduce the cost per hectare by 37% compared to conventional practices.[65]

This is one illustration, as the relative financial improvements from climate-smart agriculture are context and practice dependent. Consolidated and accessible evidence is needed to establish a clearer link between specific practices and their value based on farm and landscape types. This knowledge base would remove some of the uncertainty involved in the transition and bolster the case for change. In addition, to ensure

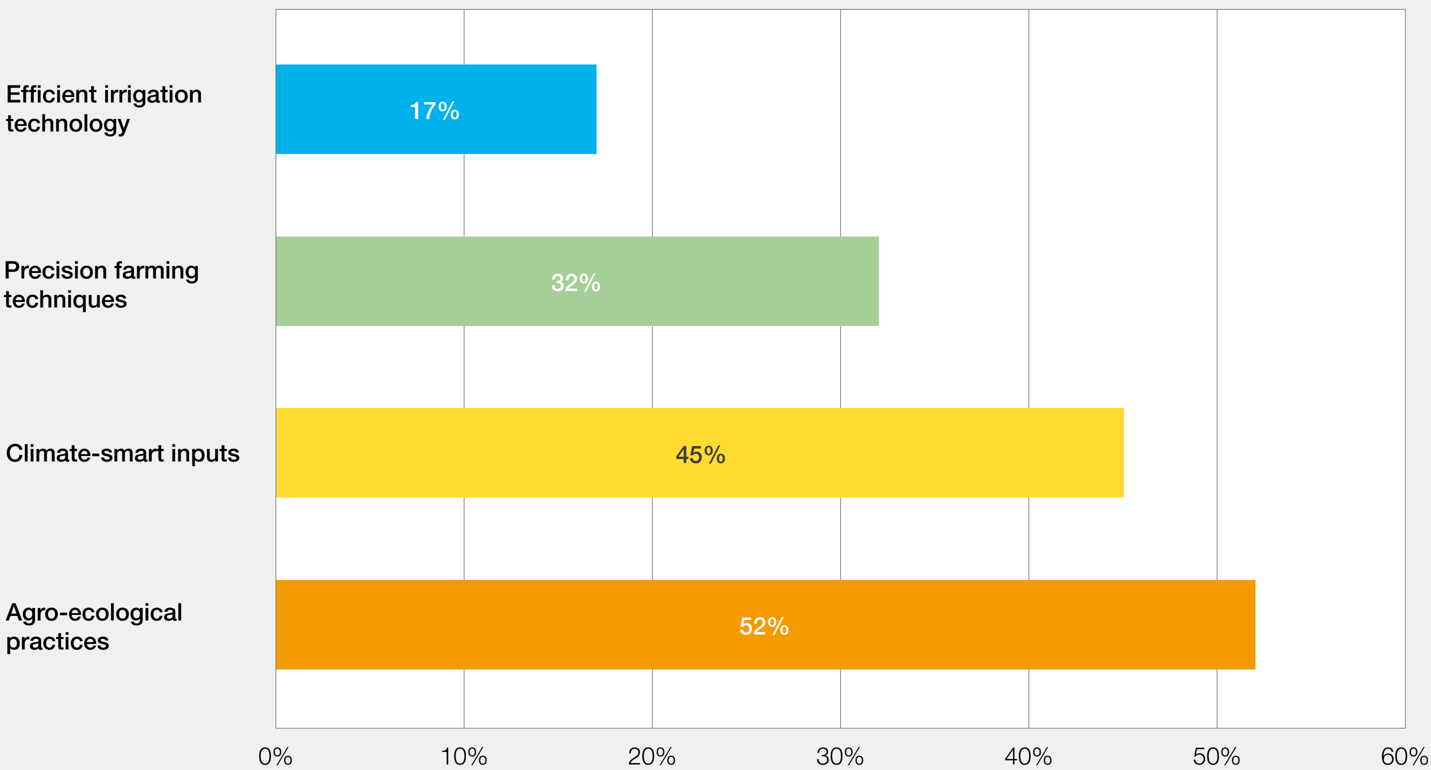
> **When I inherited the farm from my father, the soil was completely depleted. It was dead. We were using more inputs every year, but our yields were stagnating. That's when I decided to transition to regenerative agriculture. That was 10 years ago and I was met with scepticism. Nobody saw it as the solution, and fewer still considered it an economically viable option.**
>
> French cereal farmer

bottom-line improvements materialize, operational improvements should be further bolstered through new revenue streams such as carbon credits, ecosystem services payments or reduced land rent. Widely sharing the evidence that demonstrates the potential of climate-smart practices to help farmers improve their bottom line will be essential to address current gaps in understanding and knowledge.

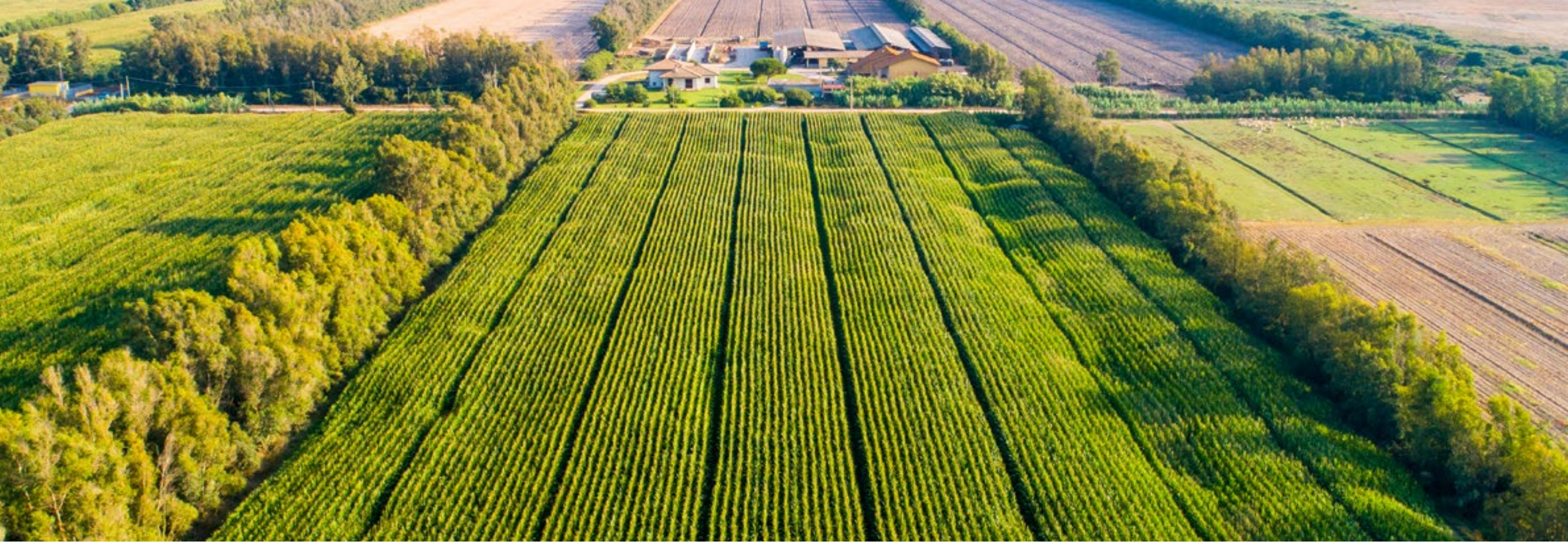
However, even if the long-term business case for climate-smart agriculture is positive, challenging farm economics limit farmers' ability to make long-term decisions and investments and hence prevent the large-scale adoption of climate-smart practices. Although 80% of farmers surveyed viewed transitioning towards sustainable agriculture as a necessity to address the current negative impacts of farming and to respond to consumer demand, adoption rates sat at an average of less than 40% for the 30 practices in the survey. This gap can be mainly explained by economics, with significant initial investment requirements ranked as the leading barrier to sustainable practice adoption across all the surveyed farmers. Indeed, in the short term, several climate-smart practices require high upfront investments. For instance, with a cost of €1,000-€2,500 per hectare, the average EU farmer would need to spend their entire annual revenue if they were to equip their farm with drip irrigation equipment.[66] As a result, despite an often positive long-term return on investment through decreased input usage, improved yields and reduced energy consumption, these investments are not made. For these reasons, farmers need tangible financial incentives to adopt practices that are better for society. As shown in Figure 5, some practices, especially those with lower upfront investment costs and lower-tech requirements, such as agro-ecological practices, have higher adoption rates.

FIGURE 5 **The adoption rates displayed across practice types vary significantly, with higher adoption rates for lower-tech and lower-cost practices**

Average adoption rate of climate-smart practices by category



Source: Farmer survey



2.2 Awareness and knowledge

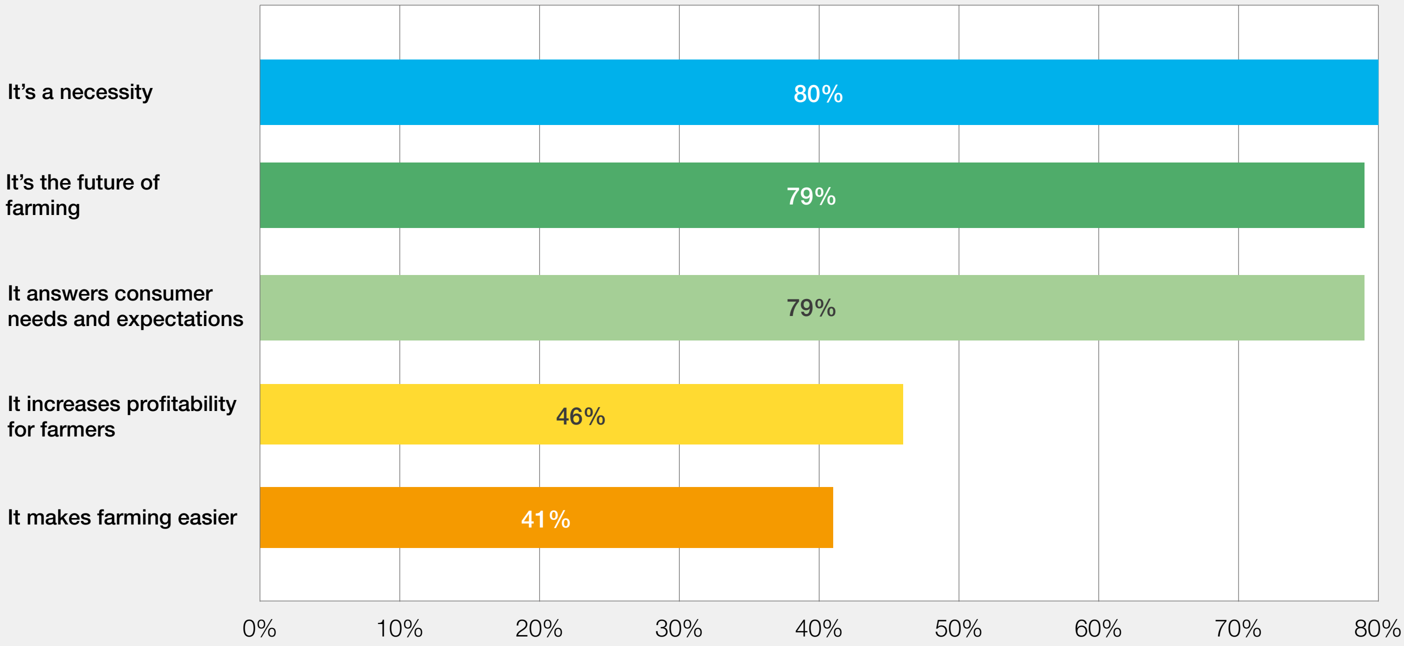
On average, for every 10% increase in farmers' perception of economic benefits, the adoption of that practice increased by 16%.

