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Mission

Innovative Sustainable Economy

Report on Carbon Farming as a business model.

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Abbreviations

CAP: Common Agricultural Policy

CO_2: Carbon dioxide

CRCF: Carbon Removals and Carbon Farming Regulation

EU: European Commission

GHG: Greenhouse gases

LULUCF: Land Use, Land Use Change and Forestry

MRV: Monitoring, Reporting and Verification

SIC: Soil inorganic carbon

SOC: Soil organic carbon

SOM: Soil Organic Matter

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Executive summary

The European Climate Law aims for climate neutrality in the land sector by 2035. The Carbon Farming business model is understood as a new innovative approach where farmers are compensated for reducing emissions or removing carbon through sustainable agricultural management.

This document is framed in activity 2.1 of the Carbon Farming MED project, whose objective was to develop a review and description of the best-suited funding options for different types of Mediterranean farmers to successfully implement Carbon Farming as a business model and a technical analysis of the potential for implementing Carbon Farming activities in the Mediterranean due to its specific agroclimatic conditions in two key management systems for the region: regenerative agricultural and agroforestry systems. Finally, it was developed a revision of the current legal status of Carbon Farming activities in the European Union.

The major findings of this document are:

- Carbon Farming as a business model has a wide range of applications in the Mediterranean basin because it is one of the most important areas for developing agriculture worldwide. However, the effectiveness of Carbon Farming activities largely depends on environmental characteristics (climate and soil) and their proper implementation in region-specific sites.
- There are different financing mechanisms (public, private, corporate supply chains and voluntary carbon market) available for farmers to generate income through Carbon Farming activities in the Mediterranean. However, one of the main barriers currently is having monitoring, reporting and verification (MRV) systems adjusted for the specific characteristics of the basin.
- The Carbon Removals and Carbon Farming (CRCF) regulation provisional agreement can establish a regulatory framework that provides certainty, reliability, and transparency for certifying carbon removal. This will also create new business opportunities.

1. Carbon Farming in the Mediterranean region

Mediterranean dryland crops are often cultivated in soils with low organic matter, sometimes falling below the 1% organic carbon threshold for soil degradation. This makes them susceptible to significant functional loss even with minor carbon depletions. While adding mineral fertilizers doesn't always improve crop yields in such soils, agricultural practices do influence organic matter levels and soil quality. The use of heavy machinery and mineral fertilizers in modern agriculture has led to a decrease in soil organic matter (SOM), contributing to the vulnerability of European lands to desertification, particularly in the Mediterranean, where the impact of climate change and agricultural intensification on soils is under-researched.

Soils of the world constitute the largest reservoir of terrestrial carbon (C) stocks, which come in two forms: soil organic carbon (SOC) and soil inorganic carbon (SIC). According to Lal (2020), soils at 0-2 m contain approximately 1558 ±19 Pg of soil SIC and 2047±39 Pg of SOC. The latter originates from live biomass, remnants of plant and animal tissues at different decomposition stages, and microbial by-products. Furthermore, SOC is primarily associated with soil functions related to carbon sequestration, nutrient supply, water retention, and crop production (Lal, 2020).

Land uses and management practices that maintain or increase SOC stocks have various benefits including climate change mitigation and adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity. The effectiveness of these practices depends on climate, soil, and implementation type. Therefore, soil management practices should be chosen based on the specific context or region (FAO, 2021). Reducing the concentration of CO_2 in the global atmosphere by applying agricultural practices to increase the SOC content is one of the most important aspects of mitigating the effects of global climate change. Finding low-cost, effective technologies to carry out carbon sequestration would lead to achieving climate neutrality.

