Interreg CENTRAL EUROPE

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Carbon Farming CE

CE GUIDE FOR CARBON FARMING BUSINESS MODELS

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CONTENT

INTRODUCTION AND SCOPE OF THE TASK

This guide was created as part of the Carbon Farming CE (CFCE) project. Carbon farming is a relatively new term and concept that is still evolving. It typically encompasses several existing farming practices (mostly described as environmentally friendly, regenerative or sustainable) that support the increase of soil carbon sequestration and new business opportunities and models aimed at commercialising the added value created through the application of these practices. In the CFCE project, we understand carbon farming as a set of agricultural practices that manage carbon pools, flows, and GHG fluxes at farm level to mitigate climate change. One of the main aims of this project is to raise awareness among farmers and other actors in Central European countries about carbon farming methods and practices, their goals, background, and how to implement them in an environmentally and economically sustainable way.

In order to achieve this goal, the CFCE project provides farmers and advisors with two separate guides, to bring the two most important aspects of carbon farming (carbon farming practices and carbon farming business/cooperation models), which are interconnected but also distinctly separate, closer to producers. The first covers farming practices and technologies, while the second – this publication – introduces the key aspects of business and cooperation models, highlighting the main steps involved in their implementation, connected with additional information, also utilizing testing experiences of the project. It is therefore worth reading the two guides in parallel, as they are closely related, particularly with regard to the knowledge that is to be interpreted and applied at the farm level. The guide on carbon farming practices (which can be accessed here) consists of a twin package: a detailed explanation, of the seven practices tested by the project partners and considered relevant for the region, supplemented by an Excel-tool as decision matrix (supporting farmers in choosing appropriate practices for their farms), where scores of different criteria for each technique that is up to debate for the farmer can be entered. The carbon farming practices guide provides considerations that must be taken into account before setting the scores in the decision matrix tool.

This guide focuses on the financial and cooperative aspects of carbon farming and is structured so that the first part summarizes the series of steps that typically occur when a farmer enters into carbon farming. It is worth emphasizing that in most cases this does not mean switching to a completely new method, but rather adjusting existing farming practices in a way that has a positive effect on soil carbon sequestration. It is also important to note that there is no single, universally applicable approach to carbon farming that all farmers must follow. Carbon farming is a complex, multifaceted set of activities, and a great deal of diverse information is available on the subject. It is our hope that this guide will present the most important points in a simple and clear manner, thus helping farmers to navigate the topic and find the elements that are potentially useful to them.

This guide commences with a brief overview of the most crucial steps required for farmers to participate in carbon farming. Where readers might want more information about the particular step, it has been organised into a separate chapter (or chapters), with references provided in the more detailed description of each step. These subsequent chapters with related detailed background information (such as standards, legislation, carbon footprint calculation methods, etc.) are especially recommended for advisors and farmers who want to delve deeper into a particular topic.

According to the plans, based on this guide prepared in English, the project countries will translate it into their own languages, while also adapting, localizing, and supplementing it to their own circumstances, so that the shared knowledge base is as tangible and useful as possible for their own farmers and advisors. Information about the localized version is to be published on the project website: https://www.interreg-central.eu/projects/carbon-farming-ce/

A COMPENDIUM OF THE KEY STEPS TO TAKE TO GET INVOLVED IN CARBON FARMING

At the farm level, we envision the transition to carbon farming and its integration into the current practices as a series of steps, leading from awareness, interest, recognition, motivation, learning, through preparation and implementation of the transition pathway, to the evaluation and sharing of results, thus providing feedback and information opportunities for new interested farmers and potential new entrants (also closing the cycle of steps). The Carbon Farming CE project also developed a strategy for mainstreaming carbon farming in Central Europe. This strategy takes a multi-layered approach, addressing relevant sectors and stakeholders, and supporting their cooperation.

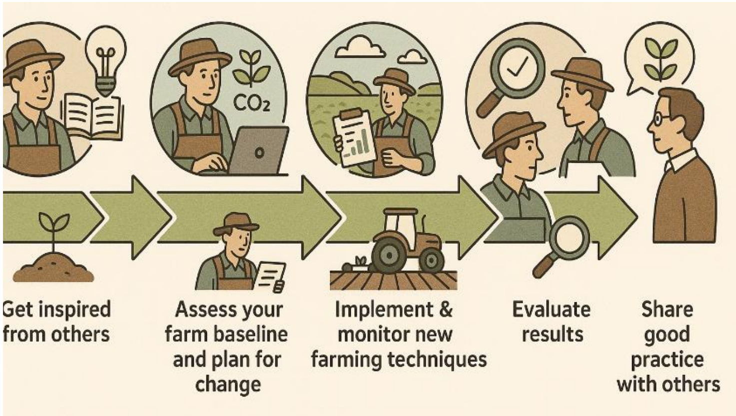


Figure 1: The most important steps in implementing carbon farming

The results generated by the Carbon Farming CE project provide direct assistance and professional support at numerous points in the process.

These results, along with the steps involved, are listed in the table below.

Table 1: CFCE project outputs that support the various stages of implementing carbon farming.

	Carbon Farming CE Project outputs					
Steps	**Country seminars**	**Guide on farming practices**	**Guide on business models**	**Trained advisors**	**Bench-marking tool**	**Website and social media**
Get inspired	X	X	X	X		X
Understand	X	X	X	X		
Learn	X	X	X	X		
Plan	X	X	X	X	X	
Implement				X		
Evaluate				X	X	
Share						X

STEP 1. UNDERSTAND AND GET INSPIRED

The first and most important step is to understand the essence of carbon farming: the introduction of management and farming practices that increase carbon sequestration and reduce greenhouse gas emissions. Introducing these practices is time-consuming and costly, but it can also bring environmental benefits and economic gains. Soil fertility and water retention can improve, farms can become more resilient to extreme weather events, and new sources of income can be tapped through the sale of carbon credits or targeted funding under the Common Agricultural Policy (CAP) of the EU. In the long term, the effects of climate change make the transition to more sustainable farming inevitable, and carbon farming can give farmers a competitive advantage in this regard. It can also improve the social image and market position of the farm, as more and more buyers and consumers are looking for sustainably produced products.

Why might carbon farming be attractive for agricultural producers?

Farmers are facing increasing challenges in operating their businesses in a sustainable and profitable manner from an environmental and economic perspective. Climate change is altering the realities of farming in most Central European countries to such an extent that farmers are required to use new methods, technologies, and crops. More and more producers are facing these problems and looking for technological solutions. In addition to the sale of farm produce, income from EU and national government subsidies and other sources of income (with accompanying legislative changes) play a key role in ensuring that the operation of the farm as a whole is profitable. Climate change adaptation and mitigation is a central element of global strategies and regional support policies. In the agricultural sector, the primary aim is to promote a shift to farming methods that have a positive impact on both production and the environment. At the level of a given farm, this means that the use of new practices can make production more resilient to climate change, and at the same time, subsidies can support this, thus strengthening the activity from two sides. Programs related to regenerative farming and carbon farming play a prominent role in initiatives of this type, as soil is one of the key assets and resources to achieve these goals.

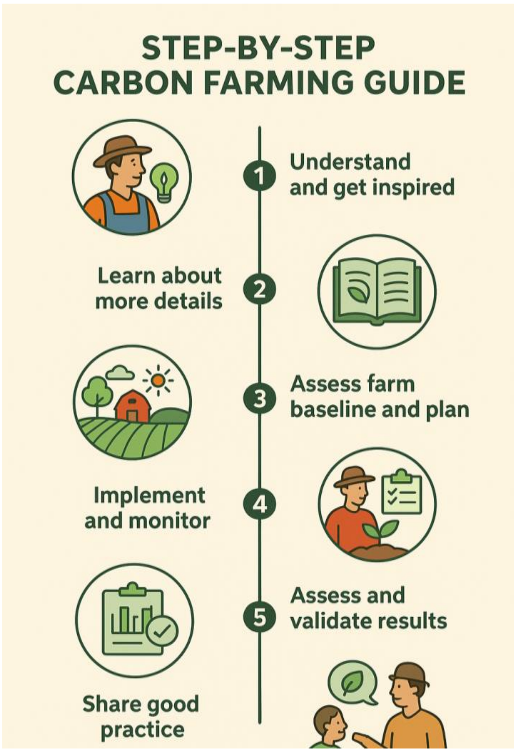


Figure 2: Step-by-step Carbon Framing guide

What can those who introduce carbon farming practices expect?

Carbon farming has a number of potentially positive outcomes:

- Mitigating the effects of climate change, more predictable crop yields
- Improvement and restoration of the quality of the soil
- Reduction in input materials, machine use, and cultivation costs
- Increased revenue from marketing activities (e.g., labeling) related to the sale of farm produce
- Better access to finance, grants, subsidies, loans and insurance schemes
- Revenue from the sale of CO2 quotas when participating in carbon credit programs
- Development of personal skills and competences through the acquisition of new knowledge
- Improvement of farm management, monitoring and administration activities
- Opportunities for cooperation, collaboration, and networking with other farmers and partners
- Commitment to the future, responsible citizenship

As with any new method or innovation, carbon farming has its potential difficulties. Some of the most notable are:

- The transition may require significant investments (e.g. the purchase of various technological components) and can take time
- Training or expert advice may be needed to acquire and apply new knowledge, related to both practices and administrative tasks
- Uncertainties may arise in the case of physical results-based accounting (e.g. in case of carbon credits)

At first glance, understanding the complexities of carbon farming may seem very difficult, as it covers an extremely wide range of topics, some of which – such as legal regulations and support policies – are constantly changing and evolving. At the farm level, it is not enough to be familiar with the relevant farming practices and agrotechnical methods, but it is also necessary to understand their economic, financial, and return on investment aspects, as these two sides—discussed separately in our project—form part of a common, interconnected knowledge from the farmer's perspective and at the farm level.

Fortunately, recognizing the need for knowledge and the lack thereof, numerous organizations and experts are working to help farmers (and their advisors) navigate these issues. Government agencies, research institutes, professional and certification organizations, EU projects, etc. provide a wide range of information on the subject in the form of publications, guides, teaching materials, videos, and training courses. Several adult education organizations have also developed training programs related to carbon farming, and a significant number of advisory organizations and systems also offer services in this area. A particularly effective form of knowledge transfer is practical demonstrations in the field, which are organized by both research institutes and advisory organizations. AKIS country reports can provide guidance on the knowledge transfer systems and activities of individual countries. For example, a recent collection published as part of the i2connect project could be a good starting point. More specific information on publications, events, and advisory services available in a given country can be found in the localized version of this guide.

To promote a better understanding of carbon farming, our project primarily recommends the professional materials it has developed (https://www.interreg-central.eu/projects/carbon-farming-ce/):

- Agrotechnical guide
- Business model guide (this publication)
- Training materials
- Policy strategy proposal
- Videos

However, the significant amount of knowledge required should not deter anyone, as carbon farming is not a separate, limited concept or activity, but consists of elements that farmers are likely to have already encountered, learned about, understood, or applied, such as various cultivation methods, crop rotation, organic fertilization, or the applications for area-based subsidies. It is therefore more a question of organizing this knowledge with a focus on carbon sequestration and supplementing it with a few additional elements of knowledge. Currently, a popular and frequently discussed and presented topic among farmers and experts alike is regenerative agriculture, which shares many common features with carbon farming. However, regenerative agriculture is a broader approach that aims to restore the health of ecosystems, while carbon farming is a specific aspect of this approach that focuses on increasing the amount of carbon sequestered in the soil and reducing atmospheric carbon dioxide. It is important to note, however, that carbon farming can be a credible and sustainable approach only within this broader context, as it is not possible to focus on a single factor in such a complex ecological system, but rather to take into account other direct and indirect effects of farming, so not only emissions directly, but also biodiversity, soil health, and other aspects.

STEP 2. LEARN ABOUT MORE DETAILS

It may be useful primarily for farm advisors, experts, managers covering larger areas or multiple farms, and enthusiastic farmers interested in the topic to learn a little more about the background of carbon farming in the areas of legislation, standardization, certification, and methodology.

LEGAL FOUNDATIONS

The EU has set ambitious targets for reducing greenhouse gas (GHG) emissions. According to the EU Climate Regulation (EU 2021), EU GHG emissions must be reduced by 55% by 2030 compared to 1990 levels.

The agriculture and land use (LULUCF) sector will play a central role in achieving these targets, with the aim of ensuring that the sector's removals exceed its emissions. To this end, the EU Carbon Removals and Carbon Farming Regulation (CRCF Regulation, EU 2024) is to offer farmers and foresters new revenue opportunities, as the carbon sequestration capacity of ecosystems not only reduces emissions but also enables soil carbon sequestration. The mechanism for offsetting the carbon intensity of imported goods (CBAM Regulation) may also indirectly contribute to the development of a uniform, transparent carbon market, according to which a carbon duty must be paid on certain products imported into the EU (e.g., fertilizers) if their carbon footprint is higher than that of products manufactured within the EU. On this basis, the value of credits generated through carbon farming may increase, especially if they comply with the EU carbon certification framework.

Main legal documents on EU level

Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land-use change and forestry into the 2030 climate and energy framework and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU (LULUCF Regulation)

Regulation (EU) 2018/842 on the determination of annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action and amending Regulation (EU) No 525/2013 (Effort sharing regulation, ESR regulation)

Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing a framework for achieving climate neutrality and amending Regulation (EC) No 401/2009 and Regulation (EU) 2018/1999 (European Climate Regulation)

Regulation (EU) 2023/839 of the European Parliament and of the Council of 19 April 2023 amending Regulation (EU) 2018/841 as regards the scope, simplification of reporting and compliance rules and the setting of national targets for 2030 and Regulation (EU) 2018/1999 as regards monitoring, reporting, monitoring of progress and review

Regulation (EU) 2023/956 of the European Parliament and of the Council of 19 May 2023 10.) on the establishment of a mechanism to offset the carbon intensity of imported goods

Regulation (EU) 2024/3012 of the European Parliament and of the Council of 27 November 2024 establishing a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products (CRCF Regulation)

CALCULATION STANDARDS: REQUIREMENTS FOR AGRICULTURAL CARBON FOOTPRINT CALCULATIONS

The Central European countries as a party to the United Nations Framework Convention on Climate Change (UNFCCC), prepare their greenhouse gas emission inventory every year, using the methodology developed by the Intergovernmental Panel on Climate Change (IPCC) and submit it together with the related report for the UN. The inventory takes into account emissions and removals associated with human activities and primarily includes the greenhouse gases listed by the Kyoto Protocol – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

The inventory requires the following breakdown of data to be published: energy, industry, waste, agriculture, land use, land use change and forestry. Based on this, direct emissions from the agricultural sector appear in three places in the inventory:

- emissions of fuel used in stationary and mobile equipment in the agricultural sector, as well as the use of electricity in the energy sector,
- emissions from nutrients and other soil amendments in the agricultural sector, as well as emissions from animal husbandry,
- and in the land use and land use change emissions sector, emissions/removals due to annual changes in woody biomass, soil cultivation practices and additions and withdrawals to cultivation are accounted for.

There are two common international frameworks used to account for corporate greenhouse gas emissions: the GHG Protocol and the ISO 14064 series of standards. Although both aim to manage emissions in a transparent and comparable manner, their roles and nature differ.

The GHG Protocol is a practical guide developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). It provides companies and organizations with clear methodological guidelines for calculating emissions, setting boundaries and reporting. It has the advantage of being freely available, freely downloadable and applicable. For this reason, it is a widely used basis in sustainability (ESG) reporting.

ISO 14064, on the other hand, is an official standard of the International Organization for Standardization (ISO) that provides a set of requirements for greenhouse gas accounting and verification. It consists of three parts: the first is about the calculation of emissions at the organizational level, the second is about emission reductions at the project level, and the third is about the rules for verification and validation. ISO standards are paid, meaning that they must be purchased for official use. This in turn ensures that emission reports prepared according to ISO 14064 can be verified by an independent third party, so they can also be used in legal and contractual environments.

Due to the diverse specialties of the agricultural sector, both ISO 14064 and the GHG Protocol have specific guidance for the agricultural sector. The two systems therefore complement each other: the GHG Protocol provides a practical, free methodological basis for calculations, while ISO 14064 is a formal, paid standard that ensures auditability and verification. More details about ISO 14060 and the GHG Protocol can be found in this chapter.

VOLUNTARY STANDARDS

Verra and the Gold Standard are among the most important voluntary carbon market standards today. In 2024, the European Union adopted the Carbon Removal Certification Framework (CRCF) regulation, which established the first EU-wide regulatory framework for the certification of carbon removal activities. However, the CRCF does not automatically integrate existing international standards, but develops its own EU methodologies. Projects implemented under the Verra and Gold Standard frameworks can only be included in the new EU system if they comply with the CRCF requirements. As a result, it is expected that voluntary standards of global importance will in the future adapt their methodologies to EU requirements in order to provide access to the European market for their projects.

Independent monitoring organizations (such as Verra and Gold Standard) – essentially establish the regulatory framework for the operation of the carbon market. They define and operationalize key concepts such as additionality, permanence or leakage, which are essential for assessing the environmental integrity of credits. The task of standards can be divided into two main functions:

1. Development of a regulatory and methodological framework: The standard sets out general rules for the development, verification and validation of projects. As part of this, it includes various methodologies that define specific requirements for various project or credit types.

2. Operation of a registration system: The register associated with the standard ensures transparent tracking of projects – it records the issued credits, their turnover and retirement.

By defining the conditions under which a project can become certified, carbon standards and their associated registries help ensure that high-quality, environmentally sound credits are primarily brought to the market.