Many climate-smart practices suffer from being perceived as an economic burden by farmers. Four out of five farmers surveyed viewed sustainability as a necessity and the future of farming, but only two out of five viewed it as a driver of profitability (Figure 6). On average, the surveyed farmers scored the economic benefits of climate-smart practices at 6.4 on a scale of ten. This relatively poor perception hinders practice adoption, which is highly correlated (R^2 greater than 0.5) with perceived economic benefits.

On average, for every 10% increase in farmers' perception of economic benefits, the adoption of that practice increased by 16% (Figure 7). Practices with positive economic perception scores of more than 7 out of 10 were adopted by 60% of the farmers on average, compared to just 6% adoption of practices with scores lower than 5. There seems to be significant scope for changing this misperception through awareness and education campaigns and for continuing to improve the financial case for change.

FIGURE 6 **Farmers understand the necessity to transition to climate-smart agriculture to respond to increased societal demand for improved environmental outcomes, but not all see the financial case for change**

Why improve the sustainability of your farm?



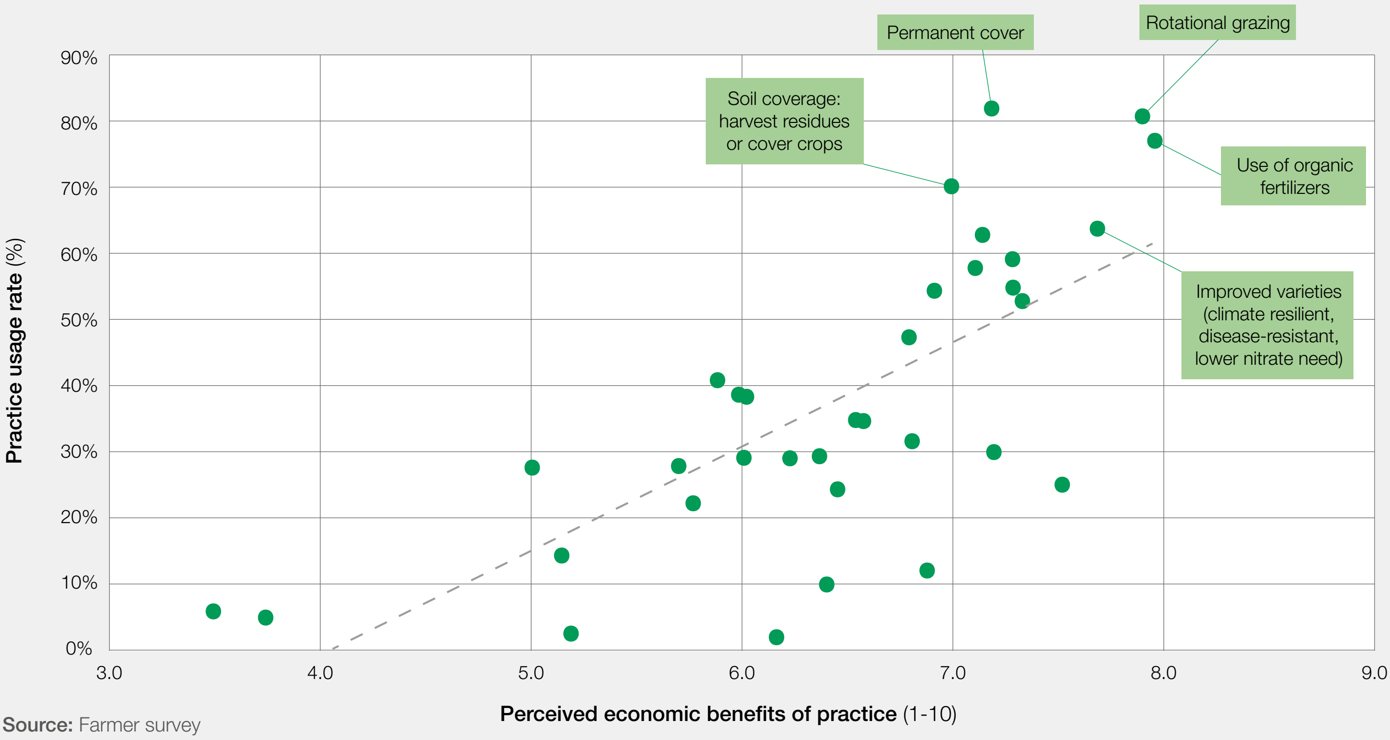
Source: Farmer survey

On average, 70% of the surveyed farmers reported having searched for information on climate-smart farming, demonstrating an interest in the area, yet only one out of four reported having a “good” or “very good” knowledge of the subject.

The transition to climate-smart agriculture will not occur without improving farmers’ knowledge and awareness of these practices. If farmers do not understand nor believe in the economic case for transitioning towards climate-smart practices, the ability to meet EU targets will be limited. Farmers’ second most cited barrier to climate-smart practice adoption, consistently across all ages, countries, crops and farm sizes, was a lack of information and awareness. On average, 70% of the surveyed farmers reported having searched for information on climate-smart farming, demonstrating an interest in the area, yet only one out of four reported having a “good” or “very good” knowledge of the subject. When it comes to carbon farming (the focus on carbon sequestration in soil) specifically, Figure 8 suggests that overall farmer interest is high. But of the farmers interested in enrolling in carbon programmes, 76% cited the lack of access to programmes or the lack of information on how to participate as the largest barrier to enrollment. Moreover, when asked which incentive would be most effective at bolstering practice adoption, 31% of surveyed farmers gave reliable (or high quality) information as their primary incentive. The results indicate that farmers do not have the information they need to understand the value of climate-smart agriculture to their farm operations, learn how to conduct the practices, justify the investments or connect to the enabling infrastructure in place to support the transition.

FIGURE 7 **Farmers are significantly more likely to adopt a practice if they think it will help them improve their bottom line**

Practice usage rate based on perceived economic value

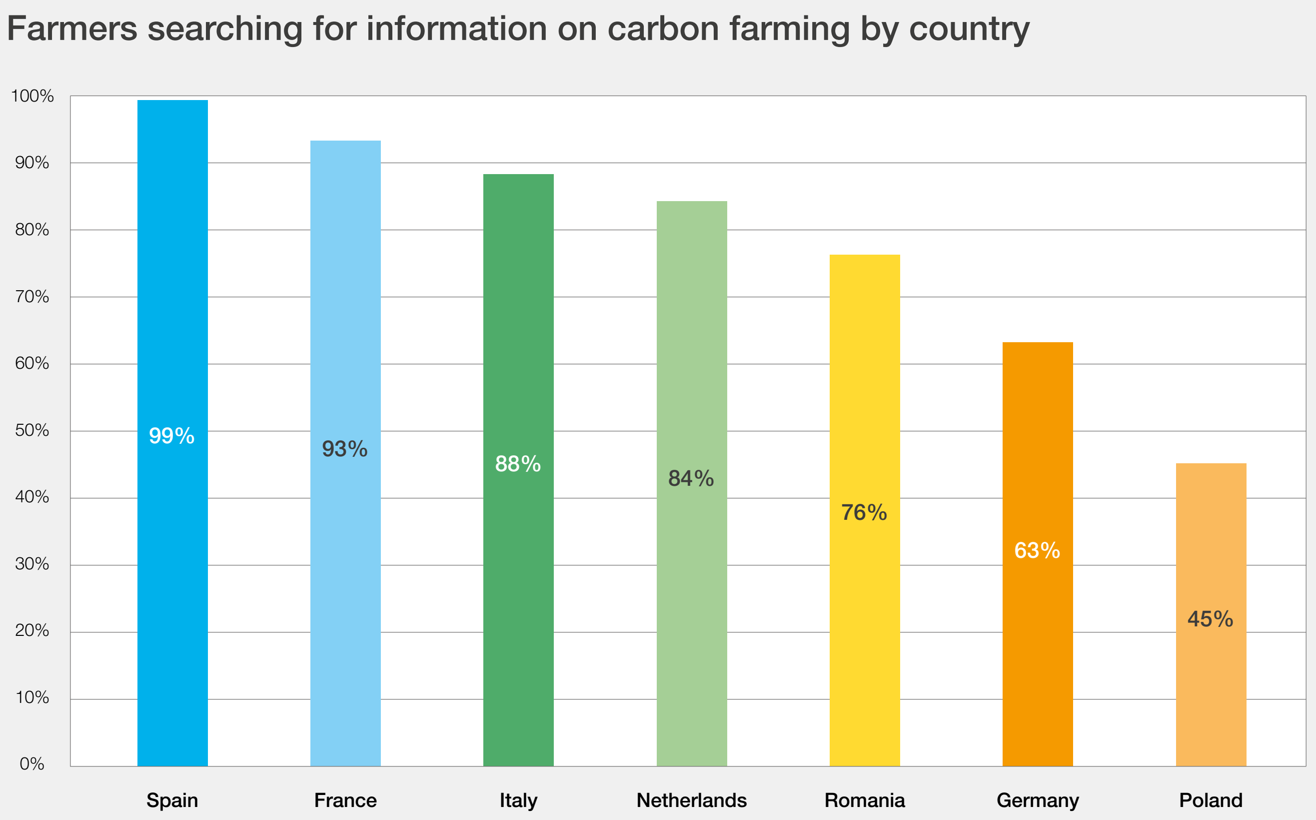


Source: Farmer survey

> **I hope climate-smart farming will evolve into a well understood and standardized label, like organic farming has.**
>
> Italian grape grower

Information on climate-smart practices is insufficient and unreliable, leaving many farmers dissatisfied. Farmers receive information from an overwhelming number of channels, including input providers, cooperative advisers, public institutions, retailers, agricultural press, private advisers and other farmers, often with insufficient and conflicting messages. Selecting which information is relevant is therefore challenging. On average, 39% of surveyed farmers are dissatisfied with the information they receive. Creating the right economic incentives, while critical, will be insufficient at driving large-scale behaviour change if not coupled with information to help farmers understand climate-smart practices and their benefits for their operations – both economically and otherwise. Improving the quality and consistency of information on climate-smart agriculture could significantly accelerate the transition to climate-smart agriculture.