These agricultural practices that can manage the carbon pool flow and greenhouse gas (GHG) fluxes at the farm level, to mitigate climate change have been called Carbon Farming activities and according to COWI Ecologic Institute & IEEP, (2020), 2020) "it refers to anthropogenic interference with carbon pools, flows and greenhouse gas (GHG) fluxes at farm-level to minimise climate change"

"Carbon farming encompasses any practice or process, carried out over an activity period of at least five years, related to terrestrial or coastal management and resulting in the capture and temporary storage of atmospheric and biogenic carbon into biogenic carbon pools or the reduction of soil emissions[1]"

In the Mediterranean region, Carbon Farming has vast potential as a business model but comes with challenges and opportunities. It promotes activities like agroforestry and reforestation to sequester carbon, with financial incentives available. Navigating carbon

[1] Provisional agreement on the Carbon Removals and Carbon Farming (CRCF) Regulationwww.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/ENVI/DV/2024/03-11/Item9-Provisionalagreement-CFCR_2022-0394COD_EN.pdf

markets, ensuring project viability, and addressing socio-economic factors are critical. Embracing innovation and collaboration can help create economic opportunities and enhance resilience.

1.1. Soil Organic Carbon (SOC) in the Mediterranean croplands.

SOC is the main component of Soil Organic Matter (SOM) and it's affected by environmental conditions and management systems. Moreover, SOC is affected by land use, compaction, and landscape (Francaviglia et al., 2018). In the specific context of the Mediterranean region, SOC plays a pivotal role in providing ecosystem services such as provisional, regulating, aesthetic, and supporting services. These services are crucial for maintaining soil health, biodiversity, and overall ecosystem functioning in the region.

SOC stocks in the Mediterranean are typically limited by several factors. These include restricted carbon inputs, the historical adoption of intensive tillage, and the practice of extended bare fallows. Additionally, the removal of crop residues for livestock feed further depletes SOC levels. Despite these challenges, substantial quantities of exogenous organic matter (EOM)—representing untapped carbon sources—remain. These could be more effectively harnessed as soil amendments to enrich SOC (Álvaro-Fuentes et al., 2014; Pardo et al., 2017).

The Mediterranean region is one of the most important areas for agriculture in the world, croplands cover around 14% of the total basin area located in the south of Europe and north of Africa, while grasslands and forests occupy 15% and 8% respectively (Zdruli, 2014). Nonetheless, Mediterranean agriculture faces challenges when Carbon Farming activities are introduced due to long summer droughts, with rainfall limited to autumn, winter, and spring. Moreover, SOC is vital in the region, where rainfed cropping systems are common, organic matter inputs in soils are low and mainly rely on crop residue availability. Losses are high due to climatic and human factors such as intensive farming practices that promote SOC mineralization. Estimates suggest that 74% of the land in Southern Europe is covered by soil containing less than 2% organic carbon, equivalent to 3.4% organic matter in the topsoil. A recent modelling study estimated the SOC reserves on the Mediterranean croplands and grassland ranged between −5 and 1.5 t C ha−1 (Fig. 1) and it was the lowest content among the European countries (De Rosa et al., 2024).

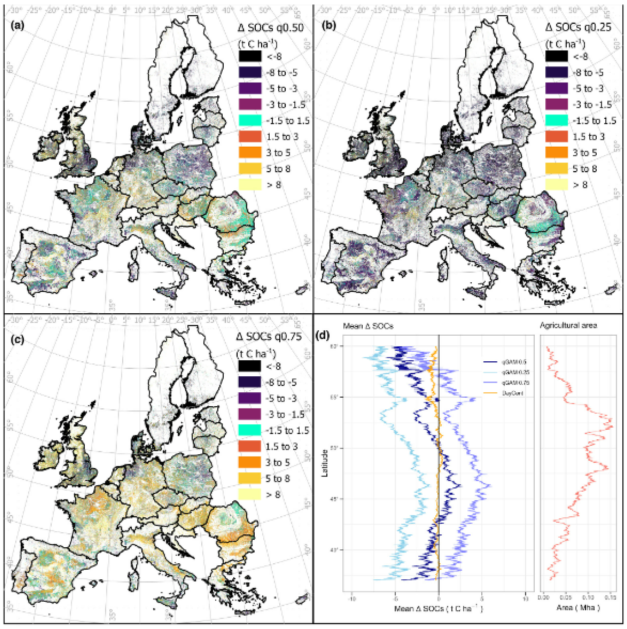

Figure 1. Soil Organic Carbon stocks in Europe. Source: (De Rosa et al., 2024)