The legitimacy of carbon market standards essentially comes from the trust of market participants, especially buyers. It is of paramount importance for large companies and other key players that the credits they purchase truly represent a measurable and lasting climate impact. Since direct verification of project quality is a resource-intensive process (e.g. verification of additionality and permanence, screening of legal and land ownership relationships), buyers delegate this task to institutions operating standards – such as Verra or Gold Standard organizations. Thanks to this, purchasing credits with a Verra or Gold Standard rating provides market participants with a quality guarantee: these projects have met minimum requirements in terms of transparency, verifiability and environmental integrity. Verra is a US-based non-profit organization that is the largest player in the market by transaction volume. Verra's standard is called the Verified Carbon Standard (VCS) and it issues credits known as Verified Carbon Units (VCU). 2022, 52% of all VCUs issued were for projects classified as nature-based solutions. Next in size is Gold Standard, another non-profit organization based in Switzerland. Their expertise focuses on the co-benefits and social and community impacts of carbon projects.

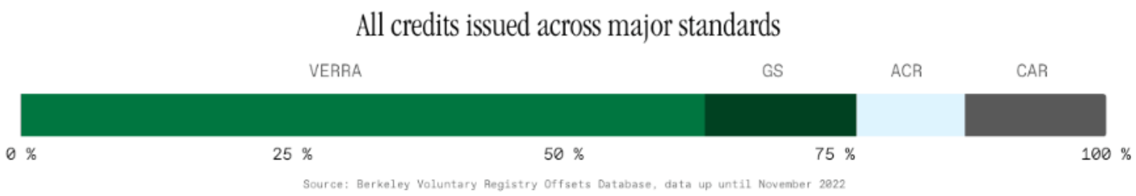


Figure 3: Carbon credits issued by the main standards until the end of 2022

CARBON CALCULATION METHODS

The IPCC issues guidelines for national greenhouse gas inventories and publishes methodologies, including calculation procedures and reference tables, in guidelines, based on which individual countries can calculate their values for greenhouse gas emissions and sequestration. It provides recommendations for three levels, depending on the capabilities of the given country and sector and the specificity of the available data. The first level is the most general and at the same time the most uncertain, the second level already uses country-specific data, while the third level uses data related to the given farmer (figure 3.). While it basically serves national-level calculations, most farm-level carbon calculation software also uses these procedures, and it is also part of the requirements of carbon credit certification standards and systems. After being published in 2006, it underwent a major update in 2019.

There are a growing number of publicly available tools – Excel spreadsheets, web-based software – available to calculate greenhouse gas flows, many of them based on the IPCC methodologies.

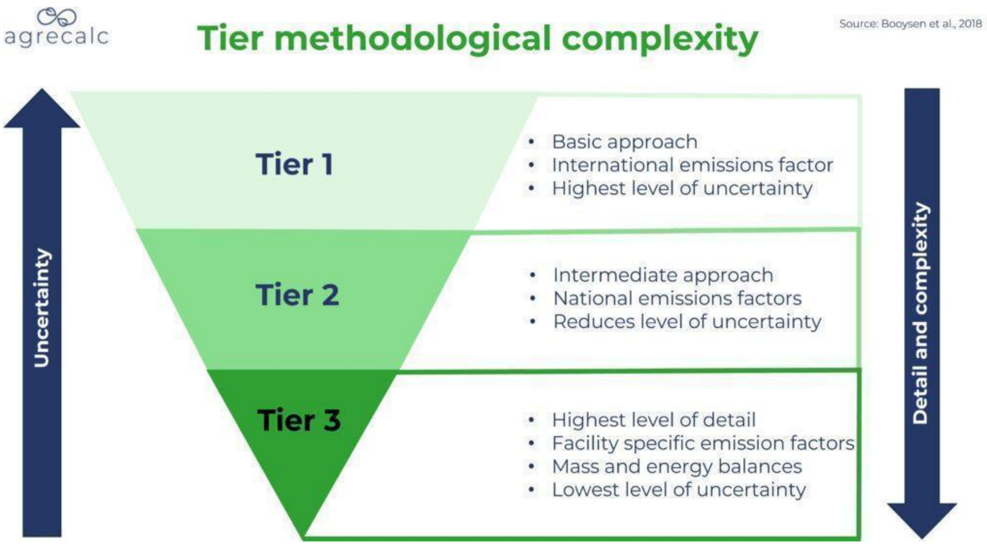


Figure 4: The IPCC carbon footprint calculation methodology

Source: https://www.agrecalc.com/home/insights/ipcc-tier-2-methodology-agriculture-carbon-footprint/

STEP 3. ASSESS FARM BASELINE AND DEVELOP TRANSITION PLAN

The most important part of the planning phase is decision-making and the development of a detailed transition and business plan. The decision is fundamentally determined by what carbon sequestration agrotechnology can be introduced in the area to be included, and what business model the farmer can safely operate in.

In addition to technical aspects, the farmer must also consider sales opportunities, as the use of carbon credits only becomes profitable if the method of entering the market is clarified in advance. Part of this is the selection of a verification standard, which determines the recognition and value of the project on international markets. The decision also includes the development of a monitoring and data collection system that authentically and consistently documents the changes, meeting the requirements of the selected standard. Finally, an essential element of planning is the identification of risks and the development of possible response measures: this is the only way to ensure that the transition is a predictable process not only from an environmental and market perspective, but also from a financial perspective.

DETAILED PLANNING OF AGRICULTURAL TECHNOLOGY, TIME SCHEDULING, COST PLANNING

The first step is to determine which specific agrotechnical practices can be introduced (e.g. sowing cover crops, no-till farming, organic matter recycling, agroforestry systems). This involves considering the practical applicability of different cultivation methods, their timing, and their suitability for local conditions and production goals. These should be included in an annual and multi-annual schedule that takes into account crop rotation, soil conditions, and weather conditions. The goal of the schedule is to ensure that changes are made gradually and while maintaining production security. It is worth planning the costs of the transition at this stage.

The CFCE-project tested seven main carbon farming techniques over two seasons in at least two regions each:

- Additional organic fertilizers. External organic fertilizers include solid and liquid manure from different animals, biogas slurry, compost, and biochar for fertilization.
- Relocation of harvest residue. Relocation of harvest residues comprises the transfer of for animal nutrition not needed forage crops (clover-grass, alfalfa, etc) to another field (mostly humus degrading row crops), systems of 'transfer-mulch', and cut & carry systems.
- Additional cover crops. Additional cover or catch crops cover the soil instead of fallow. Different cover crop mixtures might, due to different local suitability and different growing/rooting habits, entail different impact on soil organic carbon.
- Diversification of crop rotation. Diversification in crop rotation includes incorporation of diverse underutilised and varying crops in field rotation. This technique also considers undersowing, intercropping and mulching practices, leaving crop residues on the field, including crops with distinct root development and root exudate release.
- Reducing tillage. The technique 'reducing tillage' includes all kinds of reducing conventional, deep ploughing tillage. That means, shallow ploughing to different extents, any kind of non-inversion tillage with a cultivator or similar device, strip-till versions, special innovations like the Turiel-technique, up to no-tillage treatments.
- Liming/gypsum effect. This technique includes the use of lime ($CaCO_3$), gypsum ($CaSO_4$) and other agents (like basalt meal, filter dust) to provide positively charged Ca-ions to enhance the complexation of organic carbon of humus and clay minerals

Each of the techniques has complex environmental benefits: not only increasing soil carbon, but also important for nutrient management, water and soil protection, biodiversity, energy efficiency and air quality. Carbon sequestration is therefore a co-benefit, the application of these agrotechniques leads to the development of sustainable, resilient and environmentally more favorable farming systems.

The main financial/economic aspects are summarised in the table below and in this chapter, including the aforementioned complex environmental benefits. More details about these techniques can also be found in the training materials our project developed and in the guide about carbon farming agricultural practices.

Table 2: The estimated financial relations of CFCE-tested carbon farming practices

Potential financial/economic considerations of different carbon farming practices	Additional organic fertilizers	Relocation of harvest residues	Additional cover crops	Diversification of crop rotation	Agroforestry	Reducing tillage	Liming/ gypsum effect
Need for special equipment	Apply	Apply	Apply	Apply	Apply	Apply	Apply
Need for input - organic matter	Apply	Apply	No effect	Apply	No effect	No effect	No effect
Need for input - new seeds/varieties	No effect	No effect	Apply	Apply	No effect	No effect	No effect
Need for input - herbicides	No effect	Apply	Apply	No effect	No effect	Apply	No effect
Need for input - mineral fertilizers	Apply	Apply	Apply	Apply	No effect	No effect	No effect
Need for (special) storage	Apply	No effect	No effect	No effect	No effect	No effect	Apply
Labor intensive	Apply	Apply	Apply	No effect	Apply	Apply	Apply
Need for bigger early stage investment	No effect	No effect	No effect	No effect	Apply	Apply	Apply
Hard to implement in small farms	Apply	No effect	No effect	Apply	Apply	No effect	No effect
Need for input - fuel	Apply	Apply	Apply	No effect	No effect	Apply	Apply
Periodic regular cost	No effect	No effect	No effect	No effect	No effect	No effect	Apply
Delayed RoI	Apply	Apply	No effect	Apply	Apply	Apply	No effect

Apply (green)	Reduces the need for input / generates financially positive changes
Apply (red)	Increases the need for input / generates financially negative changes

Soil carbon stocks may change due to changes in tillage methods. This chapter of the guide describes a methodology for estimating changes in soil carbon stock (SOC).

EXPERTISE TO BE INVOLVED (ADVISORY)

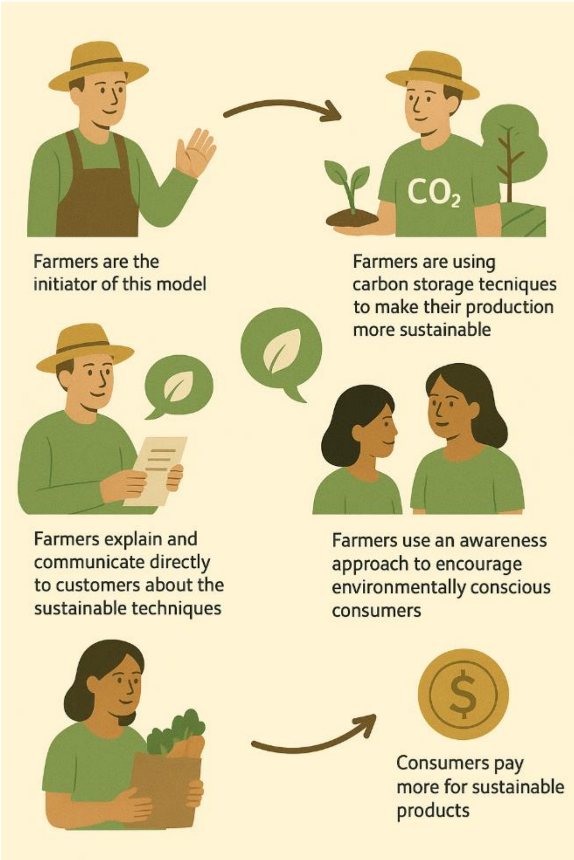
Radically changing the way someone farms is fraught with risk, as it involves a combination of technical, economic and long-term return on investment factors. A significant challenge for farmers has been identified during our project activities is the knowledge gap, which refers to the limited understanding of carbon farming technologies and practices. Nowadays, awareness of specific carbon farming practices remains limited, and knowledge regarding their effectiveness and appropriate implementation is not sufficiently disseminated or not reaching the farmer community. The scarcity of knowledge extends to the domain of carbon markets. It is challenging for farmers to acquire a comprehensive understanding of the functioning of carbon markets, the overall business model, and the process of acquiring and utilising their credits. Therefore, the introduction of carbon farming may require the use of external expertise. The transition planning may require soil, crop, environmental and economic advisors to help determine the most appropriate agrotechnical methods and to help assess market opportunities. It should be noted that the involvement of advisors may entail additional costs, which should be included in the business plan. The impetus for advisors can mainly be twofold: to facilitate community building and to support active measures to combat the ongoing degradation of land and the environment.

This leads us to the importance of cooperation models. The majority of the cooperation models tested in the CFCE project (see next section and the introductory chapter on business models) have been demonstrated to encourage enhanced training and awareness among advisors and farmers with regard to sustainability. The cooperation models can promote a culture of sustainability and adaptability by encouraging farmers to continuously learn and adopt innovative practices. The collaborative approach fosters knowledge exchange, facilitating the effective transfer of best practices, and accelerating the adoption and wider implementation of regenerative techniques. Increased and intensified communication also helps building trust, mutual understanding and long-term relationships through the whole value chain.

See: Advisory and peer support (contact lists)

MAPPING SALES CHANNELS AND COLLABORATION OPPORTUNITIES

The next step is to assess the potential demand for carbon farming activities. The agrotechnical practices described above can lead to carbon sequestration in the soil and reduce greenhouse gas emissions. These effects represent fundamental value that can be exploited in various business models. This could be through direct sales of carbon-neutral goods to consumers or companies, direct or indirect participation in carbon market platforms, or participation in research and innovation projects. The following table summarises the main models of realizing the value created through carbon farming practices.



Farmer-led cooperation (farmer-consumer)

In this type of model, farmers are the main initiators, introducing sustainable farming practices to make their products more environmentally friendly. In most cases, farmers focus directly on consumers, explaining and communicating the sustainable farming techniques used to them. One of the most common methods of this is the so-called labelling, which clearly conveys information about the product to the consumer, which can be made transparent and credible by certification organizations.

Business models based on sustainable farming practices can operate in a variety of ways, depending on whether the farmer enters the market independently, as a local supplier, or more collaboratively, as a cooperative. The chosen form fundamentally determines the cost burden, revenue opportunities, and market access strategy.

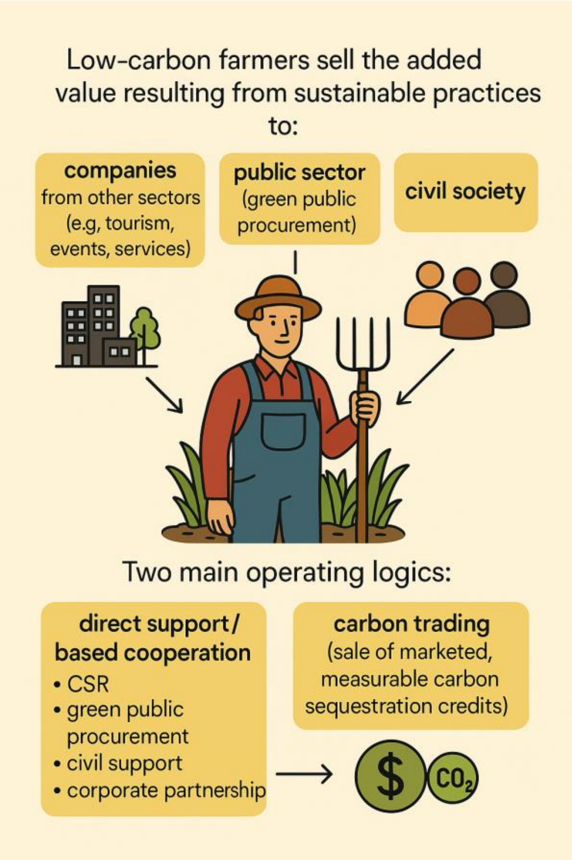
Cooperation within the food production chain

In this type of collaboration, agri-food companies are the initiators of the collaboration, with the aim of making their business more sustainable. In order to achieve their sustainability goals, they establish business partnerships with low-carbon farmers.

It is the responsibility of the farmers to integrate the sustainable, carbon farming practices into their own production. Through marketing campaigns for their products, the companies explain to their customers how they contribute to the agri-food industry's climate protection goals, and at the same time raise consumer awareness of more sustainable food consumption. The added value of their products partly flows to the farmers, who receive a higher price for their products.

Cooperation outside the food production chain

In this type of collaboration, low-carbon farmers do not sell the added value resulting from sustainable practices directly in the food chain, but to actors outside the food chain. These could be environmentally responsible companies from other sectors (e.g. tourism, events, services), the public sector (green public procurement), or civil society.



The most prominent form of this model is carbon trading, which allows carbon sequestration or emission reductions achieved by farmers to be sold in the form of certified allowances to companies that need to offset their own emissions. There are also non-trading solutions, where sustainable practices are financed through corporate social responsibility (CSR), public procurement or civic support.

This model can therefore be divided into two main operating logics:

- **direct support/based cooperation** (CSR, green public procurement, civil support, corporate partnership), or
- **carbon trading** (sale of marketed, measurable carbon sequestration credits).

Government-led cooperation

Climate change mitigation and environmental protection goals are high on the agenda of national and regional governments. Many municipalities and cities are also developing climate action plans, which include carbon sequestration measures. Carbon farming techniques are therefore often directly supported by government institutions.

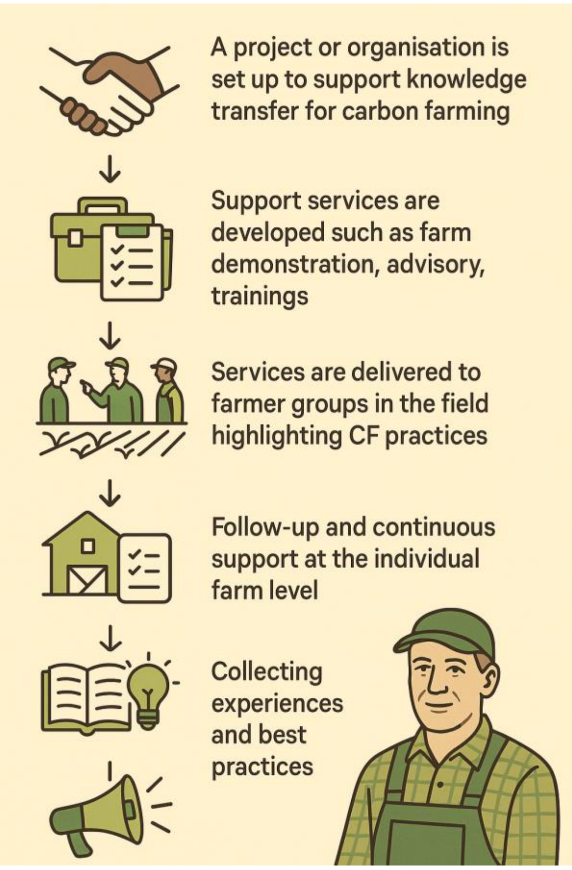
Government support can take two main forms:

- direct payments to farmers for the ecosystem services they provide (e.g. increasing soil carbon sequestration capacity, reducing emissions),
- indirect incentives, such as tax breaks or preferential green financing schemes that reduce the additional costs of sustainable farming.