FIGURE 8 | Farmers' interest in carbon farming is high



Source: Farmer survey

Information can help connect farmers to additional revenue streams for using climate-smart practices. Education can also help farmers understand the different payment schemes available to reward them for the adoption of climate-smart practices, such as public subsidies, carbon or other ecosystem credits and price premiums. Among the surveyed farmers, approximately 42% had adopted three or more climate-smart practices, but many felt they were not appropriately rewarded for these. Farmers are often not compensated for the public goods they are contributing to, such as helping fight climate change or protecting biodiversity, in addition to crop production. Increasing awareness about available incentive programmes, coupled with administrative streamlining or support, could significantly improve farmer livelihoods through these additional revenue streams.

2.3 Data and technology

Digital climate-smart practices are a cornerstone of the transition to climate-smart agriculture. Tech-enabled precision agriculture, when paired with more traditional practices such as cover crops or natural buffer zones, can reduce the environmental impact and improve the productivity of agriculture. Digital practices, such as farm management software, satellite or drone monitoring and decision support technology for input and water use optimization, can deliver a variety of benefits to farmers.[67] These benefits range from improved productivity and crop quality to more efficient operations, reduced input usage and costs, lower environmental impact and adaptation to climate change.[68] Furthermore, product attributes verification (e.g. organic or carbon neutral) allowed by digital systems can unlock new revenue streams. For example, by analysing data gathered from sensors, tractors and satellites, farmers are able to track crop and soil health, make planting decisions and precisely guide fertilizer and water use to improve the efficiency of their businesses, tackle fertilizer loss and hence, reduce farm expenses, water pollution and emissions. Another example can be found in the financial and insurance sector, where by harnessing the power of big data and satellite technology, financial and insurance institutions can lower transaction costs (through reduced need for farm inspections) and mitigate agriculture-specific risks by improving modelling, thereby

> Digital practices were adopted by 32% of farmers on average, compared to 45% for other climate-smart practices.

reducing the risks of providing insurance products to farmers.[69] Farmers' adoption of insurance products has a positive impact on investments, efficiency and income. Although digital agricultural practices offer considerable benefits, they have some attendant risks, such as leaving smallholder farmers behind or reduced crop diversity, requiring innovative governance models, greater research into understanding their impact on environmental and human health and public dialogue.

Digital tools are also critical for providing farmers and value-chain players with the data collection capabilities needed to measure the impact of the farm-based transition and support ongoing product development. To measure the impact of farm practices and outcomes, farmers and value-chain players will need access to reliable and transparent data. Digital farm measurement tools will be key in collecting, storing and analysing this data. This data can include the amount of carbon stored in the soil (soil organic carbon content), on-farm biodiversity, emissions intensity, water quality and yield, and will become increasingly required for farmers to be rewarded for the outcomes of their work. At the same time, regulations that protect data privacy need to be in place and the EU's existing framework, recognized by Human Rights Watch as one of the strongest and most comprehensive[70], provides a strong starting position to build upon.

The current adoption of many of these technology-enabled practices remains low, primarily due to a lack of knowledge and high investment costs. The surveyed farmers seemed to be less ready to adopt digital practices. Digital practices were adopted by 32% of farmers on average, compared to 45% for other climate-smart practices. Farmers cited two reasons as the largest barriers to adoption. First, many farmers were unaware of the potential benefits of digital climate-smart practices and unsure how to implement them. Second, for more tech-savvy farmers, many perceived these technologies to be too expensive and/or have excessive payback periods. Digital practice adoption rates can be bolstered by improving access to practical information and training on how to use technology, on the one hand, and improving access to capital or lower-cost technologies on the other. In addition, tailoring technology to specific crop and farm types (e.g. smaller farms) could also improve adoption rates. Furthermore, standardized digital pan-EU frameworks would help reduce costs and improve scalability for technology developers.

Most farmers mentioned using farm management software mostly for tracking and hence, optimizing crop protection product (60%) and fertilizer (57%) usage. However, there was less frequent use of management software to track and optimize irrigation (25%) or energy efficiency (18%) and carry out soil analysis (43%). These are interesting insights in light of the need to enhance the resilience of farmers to climate change and improve the environmental outcomes of agriculture. For instance, soil analysis is a central method for measuring many of the outcomes of climate-smart agriculture, such as carbon mitigation, water retention, crop health, enhanced biodiversity and even improved nutritional quality.[71,72] Farmers seeking to be rewarded for implementing certain practices might be required by certain value-chain players or frameworks to demonstrate the impact of these practices on key outcomes. Thus, helping farmers use technology for the MRV of a set of comprehensive farm outcomes will be critical to help them access relevant premiums and payments for their work.

2.4 Policy

The latest reform of the European Commission's CAP aims to pave the way for scaling climate-smart agriculture. The CAP is the EU's largest and longest-serving policy, constituting a third of the EU budget and playing a major role in influencing farmer competitiveness, both within the EU and globally. Historically, the CAP has focused on productivity and efficiency, often at the cost of the environment and equity.[73] However, over time it has begun prioritizing environmental protection alongside yields. While past attempts to "green" the CAP have had little impact on the environmental impact of agriculture in the EU,[74] the latest €270 billion reform is set to start in 2023 with a focus on achieving the goals of the European Green Deal. It mainly aims to do so through conditionality – a set of do-no-harm requirements farmers have to respect to receive CAP funds – and eco-schemes, whereby farmers are paid for taking actions that are beneficial to the environment, such as soil restoration or reduced pesticide use. Eco-schemes will make up 18% of the CAP budget.[75] These payments aim to incentivize farmers' long-term adoption of climate-smart practices by tying specific practices to new revenue streams. While conditionality and eco-schemes have been positioned as a powerful tool to green the CAP, critics fear that these are not ambitious enough to meet the Farm to Fork's and biodiversity strategies' objectives, failing to orient and support EU farmers in the transition to climate- and nature-friendly agriculture.[76]

The fragmentation in national CAP implementation risks slowing climate-smart action and distorting farmer competitiveness across the common market. The European Commission published a list of potential eco-schemes, including organic farming practices, re-wetting peatlands and planting climate-resistant crops.[77] However, to implement the CAP, each EU member state has some discretion through their national strategic plan (NSP) to outline which agricultural practices will be rewarded and by how much. While this implementation flexibility enables member states to tailor solutions to their local economies and ecosystems, it also results in a lack of standardization across the EU, which might slow overall progress on environmental and social objectives.[78] For instance, from 22 draft strategic plans analysed across 21 member states, 166 different eco-schemes were identified (up from three greening practices in the past). Typically, countries are planning between 4 and 12 eco-schemes to cater for different objectives and farming systems.[79] Overall, there seems to be very little commonality in practices promoted and subsidized between countries.

Payment modalities to farmers also differ between countries. For example, while Spanish farmers will receive a flat rate for each individual practice they adopt, Dutch farmers will be rewarded proportionally for their efforts based on a multidimensional eco-scheme with a point-based system.[80] Such wide discretion in the application of eco-schemes might lead to a market divide between farmers whose government is highly supportive of the transition to climate-smart agriculture and those who are not. For example, as illustrated in Figure 9, a carrot farmer in Poland applying all available eco-schemes could receive up to nearly four times as much income per hectare as the same farmer in Spain. As a result, eco-scheme payments could account for nearly 40% of the Polish farmer's income, as opposed to just 5% for the Spanish farmer's income, potentially putting the Polish farmer at a competitive advantage with retailers seeking sustainably produced goods.[81]

FIGURE 9 | **Differences in reward structures for eco-schemes across EU member states could lead to farmers applying the same practices receiving significantly different compensation**

Preliminary quantitative difference in eco-scheme payments

Country	Support from overlapping eco-schemes	Support from all available eco-schemes
Poland Average revenue: €6,100/ha*	**€374/ha** or 6% increase in average revenue	**€2,302/ha** or 38% increase in average revenue
Spain Average revenue: €11,200/ha**	**€314/ha** or 3% increase in average revenue	**€595/ha** or 5% increase in average revenue

* Considering average price €0.2/kg (Polish government data) and average yield 30.6 tonnes (t)/hectare (ha) (quantitative survey)
** Considering average price €0.1783/kg (Spanish government data) and average yield 63 t/ha (quantitative survey)
Source: Polish second draft of the strategic plan (July 2021); Spanish Proposal for Eco-schemes (October 2021); German draft for intervention profiles (May 2021); Italian draft for eco-schemes (October 2021); French strategic plan draft (September 2021); Dutch proposal for eco-schemes (October 2021)