1.2. Climate and soil diversity in the Mediterranean region

The Mediterranean biome comprises five areas around the world (Fig. 2) between 35° and 42° latitude. The Mediterranean basin (Africa, Asia and Europe) is characterised by mild or moderately cold humid winters and warm dry summers. The mean annual temperatures follow a distinct latitudinal gradient, with the lowest average temperatures being around – 5 °C in the higher altitudes of the Alps, and the annual average temperatures reaching > 20 °C in the southern part (EEA-UNEP, 2014). Precipitation is concentrated in autumn, winter and early spring, during which around 90% of the annual precipitation falls (UNEP/MAP/MED POL, 2003). The average annual precipitation in croplands ranges from 50 mm to 726 mm (Schillinger et al., 2008). Soils are notably higher (in altitude) than in Northern Europe, which is expected to negatively affect SOC content. This, coupled with the susceptibility of Mediterranean and dryland ecosystems to land degradation due to SOC degradation and depletion, exacerbates erosive processes (Muñoz-Rojas et al., 2015). Erosion is influenced by soil incomplete coverage, often resulting from drought or land uses like vineyards and olive groves. Low SOC levels are particularly concerning in perennial systems such as orchards and vineyards, which are prominent in Southern Europe (Meersmans et al., 2012). Grasslands and pastures are at risk of local overgrazing, posing a threat to SOM. While wildfires primarily impact forests and rangelands, they can also negatively affect SOM, albeit to a lesser extent in cultivated agroecosystems. However, abandoned agricultural lands and rangelands may experience an increase in dead plant biomass, heightening the risk of wildfires.

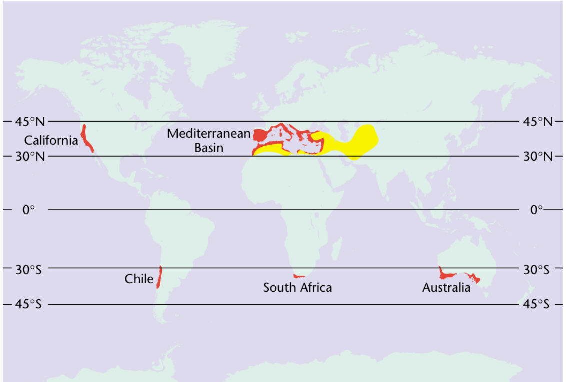

Figure 2. Mediterranean climate (red) and steppe domain (mean annual rainfall between 100 and 400 mm) according to Le Houérou, 1997. Source: (Joffre and Rambal, 2001)

Soils across the Mediterranean basin present a considerable spatial variability in their properties, often characterized by challenging physical conditions such as drought susceptibility, reduced water retention capacity, shallow depths—especially on slopes—and high content of coarse elements (Rodeghiero et al., 2011). Compared to Northern Europe, calcareous soils with neutral to slightly alkaline pH levels are more prevalent in this region, promoting the rapid decomposition of SOM (Romanyà and Rovira, 2011). The predominant soil types include Cambisols, Fluvisols, Luvisols, and Leptosols, with Cambisols widely distributed across the Iberian Peninsula, central and western Mediterranean islands, and most parts of the Italian Peninsula. Additionally, Fluvisols, Leptosols, and Luvisols are common in various Mediterranean areas, such as those influenced by the Aegean Sea, eastern Iberian Peninsula, Marmara Sea, and Ionian Sea (Rodeghiero et al., 2011).

1.3. The potential of mitigation adopting CF practices in the region.

Carbon Farming activities aim to increase terrestrial carbon storage in managed ecosystems; though, SOC is highly dynamic in both time and space, continuously being built up, decomposed, and mineralized. This high variability in timescale and spatial domain accounting represents a big challenge for its accounting and net balance in climate change mitigation. The concept of "carbon sequestration" and related terms have been used to explain the role of agricultural and forest soil in contributing to climate change mitigation. However, not every local or field-scale increase in terrestrial carbon stocks leads to carbon sequestration, and not all carbon sequestration results in negative emissions that contribute to climate change mitigation[2] (See annexe 1). In fact, the residence time of the SOC depends on i) biochemical recalcitrance, ii) chemical stabilization and iii) physical protection (Lal et al., 2015). Assessing the climate change mitigation potential of additional SOC stocks requires accounting for leakage effects (Lugato et al., 2018), which describes additional GHG emissions caused by climate change mitigation measures that either reduce the strength of a C sink or turn these measures into sources of GHGs.