The specificity of the government model is that the climate protection performance of farmers is less visible to the consumer market than in labeling or corporate cooperation models. The recognition of sustainable practices here takes place primarily at the policy and administrative level: the farmer receives feedback and compensation through participation in support systems (e.g. agro-ecological programs, green investment subsidies, tax breaks).

Project-driven cooperation (knowledge transfer-oriented)

There are many examples worldwide of different partners coming together to implement a targeted "climate project" aimed at creating a climate protection or carbon farming system. These projects typically start from R&D development sources (EU and domestic research programs) and aim to create a sustainably operating model after the initial supported period.



The project-driven model is characterized by the fact that no single actor dominates, but rather a multi-actor partnership is established: research institutes, advisory organizations, farmer groups, companies and civil society organizations all participate in it. The emphasis is on knowledge transfer, innovation and capacity building: farmers try out new practices, which are monitored, evaluated and further developed by professional partners.

The specific characteristics of a given model may show significant differences depending on the actors involved, the actors' understanding of carbon farming (as it is important to ascertain whether the primary objective of the model is carbon sequestration or whether it is designed to achieve a more extensive and multifaceted environmental and economic impact), or the monitoring mechanism of the model.

These models are presented in more detail in a separate chapter of the guide. They are illustrated with examples and address questions such as which model quantifies carbon sequestration (and how), the roles of the various stakeholders in the process, and the circumstances in which a given model is the most appropriate choice.

VOLUNTARY CARBON MARKETS - FARMERS PERSPECTIVE

In most cases, farmers and their advisors are not directly in touch with organizations that administer voluntary carbon market standards, but can join a program created by a carbon project development company, whose task and responsibility is to ensure compliance with the standard so that the carbon sequestration generated can be converted into carbon credits. These project developers collaborate with several farms in a single project to achieve the economies of scale necessary to implement it. If an aggregator company creates its project as a "group" type, individual farmers can join the project even after validation. Nevertheless, it is worth gaining insight into the background of these voluntary carbon market standards in order to better understand how the market works and the framework that ultimately determines implementation in an indirect way.

In the case of agricultural advisory organizations, there may be initiatives to set up an independent carbon project (so creating an “Advisory service led” type of business model), developing new or applying an already approved methodology (see example below). In both cases, however, it is necessary to have a direct and detailed understanding of how these standards work.

The advisory service driven model concept sits somewhere in between the “Outside of agri-food chain” and “Knowledge transfer/project” type, which are specifically discussed in this guide. However, unlike the better-known voluntary carbon market projects, where the benefits for farmers focus primarily on the financial income from the sale of carbon credits and the solid promise of such revenue, the advisory-driven model does not target just this, but is rather based on

Figure 5: A possible model built around advisory service provision

regular the agrotechnical, farm management, and administrative (monitoring) assistance provided as part of the advisory service routine, which advisors already carry out as a dominant part of their every day work. Should the collaboration prove successful in achieving the desired carbon sequestration outcome and be accredited, the financial income from the sale of carbon credits can serve as a supplementary benefit for farmers at the end of the designated period.

SELECTING A CERTIFICATION SYSTEM (STANDARD)

The emphasis placed directly on carbon sequestration varies between different cooperation models. In numerous instances, it is regarded as an integral component of sustainable food production, one that is in harmony with the environment and does not involve the depletion of natural resources. In other instances, it constitutes a component of government-backed initiatives, in Central European context predominantly within the framework of eco-schemes under the CAP strategy plans, and is executed in an action-based manner. It is evident that initiatives and models which regard the generation of carbon credits as both a viable prospect and an attainable objective in a results-based manner, whether in the present or in the future, will undoubtedly accord this aspect a significantly higher degree of importance.

In order to sell carbon credits on the market, it is essential for the farmer to choose the certification system according to which he wishes to officially certify the carbon sequestration/emission reduction achieved during his farming. The most common ones (as it was mentioned before) include the voluntary Verra, the Gold Standard and the EU Carbon Removal Certification Framework (CRCF) to be developed by the EU in the future. The additional costs of this must be taken into account when switching to carbon farming. It is also acknowledged that the measurement methods and procedures themselves contain some uncertainty, even for established methodologies. The long-term commitment required for the model, coupled with its latent inefficiency, has the potential to lead to disappointment. Examples show the importance of a robust MRV system, accompanied by a clear and well-defined methodology. Action-based models have been shown to present certain challenges in this respect, even if not to the same extent as result-based approaches. It is important to consider the issue of the complexity of monitoring and data collection.

PLANNING MONITORING AND DATA COLLECTION

The basis for successful verification is the availability of accurate and verifiable data. The farmer must develop a monitoring system that defines what data will be collected (e.g. soil organic matter content, cultivation practices, input use), how often the measurements will be made, and how they will be documented. The monitoring plan must be adapted to the requirements of the chosen verification standard. See more about this topic in the Implementation section.

Closely related to the gathering of accurate data and may be useful for both farmers and advisors to gain a deeper understanding of the methods, standards, and tools that serve to reliably measure, calculate, and certify carbon sequestration resulting from farming practices. This is not only of particular interest in the carbon credit market, although it is given special emphasis there, but also in any carbon farming business model where it is important to be able to accurately calculate and present the results to those participants who cooperate with farmers in the given models. Within the framework of cooperation in the agricultural value chain, it may also be necessary to objectively substantiate the carbon sequestration results of a given crop or the carbon footprint of the farm as a whole to buyers and purchasers. In the case of agreements with other sectors, such as banks and insurance companies, the use of more sustainable and climate-conscious farming methods may also be considered. In the case of government subsidies, it is also important to consider the impact of individual techniques on carbon sequestration at the field level or on the carbon footprint examined in a broader context when determining compensation amounts.

Most of the tools cover a wide range of areas related to emission reduction and carbon sequestration, as their aim is to determine the most complete carbon footprint possible in relation to the activities of a given farm. However, this guide focuses mainly on methods related to soil carbon sequestration. In a separate chapter, we provide a summary of the tools that are widely used in practice and can also be applied at the farm level from this perspective. These tools are: Cool Farm Tool, Farm Carbon Toolkit, AgreCalc, Sandy Carbon Footprint Module, Solagro Carbon Calculator and the CFCE Gross Margin Calculation and Benchmarking.

There are many carbon calculator tools available worldwide, some tailored to a specific region or country, free to use or for a fee. Most of them work with standard reference data, the most common of which are the methodologies included in the IPCC guidelines.

RISK MANAGEMENT

In general, carbon farming practices produce results over a relatively long timeframe and entail significant, sometimes radical, changes. The protracted return on investment, coupled with the need for long-term commitment and the potential for implementation difficulties, poses significant risks.

It is advisable to develop a risk management plan in the transition and business plan, which should take into account possible uncertainties regarding potential costs and benefits, with particular regard to the timing of income and expenses.

Some of the most notable risks are:

- New agrotechnical methods (e.g. no-tillage cultivation) may initially cause crop losses or yield fluctuations.
- The costs of the transition (mechanization, consulting, certification and monitoring) can be significant, while the revenues (e.g. credits, subsidies) arrive with a delay.
- The estimated carbon sequestration/emission reduction may differ from the actual measured value, or the inability to enhance carbon levels. In the event that farmers (along with intermediaries) are unable to enhance soil carbon content, the issuance and subsequent sale of carbon credits becomes impossible.
- In the longer term, the amount of new carbon that can be sequestered is expected to decrease, rendering the business model less attractive. Concurrently, there is a possibility that other agricultural subsidies may include carbon sequestration practices as a mandatory component, which could pose a problem with regard to additionality.
- A significant challenge confronting diverse carbon farming cooperation models pertains to the issue of regulation and the associated administration. There is currently no comprehensive regulation of the carbon markets, and also the different frameworks supporting the dissemination of carbon farming practices are subject to ongoing evolution and debate.

When making a decision, these uncertainties must be incorporated into the cost-benefit analysis and the decision must be made taking this into account. If we decide to switch, it is necessary to determine the risks that, if they occur during the implementation phase, will cause us to suspend or terminate carbon farming and return to conventional practices.

STEP 4. IMPLEMENTATION

In the implementation phase, the planned practices will be implemented according to the defined transition and business plan, and the continuous monitoring of issuance and settlement data will begin. The data must be recorded in a systematic manner and then verified according to the requirements of the chosen standard.

Accounting for income and expenses: as part of the process, it is advisable to keep accurate financial records. This includes accounting for revenues from the sale of credits and costs related to transition, operation, monitoring and verification, which is necessary to assess the success and economy of carbon farming.

The most logical solution for keeping related data records is, of course, if someone already has some kind of farm management system (FMS), to set it up in such a way that it can also support carbon farming monitoring as effectively as possible. However, many farmers do not have such a system in place, and it is even more true across the EU that, under the Common Agricultural Policy, everyone applies for some form of support, and the paying agency may request a wide variety of data electronically for control purposes, and in some countries, a comprehensive farm log must also be kept. Software supporting e-government reporting and data provision, whether developed by external developers or by the government's internal systems, may be suitable for generating data requests and reports that largely meet the requirements of carbon farming monitoring, as the areas, operations, materials, quantities, and costs can largely be found in these "basic" systems.

Example: Farm logbook software with carbon farming module (Hungary)

Based on the types of operations, the example log software shown in the figures below calculates carbon dioxide emissions and carbon sequestration compared to previous years using IPPC multipliers and formulas specified at the national level.

gn.eurofarmer.hu/__karbon/?p=tm_view

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Tables - agrotechnical operations (GN07)

Serial number (EC)	Blockade	Area	Code of Use	Operation	Depth (cm avg)	Processing	CO2 Output
1 (2012)	HD7D1N11	0.9400	IPA02 (Rapeseed)	Cultivation	8.000	1	1.1891
1 (2012)	HD7D1N11	0.9400	IPA02 (Rapeseed)	Processing		0	0
1 (2012)	HD7D1N11	0.9400	IPA02 (Rapeseed)	Algae spraying		0	0
1 (2012)	HD7D1N11	0.9400	IPA02 (Rapeseed)	Bacterial spraying		0	0
1 (2012)	HD7D1N11	0.9400	IPA02 (Rapeseed)	Fertilization	40.000	0	0
2 (2012)	HD7D1N11	2.2500	IPA02 (Rapeseed)	Cultivation	8.000	1	2.8463
2 (2012)	HD7D1N11	2.2500	IPA02 (Rapeseed)	Processing		0	0
2 (2012)	HD7D1N11	2.2500	IPA02 (Rapeseed)	Algae spraying		0	0
2 (2012)	HD7D1N11	2.2500	IPA02 (Rapeseed)	Bacterial spraying		0	0
2 (2012)	HD7D1N11	2.2500	IPA02 (Rapeseed)	Fertilization	40.000	0	0
3 (2012)	HXFL1N11	0.7000	IPA02 (Rapeseed)	Cultivation	8.000	1	0.8855
3 (2012)	HXFL1N11	0.7000	IPA02 (Rapeseed)	Processing		0	0
3 (2012)	HXFL1N11	0.7000	IPA02 (Rapeseed)	Algae spraying		0	0
3 (2012)	HXFL1N11	0.7000	IPA02 (Rapeseed)	Bacterial spraying		0	0
3 (2012)	HXFL1N11	0.7000	IPA02 (Rapeseed)	Fertilization	40.000	0	0
4 (2012)	HXFL1N11	3.1500	IPA02 (Rapeseed)	Cultivation	8.000	1	3.9848
4 (2012)	HXFL1N11	3.1500	IPA02 (Rapeseed)	Processing		0	0
4 (2012)	HXFL1N11	3.1500	IPA02 (Rapeseed)	Algae spraying		0	0
4 (2012)	HXFL1N11	3.1500	IPA02 (Rapeseed)	Bacterial spraying		0	0
4 (2012)	HXFL1N11	3.1500	IPA02 (Rapeseed)	Fertilization	40.000	0	0
5 (2012)	H21D7A11	0.5000	IPA02 (Rapeseed)	Cultivation	8.000	1	0.6325
5 (2012)	H21D7A11	0.5000	IPA02 (Rapeseed)	Processing		0	0
5 (2012)	H21D7A11	0.5000	IPA02 (Rapeseed)	Algae spraying		0	0
5 (2012)	H21D7A11	0.5000	IPA02 (Rapeseed)	Bacterial spraying		0	0
5 (2012)	H21D7A11	0.5000	IPA02 (Rapeseed)	Fertilization	40.000	0	0
6 (2012)	H21D7A11	0.7200	IPA02 (Rapeseed)	Cultivation	8.000	1	0.9108
6 (2012)	H21D7A11	0.7200	IPA02 (Rapeseed)	Processing		0	0
6 (2012)	H21D7A11	0.7200	IPA02 (Rapeseed)	Algae spraying		0	0
6 (2012)	H21D7A11	0.7200	IPA02 (Rapeseed)	Bacterial spraying		0	0
6 (2012)	H21D7A11	0.7200	IPA02 (Rapeseed)	Fertilization	40.000	0	0
7 (2012)	HF661H11	4.5500	IPA02 (Rapeseed)	Cultivation	8.000	1	5.7558

Table 3: Calculation of CO_2 output

Tillage method	Depth (cm)	Organic residues incorporated in the soil	Multiplication coefficient for C output
Ploughing	22-25	Yes	0.82
Ploughing	22-25	No	2.58
Ploughing	28-32	Yes	0.975
Ploughing	28-32	No	2.70
Disc tiller	16-20	Yes	0.39
Disc tiller	16-20	No	0.59
Disc tiller	6-8	Yes	0.33
Cultivator	6-10	Yes	0.345

**CO_2 output calculation: CO_2 (t) = Area (ha) * multiplication coefficient * 44 / 12*

There are also service providers specialised for supporting the whole cycle of carbon farming monitoring, such as Agrocares.

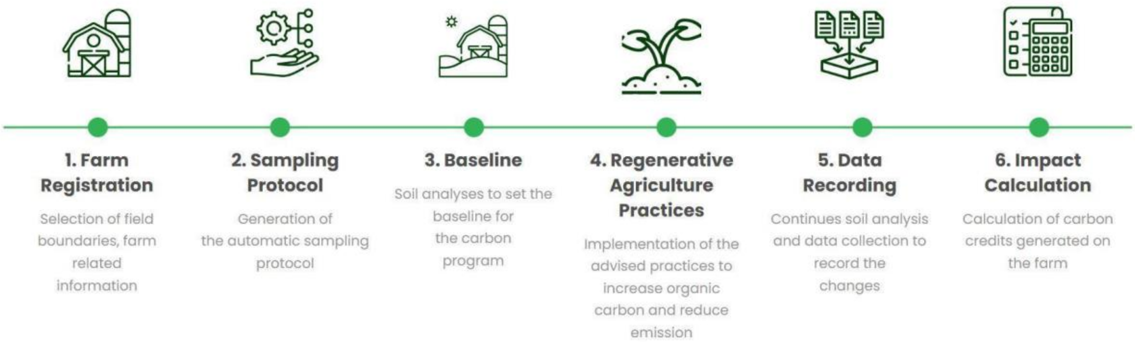


Figure 6: The process of carbon farming monitoring in Agrocares

Source: https://agrocares.com/carbon/carbon

STEP 5. VALIDATION, ASSESSMENT OF RESULTS, FEEDBACK

In the operational phase following the transition period, the results of the implementation should be continuously evaluated in relation to the set goals. Based on this, a decision can be made to end carbon farming, modify, continue or further expand agrotechnical solutions to other areas, or introduce additional business models. The aim of the feedback is to ensure that the carbon farming process remains sustainable and economically profitable in the long term.

The following chapters of the guide provide more detailed information (standards, practices, economic considerations and tools) relating to the various steps for consultants and farmers wishing to gain a deeper understanding of each step.

CARBON FOOTPRINT CALCULATION STANDARDS: ISO 14060 AND THE GHG PROTOCOL

ISO 14060 STANDARD FAMILY

The ISO 14060 family of standards clearly and consistently provides for the quantification, monitoring, reporting and validation or verification of GHG emissions and removals to support sustainable development through a low-carbon economy, benefiting organizations, project sponsors and stakeholders worldwide. Specifically, the application of the ISO 14060 family of standards:

- enhances the environmental integrity of GHG quantification;
- enhance the credibility, consistency and transparency of GHG quantification, monitoring, reporting, validation and verification;
- promotes the development and implementation of GHG management strategies and plans;
- facilitates the development and implementation of mitigation measures by reducing emissions or increasing removals;
- makes it easier to track performance and progress in reducing GHG emissions and/or increasing GHG removals.

The applications of the ISO 14060 family of standards are as follows:

- corporate decisions, such as identifying opportunities to reduce emissions and increase profitability by reducing energy consumption;
- managing risks and opportunities, such as climate change-related risks, including financial, regulatory, supply chain, product and customer, litigation, reputational risks and business opportunities (e.g. new market, new business model);
- voluntary initiatives, such as participation in voluntary GHG inventories or sustainability reporting initiatives;
- GHG markets, such as buying and selling GHG emission allowances or credits;
- regulatory/government GHG programs, such as early action credits, agreements, or national and local reporting initiatives.

The document details the principles and requirements for planning, developing, managing and reporting on an organization-wide GHG inventory. This includes defining the boundaries of GHG emissions and removals, quantifying the organization's GHG emissions and removals, and identifying specific corporate actions or activities to improve GHG management. It also includes requirements and guidance on inventory quality management, reporting, internal auditing and responsibilities for the organization's verification activities.