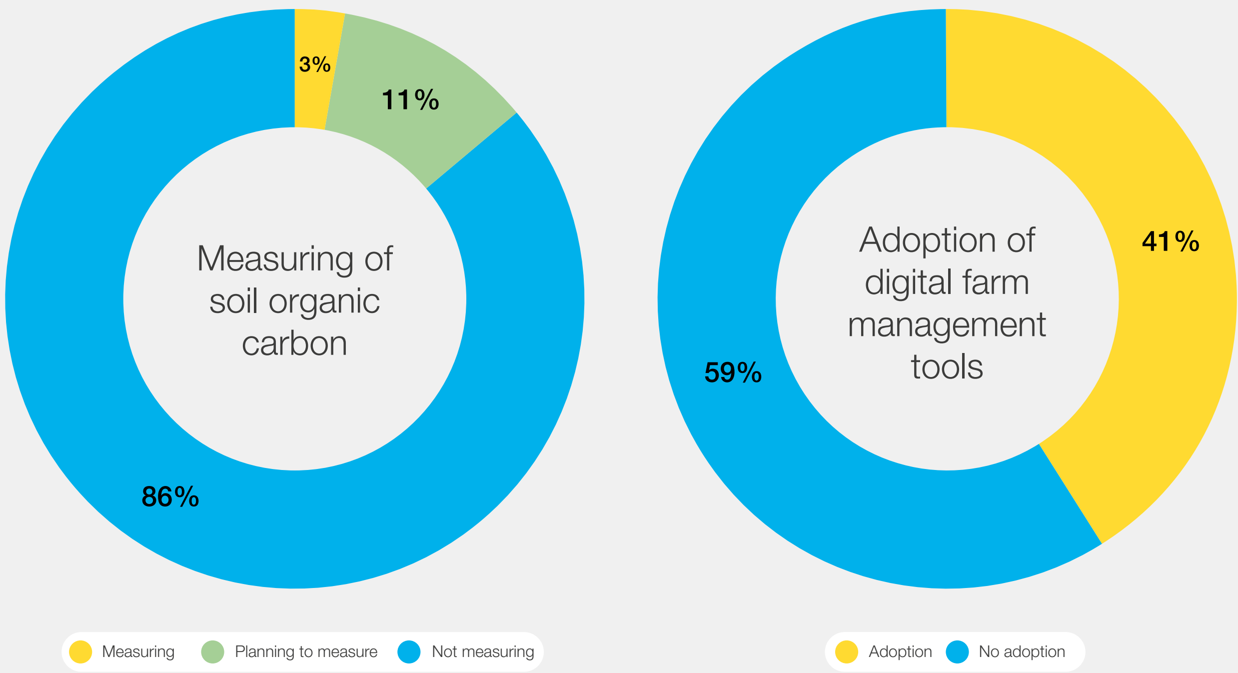
The fragmentation in government support for climate-smart agriculture across the EU also hinders private-sector investment. Private sector players across the food value chain that want to implement net-zero or nature-positive strategies are already actively seeking to transform their business operations and support farmers with climate-smart agriculture.[82] Financial players, for example, are launching new loans and insurance products that can de-risk the transition. Food companies that look to lower supply-chain risk and reduce their ecological footprint are defining new purchase agreements with farmers.[83] And agricultural input and technology companies are developing new products to respond to new farmer needs. However, for real transformation to occur, these positive examples need the ability to scale and a compelling business case to justify their investments. If farmers are all adopting different practices and receiving financial support, accurately addressing farmers' needs might be complicated and time-consuming. For organizations with EU-wide operations managing each country's specifications separately, this would create additional overheads and costs, which might get passed on to consumers or discourage private-sector investment, innovation and agility. In addition, these differences might slow the development of a consistent consumer-facing label and create ambiguity for consumers.

In addition to the CAP eco-schemes, the European Commission is developing additional incentive schemes focused on carbon markets. However, farmers are not equipped to participate. Beginning in 2030, agricultural and land-use emissions will be included in the EU's climate and energy framework and hence, in its overall emissions reduction goals.[84] However, the recognition that the EU is currently not on track to meet its target of net-zero GHG emissions by 2050 is leading to the development of a carbon market for agricultural credits that can be used to scale the deployment of carbon removal solutions.[85] Carbon markets could act as an integral part of the long-term sustainability of the climate-smart transition by offering payment to farmers for the positive societal outcomes they deliver over and beyond yields. The European Commission is planning to develop a common regulatory framework to monitor and verify

“ Carbon markets could act as an integral part of the long-term sustainability of the climate-smart transition by offering payment to farmers for the positive societal outcomes they deliver over and beyond yields.

the authenticity of carbon removals in agriculture (and forestry) for publication in 2023 to help standardize current public and private schemes. In contrast to CAP incentives, which are largely action-based payments for compliance with very specific farming practices or technologies, the carbon market framework will be result-based, with the incentive payment linked to measured outcomes on the farm, irrespective of the precise farming practices that are applied.[86] However, to access these incentives, farmers will need to be able to comply with stringent requirements for MRV, additionality and permanence, for which our evidence suggests farmers are ill-prepared. Despite 50% of surveyed farmers expressing interest in carbon markets, only 3% are currently measuring soil organic carbon, a key metric for measuring many outcomes on soil quality, climate change mitigation and biodiversity (Figure 10).[87] Further, over half of the farmers mentioned not using supporting digital farm management tools to store, verify and report on measured farm data. Given that the European Commission has established recommendations for carbon programmes that entail strict MRV requirements and place the burden of proof of additionality on farmers, the low impact measurement currently happening on farms will likely be a hurdle to participation in carbon or other ecosystem payment programmes; hence, limiting the ability to create a broader "ecosystem services marketplace".

FIGURE 10 **Only 3% of farmers surveyed currently take soil organic carbon measurements and less than 50% use digital farm management tools**



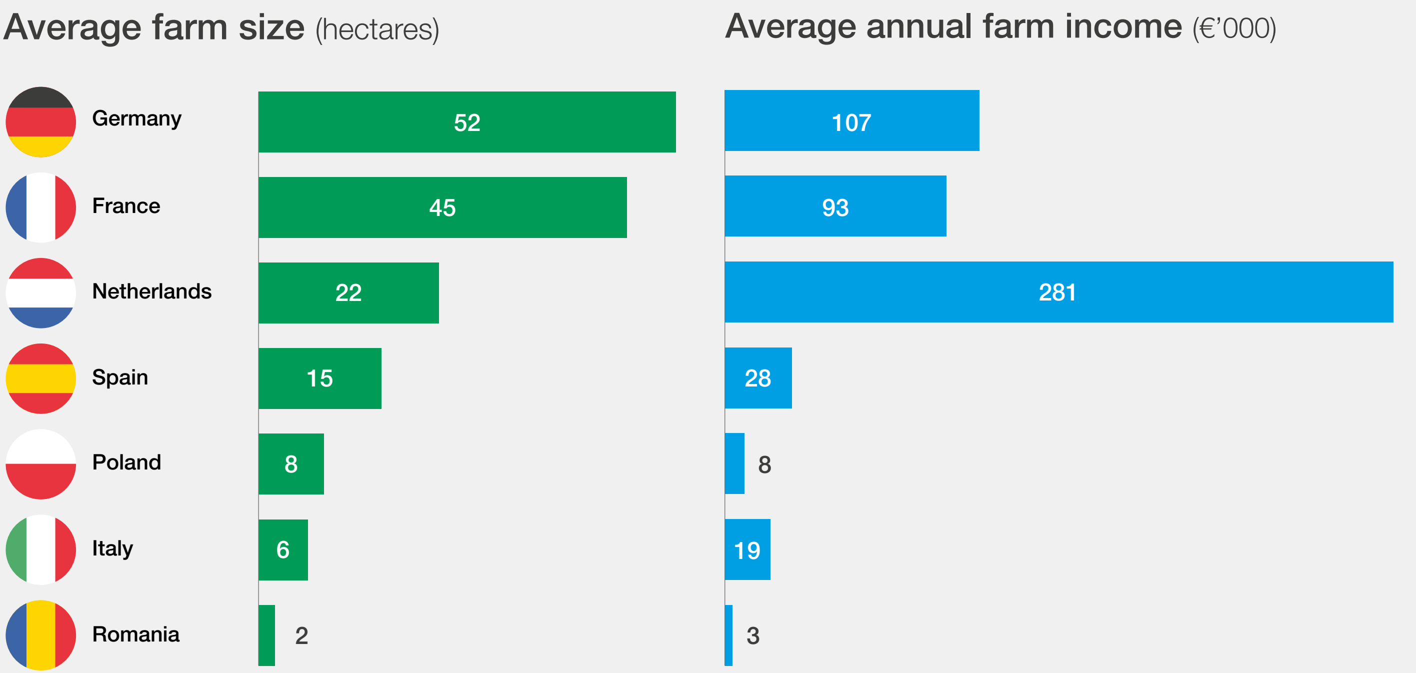
Source: Farmer survey

In order to accelerate the achievement of agricultural-related goals on climate and biodiversity, the European Commission launched its soil strategy on 17 November 2021. This strategy aims to ensure farmers are equipped with the tools and data needed to embark on the transition. For instance, to support and scale farmer access to MRV systems, the Commission is helping member states to put in place access to free soil analyses while improving its geospatial analysis and modelling capacity for soil-related processes, thereby harmonizing monitoring and reporting requirements.[88] For instance, it is developing a digital service platform (FaST) that will integrate space data with public datasets to provide capacity building for sustainable and competitive agriculture to EU farmers, member state paying agencies, farm advisers and developers of digital solutions.[89] In addition to helping farmers enrol in carbon programmes, these efforts could also help to improve farmer profitability by optimizing farm operations.

If the suite of initiatives from the European Commission offers a strong foundation for building more robust MRV systems for farmers and scheme developers, their success is contingent on effective national implementation. Currently, for example, the launch of the free digital farm platform is geographically limited to only some regions within a few countries.[90] In addition, many of these initiatives are provided as recommendations that are not binding and rely on national funding. While supportive, the broad policy ecosystem in the EU might not be effective in supporting the change it seeks without strong national and private sector buy-in.

2.5 Farm diversity

FIGURE 11 **The agricultural landscape varies greatly between the countries surveyed in terms of farm size and income**



Source: Analysis of Eurostat data

The economic and demographic diversity across EU countries' agricultural landscapes requires a fine balance between standardization and locally-relevant approaches. Farm economics, demographics and natural ecosystems vary greatly between EU countries. The average German farm is 25 times larger than in Romania, for example. Although some of the differences illustrated in Figure 11 are due to structural differences regarding the type of crops grown, overall, they highlight that Western European farms tend to be larger and more profitable than Eastern European farms. Western European farms also tend to be owned by cooperatives and engaged in more technology-based agriculture techniques.[91] In addition, the survey results indicate additional differences with regards to behavioural patterns, informational preferences, and practice and tool uptake. This diversity means solutions developed to support farmers in their transition to climate-smart agriculture will need to be tailored to be effective, giving private and public players the challenging task of balancing between standardization and customization.

Farmers have different approaches to research and information gathering, which will impact efforts to enhance farmer education and awareness. The amount of interest farmers express in climate-smart agriculture differs significantly. For example, 99% of all Spanish farmers mentioned having searched for information on carbon farming, compared to 45% of Polish farmers. The reasons for this difference can potentially be explained by the exposure to climate-smart topics provided by the information channels used by farmers. Western European farmers mentioned preferring more formal sources such as the agricultural press, cooperative advisers and the ministries of agriculture. On the other hand, farmers in Eastern Europe seem to rely mostly on informal information sources through farmer-to-farmer knowledge sharing and private advisers. In such a decentralized model, if initial farmer knowledge and the awareness of new forms of farming are low, overall knowledge and uptake will remain low. Gaps also exist within the broader east/west regions. For example, while 37% of Dutch farmers trust the agricultural press, only 3% of Spanish farmers do. These differences might explain why Western European farmers' climate-smart practice adoption rate is twice as high as in Eastern Europe, at 45% on average compared to 21% in the latter region. This variability also has an impact on programme design for farmer awareness and training programmes, as farmers will respond differently based on their information channel preference.