[2] In a recent scientific publication Don et al., (2023)reviewed definitions of the terms C sequestration, SOC sequestration, climate change mitigation, negative emissions, SOC storage, and SOC accrual, with the goal of clarifying their meaning and ensuring their appropriate and accurate usage going forward. The entire information is available in the policy brief (December 2023) of the EJP soil Programme. Consulted on June 20024.
https://ejpsoil.eu/fileadmin/projects/ejpsoil/WP8/Policy_briefs/EJPSOIL_Policy_Brief_C_sequestration_terminology_FINAL_08012024.pdf

The most common Carbon Farming activities are cover crops, improved rotations, peatland restoration or expanding agroforestry systems rely on and work with natural processes in agroecosystems. Moreover, Carbon Farming activities can deliver many co-benefits for the environment and the sustainability of agriculture. The potential mitigation of each option was requested by the ENVI committee of the European Parliament, and the overview is shown in Table 1.

Table 1. Review of Carbon Farming Alternatives Evaluation.

Criteria for assessing	Managing peatlands	Agroforestry	Maintain and enhance SOC on mineral soils	Livestock and manure management	Nutrient management on croplands
Carbon Farming Actions	Peatland rewetting, maintenance, management	Creation, restoration, and management of woody features in the landscape	Cropland and grassland management	Technologies to reduce enteric methane, manure management, increase herd and feed efficiency	Improved nutrient planning, timing, and application of fertilisers; reduction in fertilisers
Total EU mitigation potential (Mt CO_2-e/yr)	51-54 Mt CO_2-e/yr	8–235 Mt CO_2-e/yr	9–70 Mt CO_2-e/yr	14–66 Mt CO_2 e/yr	19 Mt CO2 -e/yr
Mitigation mechanism	Avoided emissions	Removal	Removal and avoided emissions	Reduced emissions	Reduced emissions
Co-benefits	Biodiversity conservation, flood protection, water conservation	Improves soil health, prevents erosion, avoids nutrient leaching, and increases biodiversity	Increase SOC content, and water holding capacity and avoid soil erosion	Decreased nutrient runoff, decreased ammonia emissions	Reduces the use of fertilisers, avoid the leaching, run-off, and eutrophication

Source: Adapted from McDonald et al. (2021).

The different Carbon Farming activities in the Mediterranean basin show a reduced and limited potential mitigation (<50% of the feasible potential) in categories such as managing peatlands, maintaining and enhancing SOC on mineral soils, livestock and manure management, and nutrient management; but the most important mitigation potential was founded in the agroforestry practices were the feasible potential of mitigation can be almost the 80% (Domínguez et al., 2020; Roe et al., 2021).

Thus, increasing SOC through improved management practices is paramount in the Mediterranean region to combat climate change, and desertification and avoid climate change emissions. The scientific evidence shows that applying external and internal organic inputs to the soil and reducing soil disturbance are the most effective methods for maximizing SOC levels (Aguilera et al., 2013). For example, in rainfed regions, the availability of soil water during grain filling is crucial for crop yield. Practices like conservation tillage and crop residue management play significant roles in water conservation and crop productivity, especially during droughts. Improving irrigation efficiency is vital for irrigated agriculture, including upgrading water transport infrastructure and adopting efficient irrigation technologies. Water management strategies need to consider not just the total water available but also the timing of water deficits. Techniques like regulated deficit irrigation and alternative crops with lower water requirements can enhance water productivity (del Pozo et al., 2019).

Promoting and enhancing C sequestration can be achieved more effectively by combining these practices using a holistic approach instead of conventional management. These practices can be collectively referred to as "regenerative agricultural practices," which can offer additional benefits beyond C sequestration, such as improving soil health, increasing biodiversity, and ensuring crop quality. There is also extensive evidence suggesting that woody perennial practices are more effective for SOC sequestration than arable cropland, indicating that agroforestry practices are one of the best options for the region (Bumbiere et al., 2022; Burgess and Rosati, 2018; Carranca et al., 2022; del Pozo et al., 2019; Villat and Nicholas, 2023).