ISO 14064-2 details the principles and requirements for establishing baselines and monitoring, quantifying and reporting project emissions. It focuses on GHG projects or project-based activities that reduce GHG emissions and/or enhance GHG removals. It provides a basis for the verification and validation of GHG projects.

ISO 14064-3 details the requirements for the verification of GHG claims related to GHG inventories, GHG projects and product carbon footprints. It also describes the verification or validation process.

GHG PROTOCOL

The GHG Protocol Agricultural Guidance was published in 2014 and serves as a supplement to the GHG Protocol Corporate Standard. The guidance aims to assist agricultural companies and organizations in measuring and reporting their greenhouse gas emissions. As the agricultural sector operates with specific emission sources, biological processes and highly variable environmental factors, the existing general corporate standard alone was not sufficient. The Agricultural Guidance was therefore developed with the aim of translating the principles of the Corporate Standard to the specificities of agricultural practices and providing a transparent, comparable and consistent framework for reporting organizations. These additions are mainly as follows:

- the strong influence of environmental factors on agricultural greenhouse gas emissions and sequestration, which makes it difficult to separate human activity from natural processes and thus to use GHG inventories as an effective management tool,
- producing accurate, location-specific data in an environment where conditions vary greatly from region to region,
- setting and monitoring emission reduction targets in the face of changing GHG flows, and accounting for changes in carbon sequestration and the management and ownership of different carbon stocks,
- the fact that emissions from agricultural activities often do not occur immediately (for example, during the decomposition of organic matter after harvest),
- organizational structures and operating practices specific to agriculture.

This guidance provides recommended approaches to address these and other issues relevant to the sector, while maintaining the core requirements of the Corporate Standard. As agriculture is extremely diverse, the Guidance aims to provide a common framework that can be applied across different sub-sectors of the sector. The guidance can be used as a stand-alone tool for preparing GHG inventories, but some topics, such as the verification of GHG inventories or the setting of emission reduction targets, are not covered (these are covered in the Corporate Standard).

The specific objectives of this guide are:

- increasing consistency and transparency in GHG accounting and reporting in the agricultural sector,
- helping companies to cost-effectively prepare a GHG inventory that provides a true and credible picture of their impact on the climate,
- ensuring that GHG inventories meet the decision-making needs of both internal management and external stakeholders, such as investors, and thus facilitate more effective management of agricultural emissions.

It is important to emphasize that the guidance does not contain specific emission factors, but rather directs users to use values from the IPCC and other national databases as a basis. The Agricultural Guidance is therefore not a calculation manual, but a methodological framework. It does not replace the guidelines of the IPCC or other professional organizations, but helps them to be applied in a corporate context. Its essence is to provide a common language for agricultural sector emission data, which can be used by different companies, countries and initiatives. In this way, the guidance contributes to making the measurement and reporting of agricultural emissions more transparent, reliable and internationally comparable.

There are a growing number of publicly available tools – spreadsheets, software and protocols – for calculating GHG fluxes based on emission factors, models or a combination of these approaches. Annex III to the GHG Protocol contains a non-exhaustive list of such tools.

THE MAIN VOLUNTARY CARBON MARKET STANDARDS IN DETAILS

Verra and the Gold Standard are among the most important voluntary carbon market standards today.

- The **Verra VCS** is a simpler standard suitable for small and medium-sized enterprises that want to reduce their carbon footprint without excessive investment. It covers a wider range of projects, including renewable energy, forestry and land use.
- The **Gold Standard** in contrast, a more stringent standard that is ideal for businesses aiming to significantly reduce their carbon footprint and support sustainable development. It focuses on renewable energy, energy efficiency, waste management and community service projects, with a strong emphasis on social benefits and sustainable development.

When choosing between these two standards, businesses should consider their specific needs, values, and sustainability goals, as well as factors such as project types, verification processes, costs, social impact, market recognition, and business suitability.

Table 4: Comparison of Vera VCS and Gold Standard

Aspect	Verra VCS	Gold Standard
Project focus	Renewable energy, forestry, agriculture	Primarily renewable energy
Project types	Broader (renewable energy, forestry, land use)	Narrower focus (renewable energy, energy efficiency, waste management, community services)
Certification process	Third-party verification	Third-party verification, regular audits and monitoring
Expenditures	Generally lower costs	Higher costs due to stricter requirements
Social impact	Limited focus on social benefits	Strong focus on sustainable development and social benefits
Market recognition	Widely accepted in compliance and voluntary markets	Recognized in voluntary markets and some compliance markets
Business suitability	Suitable for small and medium-sized businesses	Suitable for businesses with high sustainability goals

**Source:* *https://www.ecohedge.com/blog/carbon-offset-standards-comparison-verra-vcs-vs-gold-standard/)*

VERRA VERIFIED CARBON STANDARD (VCS)

The core function of the Verra Verified Carbon Standard (VCS) framework is not to directly measure or calculate carbon sequestration, but to verify that the emission reductions or carbon sequestrations demonstrated by a project have been achieved in accordance with the relevant methodological specifications. VCS provides a global framework for projects and programs to reduce and remove greenhouse gas emissions. The standard is based on the requirements of the international standards ISO 14064-2, ISO 14064-3 and ISO 14065. The three key documents of the program are the VCS Program Guide, the VCS Standard and the VCS Methodology Requirements.

- The VCS Program Guide sets out the regulations governing the operation of the system, describing, among other things, the project and program registration process, the operation of the Verra registry, the rules for developing and reviewing methodologies, and the accreditation requirements for validating and verifying organizations.
- The VCS Standard contains requirements for the development of projects and programs, covering validation, monitoring and verification requirements for emission reduction and carbon removal activities.
- The VCS Methodology Requirements define the rules for the development and approval of new methodologies.

The program documents should be applied in a hierarchical order: reviewing the VCS Program Guide is a prerequisite for using the VCS Standard and VCS Methodology Requirements. During the process:

- Project developers prepare their calculations based on methodologies accepted by the VCS, which include determining the baseline, quantifying the project's impacts, and fulfilling monitoring and reporting obligations.
- The project documentation and the data collected during monitoring are checked by independent, accredited Validation and Verification Bodies (VVB).
- Verra's job is to ensure that the methodology is applied correctly, the calculations are conservative, and the results are reliable.

If the project meets the requirements, Verra will approve the demonstrated amount in its registry and issue the corresponding number of Verified Carbon Units (VCU). One VCU represents the removal or avoidance of one tonne of carbon dioxide equivalent (tCO_2e) from the atmosphere.
The documentation also includes critical clauses from ISO 14064-2 and ISO 14064-3, as the International Organization for Standardization (ISO) contributed to their inclusion in order to make the application of the requirements more transparent and easier to understand.

GOLD STANDARD

The certification process under Gold Standard for the Global Goals is set-up to help design a project for maximum positive impact. The application of conservative and considered methodologies ensures accurate quantification of impact, a unique approach to stakeholder inclusivity helps support long term project success, and the assurance process uses approved third-party validation and verification bodies (VVBs) to audit the projects and ensure verified impacts - resulting in high quality projects with credible claims that can attract premium prices. From 5 December 2024 Gold Standard is introducing an updated assurance process. Project planning is a key stage of any climate and development initiative. Before embarking on the Gold Standard certification process project developers are encouraged to review the relevant methodologies, standard documentation and terms of use to check that the project meets the Gold Standard for the Global Goals principles and requirements and could be eligible for Gold Standard certification. Before the project starts, Project Developers should:

1. Identify if there is an applicable methodology for the proposed project. View the mitigation and removals options for a high-level overview of feasible scopes (both current and upcoming) under the Gold Standard for the Global Goals. For a more detailed review, the methodology tool can be used to find eligible and available methodologies for the Gold Standard for the Global Goals. For new technologies, measures and/or interventions, where a methodology is not yet available, there is a methodology approval procedure. Initial ideas, both for brand new methodologies or methodology revisions, can be submitted to check eligibility using the concept note template. Submissions should be emailed to methodology@goldstandard.org .

2. Once finding a methodology, the next step is to check project eligibility within the Principles & Requirements and the relevant Project Activity Requirements.

3. For projects that plan to issue Gold Standard carbon credits, additional requirements are located in the GHG emission reductions and sequestration product requirements.

4. Confirm the basic project design and assess against Gold Standard safeguarding principles.

The certification process consists of eight steps, illustrated in the following figure:

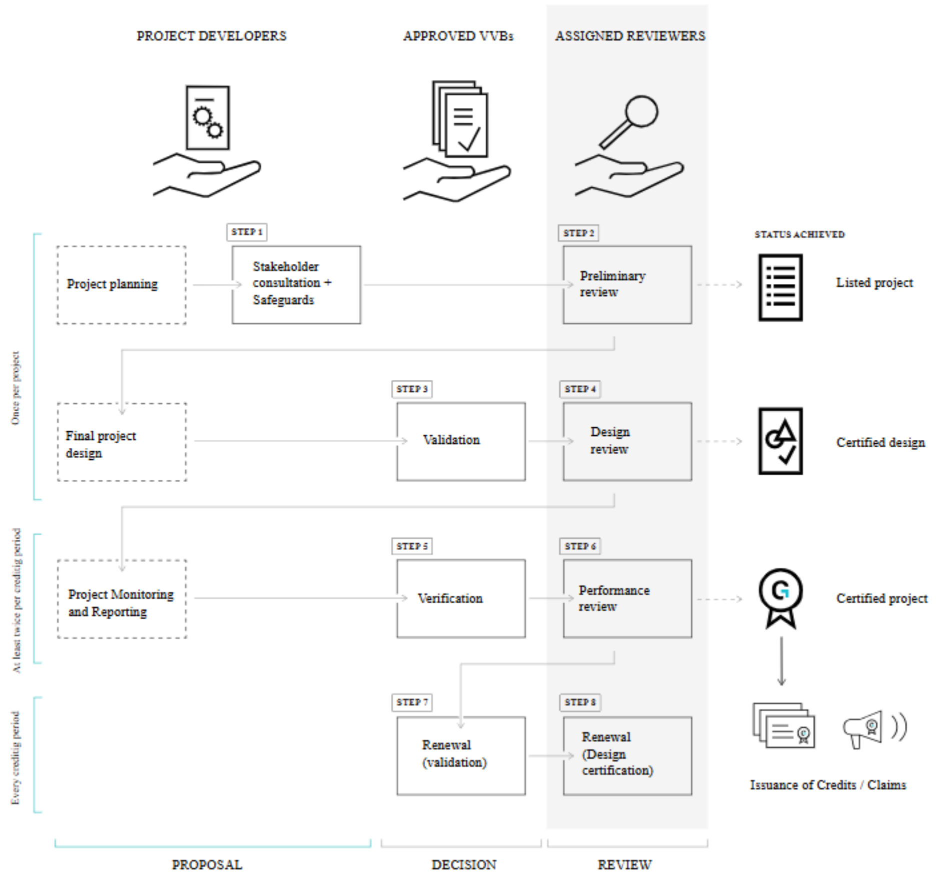


Figure 7: Gold Standard certification process

Source: https://www.goldstandard.org/publications/certification-process-stepbystep

ESTIMATION OF SOIL CARBON STOCK CHANGE ACCORDING TO THE IPCC, 2006 METHODOLOGY

Soil carbon stock may change due to the conversion of a given area to another land use, the conversion of land within a land use subcategory to another subcategory (e.g., setting aside land, converting it to plantations), or a change in the method of tillage (e.g., reduced or no-till tillage) within a given land use subcategory. Subcategories of changes that occur in the soil carbon stock are referred to together below. The sum of all soil carbon stock changes for the entire land use sector is estimated using the following formula:

The estimate of the change in soil organic carbon stock (ΔC) for Tier1 is made using the first formula of the 2006 IPCC CL 2.25 equation:

$\Delta C = (SOC0 - SOC0\text{-}T) / D$ (Equation 2.25.1)

where

ΔC = annual area-specific soil organic carbon stock change, tCha-1year-1;

SOC0 = SOC soil organic carbon stock in the inventory year, tC;

SOC0-T = SOC soil organic carbon stock in the year preceding the inventory year, tC;

T = number of years during an inventory period, year, T = 1 year;

D = default duration for transition between equilibrium SOC values, years (default value = 20 years).

To estimate SOC (both for the inventory year and the year T preceding it) for soil carbon stock change, the second formula of the 2006 IPCC equation 2.25 is:

$SOC = A * SOCREF * FLU * FMG * FI$ (Equation 2.25.2)

where

A = land area in the inventory year, if

SOCREF = site-specific soil organic carbon reference value, tCha-1

FLU, FMG and FI are specific land use (LU), management (MG) and nutrient supply input (I) stock change factors, for which default values are as follows:

Table 5: Relative stock change factors (flu, fmg, and fi) (over 20 years) for different management activities on cropland

Factor value type	Level	Temperature regime	Moisture regime1	IPCC defaults	Error2,3
Land use (FLU)	Long-term cultivated	Temperate/ Boreal	Dry	0.80	± 9%
			Moist	0.69	± 12%
		Tropical	Dry	0.58	± 61%
			Moist/ Wet	0.48	± 46%
		Tropical montane4	n/a	0.64	± 50%
	Paddy rice	All	Dry and Moist/ Wet	1.10	± 50%
	Perennial/Tree Crop	All	Dry and Moist/ Wet	1.00	± 50%
	Set aside (< 20)years)	Temperate/ Boreal and Tropical	Dry	0.93	± 11%
			Moist/ Wet	0.82	± 17%
		Tropical montane4	n/a	0.88	± 50%
Tillage (FMG)	Full	All	Dry and Moist/ Wet	1.00	NA
	Reduced	Temperate/ Boreal	Dry	1.02	± 6%
			Moist	1.08	± 5%
		Tropical	Dry	1.09	± 9%
			Moist/ Wet	1.15	± 8%
		Tropical montane4	n/a	1.09	± 50%
	No-till	Temperature/ Boreal	Dry	1.10	± 5%
			Moist	1.15	± 4%
		Tropical	Dry	1.17	± 8%
			Moist/ Wet	1.22	± 7%
		Tropical montane4	n/a	1.16	± 50%
Input (FI)	Low	Temperate/ Boreal	Dry	0.95	± 13%
			Moist	0.92	± 14%
		Tropical	Dry	0.95	± 13%
			Moist/ Wet	0.92	± 14%
		Tropical montane4	n/a	0.94	± 50%
	Medium	All	Dry and Moist/ Wet	1.00	NA

Factor value type	Level	Temperature regime	Moisture regime1	IPCC defaults	Error2,3
	High without manure	Temperate/ Boreal and Tropical	Dry	1.04	± 13%
			Moist/ Wet	1.11	± 10%
		Tropical montane4	n/a	1.08	± 50%
	High with manure	Temperate/ Boreal and Tropical	Dry	1.37	± 12%
			Moist/ Wet	1.44	± 13%
		Tropical montane4	n/a	1.41	± 50%

**Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Chapter 5: Cropland Table 5.5*

Example:

In a cool, temperate, dry climate, permanent annual arable land is found on HAC (high activity clay) soils. The region's native reference carbon stock (SOCREF) is 50 tonnes C ha-1(see Table …., IPCC 2006 Table 2.3).

The organic carbon stock (FLU) of arable land is 20% less than that of natural soils (FLU=0.8), i.e. 50 x 0.8 = 40 tC. If no-till cultivation is introduced in an area, it can increase the organic carbon stock of the soil by 10% over a 20-year period (F = 1.1) with a medium nutrient input (FI= 1), i.e. 50 x 0.8 x 1.1 x 1 = 44 tC. Since the IPCC methodology assumes that 20 years of this type of farming are needed to achieve the transition between equilibrium SOC values, the annual carbon sequestration rate is (44-40)/20 = 0.2 C ha^{-1} $year^{-1}$.

Since the market value of carbon sequestration certificates is currently around 25–35 EUR/tonne CO_2-equivalent, while certification and monitoring costs are typically around 10 EUR/ha/year and the amount of sequestered C can be calculated into CO_2-equivalent using the conversion rate of 44/12, we can expect an income of 0.2 tC x 44/12 x ~ 20 EUR/tonne = 14.7 EUR/ha.

Table 6: Default reference soil organic C stocks (socref) for mineral soils (tonnes c ha-1 in 0-30 cm depth)

TABLE 2.3
DEFAULT REFERENCE (UNDER NATIVE VEGETATION) SOIL ORGANIC C STOCKS (SOC_{REF}) FOR MINERAL SOILS (TONNES C HA^{-1} IN 0-30 CM DEPTH)

<table>
<tr><th>Climate region</th><th>HAC soils[1]</th><th>LAC soils[2]</th><th>Sandy soils[3]</th><th>Spodic soils[4]</th><th>Volcanic soils[5]</th><th>Wetland soils[6]</th></tr>
<tr><td>Boreal</td><td>68</td><td>NA</td><td>10[#]</td><td>117</td><td>20[#]</td><td>146</td></tr>
<tr><td>Cold temperate, dry</td><td>50</td><td>33</td><td>34</td><td>NA</td><td>20[#]</td><td rowspan="2">87</td></tr>
<tr><td>Cold temperate, moist</td><td>95</td><td>85</td><td>71</td><td>115</td><td>130</td></tr>
<tr><td>Warm temperate, dry</td><td>38</td><td>24</td><td>19</td><td>NA</td><td>70[#]</td><td rowspan="2">88</td></tr>
<tr><td>Warm temperate, moist</td><td>88</td><td>63</td><td>34</td><td>NA</td><td>80</td></tr>
<tr><td>Tropical, dry</td><td>38</td><td>35</td><td>31</td><td>NA</td><td>50[#]</td><td rowspan="4">86</td></tr>
<tr><td>Tropical, moist</td><td>65</td><td>47</td><td>39</td><td>NA</td><td>70[#]</td></tr>
<tr><td>Tropical, wet</td><td>44</td><td>60</td><td>66</td><td>NA</td><td>130[#]</td></tr>
<tr><td>Tropical montane</td><td>88*</td><td>63*</td><td>34*</td><td>NA</td><td>80*</td></tr>
</table>

Note: Data are derived from soil databases described by Jobbagy and Jackson (2000) and Bernoux *et al.* (2002). Mean stocks are shown. A nominal error estimate of ±90% (expressed as 2x standard deviations as percent of the mean) are assumed for soil-climate types. NA denotes 'not applicable' because these soils do not normally occur in some climate zones.