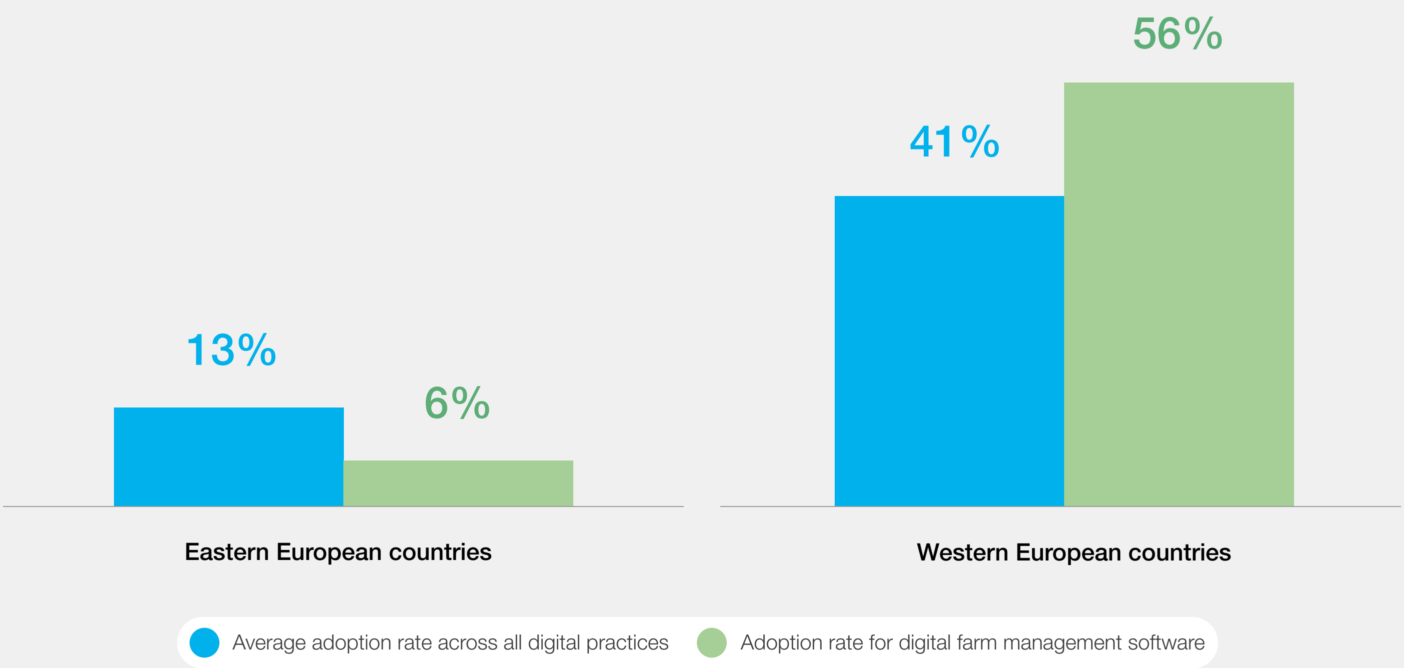
Eastern European farmers lag behind Western European farmers when it comes to the adoption of digital climate-smart practices. 41% of Western European farmers reported using digital

Demographic and socioeconomic differences might explain why Western European farmers' climate-smart practice adoption rate is twice as high as in Eastern Europe, at 45% on average compared to 21% in the latter region.

tools, compared to only 13% of Eastern European farmers. This gap can be explained by differences in demographics, education levels, farm structures, information channels and overall digital connectivity. Western European farmers tend to have greater access to education and operate in countries with more developed digital infrastructure such as broadband and mobile connectivity, creating a more conducive environment for the adoption of digital agriculture practices.[92,93] In addition, as Western European farms tend to be larger, farmers are more inclined to "professionalize" their activities and can justify and spread the investment costs for digital tools over larger operations. With survey results showing a significant positive correlation between farm size and practice adoption rates, especially for digital practices, acknowledging these differences is important for designing relevant solutions. For instance, with only 6% of Eastern European farms reporting being equipped with farm management software, compared to 56% adoption in the West (Figure 12), Eastern European farmers, in particular, could be better supported through improved access to digital-focused knowledge and awareness programmes, as well as the financial support needed to make these investments.

FIGURE 12 **The digital divide is more pronounced in Eastern Europe**

Adoption rate of all digital practices and farm management software in Eastern and Western Europe



Source: Farmer survey

Climate-smart adoption rates are also significantly impacted by farmer demographics, values and social factors. For instance, the survey results indicate that farmers under the age of 36 are up to 5 times more likely to adopt certain practices (e.g. farm management software or soil cover) than older farmers. Given that only 11% of farm managers in the EU are under the age of 40, making farming attractive and exciting again for the younger generation, on the one hand, and designing more approachable solutions for older farmers, on the other, are important considerations.[94] In addition, other assessments found that farmer social values and conceptions of "the good farmer" and "a good landscape", can discourage climate and biodiversity-friendly behaviour, with, for example, no weeds, tidy row lines and high yields perceived as characteristics of a "good landscape".[95]

Agri-food value-chain players seeking to support the transition to climate-smart agriculture should understand the local technological, social and demographic factors that will make the designed solutions work or not in specific regions. Solutions developed will have to effectively balance standardization for scale with nuanced adaptation to local contexts to meet farmers where they are and maximize the likelihood of adoption.

3 The path forward: Opportunity spaces to accelerate the transition to climate-smart agriculture

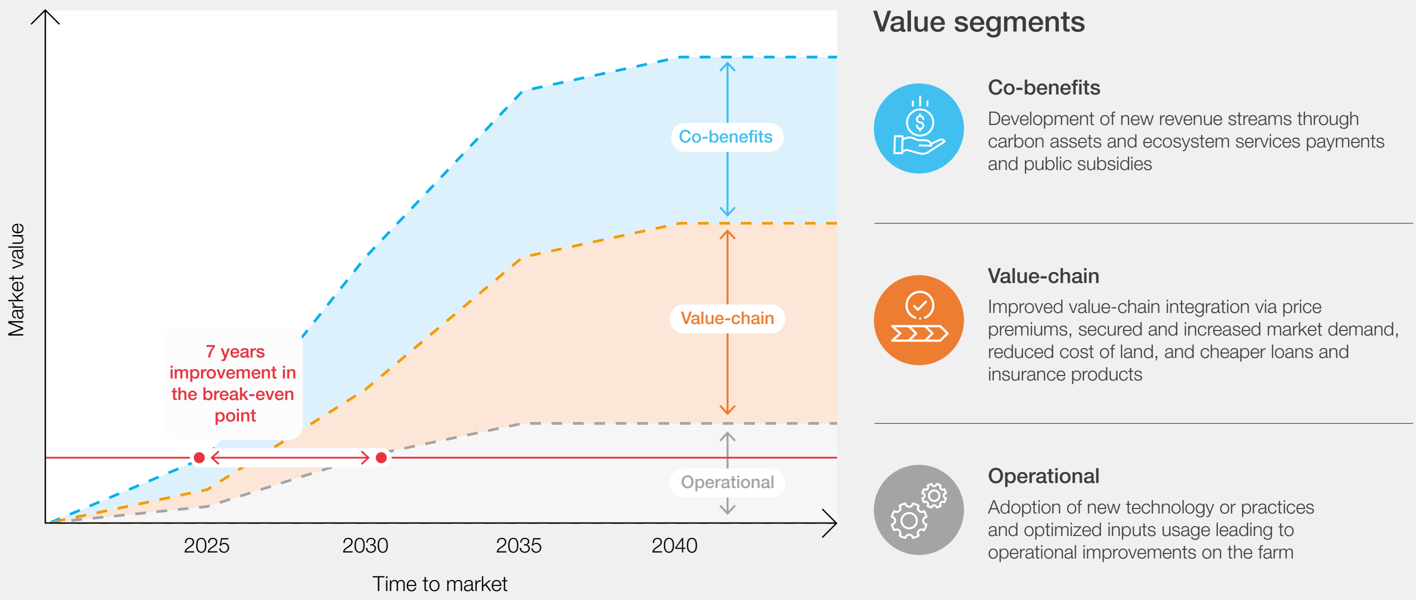
The transition to climate-smart agriculture will require significant investment and model changes across the food value chain, with farmers, retailers, investors and consumers each needing to act.

The transition to climate-smart agriculture should be seen as an opportunity for businesses, governments and farmers to thrive. The trajectory of current food systems on climate, nature and people is set to put the EU economy and food security at risk. Restoring and transforming the EU's agricultural land offers untapped opportunities, which would support the EU in meeting its ambition of becoming carbon neutral by 2050 and restoring its biodiversity. Indeed, if an additional 20% of farmers were to adopt climate-smart agriculture in the EU by 2030, annual agricultural carbon emissions could be reduced by 6%, soil health could be improved over 14% of EU's agricultural land and farmers livelihoods could be enhanced by between €1.9 and €9.3 billion annually. However, any attempt to reform agriculture should be made hand in hand with the farmers.

To achieve this potential, public and private sector players need to work together to build a stronger economic case for the transition and address the complex and interconnected challenges faced by farmers. Currently, farmers transitioning to climate-smart action only receive operational level benefits such as reduced input costs or improved resistance to weather events. Given the multi-year payback period of these changes and the associated risks, operational value improvements alone are not enough to convince farmers to adopt the necessary changes at the scale and speed required by society and natural ecosystems. As a result, it is imperative that stakeholders develop and deploy additional value segments which go beyond operational efficiencies in ways that pay for the societal value of climate-smart action. Two additional revenue streams can be unlocked: first, value-chain level revenues and incentives, whereby the entire value chain is made to contribute through elements such as procurement guidelines, offtake agreements or cheaper loans for climate-smart action; and second, co-benefits revenues, through carbon or other ecosystem service credits. By unlocking these additional value segments, Figure 13 suggests that the payback period for climate-smart action could be reduced by approximately seven years, creating a more compelling and faster case for change.

This report found that farmers currently face several challenges in unlocking these value-chain and co-benefits value segments, which, if left unanswered, will prevent the transition to climate-smart agriculture at the scale required. The report also informs a number of public and private coordinated interventions across four key areas that will spur and sustain the transformation and reach a meaningful tipping point of adoption among farmers. These areas are financing and risk management, innovation ecosystems (including data and technology), education and awareness (including technical assistance) and the policy environment (including repurposing subsidies and incentives).