1.3.1. Regenerative agriculture potential

Regenerative agriculture presents a promising strategy for carbon sequestration in the Mediterranean. This approach, adapted to local conditions, includes sustainable practices aimed at soil regeneration, water quality improvement, biodiversity enhancement, and carbon sequestration. The practices, suitable for farming and grazing systems, encompass techniques from organic farming and conservation tillage, such as no-till or reduced tillage, crop rotation, composting, and pasture cropping (Andrés et al., 2022).

Regenerative agriculture can significantly reduce greenhouse gas emissions, potentially leading to negative emissions (Scott, 2024). He et al. (2019) estimate that regenerative methods can achieve a net carbon footprint ranging from -628 to -3545 kg CO2-eq/ha, compared to +488 kg CO2-eq/ha for conventional farming, reducing emissions by 1.1 to 4 t C/ha/yr. In their meta-analysis, Jordon et al. (2022) observed revealed significant SOC increases with reduced tillage intensity and ley-arable rotations over 15 years, but no significant effect from cover cropping. Importantly, these practices did not reduce yields during cropping years.

In particular, the Carbocert guide (2020) showcases the following figures for some of the most important practices of Regen Ag in the Mediterranean region:

Minimal Tillage: Reducing soil disturbance through minimal tillage decreases carbon loss and enhances microbial activity essential for soil health. Studies in southern Spain have shown SOC increases of approximately 0.30 t C/ha/yr with minimal tillage compared to conventional tillage.

Cover Cropping: Planting cover crops prevents erosion, improves soil structure, and enhances nitrogen fixation. Research indicates that cover cropping can increase SOC levels by 0.22 to 1.19 t C/ha/yr.

Crop Rotation: Alternating crop species disrupts pest and disease cycles and promotes soil health. Diverse rotations have shown SOC increases of approximately 0.15 to 0.30 t C/ha/yr.

Organic Amendments: Applying compost and organic materials boosts SOC by improving soil structure and fertility while sequestering carbon. The CarboCert project highlights SOC increases ranging from 0.20 to 0.40 t C/ha/yr with organic amendments.

Adopting regenerative practices aligns with the EU's goal of increasing healthy soils by 75% by 2030. Seven regenerative practices studied by Villat and Nicholas, (2023) contributed to below-ground carbon sequestration, supporting climate goals and providing co-benefits. Moreover, woody perennial crops like grapevines showed greater potential for SOC sequestration compared to arable cropland.

Soil erosion, a significant contributor to anthropogenic greenhouse gas emissions, can be nearly eliminated through regenerative practices, which also enhance soil carbon content

(Teague et al., 2016). Healthier soils retain water better, reducing water consumption and improving resilience to droughts and natural disasters, enabling faster recovery.

A holistic application of multiple practices can enhance carbon sequestration significantly (Villat and Nicholas, 2023). Future research should address the compounding effects of a synergetic implementation of the practices.

1.3.2. Agroforestry practices potential

Agroforestry practices in the Mediterranean basin have a vast potential for climate change mitigation and carbon sequestration due to their singular pedoclimatic conditions. These systems combine woody vegetation (trees or shrubs) with crops and/or animal systems, storing carbon in both above-ground biomass and soils. The ability to store carbon depends on factors such as environmental conditions, land use, tree density, plant species, and management practices. Covering about 8.8% of the EU's agricultural area, these systems are predominantly found in the Mediterranean and southeast Europe most of them are silvopastoral agroforestry systems, which typically combine animal grazing, foraging or fodder production with trees or other woody perennials with the pasture (Burgess and Rosati, 2018). Most EU agroforestry systems are silvopastoral, integrating animal grazing or fodder production with trees. Examples include the “Dehesa” in Spain and “Montado” in Portugal. Modern silvoarable agroforestry, or alley-cropping, involves alternating strips of crops and woody perennials (Kay et al., 2019).