[#] Indicates where no data were available and default values from *1996 IPCC Guidelines* were retained.

* Data were not available to directly estimate reference C stocks for these soil types in the tropical montane climate so the stocks were based on estimates derived for the warm temperate, moist region, which has similar mean annual temperatures and precipitation.

[1] Soils with high activity clay (HAC) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols).

[2] Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols).

[3] Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural analyses (in WRB classification includes Arenosols; in USDA classification includes Psamments).

[4] Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols)

[5] Soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols)

[6] Soils with restricted drainage leading to periodic flooding and anaerobic conditions (in WRB classification Gleysols; in USDA classification Aquic suborders).

***Source**: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories. Table 2.3

Example:

The following example (taken from the IPCC guidelines) shows the calculation of the total area of carbon stock change in arable land.

In a warm, temperate, humid climate, there are 1 million hectares of permanent annual cropland on Mollisol soils. The native reference carbon stock (SOCREF) of the region is 88 tonnes C ha-1. At the beginning of the inventory period (in this example 10 years earlier, in 1990), the distribution of cropland systems was as follows: 400,000 hectares of low-carbon, fully tilled annual cropland and 600,000 hectares of medium-carbon, fully tilled annual cropland.

Thus, the initial soil carbon stock of the area was:

400,000 ha * (88 tonnes C ha-1 * 0.69 * 1 * 0.92) + 600,000 ha * (88 tonnes C ha-1 * 0.69 * 1 * 1) = 58.78 million tonnes C.

In the last year of the inventory period (in this example, the last year is 2000), we can observe: 200,000 ha of annual crop production under full cultivation and low carbon dioxide input, 700,000 ha of annual crop production under reduced cultivation and medium carbon dioxide input, and 100,000 ha of annual crop production without cultivation and medium carbon dioxide input.

Thus, the total soil carbon stock in the inventory year is:

200,000 ha * (88 tonnes C ha-1 * 0.69 * 1 * 0.92) + 700,000 ha * (88 tonnes C ha-1 * 0.69 * 1.08 * 1) + 100,000 ha * (88 tonnes C ha-1 * 0.69 * 1.15 * 1) = 64.06 million tonnes C.

Thus, the average annual stock change over the given period for the entire area is:

64.06 – 58.78 = 5.28 million tonnes/20 years = 264,000 tonnes C/year soil C stock increase

(Note: 20 years is the time dependence of the stock change factor, i.e. the factor represents the rate of annual change over 20 years).

ECONOMIC, ENVIRONMENTAL AND SOCIAL ASPECTS OF CARBON FARMING PRACTICES

ECONOMIC CONSIDERATIONS

In this section of the cooperation model guide, we summarize the main financial and cost-related information about the seven techniques CFCE-project tested over two seasons in at least two regions each. More details about these techniques can be found in the training materials our project developed and in the guide about carbon farming agricultural techniques.

Additional organic fertilizers

External organic fertilizers include solid and liquid manure from different animals, biogas slurry, compost, and biochar for fertilization.

Main economic considerations:

- Specialized equipment for the application of organic fertilizers may be needed (investing or renting).
- Farm without livestock should purchase fertilizer, and transportation costs also occur, sometimes from long distances (as usually high quantities needed).
- Certain requirements for adequate storage facilities may lead to additional high construction costs.
- The above aspects need careful logistics to come over (coordination cost).
- In terms of compost, if a farm produces its own, compost turning is work-intensive and therefore expensive.
- Reduced dependence on price fluctuation of chemicals: Organic fertilizers have a complex composition of nutrients, which helps reduce dependence on the purchase and use of mineral fertilizers.
- Alternative economic opportunities: The production, marketing, and distribution of organic fertilizers can open new income streams for farmers and businesses.

Relocation of harvest residues

Relocation of harvest residues comprise the transfer of for animal nutrition not needed forage crops (clover-grass, alfalfa, etc) to another field (mostly humus degrading row crops), systems of 'transfer-mulch', and cut & carry systems.

Main economic considerations:

- The process of collecting, relocating, and managing residues can be labour-intensive and time-consuming, particularly during busy harvest periods.

- Calculations showed that approximately 2.5 to 3 hectares of alfalfa would be needed to cover 1 hectare of maize with the same thickness and amount used in our experiment. This significantly increases the costs associated with maize cultivation.
- By repurposing post-harvest residues, as natural by-products of farming, this method reduces the need for expensive synthetic fertilizers. In comparison with commercial organic fertilisers suitable for use in organic agriculture, all cyclebased action using translocation of on-farm chopped alfalfa except of slurry cooperation (exchange alfalfa to slurry between farmers) and addition of charcoal for better composting achieved net cost savings in terms of nitrogen supply. In comparison with commercial conventional fertilisers not suitable for use in organic agriculture no method achieved net cost savings in terms of nitrogen supply only.

Additional cover crops

Additional cover or catch crops cover the soil instead of fallow. Different cover crop mixtures might, due to different local suitability and different growing/rooting habits, entail different impact on soil organic carbon.

Main economic considerations:

- Seed costs of valuable mixtures are considered too expensive for the majority of farmers.
- High risk, as the timing for terminating cover crops is crucial, and if weather or soil conditions delay certain operations (e.g. sowing or cutting the cover crops), the benefits could be lost.
- In the short term many farmers consider this technique an additional workload as they are not aware of the multiple positive effects, which often lead to net savings in costs and labour in the long term.
- As cover crops are effective in suppressing weeds, reducing the need for chemical treatments and thus lowering associated costs.
- Reduction in fertilizer costs. as some cover crops can fix nitrogen or recycle nutrients from the soil.
- No or low investment costs: Technique can be implemented with common on-farm machinery to a sufficient extent.

Diversification of crop rotation

Diversification in crop rotation includes incorporation of diverse underutilised and varying crops in field rotation. This technique also considers undersowing, intercropping and mulching practices, leaving crop residues on the field, including crops with distinct root development and root exudate release.

Main economic considerations:

- The practice enhances soil nutrient levels by diversifying crop demands and incorporating nutrient-restoring plants, such as legumes. Utilization of green manure can lower fertilizer costs significantly.
- Different crops or cropping systems may require specialized machinery, increasing costs and operational complexity
- Transitioning to a highly diverse crop rotation can lead to reduced income, increased working time and production costs in the short term as farmers adjust to new systems and markets.
- Increased income security for farms by providing yield assurance through the diversification of cash crops and therefore reducing the risk of total yield failure.
- Trading new and innovative crops is often difficult and should be planned carefully in advance, e.g., by contract farming.

Agroforestry

Agroforestry includes different silvo-pastoral (trees and animals) and silvo-arable (trees and arable field crops) systems with interactions of the agricultural and the forestry part.

- Establishing and maintaining an agroforestry system within its first years can be costly
- To establish agroforestry systems, where forestry parts are included in lines or in islands within pastures or fields, large areas must be available.
- In multi-use hedges, tree species are chosen that provide additional benefits for the farm such as edible and non-food goods (e.g., wild fruit, nuts, mushrooms, oil), fuel wood or high grade crafting wood.

Reducing tillage

The technique 'reducing tillage' includes all kinds of reducing conventional, deep ploughing tillage. That means, shallow ploughing to different extents, any kind of non-inversion tillage with a cultivator or similar device, strip-till versions, special innovations like the Turiel-technique, up to no-tillage treatments.

- Problematic weed control: Mechanical weed control may be unable to destroy over-wintering legumes, which can become competitors for main crops under strip tillage. This means growing herbicide costs.
- The adoption of reduced tillage often requires the purchase of specialized machinery, such as no-till drills, which are costly.
- Sewer passes over the field with machinery significantly lower fuel consumption and operational expenses.
- Reduced tillage may simplify logistics for cultivation and sowing on larger plots, streamlining farm management.

Liming/gypsum effect

This technique includes the use of lime ($CaCO_3$), gypsum ($CaSO_4$) and other agents (like basalt meal, filter dust) to provide positively charged Ca-ions to enhance the complexation of organic carbon of humus and clay minerals.

- Both, lime and gypsum, can be costly to apply, especially on large-scale farms, with transportation and application costs adding to the financial burden.
- Liming and gypsum applications may need to be repeated periodically, adding to the long-term cost and maintenance.
- The costs of liming are usually compensated by higher yields and income

ENVIRONMENTAL AND ADDITIONAL BENEFITS OF CARBON FARMING AGROTECHNICAL PRACTICES

The use of carbon sequestration agrotechnical practices not only contributes to the mitigation of atmospheric greenhouse gases but also has a number of other environmental benefits. While carbon sequestration can be quantified and the value of credits can be expressed in monetary terms, other effects – such as improved water quality, increased soil fertility, biodiversity conservation or enhanced climate adaptation capacity – occur as ecosystem services and bring additional economic benefits. These social and environmental benefits cannot always be directly priced, but they fundamentally contribute to the development of sustainable agricultural systems and increase the resilience of farming in the long term.

Table 7: Environmental benefits of different carbon farming practices

Agrotechnics	WP1	ΔSOC_{REL} (Mg C ha^{-1} yr^{-1}, 0-30 cm)[1]	Carbon sequestration	GHG reduction	Nutrient management	Plant protection	Water quality	Water quantity	Soil protection	Biodiversity	Energy (RE, EE)	Air quality	TOTAL
A.1 Manure, biogas slurry, compos, biochar	x	0.52 ± 0.47	x		x		x	x	x				5
A.2 Harvest residues	x	0.38 ± 0.37	x		x		x	x	x				5
B.1 Cover/catch crops	x	0.14 ± 0.06	x		x	x	x	x	x				6
B.2 Crop rotation	x	0.40 ± 0.32	x		x	x	x	x	x	x			7
B.3 Intercropping		0.21 ± 0.16	x		x	x	x	x	x	x			7
B.4 Agroforestry	x	no data	x	x	x	x	x	x	x	x	x		9
C.1 Reducing tillage to different extents	x	0.21 ± 0.08	x		x		x	x	x		x	x	7
C.2 Peatland restoration		0.24 ± 0.34	x				x	x		x		x	5
C.3 Conversion of CL to GL or FL		0.79 ± 0.47	x	x	x		x	x	x	x	x	x	9
C.4 Liming effect on Corg-clay aggregation	x	no data	x	x					x				3

***Source:** [1]Tashina Petersson, Gabriele Antoniella, Lucia Perugini, Maria Vincenza Chiriacò, Tommaso Chiti, Carbon farming practices for European cropland: A review on the effect on soil organic carbon, Soil and Tillage Research, Volume 247, 2025, 106353, ISSN 0167-1987, https://doi.org/10.1016/j.still.2024.106353.

Carbon sequestration and GHG reduction

- All measures (A.1-A.2, B.1-B.4, C.1-C.4) contribute to increasing soil organic carbon stocks or reducing losses.
- Agroforestry (B.4), grassland/afforestation (C.3) and peatland rehabilitation (C.2) are particularly effective in long-term carbon storage.

The market value of carbon sequestration certificates is currently around 25–35 euros/tonne CO_2-equivalent, while certification and monitoring costs are typically around 10 euros/ha/year (the amount of C can be calculated into CO_2-equivalent using the conversion rate of 44/12).

Nutrient management

- Organic fertilizers and compost (A.1) replenish nutrients, increase the nutrient-supplying capacity of the soil, and reduce the need for artificial fertilizers.
- Cover crops (B.1), diversified crop rotation (B.2) and intercropping (B.3) improve biological N fixation and nutrient utilization.
- Reduced tillage (C.1) can help maintain soil biodiversity and organic matter accumulation, which improves nutrient cycling and longer-term nutrient availability.
- Agroforestry systems (B.4) and crop rotation to grassland or forest (C.3) reduce nutrient use and nutrient loading.

Plant protection

- Cover crops (B.1) and crop rotation (B.2) can contribute to weed control and help break pest and pathogen cycles.
- Intercropping (B.3) and agroforestry (B.4) can increase the resilience of the agroecosystem with their diverse plant populations.

Water quality

- Organic fertilizers and biochar (A.1) and crop residues (A.2) provide organic nutrient supply, thereby reducing the need for chemical fertilizers and the risk of nutrient loading.
- Cover crops (B.1), crop rotation (B.2) and intercropping (B.3) can contribute to the mitigation of nitrate and phosphorus leaching by increasing soil cover, improving nutrient utilization and interrupting unilateral nutrient accumulation.
- Reduced tillage (C.1) reduces soil erosion and nutrient leaching.
- Agroforestry (B.4) and grassland/afforestation (C.3) have a filtering effect, reduce nutrient loads to watercourses, and require lower nutrient inputs compared to arable land.
- Peatland restoration (C.2) improves water quality by retaining nutrient loads.

Water conservation

- Organic fertilizers and biochar (A.1) and crop residues (A.2) increase the organic matter content of the soil, which improves the water retention capacity and water storage function of the soil.
- Cover crops (B.1) and reduced or no-till cultivation (C.1) reduce evaporation losses and contribute to soil moisture conservation.
- Crop rotation (B.2) and intercropping (B.3) improve soil structure and increase water infiltration, thereby enhancing the water-holding capacity of the soil.
- Agroforestry (B.4) and grassland/afforestation (C.3) reduce evaporation losses and surface runoff through their shading and soil protection effects.
- Peatland rehabilitation (C.2) contributes to the restoration of higher groundwater levels, which play a key role in water retention.

Soil protection

- Organic matter supplementation with organic fertilizers (A.1) and crop residues (A.2), cover crops (B.1), crop rotation (B.2) and intercropping (B.3) all increase structural stability and humus formation.
- Agroforestry (B.4), grassland and afforestation (C.3) reduce erosion through root action.
- Reduced/no-till (C.1) and liming (C.4) play a role in preserving soil structure and aggregate stabilization.

Biodiversity

- Diversified crop rotation (B.2), intercropping (B.3) and agroforestry (B.4) increase the heterogeneity of agricultural habitats.
- Grassland and afforestation (C.3) and peatland restoration (C.2) have significant conservation value.

Energy consumption

- Reduced/no-till (C.1) reduces machine energy use and input material requirements.
- Agroforestry (B.4) and biomass-intensive systems (e.g. afforestation C.3) can also provide a renewable energy source.

Air quality

- Improper handling of organic manures can cause NH_3, CH_4 and odor emissions (A.1), but with good management and a combination of biochar and compost, these can be mitigated.
- Peatland (C.2) and grassland (C.3) reduce CO_2 and particulate emissions.
- Reduced tillage (C.1) reduces dust emissions, which improves air quality.

A DETAILED INTRODUCTION TO CARBON FARMING BUSINESS MODELS

The agrotechnical practices described in the previous chapter can lead to carbon sequestration in the soil and reduce greenhouse gas emissions. These effects represent fundamental value that can be exploited in various business models. This value stems from the fact that more and more players are looking for solutions that demonstrably contribute to climate protection. This can be valuable for companies seeking to offset their own emissions; consumers who reward sustainability through conscious purchasing decisions; buyers who pay a premium for sustainably produced products; or research and development programs that provide support and funding for testing such practices. Carbon sequestration is therefore not only valuable from an environmental perspective, but also from a market and social perspective, as multiple stakeholders are willing to pay compensation or a premium for it.

Below, we present these "sales" channels, which are not exclusive and can be combined with each other.

FARMER-LED COOPERATION (FARMER-CONSUMER)

In this type of model, farmers are the main initiators, introducing sustainable farming practices to make their products more environmentally friendly. In most cases, farmers focus directly on consumers, explaining and communicating to consumers the sustainable farming techniques used. One of the most common methods of this is the so-called labelling, which clearly conveys information about the product to the consumer, which can be made transparent and credible by certification organizations.

Business models based on sustainable farming practices can operate in a variety of ways, depending on whether the farmer enters the market independently, as a local supplier, or more collaboratively, as a cooperative. The chosen form fundamentally determines the cost burden, revenue opportunities, and market access strategy.

Custom model (as a local supplier)

The farmer implements sustainable carbon sequestration techniques on his own decision and delivers the product to consumers through direct sales channels (e.g. market, box system, short supply chain). The certification body provides the sustainability guarantee (e.g. CF label), and communication and marketing are largely the responsibility of the farmer. The costs mainly arise from the transition and direct marketing, the source of income is the premium paid by consumers.

When is it worth it?

- a smaller farm that maintains direct contact with customers,
- strong local embeddedness, community market, local consumer trust,
- flexible and personalized communication (e.g. telling the producer's story).

Cooperative model (in the form of an association or cooperative)

Several farmers jointly develop sustainable production practices, with uniform certification and joint branding. The cooperation enables joint logistics, sharing of costs (conversion, certification, marketing) and providing greater volume to traders. Traders help to increase the market visibility of premium products through prominent placement and marketing, and the revenues are shared among the members.

When is it worth it?

- There is a need to produce larger quantities of products (e.g. retail chains).
- Farmers would not be able to finance the conversion and marketing costs on their own.
- The goal is to build a common brand and market presence in the long term.

Quantifying carbon sequestration

In these types of business models, it is not always necessary to quantify carbon sequestration precisely in order for products to receive a premium. Rather, the essence of the model is to authentically communicate sustainable farming practices that consumers understand and value (e.g. soil conservation, crop rotation, organic matter replenishment, less fertilizer). However, at the level of certification (e.g. CF label), some measurable indicator is often needed to support that the practice is truly climate-friendly.