FIGURE 13 **To make the economic case for climate-smart action, additional value segments need to be unlocked in addition to operational benefits**



3.1 Financing and risk management

Evidence suggests that climate-smart agriculture delivers a series of benefits, including for farmers' bottom line and operations, through reduced costs, increased resilience to shocks and new revenue streams. However, farmers tend to be poorly informed on the business case and discouraged by the initial investments and risk-taking required. For example, there is no guarantee for farmers on whether the investments they make will deliver the expected results within the expected timeline. Given the economic challenges most farmers are faced with, expecting them to pay for and bear the full risk of the transition on their own is unrealistic. Innovative forms of upfront capital, guaranteed revenue streams and insurance need to be developed to help farmers embark on the climate-smart journey. Loan products can be tailored to farmers' needs by providing the optimal maturities, interest rates, guarantees and other features that favour more sustainable farmers. Retail and trader procurement guidelines, together with long-term purchase agreement guarantees, can steer demand and pay premiums for produce supplied by climate-smart farms. Insurance products can incentivize the uptake of more sustainable practices by covering potential yield or revenue loss during the transition period, protecting not only farmers but also investors and produce buyers who work with farmers. Carbon credits and other forms of ecosystem services payments can allow farmers to monetize the broader societal value they deliver. National governments should also make sure that CAP eco-schemes are designed to support farmers who help them meet their national goals on climate and nature.

When brought together, these diverse financial mechanisms can be deployed in ways that help spread the costs and risks of the transition across value-chain players in a fair and transparent manner. Farmers would feel supported, potentially bolstering their confidence in their ability to benefit from the transition. However, the financing gap for agriculture in the EU is estimated to be between €19.8 and €46.6 billion, a gap which is likely to have worsened during the COVID-19 period.[96] To have any chance of scaling climate-smart agriculture, the private sector needs to take advantage of the enabling environment recently developed by the EU and use its financial clout to deliver better outcomes for society.

3.2 Innovation ecosystems

> ❝ Farmers are constantly forced to make crucial decisions based on countless variables whose outcomes affect society at large. New technologies can offer a way to support farmers in the challenge of delivering optimal results for all.

Innovation and new technologies present a major opportunity to accelerate food systems' transition at scale – one that has been underused in the EU and globally. Farmers are constantly forced to make crucial decisions based on countless variables whose outcomes affect society at large. New technologies can offer a way to support farmers in the challenge of delivering optimal results for all. These include precision agriculture for input and water use, such as information technology, automation, robotics and decision support technologies that take the guesswork out of fertilizer and pesticide use, irrigation and livestock management, making farming more efficient, profitable and sustainable. These technologies also include gene editing for multi-trait seed improvements, resulting in crops that are less vulnerable to drought, pests and disease, and biological-based crop protection and micronutrients for soil management. Finally, they include MRV tools to drive traceability and transparency across the value chain and allow the generation and analysis of reliable data for key farm outcomes. This type of impact data is essential for monitoring key farm outcomes and unlocking payments from carbon and other outcome-based payment schemes, and increasing the uptake of more innovative index-based insurance solutions.

The level of transparency and evidence this data will provide could help further make the business and environmental case for the transition.

It is important to continue developing, improving and reducing the costs of these technologies, which are often prohibitive for smaller farmers, while acknowledging and fully utilizing the benefits of low-tech climate-smart agronomic practices that have already demonstrated their value and are relatively low cost to adopt for farmers. It will also be important to consider the broader impacts of these technologies, including the potential for unintended consequences concerning data privacy, equity among farmers and the environment.

Every stakeholder can play a role in realizing this potential. The lower levels of investment and innovation in food systems are due in great part to the complexity of the sector. But collaborative public-private stakeholder action can address this challenge to create the necessary innovation ecosystems that will deliver change. Governments can deliver infrastructure, incentives and innovative policy. Companies can collaborate to open new markets through sharing data and intellectual property. Investors and donors can provide growth capital to attract and de-risk entrepreneurial investments.

3.3 Education and awareness

The farming community is faced with an increasing number of demands and requirements while having to deal with difficult and worsening farm economics and climate shocks. Expecting farmers to self-inform on the importance and technical knowledge of climate-smart agriculture is unrealistic. Information on the business case should be made readily available in a format that is relevant to farmers on the ground. It should clarify the time, capital, skills and resources required to implement practices with supporting case examples. Farmers also mentioned they wanted to be able to observe and exchange with farms from their community, having gone through the transition through local on-farm teaching demonstrations or peer-to-peer learning platforms. To do so, public schemes, such as the CAP, and private programmes should aim to align their definitions and requirements to allow for the creation of a better learning and experience-sharing ecosystem. A holistic farmer training programme could be centralized and scaled through a shared platform, such as an EU-supported farmer university programme, which should include options to narrow down on local farmers and farm characteristics, preferences and behaviour. Finally, to help farmers make the right decisions on their farm when starting their learning journey with climate-smart agriculture, they could be supported by tools that could guide them towards the best practices based on their farm, climate, soil and crop type, as well as the national incentive scheme system.

However, awareness-raising campaigns on the importance and urgency of scaling climate-smart agriculture are also needed among the broader public. Most people are currently unaware of the importance of soil health for food security and human health,[97] and know even less about the role of soil and agriculture in climate change or the economic bill of soil degradation in the EU. Consumers' purchasing decisions and taxpayers' votes are likely to influence policy-making and private sector investments more significantly than farmer communities alone.

3.4 The policy environment

Political leadership and action are critical for creating the right enabling environment. The European Commission has already launched a suite of policy reforms and initiatives demonstrating its willingness to bring agriculture within its environmental ambition and increase the CAP's effectiveness at delivering public goods. However, without effective implementation, these policies and frameworks are meaningless. A special report from the European Court of Auditors found that past CAP reforms have not significantly contributed to the EU's climate change mitigation and adaptation efforts and needs, with less than 5% of the area under greening having seen a change in practice management.[98] While allowing member states to better adjust policy interventions to their local conditions and needs, the flexibility and lack of minimum conditionality that member states are given in implementation have often resulted in a general lack of action regarding the climate and nature. While final NSPs proposed by member states are still being submitted at the time of publication, draft versions have fallen short of expectations, with only 19% of eco-schemes deemed likely to deliver on their stated environmental objectives.[99] However, there is still hope for the European Commission to take strong and decisive action when reviewing the strategic plans and for the member states to review their drafts and raise their environmental ambition.

In addition to implementation issues, it is also important to ensure consistency while allowing for nuanced interventions related to local realities. For instance, consistency and standardization in carbon market frameworks, MRV schemes and national plan policies will allow for scale and encourage private sector investment at an EU-wide level. National eco-schemes should be complemented by broader policy alignment, not only within the agricultural sector but also in other sectors such as the energy and health, to meet the goals of the EU Green Deal.

Ensuring national governments step up to the task and do so with an implementation focus is critical, and the private sector actors can help motivate and shape this change by advocating for these reforms and signalling their readiness to transition.

3.5 From ideation to implementation

Ideas and understanding are only as good as their implementation. Based on the insights generated through the farmer survey, the EU Carbon+ Farming Coalition is committed to working with farmers to demonstrate the feasibility and impact of solutions across these four key intervention areas through demonstration flagship pilots. Solutions under consideration aim to achieve objectives such as enhancing knowledge sharing with and among farmers, developing climate-smart procurement guidelines for retailers and traders, identifying cost-effective MRV solutions to help build a reliable carbon market, designing innovative risk transfer and sharing options between farmers and value-chain players, and the implementation of regenerative farming in specific crop segments. Recognizing the interconnectedness and complementarity of these pilots, the coalition aims to bring them to life through a holistic and phased implementation approach that builds upon their synergies.

The willingness of the coalition members to jointly design and execute these pilots demonstrates the transformative power of pre-competitive collaboration among private sector actors, civil society and farmers. The hope for this collaborative effort is that the results of the implementation of selected pilots will inspire and guide stakeholders in other regions and countries to move into action to support the transition. It allows for more ownership in the hands of the farmers in a way that makes farming exciting again and farmers proud of the work they do. Scaling climate-smart agriculture across the EU is an overwhelming challenge, but the task at hand is clear with the convincing case that when working together, businesses, governments and farmers can create sustainable solutions to many of societies' greatest challenges.

Appendix

Survey methodology

Goals
The survey and analysis referenced throughout this document were conducted to support the Carbon+ Farming Coalition's goal of deploying climate-smart practice adoption on farms across the EU. The goal of the survey was to understand farmer pain points, their perceptions of climate-smart practices, what requirements are necessary to increase adoption, what roadblocks are currently hindering adoption and what challenges they will face moving forward.

Survey approach

Country-crop combination (CCC) sample
To obtain a highly representative sample, the coalition identified 10 major country-crop pairings across 7 countries and 6 crops. These pairings were intentionally designed based on their strategic importance to Europe in terms of land use coverage (wheat, corn), relevance to food processors (potatoes, tomatoes, apples) and relevance to consumer markets (carrots, tomatoes, apples). In addition, geographies were targeted to include both Eastern (Poland, Romania) and Western (Spain, Italy, France, Germany, the Netherlands) Europe. Overall, the countries included in the survey cover 75% of the EU's farmers, 30% of the EU's harvested area and 43% of the EU's agricultural production. The pairings and associated sample sizes are as follows:

Country-crop combination	Number of farmers surveyed
France-wheat/oilseed rape (OSR)	170
France-corn	176
Poland-apple	200
Germany-wheat/OSR	201
Germany-potato	199
Italy-tomato	75
Netherlands-potato	153
Poland-carrot	150
Romania-carrot	198
Spain-carrot	73
Total	**1,595**

Qualitative survey
The survey began with qualitative focus groups to inform the development of the larger quantitative survey to be conducted. These focus groups consisted of online workshops of between 5 and 10 farmers for each CCC conducted in English or the local language. The sessions focused on developing a baseline understanding. Each session lasted approximately three hours and farmers were compensated for their time. Experience with climate-smart farming was a prerequisite for participation in the focus groups.

Quantitative survey

With the details provided by the focus groups, a quantitative survey was developed. Sample sizes were between 100-200 (depending on the size of the total farmer population within the CCC and farmer participation). Participants were recruited via telephone calls and needed to be either the owner or the manager of the farm, have at least three years of experience in farming and be planning to continue farming for the next five years. Lastly, farmers had to confirm that they did not work for a crop protection product/seed manufacturer or distribution company.

Farmers were offered a choice from three types of interview: 1) a 35-minute telephone questionnaire on the spot; 2) an appointment for a telephone survey at a later time; and 3) an online survey with a deadline. In Romania, interviews were conducted in person with local interviewers experienced in agriculture research.

The survey consisted of a list of questions pertaining to the following categories:

– Demographics
– Familiarity with and knowledge about sustainable and climate-smart practices
– Knowledge of and enrollment in carbon programmes
– Pain point criticality level and frequency
– Level of adoption of climate-smart practices, including MRV-enabling practices
– Likelihood of adoption of climate-smart practices
– Economic and non-economic incentives to adopt new practices
– Barriers to adopting climate-smart practices

Analysis

Questions asked in the survey spanned key areas as follows:

Episodic pain points	CCC tested
Frost	Romania-corn, Poland-apple, Spain-carrot
Hailstorms	France-wheat/Oilseed rape (OSR), Germany-wheat/OSR, Italy-tomato, Poland-apple
Difficulty to find contracts and distribution channels for production	Poland-apple
Low selling prices because of overproduction (nationwide or worldwide)	Poland-apple, Poland-carrot
Contamination from crop protection product drift from neighbouring farms	Poland-apple
Droughts	France-wheat/OSR, Germany-wheat/OSR, France-corn, Romania-corn, Italy-tomato, Netherlands-potato, Germany-potato, Poland-carrot
Harvest thefts	Romania-corn
Arson fires	Romania-corn
Unforeseen need to plough deeply	Romania-corn
Flood	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn, Italy-tomato, Netherlands-potato, Germany-potato, Spain-carrot
Strong buyer bargaining power and lack of adherence to initial selling contract terms	Netherlands-potato, Germany-potato
Crop damage by wild fauna: e.g. birds, boars	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn
Not enough high-quality harvest to feed farm animals	France-corn

Systemic pain points	CCC tested
Fast spread of diseases and/or pests in the farmer's region	Poland-apple
Increased diseases' resistance to crop protection products	Poland-apple
Use of varieties that are not adapted to the local climate	Poland-apple
Decreasing the number of authorized active ingredients to effectively protect their crop	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn, Romania-corn, Italy-tomato, Netherlands-potato, Germany-potato, Poland-apple, Poland-carrot, Spain-carrot
Lack of affordable insurance to cover crop or yield loss	Netherlands-potato, Germany-potato, Poland-apple
Lack of subsidies from the government or the EU	Poland-apple
Lack of agronomical knowledge to take specific decisions	Poland-apple
High administrative workload	Poland-apple, Spain-carrot
Lack of access to market data to better plan for next season	France-corn, Romania-corn
High exposure or excessive reliance on unprofitable long-term contracts	Romania-corn, Poland-carrot
Excessive land fragmentation	Romania-corn, Poland-carrot
Advisory sources nationally available (especially public) are not useful nor advanced	Romania-corn, Italy-tomato, Netherlands-potato, Germany-potato, Poland-carrot, Spain-carrot
Poorly maintained/old equipment and infrastructure	Romania-corn
High investments force the farmer to run a monoculture to remain profitable	Romania-corn
Lack of reliable and accurate weather forecasts for the farm	Romania-corn, Poland-carrot
Soil erosion because of deep ploughing	Romania-corn, Spain-carrot
Climate change and unpredictable weather	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn, Romania-corn, Italy-tomato, Netherlands-potato, Germany-potato, Poland-carrot, Spain-carrot
Lack of data analysis capabilities to make informed agronomic decisions	Romania-corn, Netherlands-potato, Germany-potato, Poland-apple, Poland-carrot, Spain-carrot
Extreme weather events are not all fully covered by available insurance	Romania-corn, Poland-carrot
Difficulty in recruiting/retaining labour force, especially skilled workers	France-wheat/OSR, Germany-wheat/OSR, France-corn silage, Italy-tomato, Netherlands-potato, Germany-potato, Poland-carrot
Private insurance for extreme weather and market risks is not affordable	Italy-tomato, Poland-carrot
Old and defective water drainage infrastructure running beneath the farmer's field	Poland-carrot

Systemic pain points (continued)	CCC tested
Preventive product application because of the difficulty in accurately monitoring weeds/pests/diseases	Poland-carrot
Losses due to retailers' aesthetic requirements (weight, diameter, length, shape)	Poland-carrot, Spain-carrot
Need to fumigate to maintain an intense crop rotation	Spain-carrot
Water scarcity	Spain-carrot
Need to invest heavily to ensure the farm's compliance with regulations	Spain-carrot
Rapidly changing regulations complicate long-term decision-making	Netherlands-potato, Germany-potato
Fertilizer regulation inducing yield reduction	France-wheat/OSR, Germany-wheat/OSR, Netherlands-potato, Germany-potato
Administrative complexity to apply for subsidies	France-corn, Netherlands-potato, Germany-potato
Administrative complexity to apply for subsidies and development programmes	France-wheat/OSR, Germany-wheat/OSR, Netherlands-potato, Germany-potato
Tax liabilities linked to subsidy access	Netherlands-potato, Germany-potato
Higher costs for the delivery of soil-free potatoes	Netherlands-potato, Germany-potato
Unreliable new varieties against weeds, diseases and pest resistance	Netherlands-potato, Germany-potato
Weed, disease and pest resistance	France-wheat/OSR, Germany-wheat/OSR, France-corn
Subsidies for the adoption of practices were created after the farmer had already adopted them	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn silage
Public and private insurance is either not reliable or not affordable	France-wheat/OSR, Germany-wheat/OSR, France-corn
Available advisory sources lack competencies or services tailored to carbon farming	France-corn
The low profitability of other crop rotations forces the farmer to resort to monoculture	France-wheat/OSR, Germany-wheat/OSR, France-corn
Lack of knowledge to manage contracts (e.g. forward contracting) to hedge market risks	Italy-tomato
Lack of consumer value perception for processed tomatoes	Italy-tomato
Publicly subsidized insurance is not reliable (e.g. late payments)	Italy-tomato
Subsidy schemes not well adapted to horticultural farms	Italy-tomato
Lack of a centralized source of information on regulations	Italy-tomato
Difficulty in complying with maximum residue levels	Italy-tomato

Systemic pain points (continued)	CCC tested
Increasing farm operations due to decreasing crop protection products' effectiveness	France-wheat/OSR, Germany-wheat/OSR
Social pressure to protect water resources in terms of use or pollution	France-wheat/OSR, Germany-wheat/OSR
Administrative complexity to apply for subsidies, different from one region to another	France-corn silage
Uncertain profitability levels due to produce price instability (e.g. milk)	France-corn silage
Crop management taking time from livestock management	France-corn silage
Difficulty in determining optimal harvest dates	France-corn silage
Excessive bureaucratic complexity for ensuring regulatory compliance	France-corn silage
Lack of instruments to cope with crop damage risks caused by wild fauna (e.g. birds, insects)	France-corn silage

Practices	CCC tested
No-till farming	Romania-corn
Irrigation system (e.g. central pivot, spray gun)	Romania-corn
Use of natural fertilizers (e.g. mushroom derived or slurry)	Spain-carrot, Romania-corn, Poland-apple, Poland-carrot
Organic mulch from harvest residues	Spain-carrot, Romania-corn, Italy-tomato, Poland-carrot
Applying fertilizers through the irrigation system	Spain-carrot, Romania-corn, Poland-apple, Poland-carrot
Use of cover crops (e.g. alfalfa, mustard, leguminous crops)	Spain-carrot, Romania-corn, Italy-tomato, Netherlands-potato, Germany-potato, Poland-carrot
Soil analyses modelling (e.g. nutrient content, soil carbon)	Spain-carrot, Romania-corn, Poland-apple, Poland-carrot
Satellite/drone monitoring (e.g. humidity, diseases)	Spain-carrot, France-wheat/OSR, Germany- wheat/OSR, France-corn, France-corn silage, Romania-corn, Italy-tomato, Netherlands-potato, Germany-potato, Poland-apple, Poland-carrot
Nutrient management planning tools (e.g. soil nutrient analysis and harvest cartography)	Spain-carrot, France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn silage, Romania-corn, Italy-tomato, Poland-apple, Poland-carrot
Moisture sensors for irrigation system	Spain-carrot, Netherlands-potato, Germany-potato, Poland-apple, Poland-carrot
Decision support apps for crop health management (e.g. disease/pest alerts)	Poland-apple
Farm management software	Spain-carrot, France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn silage, Romania-corn, Italy-tomato, Netherlands-potato, Germany-potato, Poland-apple, Poland-carrot
Buffer strips or permanent vegetation	Spain-carrot, France-corn silage, Romania-corn, Poland-apple, Poland-carrot

Practices (continued)	CCC tested
Organic mulch from pruning residues	Poland-apple
Biostimulants (e.g. mycorrhizae)	Spain-carrot, France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn silage, Italy-tomato, Netherlands-potato, Germany-potato, Poland-apple
Improved varieties (climate resilient, disease-resistant, lower nitrate need)	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn silage, Romania-corn, Italy-tomato
Private weather station	Poland-carrot
Rental/leasing of up-to-date machinery and infrastructure (e.g. storage space)	Poland-carrot
Biologicals crop protection products (e.g. Trichoderma)	Spain-carrot
Soil nutrient cartography	Netherlands-potato, Germany-potato
Variable fertilizers application adjusted to soil needs	Netherlands-potato, Germany-potato
Use of fertilizers with low carbon footprint produced locally or in the EU	Netherlands-potato, Germany-potato
Use of drip irrigation	Netherlands-potato, Germany-potato
Use of organic fertilizers (e.g. manure or slurry)	France-wheat/OSR, Germany-wheat/OSR, France-corn, Italy-tomato, Netherlands-potato, Germany-potato
No-till farming and direct seeding	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn silage
Soil coverage: harvest residues or cover crops	France-wheat/OSR, Germany-wheat/OSR, France-corn
Moisture sensors and related decision support tools for the irrigation system	France-corn, Italy-tomato
Dynamic fertilizer application according to biomass index	Italy-tomato
Use of nitrification inhibitors	Germany-wheat/OSR
Variable rate seeding and fertilization based on nutrient plan	France-wheat/OSR, Germany-wheat/OSR, France-corn, France-corn silage
Rotational grazing	France-corn silage
Permanent cover	France-corn silage

Impact opportunity size

Overview

The impact sizing analysis represents the estimated directional opportunity for climate-smart agriculture in the EU for three key outcomes: reduced or sequestered GHG emissions, improved soil health and increased farmer profits. It seeks to answer what impact would occur if an additional 20% of farmers adopted climate-smart practices. Five climate-smart practices were included in the scope of the impact sizing:

1. Conservation agriculture: Using crop rotation, cover cropping and reduced tillage to enhance biosequestration
2. Farm irrigation technology: Using energy-efficient irrigation practices that increase crop yields while reducing energy consumption
3. Nutrient management: Using fertilizer more efficiently by optimizing application to match plant needs
4. Tree intercropping: Employing an agroforestry system that grows trees alongside annual crops in a given area at the same time
5. Managed grazing: Using practices that sequester carbon in grassland soils by adjusting livestock stocking rates, timing and intensity of grazing

The model does not seek to predict the future of what will happen in the EU, nor calculate the exact impact as further research and evidence are necessary to determine precise impact figures. Also, the model does not estimate indirect economic benefits such as avoided pollution or health costs. Although research from the EU suggests the impact of these practices on yield is positive, their impact when implemented at scale must be thoroughly assessed, especially when considered within the food security and Ukraine crisis context at the time of the release of this report. In addition, the resulting impact numbers cannot be achieved through farmer adoption of practices in isolation; rather, farmers must be supported by cross-value-chain efforts to provide the required financial, educational, data and revenue structures needed to support the transition.