Structure and operation of the business model

Main actors:	
originator:	farmers
target group:	environmentally conscious consumer (buyer)
intermediaries:	association, cooperative
	certification body (CF label)
	salesperson, trader
Business model	
expenditure:	income:
additional conversion costs	premium surcharge for products
additional cost of cooperation	
marketing costs	

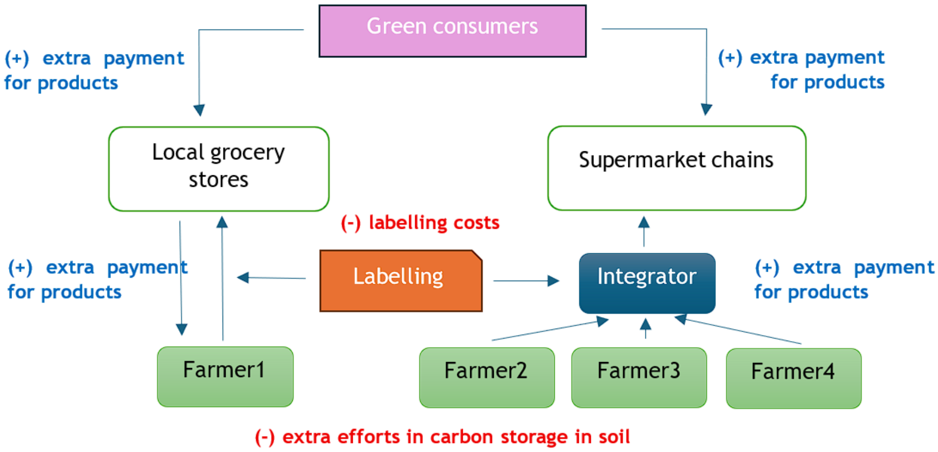


Figure 8: Cooperation/business models at farm level

Examples:

The Association of Soil Regeneration Farmers (TMG, tmg.hu) is a professional organization of certified, practicing farmers with many years of experience in regenerative farming. The Association has created a farmer-friendly, real-world practice-reflecting regenerative certification with minimal administrative burden. The certification includes a well-defined framework that can be used to determine whether a given farm has reached a level that truly supports the regeneration of the soil and the entire ecosystem. The system is simple and based on a comprehensive points system that determines the ecological status of a given farm by taking into account the parameters of the entire farm. Thanks to this, we get an accurate picture of whether a given farm meets the certification requirements. The certification system consists of three categories, representing three different added-value levels:

- **Field**: basic category that a regenerative agriculture must meet.
- **Natural**: in addition to the Field category, indicates that the crop was produced without chemical residues in the given marketing year.
- **Animal**: the animals are kept in extensive housing conditions, in intermittent, holistic grazing, according to the requirements of the regenerative system.

Josephbrot is an Austrian bakery founded in 2009 with the aim of producing the best bread and reinventing traditional recipes using traditional, rare grain varieties and artisanal products. Josephbrot uses 100% organic ingredients and sources the grains from hand-selected organic small farmers. Today, 18-20 farms supply Josephbrot with their rare grain varieties. By calculating humus balances for the crop rotations and farming systems of these farmers, Josephbrot wants to emphasize the sustainability of its supply chain and convey this message to its customers. Josephbrot's vision is to support the sustainable cultivation of grain varieties on an agricultural area of around 1,600 hectares, the size of Austria's smallest national park. By calculating humus balances, the carbon sequestration of Josephbrot producers is ensured and can be expressed in numbers.

COOPERATION WITHIN THE FOOD PRODUCTION CHAIN

In this type of collaboration, agri-food companies are the initiators of the collaboration, with the aim of making their business more sustainable. In order to achieve their sustainability goals, they establish business partnerships with low-carbon farmers. It is the responsibility of the farmers to integrate these sustainable practices into their own production. Through marketing campaigns for their products, the companies explain to their customers how they contribute to the agri-food industry's climate protection goals, and at the same time raise consumer awareness of more sustainable food consumption. The added value of their products partly flows to the farmers, who receive a higher price for their products.

Quantifying carbon sequestration

The model does not always require precise quantification of carbon sequestration. Companies often rely on certification, standards or audited processes based on "good practices", which are communicated to consumers in simple and understandable messages. However, if a company commits to climate goals in its global sustainability reports or CSR strategy, it is often necessary to quantify the reduction of carbon footprint from suppliers. This is therefore more a part of corporate transparency than a primary element of consumer communication.

Structure and operation of the business model

Main actors:	
originator:	agri-food companies
target group:	environmentally conscious consumer (buyer)
	farmers (with carbon sequestration technologies)
intermediaries:	certification body (CF label)
Business model	
expenditure:	income:
additional conversion costs	premium surcharge for carbon capture technologies

In this case, the costs of organizing a sustainable supply chain, certification and auditing, and corporate marketing campaigns are borne by the agri-food company.

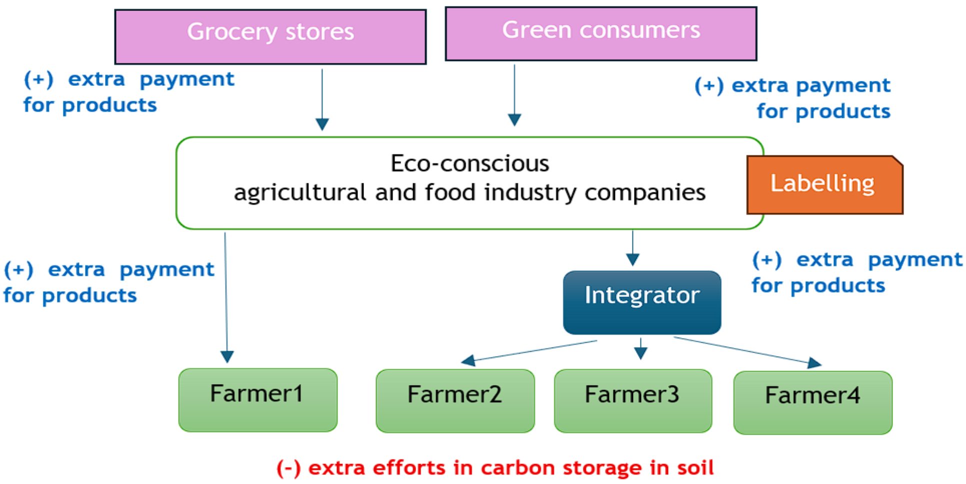


Figure 9: Cooperation within the food production chain

When is it worth it?

For a food company:

- if the company has a strong sustainability strategy and wants to make this visible to consumers,
- if consumer demand shifts towards sustainable, low-carbon footprint products,
- if the company has great marketing and market power, which allows it to reach a wide range of consumers,
- if the company wants to demonstrate quantified emission reductions in sustainability reports (especially in the Scope 3 round).

For the farmer:

- if farmers would not be able to enter the market directly on their own, but would like to join a corporate purchasing system,
- if stable, predictable demand and the associated higher purchase price or direct payment for sustainable practices are important to them,
- **if the farmer is included in the certification system acquired or used by the company, which also means credibility, professional recognition and market advantage for him.**

Examples:

Nestlé, the world's largest food company, sees its responsibility to promote the widespread adoption of renewable food supply chains. It aims to reduce its emissions to net zero by 2050 at the latest through comprehensive measures across its entire value chain and by achieving key milestones. Around two-thirds of Nestlé's greenhouse gas emissions come from agriculture. The first and most important step is to promote regenerative agriculture, which has huge potential to combat climate change, support communities and protect and renew natural resources. Nestlé will invest CHF 1.2 billion by 2025 to promote regenerative agriculture methods across its entire supply chain. Healthier soils are more resilient to the impacts of climate change and can therefore lead to higher crop yields, which can help improve farmers' livelihoods. To determine the level of development of the implemented regenerative agricultural practices and to assess the support needs of farmers in the transformation process, Nestlé created a Farm Assessment Tools (FAT), which scores individual practices and results related to each agricultural resource.

The Landscape Enterprise Networks (LENs) initiative, operating in Hungary, Italy, Poland and the United Kingdom, connects farmers, experts and businesses to raise awareness of the economic value of crops and ecosystem services. The Hungarian program involved 22 producers in 2024 and measures are being implemented on more than 10,000 hectares in the western part of the country, in the area of the Nestlé Purina factory in Bük.

COOPERATION OUTSIDE THE FOOD PRODUCTION CHAIN

In this type of collaboration, low-carbon farmers do not sell the added value resulting from sustainable practices directly in the food chain, but to actors outside the food chain. These could be environmentally responsible companies from other sectors (e.g. tourism, events, services), the public sector (green public procurement), or civil society.

1. Non-food companies:

a) Energy-intensive industries (companies with high quota requirements): Examples include cement, steel and chemical companies, energy service providers, and airlines. These companies have mandatory emission reduction targets (e.g. in the EU ETS system), and therefore purchase large quantities of carbon credits.

b) Other non-food companies (e.g. events, tourism, services). These companies want to reduce or offset their own carbon footprint for CSR and/or image-building purposes. They collaborate with low-emission farmers and support sustainable practices either through direct financing or through intermediary cooperation.

2. Public sector (green public procurement):

State or local government institutions (e.g. public catering, green infrastructure procurement, biomass raw material for renewable energy production, biofuels, etc.) give priority to products with a low carbon footprint in their procurement.

3. Civil society (community, social cooperation):

Individuals, foundations, and NGOs voluntarily support sustainable farming to contribute to common climate goals. This can take the form of donations, membership systems, or subscriptions.

The most prominent form of this model is carbon trading, which allows carbon sequestration or emission reductions achieved by farmers to be sold in the form of certified allowances to companies that need to offset their own emissions. There are also non-trading solutions, where sustainable practices are financed through corporate social responsibility (CSR), public procurement or civic support.

This model can therefore be divided into two main operating logics:

a) direct support/based cooperation (CSR, green public procurement, civil support, corporate partnership),

b) carbon trading (sale of marketed, measurable carbon sequestration credits).

Quantifying carbon sequestration

In this model, the quantification of carbon sequestration is key. The basis of quota trading is measurable, verified carbon sequestration or emission reductions, which are verified by accredited certification bodies. The quotas can be sold at market prices, thus providing farmers with direct income. In the case of forms without quota trading, the quantification is less rigorous, and is based more on the demonstration of practices and their qualification.

One of the biggest risks of carbon trading is that the market price of carbon credits can be volatile. Therefore, participation in carbon trading is worthwhile if the expected market price consistently covers or exceeds the additional costs of sustainable practices.

Structure and operation of the business model

Main actors:	
originator:	non-food industry actors (market, public sector, civil society) or carbon market intermediary organizations
target group:	farmers (with carbon sequestration technologies)
intermediaries:	certification body
	carbon market intermediary organizations
Business model	
expenditure:	income:
additional conversion costs	revenue from the sale of carbon quotas
Cost of certification and monitoring (quantification of carbon sequestration)	CSR contribution of non-food companies
	green public procurement premium from the public sector

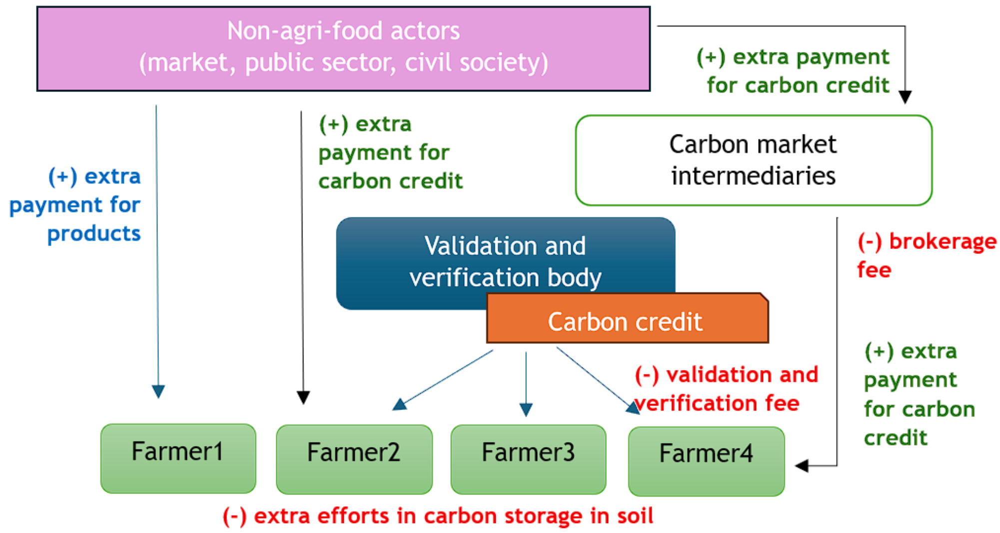


Figure 10: Cooperation outside the food production chain

When is it worth it?

For the farmer:

- If the farmer is able to credibly quantify and certify its carbon sequestration results,
- if the farmer does not have direct market connections to consumers or food retailers, but would like to market your sustainable practices,
- if a diversified source of income that is independent of food market fluctuations is important to the farmer.

For companies/public sector/civil actors outside the food chain:

- if they want to compensate for their own emissions (reducing Scope 3 emissions),
- if they want to strengthen their environmental and social responsibility,
- if they want to contribute to climate protection goals in a transparent, local and controlled way.

Examples

Carbon quota-based cooperation

In this model, carbon sequestration from sustainable farming practices is sold in a verified and quantified form, through carbon credits. These credits are purchased by companies that need to offset emissions or that want to achieve their CSR/ESG goals. A good example is the Hungarian company Blacksoil, founded by regenerative agriculture experts and consultants that helps farmers transition to regenerative practices and then sells the carbon sequestration in the form of certified credits. A portion of the revenue goes to the farmers, while Blacksoil partners with food and other companies that use the credits to meet their sustainability goals.

Figure 11: Quantifying carbon sequestration (Source: Blacksoil)

Direct cooperation (without quota trading)

- **Event industry**: a festival advertises itself as a “climate-friendly event” because a portion of ticket sales supports local carbon-scavenging farmers. An ecotourism hotel sources its meals from sustainable farmers, offering its guests a carbon-neutral package.
- **Public sector (green procurement)**: a city government requires that 30% of school meals be made from carbon-neutral, locally sourced food.
- **Civil society**: a non-governmental organization is launching a campaign where the public can “adopt” a hectare of low-emission agriculture and receive regular updates on how the area is contributing to carbon sequestration

GOVERNMENT-LED COOPERATION

Climate change mitigation and environmental protection goals are high on the agenda of national and regional governments. Many municipalities and cities are also developing climate action plans, which include carbon sequestration measures. Carbon farming techniques are therefore often directly supported by government institutions.

Government support can take two main forms:

- **direct payments** to farmers for the ecosystem services they provide (e.g. increasing soil carbon sequestration capacity, reducing emissions),
- **indirect incentives**, such as tax breaks or preferential green financing schemes that reduce the additional costs of sustainable farming.

The specificity of the government model is that the climate protection performance of farmers is less visible to the consumer market than in labeling or corporate cooperation models. The recognition of sustainable practices here takes place primarily at the policy and administrative level: the farmer receives feedback and compensation through participation in support systems (e.g. agro-ecological programs, green investment subsidies, tax breaks).

However, governments have the opportunity to develop marketing tools that make support policy goals visible to the market and society, which indirectly increase the social recognition of farmers and make farmers' contribution to climate protection goals visible. Such tools could include promoting best practices, introducing labels/trademarks for farmers participating in such programs, etc.

Quantifying carbon sequestration

In this model, quantification is a basic requirement for the government, as the use of public funds and the achievement of climate policy goals must be credibly demonstrated. However, in practice, measurements are not always tonne-based, and payment systems are often tied to indicators (e.g. cultivation method, soil cover, input use).

Structure and operation of the business model

Main actors:	
originator:	national and local governments, municipalities, EU programs
target group:	farmers (with carbon sequestration technologies)
additional actors:	agricultural paying agencies
	Organizations and assessors preparing GHG inventories

	agricultural marketing organizations
Business model	
expenditure:	income:
additional conversion costs	direct payments for ecosystem services
administrative costs (tender, banking, etc.)	tax breaks
	preferential green loans

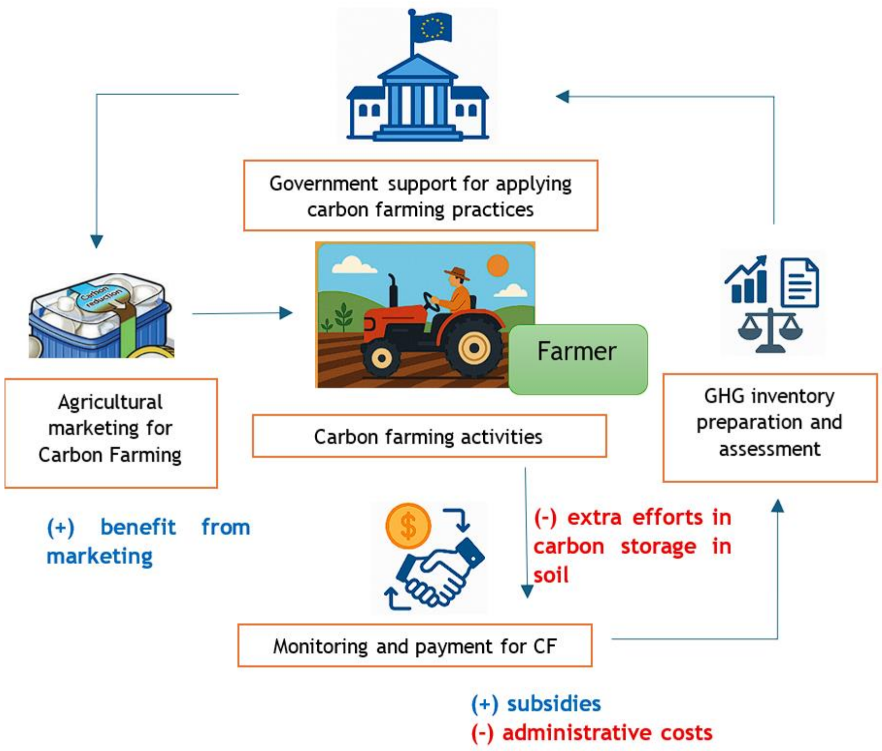


Figure 12: Government led cooperation

When is it worth it?

For Government:

- if specific climate targets need to be met at national or local level (the EU has mandatory GHG emission targets for 2030 and 2050, respectively),
- if reducing emissions from the agricultural sector is essential for the overall climate strategy (see LULUCF Regulation),
- If supporting sustainable agriculture also brings social and rural development benefits (e.g. rural development, job preservation).

For the farmer:

- if the additional costs required to introduce sustainable practices can only be financed with external support,
- if the government payment represents a stable, predictable income supplement,
- if legal compliance and the ability to create a safer farming environment through government subsidies are important to them.

Examples:

The EU CAP carbon farming support scheme

Climate action has now become one of the most important strategic pillars, and carbon sequestration and emission reduction measures have become central to the CAP's "green architecture".

1. Greening and conditionality

The 2014-2020 programming period saw the introduction of a mandatory element of ‘greening’, which linked 30% of direct payments to environmentally friendly standards. Crop rotation, the maintenance of permanent grassland and the designation of ecological focus areas all contributed to carbon sequestration and emissions reduction. In the new CAP, valid from 2023, the system of conditionality has been further tightened: basic payments are conditional on farmers complying with basic climate and environmental standards (e.g. ensuring soil cover, protecting wetlands).

2. Agro-ecological basic programs

One of the most important innovations of the new CAP is the introduction of agro-ecological basic schemes (eco-schemes). A certain proportion of direct payments – at least 25% – must be allocated to this heading. This means that for a quarter of direct payments, farmers must undertake additional environmental and climate protection performance, although participation in the measures is voluntary.

The farmer can decide whether to accept a lower basic payment or whether he is willing to make additional environmental and climate protection commitments.

Member States were able to draw up their own range of measures to be supported under the agro-ecological framework, taking into account their own agricultural and environmental conditions. A detailed EU guide was prepared on the measures eligible for support under the agro-ecological framework.

3. Rural development pillar and climate-friendly investments

The second pillar of the CAP, the rural development programmes, also play a key role in supporting climate action. This is where longer-term projects requiring farmer transitions and investments appear, often requiring multi-year commitments. Participation in these programmes is voluntary.

Green loan: Agricultural Széchenyi Investment Loan MAX+

In Hungary, the Agrár Széchenyi Investment Loan MAX+ loan structure, offered by several banks, includes loans supporting the green transition and sustainable development. In the Agrár Széchenyi Investment Loan MAX+ "GREEN" substructure, the fixed net interest rate is half the normal transaction interest rate, 1.5%. The loan objectives include improving energy efficiency, technological change, and investments that support the green transition and sustainable development.

The Central Bank of Hungary (MNB) also encourages banks to lend to as many environmentally friendly investments as possible through special regulations. In the case of green loans that meet certain conditions, it provides a capital requirement discount, which provides relief to banks and can thus indirectly contribute to the creation of more favorable lending conditions. Carbon sequestration is also included among the environmental objectives set by the MNB.

PROJECT-DRIVEN COOPERATION (KNOWLEDGE TRANSFER-ORIENTED)

There are many examples worldwide of different partners coming together to implement a targeted "climate project" aimed at creating a climate protection or carbon farming system. These projects typically start from R&D development sources (EU and domestic research programs) and aim to create a sustainably operating model after the initial supported period.

The project-driven model is characterized by the fact that no single actor dominates, but rather a multi-actor partnership is established: research institutes, advisory organizations, farmer groups, companies and civil society organizations all participate in it. The emphasis is on knowledge transfer, innovation and capacity building: farmers try out new practices, which are monitored, evaluated and further developed by professional partners.

Project-led cooperation is particularly well suited to address the initial uncertainties associated with the introduction of sustainable farming practices. Through knowledge transfer, pilot interventions and ongoing professional support, the competencies required for the wider application of carbon farming practices can be gradually developed. In the medium term, this process will allow the establishment of an ecosystem of value chain actors, from farmers to certification bodies and trading partners to financial and regulatory institutions, necessary for the operation of the entire business model.

When is it worth it?

- if the goal is to test and disseminate new technologies and farming methods,
- if research and development background is needed to introduce local practices,
- if an independent, sustainable farming system can be established after the project period,
- if it is important to involve the local community and demonstrate social utility.

Structure and operation of the business model

Main actors:	
originator:	research institutes, policy institutions
target group:	farmers (with carbon sequestration technologies)
additional actors:	civil organizations
	companies interested in carbon sequestration
	consulting organizations
Business model	
expenditure:	income:
project development and management costs (own funds)	research grant
	participation in knowledge-based services (advice, learning about good practices, etc.)

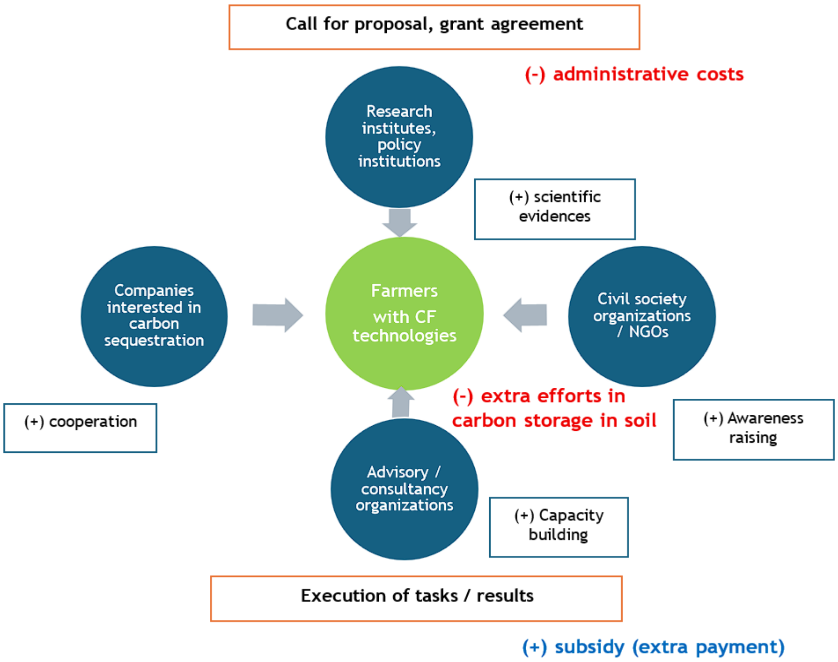


Figure 13: Project-driven cooperation (knowledge transfer-oriented)

Examples

Climate Farm Demo: Supporting farmers in growing resilience and tackling climate change

Climate-smart farming (CSF) is an approach to agriculture that helps farmers grow resilience to the impacts of climate change, reduce greenhouse gas emissions and improve carbon sequestration. CSF also promotes overall agricultural productivity and food security. With this in mind, the EU-funded Climate Farm Demo project promotes CSF practices in 28 European countries. It takes a multi-actor approach by connecting 1,500 farmers (known as pilot demo farmers) and their climate farm advisors to implement adaptation and mitigation action plans with the aim of increasing knowledge exchange and cross-fertilisation. Technical and social innovations are demonstrated to the wider farming community through six annual demo campaigns, and new CSF solutions are co-created in 10 Living Labs across Europe.

ClimateSmartAdvisors

This project gathers 1.500 Advisors, 140 Coaches, 27 National Coordinators, and 12 Thematic Leaders in one place, building a community of interested and qualified stakeholders with a common aim to shift the European farming sector to a new level of climate-smarter agricultural practices. xTo reach this objective, ClimateSmartAdvisors focuses on the crucial role of advisors in the development and dissemination of CS innovations and practices. The project will organize activities focusing on strengthening the advisors' capacity in providing CS advice and boosting the advisors' role in the transition towards CS farming through their involvement in innovation projects, CS-AKIS, and EU projects and initiatives.

Table 8: The main aspects of the different cooperation models based on the results of the tests conducted as part of the CFCE project

Important aspects / Model type	Farmer-led	Within the agri-food chain	Outside the agri-food chain	Government -led	Knowledge transfer oriented
Technical and economic aspects					
Cost reduction (especially long term, synthetic inputs/energy use)	+	+	+	+	-
Availability of financial incentives / subsidies	+	+	++	++	-
Mitigating the effect of climate change	+	+	++	+	+
Market benefits, better positioning of products	++	++	+	+	-
Diversification, economic stability	++	++	+	+	-
Yield reduction (especially short term)	+	+	+	+	+
Environmental factors and local conditions (e.g. extreme weather, specific soils)	++	+	+	+	++
Significant upfront costs, need for investment	+	++	++	+	+
Long return on investment, long-term commitment	+	+	++	-	-
Economy of scale, not available for small farms	-	+	++	-	+
Measurement, monitoring, validation					
Risk of the inability to enhance carbon levels	-	+	++	+	-
The need for MRV-methods	-	+	+	-	-
Collecting accurate, reliable data	+	+	++	+	+

Important aspects / Model type	Farmer-led	Within the agri-food chain	Outside the agri-food chain	Government -led	Knowledge transfer oriented
Regulation and administration					
Clear regulation	-	+	++	++	-
Transparency of carbon markets	-	+	++	+	-
Changing mandatory components pose a problem with regard to additionality	-	+	+	+	-
Administrative obligations (applying for tenders, collecting and maintaining records)	+	+	+	++	-
(Frequent) changes in state subsidy allocation	-	-	+	++	-
Awareness and knowledge					
General lack of understanding	++	+	++	+	+
Bias against novel carbon farming methods and technologies	-	+	-	++	+
Promotion of sustainability and adaptability	+	++	++	+	++
Transparency and understanding of carbon markets	-	++	++	+	-
Need for an integrated support mechanism	-	+	-	+	-
Customer awareness	++	++	+	-	-
Social aspects, coordination and communication					
Building trust through the value chain	+	++	-	-	-
Need for involvement or interaction of key partners	-	+	-	-	-
Complexity of partnerships, need to build more integrated approach	+	++	+	-	+

MAIN CARBON FOOTPRINT CALCULATION SYSTEMS

Most of the tools cover a wide range of areas related to emission reduction and carbon sequestration, as their aim is to determine the most complete carbon footprint possible in relation to the activities of a given farm. However, our project focuses on methods related to soil carbon sequestration. Below, we provide a summary of the tools that are widely used in practice and can also be applied at the farm level from this perspective. There are many carbon calculator tools available worldwide, some tailored to a specific region or country, free to use or for a fee. Most of them work with standard reference data, the most common of which are the methodologies included in the IPCC guidelines.

The most popular international online calculators are as follows:

- Cool Farm Tool
- Farm Carbon Toolkit
- AgreCalc
- Sandy
- Solagro

The CFCE project also made available a Gross Margin Calculation and Benchmarking tool.

COOL FARM TOOL

Website: https://coolfarm.org

Operator: Cool Farm Alliance

One of the most popular calculators, which is suitable for accurate online measurement of water use and biodiversity in addition to carbon footprint. Available in several Central European languages.

The Cool Farm Tool (CFT) is an online platform designed for farmers to help them measure and reduce their carbon emissions. The tool was developed by the Cool Farm Alliance, an international organization focused on promoting sustainable agricultural practices. The calculator aims to help farmers easily assess the environmental impact of their activities and receive recommendations that will help them reduce emissions.

CFT is primarily applicable to crop and livestock production and offers customized calculations for different farming sectors. Users can calculate the carbon dioxide and other greenhouse gas emissions from their farm based on various inputs such as fertilizers, water use, energy use and other farming factors. The tool can also break down the results by product, giving farmers precise information on which production processes are most environmentally damaging.

The advantage of Cool Farm Tool is that it is user-friendly, and does not require professional knowledge. Users can easily register and add their farm details. Additionally, the tool generates detailed reports after entering the data, helping farmers understand how they can reduce their carbon footprint. The calculator also supports smart farming practices, making it an ideal tool for farmers committed to sustainability.

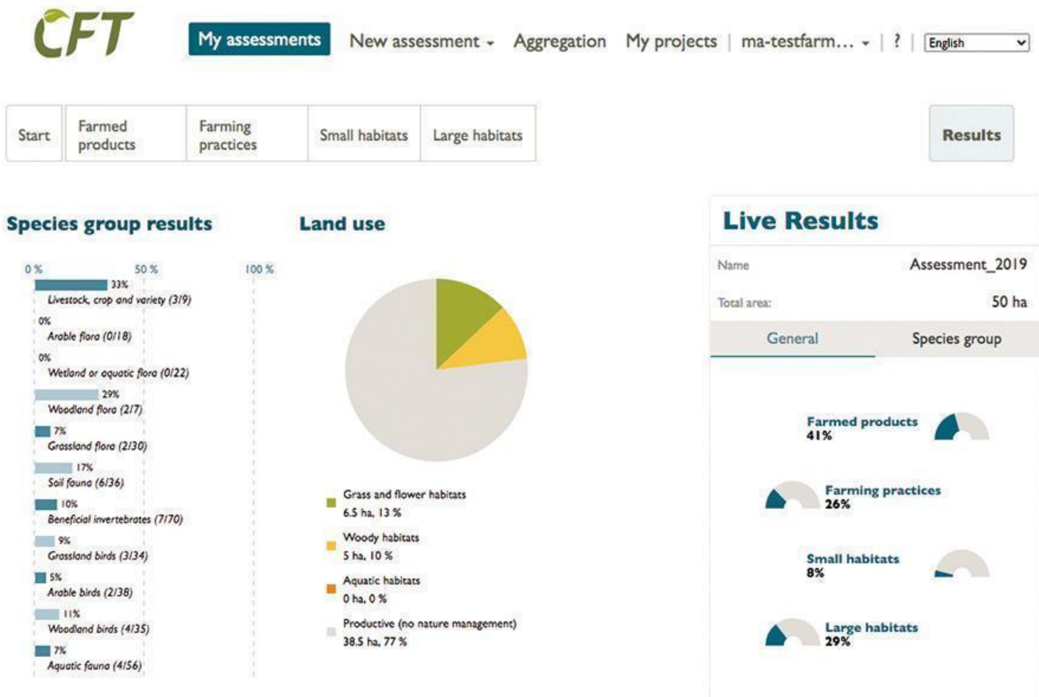


Figure 14: Cool Farm Tool computer screenshot

Source: https://www.fwi.co.uk/news/environment/how-do-three-main-farm-carbon-calculators-compare

One of the biggest advantages of the Cool Farm Tool is that it is not only available locally but also globally, as it is available in multiple languages and can be customized for different climates and farming environments. This allows farmers from different regions to work on a common platform to increase sustainability. The tool is used not only by farmers, but also by food companies, research institutes and other stakeholders to help make the food chain more sustainable.

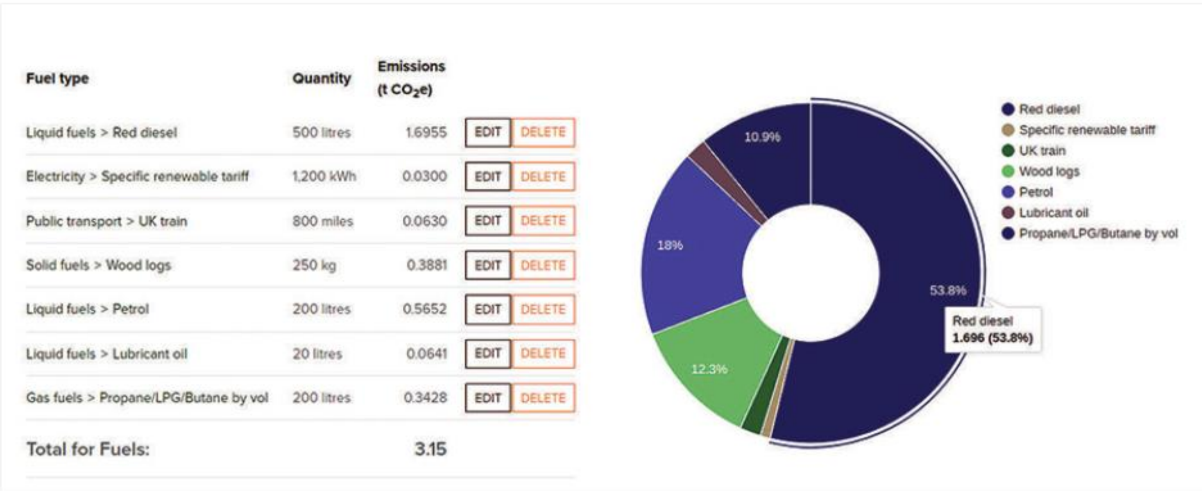
FARM CARBON TOOLKIT

Website: https://farmcarbontoolkit.org.uk

Operator: Farm Carbon Toolkit

The Farm Carbon Toolkit is also an online tool designed for farmers to help them measure and reduce their farms' carbon footprint. It aims to promote sustainable agricultural practices while providing farmers with practical and easy-to-use solutions. The calculator allows farmers to gain a comprehensive view of how their farm's activities impact the environment and how they can reduce greenhouse gas emissions.

The Farm Carbon Toolkit covers a wide range of agricultural sectors, including crop production, livestock production, and individual farming systems such as arable and grassland farming. The tool provides customized calculations for different farming operations, such as fertilizer and feed use, greenhouse gas emissions, and soil management. Farmers can enter their own farm data and the tool automatically calculates the carbon footprint.