Assumptions

1 GHG and financial impact of climate-smart practices: Assumptions are based on the meta-analysis of scientific literature conducted by Project Drawdown, which includes estimates for the impact of four practices (conservation agriculture, farm irrigation technology, tree intercropping and managed grazing), as well as widely accepted research on the impact of nutrient management (Roe et al.).

Impacts were assessed across the following areas:

- CO_2e reduction and sequestration potential per hectare per year
- Initial investment costs per hectare
- Farmer profit per hectare per year

Practice name	Practice description	Emissions reduction (tonnes of CO_2e/ha/year)	Initial investment (EUR/ha)	Change in farmer profit (EUR/ha/year)
Conservation agriculture	Using crop rotation, cover cropping and reduced tillage to enhance biosequestration	**0.23 (reduction)** **0.25 (sequestration)**	**€315.99**	**€50.00**
Nutrient management	More efficient usage of fertilizers through optimizing application to match plant needs	**0.39**	**–**	**€2.85**
Farm irrigation technology	Energy-efficient irrigation practices that increase crop yields while reducing emissions	**0.184**	**€805.00**	**€109.49**
Tree intercropping	Agroforestry systems that grow trees together with annual crops in a given area at the same time	**1.7**	**€879.43**	**€130.13**
Managed grazing	Practices that sequester carbon in grassland soils by adjusting stocking rates, timing and intensity of grazing	**1.1**	**€66.76**	**€40.92**

Note: Numbers are based on meta-analysis of ~10-30 academic studies aggregated for each figure. Some figures are segmented by eco-region type (e.g. temperature/boreal humid, tropical semi-arid) and tailored to the predominant eco-region in the EU (temperature/boreal semi-arid).

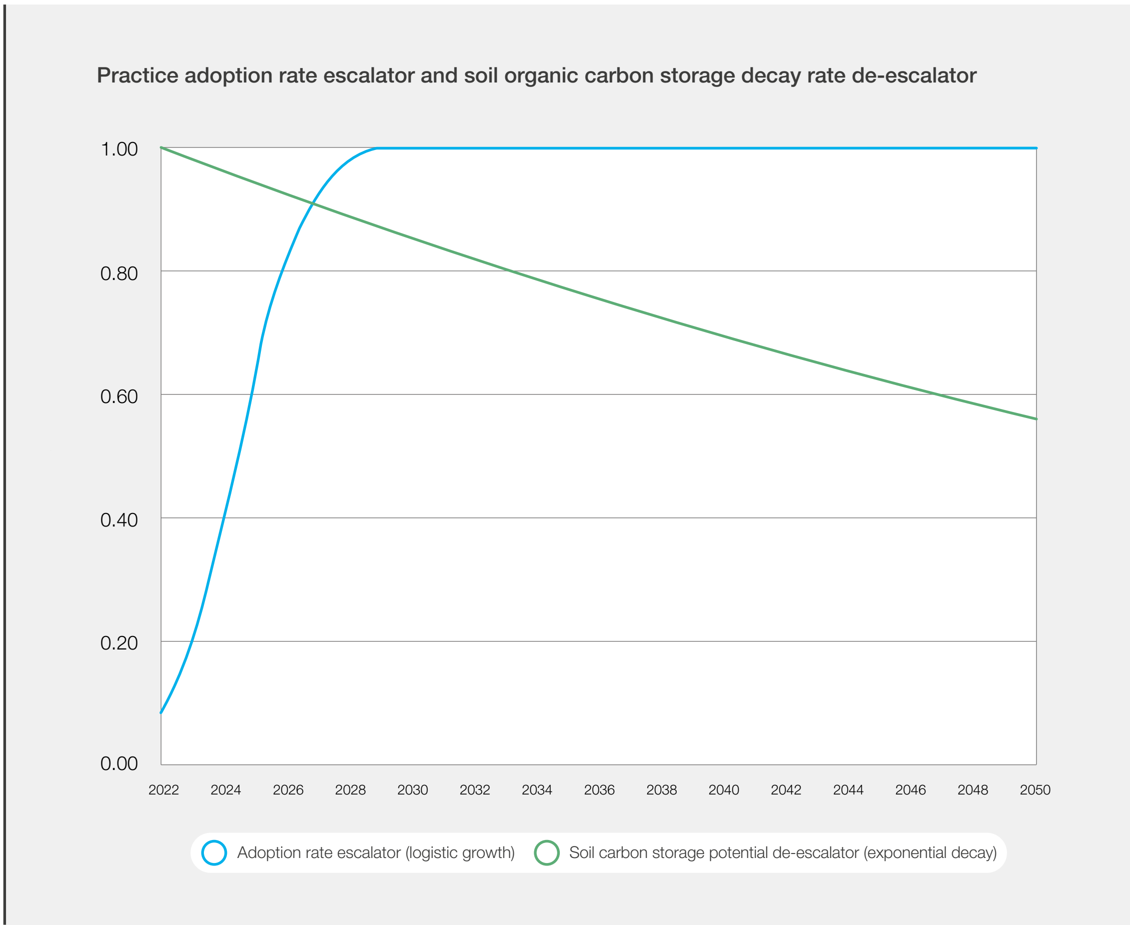
2 **Land usage:** The agricultural land adapted to each practice considered differs based on its characteristics

Land type	Total land	Practies included	Source
EU agricultural cropland	111,365,621 hectares (ha)	Conservation agriculture, nutrient management	FAOSTAT
EU irrigated cropland	10,200,000 ha	Farm irrigation technology	European Commission
EU priority silvoarable land	9,959,142 ha (out of a possible 95,890,000 ha)	Tree intercropping	European Commission
EU grazing land	55,557,732 ha	Managed grazing	FAOSTAT

3 **Practice adoption rate:** The model seeks to understand the impact of climate-smart practices if an incremental 20% of farmers adopted those practices (on top of the number of farmers already using these practices). To replicate projected real-world adoption, a logistic curve was applied, with maximum (20%) practice adoption being reached within eight years.

4 **Learning curve ramp-up:** To account for the time it takes for farmers to learn to effectively employ climate-smart practices and for the soil to adapt, the model assumes that outcomes progressively materialize over a period of five years. Hence, farmers realize 20% of total carbon reduction and sequestration and profit per hectare in year 1, 40% in their year 2, 60% in their year 3, 80% in their year 4 and 100% in year 5 and onwards.

5 **Soil carbon decreasing marginal rate of sequestration:** The soil's diminishing capacity for sequestering carbon was accounted for by applying a 2% decreasing marginal rate of CO_2e sequestration potential per hectare per year over time, based on expert interviews.



6 Additional farmer financial benefits: The lower range provided for improvement in farmer profits is provided by the operational improvements (estimated using Project Drawdown's figures). The upper range for farmer profits adds three additional revenue streams, which could be provided by private and public stakeholders.

a. Participation in carbon markets:

- The model accounts for a five-year period before farmers are eligible to claim carbon credits.
- The certification and MRV costs borne by farmers are assumed to be €15/ha/year, with a 2% annual decrease in cost as expected improvements in cost-effective measurement technologies materialize.
- The carbon market price is based on the average price from two EU agricultural carbon schemes: Soil Capital (€27.66/tonne of CO_2e) and Label Bas Carbone (€30/tonne of CO_2e) at the time of the analysis (March 22, 2022), and assumes a 2% annual growth in price in line with research.

b. Price premiums:

Price premiums for climate-smart food products were assumed to be 29.5% higher than prices for conventionally produced products based on a scientific meta-analysis of global consumers' willingness to pay a premium for sustainable food products. This price premium decreases by 2% annually as climate-smart products become gradually less differentiated. The model assumes that farmers would earn 20% of the total gains among players across the value chain.

c. Subsidy support:

- 40% of the CAP for climate-related subsidies (within eco-schemes and rural development) was assumed to be earmarked specifically for the five practices in scope based on an analysis of Italian and German national strategic plan proposals.
- The model assumes (based on survey responses) that currently 35% of farmers are already implementing these practices and are benefiting from subsidy payments (hence sharing the payments with the additional 20% of farmers adopting these practices).
- Subsidy payments are assumed to extend through to 2030 (similar to the past two-year extension to bridge the transition to the new policy) and farmers receive subsidies after adopting the practices for at least one year.

Cap description	Value
Annual CAP budget 2023–2027	€77.3 billion
Portion of CAP dedicated to climate action (eco-schemes and rural development)	€32.9 billion
Estimated portion of CAP climate action funding allocated to five practices in scope of analysis	€13.2 billion
Portion of CAP climate action subsidy captured by farmers in scope of analysis	€4.8 billion

7 Measurable soil improvement: The model assumes five years of climate-smart practice usage required for soil health to measurably improve. The two climate-smart practices, and their associated land types, which were utilized to calculate the hectares of land with measurable soil improvement, are conservation agriculture and managed grazing.

2030 results

Climate	Nature	Farmer profit
24.55 million tonnes of CO_2e emissions reduced or sequestered **(6% reduction compared to BAU)***	21.30 million hectares of land with improved soil health	€1.87 billion in operational profit €9.33 billion in combined operational profit and additional revenue from carbon credits, public subsidies and price premiums

*The business as usual (BAU) scenario was determined by projecting 2018 EU agricultural GHG emissions and projecting this to 2030. Emissions were projected to remain constant given the relative stabilization of agricultural GHG emissions over the past 10 years in the EU.

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