Fuel type	Quantity	Emissions ($t\ CO_2e$)		
Liquid fuels > Red diesel	500 litres	1.6955	EDIT	DELETE
Electricity > Specific renewable tariff	1,200 kWh	0.0300	EDIT	DELETE
Public transport > UK train	800 miles	0.0630	EDIT	DELETE
Solid fuels > Wood logs	250 kg	0.3881	EDIT	DELETE
Liquid fuels > Petrol	200 litres	0.5652	EDIT	DELETE
Liquid fuels > Lubricant oil	20 litres	0.0641	EDIT	DELETE
Gas fuels > Propane/LPG/Butane by vol	200 litres	0.3428	EDIT	DELETE
Total for Fuels:		3.15		

Figure 15: Carbon Farm Toolkit computer screenshot

Source: https://www.fwi.co.uk/news/environment/how-do-three-main-farm-carbon-calculators-compare

One of the biggest advantages of the Farm Carbon Toolkit is that it is easy to use and no prior professional experience is required to operate the calculator. The tool provides detailed results and recommendations for farmers, helping them reduce emissions and adopt more sustainable farming practices. The calculator analyses each production process and its environmental impact in detail, so farmers can see exactly which activities have the greatest impact on carbon emissions and how they can achieve more sustainable results.

The Farm Carbon Toolkit is a useful tool not only for farmers, but also for various agricultural professional organizations, research institutes and consultants. The platform allows users to track the reduction of their farm's carbon dioxide emissions over time and thus achieve measurable impacts in the application of sustainable agricultural practices. The tool is offered in English, but is used in several countries, thus contributing to reducing the environmental impact of agriculture not only locally, but also globally.

AGRECALC

Website: https://www.agrecalc.com

Operator: SAC Consulting

Their basic model is based on the greenhouse gas reporting guidelines that the IPCC has developed for national inventories. Since its inception in 2007, Agrecalc has produced tens of thousands of carbon reports for over 10,000 agricultural businesses and worked with over 180 agricultural consultants. Our Farm Carbon Calculator is based on the latest published scientific research from SRUC researchers and consultants.

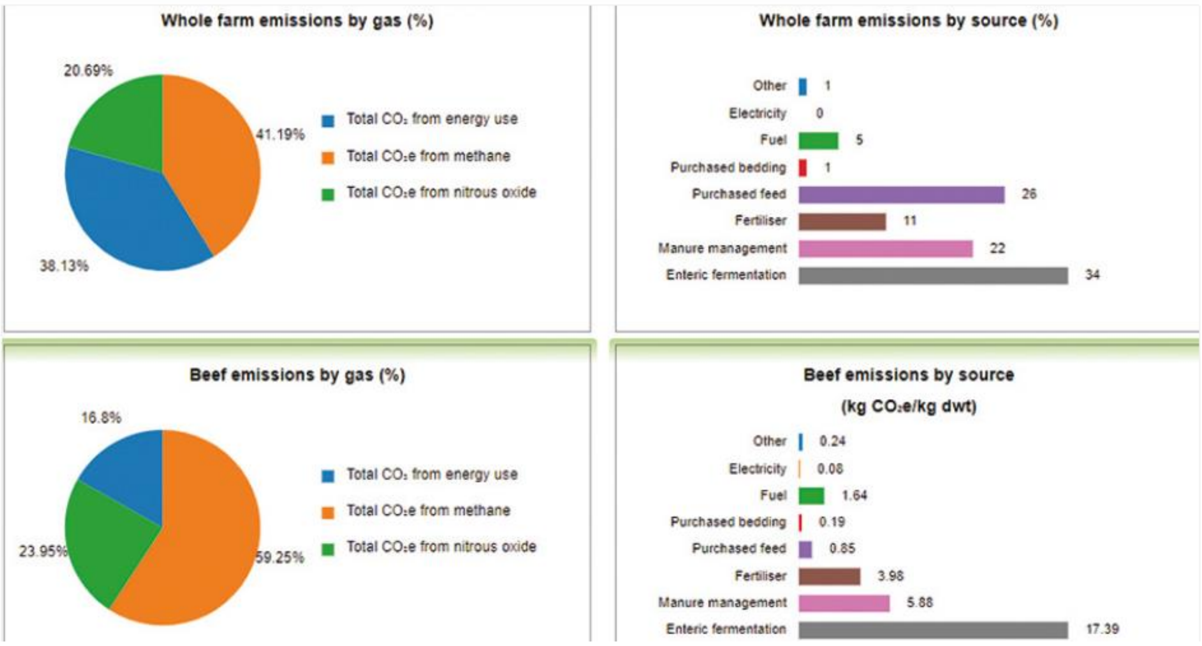


Figure 16: AgreCalc computer screenshot

Source: https://www.fwi.co.uk/news/environment/how-do-three-main-farm-carbon-calculators-compare

Main features:

- It produces accurate carbon footprint reports for all agricultural businesses.
- Identifies the main sources of GHG emissions (carbon dioxide, methane and nitrous oxide).
- It calculates emissions across the entire economy.
- Calculates emissions per agricultural enterprise.
- Calculates the emissions per kilogram of the product.
- The largest benchmarking database allows you to compare business performance
- It allows users to simulate scenarios to understand the impact of potential changes and track progress.

- It offers the opportunity for data validation by experienced consultants.
- Group access portals enable high-level overviews to monitor the performance of the agri-food supply chain.

SANDY CARBON FOOTPRINT MODULE

Operator: Trinity AgTech

The Sandy platform was developed by Trinity AgTech, a UK-based agri-tech company. Sandy is a digital agricultural platform that helps farmers and agribusinesses achieve sustainable farming and reduce their carbon footprint. A key part of the platform is the Carbon Footprint Module, which analyses various emission sources and helps reduce greenhouse gases (GHG). The exact launch date of Sandy's carbon footprint module is not public, but Trinity AgTech started operations in 2020, so it is likely that the module will become available in the following years.

Main features:

- Calculates for the entire economy and at the product level - It takes into account the carbon footprint of the entire economy, but also allows for crop and product level analysis.
- Complex emissions calculations - Accounts for CO_2, methane (CH_4) and nitrous oxide (N_2O) emissions, as well as carbon sequestration opportunities.
- Soil Carbon Sequestration and Regenerative Agriculture - Highlights the role of soil in carbon sequestration, especially for those using regenerative farming methods.
- It supports all major farming systems: conventional, organic and regenerative.
- Automatic data connections - It is possible to import various economic data, so calculations can be faster and more accurate.
- Tracking changes over time - The impact of individual measures can be analyzed over the long term, allowing farmers to see how their emissions are decreasing, which helps farmers develop sustainability strategies.
- It provides tailored measures to optimize carbon neutrality and improve farm sustainability. It includes state-of-the-art tools for soil carbon, agroforestry, anaerobic digestion, biochar production and greener energy solutions.

The calculator is ISO 14067 certified and complies with PAS 2050 and the GHG Protocol. It is based on the IPCC 2019 methodology with a Tier 2 soil carbon model.

It is an even less well-known and widespread tool, so there is less support and user experience available for it. It promises a flexible and structured input process for efficient user management.

SOLAGRO CARBON CALCULATOR

Website: https://solagro.org/carbon-calculator

Operator: Solagro

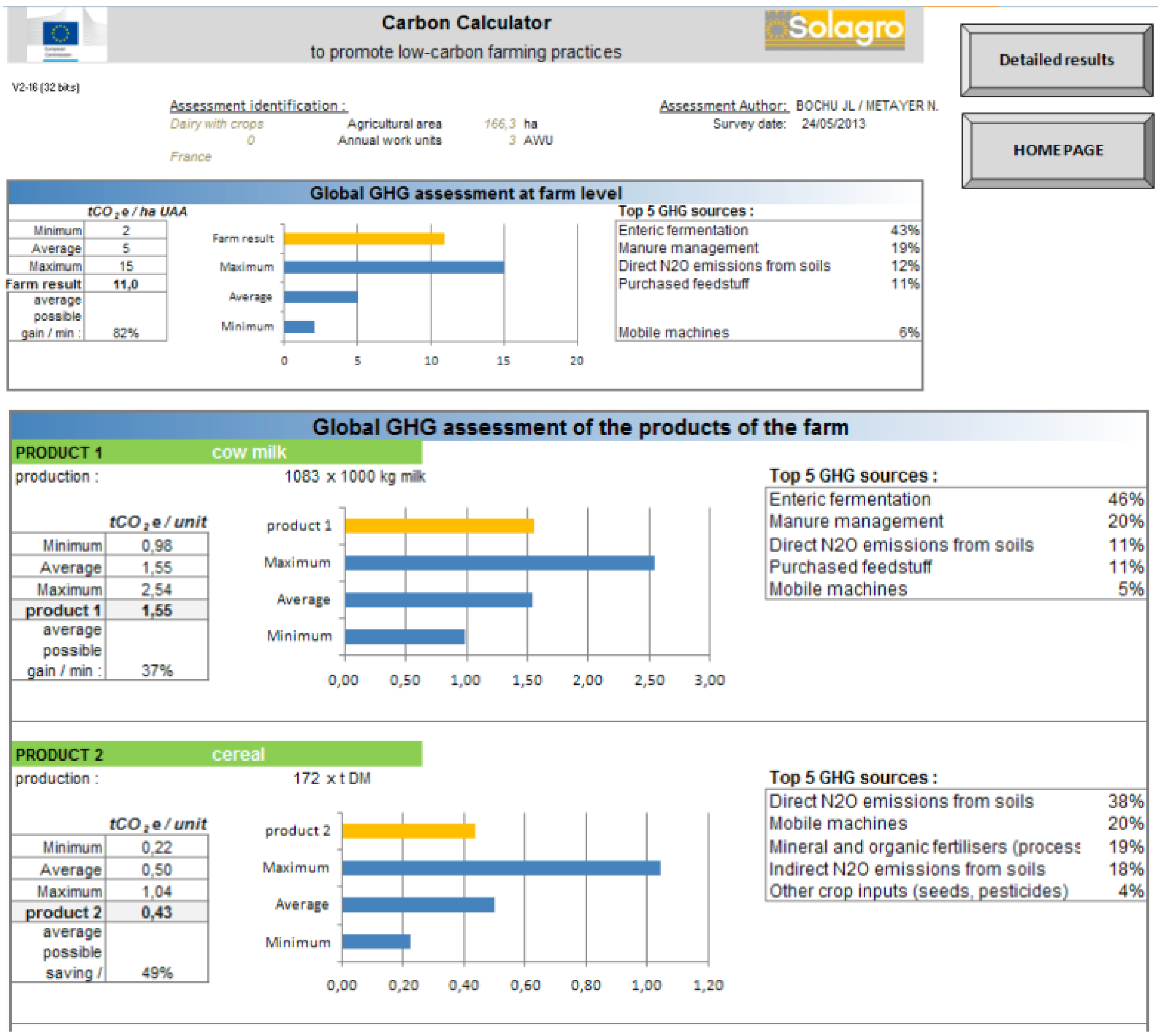


Figure 17: Results shown in the Solagro Carbon Calculator

Source: https://solagro.org/medias/publications/f60_methdology-guidelines-final-final.pdf

This tool was created in the 2010s as part of an EU project led by the French non-profit organization Sologaro. Its aim is to quantify greenhouse gas emissions at the farm level, as well as the possibilities for their reduction and prevention, in direct and indirect connection with farming activities, for which it also provides recommendations. Changes in soil carbon stocks are also part of the analysis. The user can choose from a total of 16 emission reduction and carbon sequestration recommendations, in which the impact of the change on the GHG profile is evaluated tailored to the given farm. In addition to farmers, consultants can also use it well, for example by comparing the profiles of farms with similar types of farming. The program can display the results at the farm level or for the 5 most important crops, for a given farming year. Regarding the change in soil carbon stock, it takes into account agrotechnical practices and land use change (e.g. arable -> grassland), as well as the presence of trees and hedges. It has been primarily adapted to the EU 27, so it contains the most typical farming methods, climate categories, from which the user must select the classification that is characteristic of him, and provide additional general data, such as average precipitation, temperature, soil type, soil structure, pH, etc. The user interface has been designed for simplicity, dividing the main parts into separate worksheets, such as basic data, animal husbandry, crop production data and other inputs. The Solgaro Carbon Calculator is technically an MS Excel-based application and can be downloaded for free from the developer's website (after opening, macros must be allowed to run). The also public methodological description contains details of the calculation procedure. The methodology is basically based on the IPCC recommendations, adapted to the farm level.

CFCE GROSS MARGIN CALCULATION AND BENCHMARKING

Website: https://farmstool.eu/cfce/gm/

Perhaps the simplest, fastest, easiest to understand and apply tool is the agricultural parcel-level 'direct cost-income calculator', based on which its contribution to the margin can be calculated.

According to the definition of business economics, gross margin is the difference between the production value of a given product or service and its variable costs, which the business uses to cover fixed costs and achieve profit. This amount indicates how much the given product contributes to fixed costs and to the business's profit. In simple terms, if gross margin is positive, it is advisable to maintain the given activity and it is worth choosing an alternative that provides a higher contribution margin.

In agricultural usage, the production value is the monetary value of the yield, which is the product of the yield and the associated price. At the EU level, the definition of the production value (Standard Output) and Gross Margin, as defined in the FADN (Farm Accountancy Data Network) methodology, is as follows:

The principle of both concepts SGM and SO is the same; only the way they are calculated differs: SGM = Output + Direct Payments – Costs; SO = Output

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Standard_output_(SO)

The total SGM of a farm also indicates its economic size in European Size Units (ESU). By analysing the proportions of SGM in different branches of production, the farm can be classified according to its line of activity, for example as a farm specializing in permanent crop production or mixed livestock farming.

When planning the transition to more sustainable agricultural practices, the calculation of the gross margin can play a particularly useful role, since if we have the necessary data on the income and expenditure side for a given agricultural plot, we can record, calculate and compare the gross margins of different technological implementations. The use case of carbon farming also shows the usefulness of being able to calculate with direct payments added to the production value (yield multiplied by price) on the income side, since we can contrast a cost structure that includes a different technology - sequence of operations, material use (etc.) - (e.g. plowing/reduced tillage/no till) with a revenue structure where, in addition to the production value, subsidies and other income can also be calculated beyond the basic income support, such as eco schemes, agro-environmental measures, agro-ecological transition, and possible revenues from carbon credit programs. We also have the option of including additional revenue from sales at a higher price (e.g. eco, bio, carbon label) in our calculation (by modifying the price value when calculating the given technology).

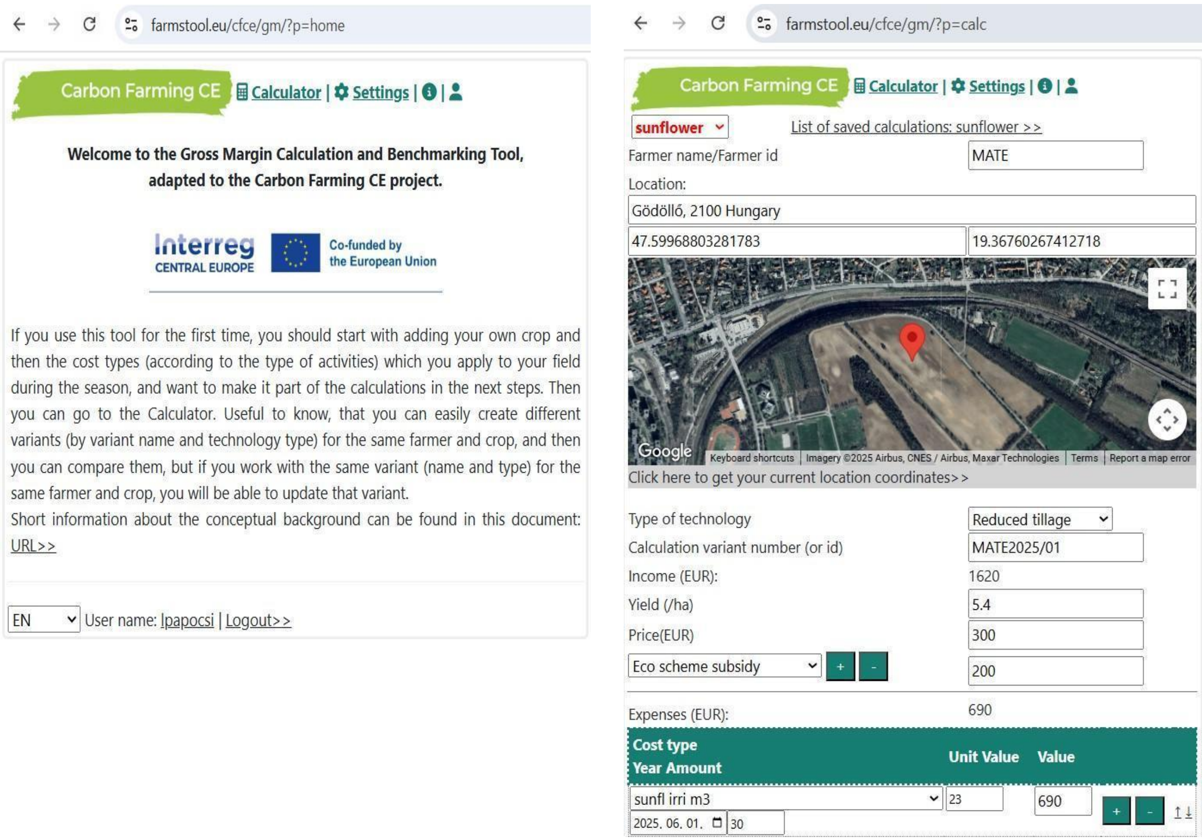


Figure 18: CFCE Gross Margin Calculation and Benchmarking. Hompage on the left and Calculation interface on the right.

We have adapted such an SGM calculator tool to the needs of our project, in order to facilitate presentation, education and dissemination of use. The tool is available in several languages, and the user interface can be localized very easily. In addition to the language, users can select the currency in their own profile, as well as set up the list of the main technological and subsidy variants. It is also possible to add rows of crops at the user level, and record the agricultural operation elements and other cost elements characteristic under them. Once these are done, the user can move on to the calculation interface, where the data of a given technological variant for a given agricultural plot can be entered, to be followed by the comparison of the different variants (benchmarking).