The Agforward project (Pagella et al., 2014) developed a review of agroforestry practices in some countries of the Mediterranean basin focused on identifying examples of lessons learnt from successful agroforestry practices established in North Africa and the eastern Mediterranean region. They provided a characterization of different farming systems. They concluded that combining with farmers’ local knowledge about local tree cover dynamics improves our understanding of farmers’ exposure, sensitivity and adaptive capacity to social, economic and environmental hazards, trends and disturbance.

In a recent publication, Carranca et al. (2022) reviewed land use strategies aimed at enhancing carbon sinks in Mediterranean conditions using agroforestry systems. The key findings indicate that combining agroforestry with practices such as no-tillage, residue mulching, and crop rotation has the potential to reduce agricultural greenhouse gas emissions by increasing soil carbon stock and sequestering CO_2. Additionally, they highlighted that the Mediterranean agroforestry systems often have low soil fertility due to shallow soil depth and limited water and nutrient availability. To address this, farmers in the Iberian Peninsula began planting legume-rich mixture pastures, which increased productivity and SOC concentration while preventing soil degradation. Permanent pastures, alongside trees, build soil carbon quickly due to their perennial species with extensive roots, minimal soil disturbance, enhanced soil organism activity, and reduced erosion from increased soil cover.

The total mitigation potential of agroforestry in the European member states (plus Switzerland) was estimated between 0.09 to 7.29t C ha^{-1} a^{-1} (7.7 – 234.8 Mt CO_2/yr) (Kay et al., 2019). Besides, a meta-study found that under hedgerows, the rate of SOC sequestration ranges from 1.1 to 3.3 t CO_2-e/ha/yr, and hedgerow biomass accumulation ranges from 6.2 to 15.8 t CO_2-e/ha/yr over 20 and 50 years, comparable to forest sequestration rates (Drexler et al., 2021). However, the permanence of carbon removal in agroforestry depends on the type of trees and their end use, such as timber for fuel versus construction. While poor management and natural events can result in the loss of sequestered carbon, the fire risk in agroforestry systems is generally lower than in forest areas because the intervening crops can act as firebreaks (McDonald et al., 2021).

1.4. Barriers and Challenges to the implementation of Carbon Farming as a business model in the region

For the implementation of sustainable SOC sequestration, the development strategy should establish region-specific and soil-specific policies, in both the climate sector (with a focus on mitigation) and the agriculture sector (with a focus on soil health) needed to achieve substantial, cost-effective SOC protection and enhancement to meet climate targets and improve resilience (Bossio et al., 2020). These policies need to be elaborated after a detailed assessment of the ecological, social, and economic constraints of a specific region or country. It is important to develop a framework that evaluates the impact of increasing SOM on the value of environmental services provided by soils. These environmental services can be a useful tool for assessing the effects of various soil management strategies and can provide a measurable incentive for preserving SOM and promoting sustainable societal behaviour. One potential solution to encourage the adoption of SOC sequestration practices is to provide payments for environmental services (Lal et al., 2015).

Due to SOC spatial variability and annual changes, monitoring, reporting, and verification (MRV) strategies are still in development. While SOC-rich soils are known to be healthy and fertile, the precise relationship between SOM and soil quality remains unclear. Recent methodological advances have improved the understanding of the interactions among physical, chemical, and biological soil processes. However, translating these scientific insights into practical management strategies is still a challenge. Increasing biodiversity in agricultural landscapes appears crucial for enhancing agricultural productivity and SOC storage.

1.4.1. Specific barriers

A detailed review focused on the Adoption of Carbon Farming Policies in the EU (Van Hoof, 2023) identified three main categories of barriers (Table 2). It concluded that there has been a more limited adoption of mitigation policies for agriculture in the EU compared to other sectors. It is necessary a strategic coordination by governments, multilateral efforts, and the involvement of farmers in the policy process.

Table 2. Categories of the barriers to the adoption of Carbon Farming Policies in the European context. Source: Own elaboration modified from Van Hoof, (2023).

Category	Barrier	Summary
Sector complexity	Fragmented nature of the sector. MRV at the farm level. MRV in national GHG inventories.	- Agriculture is a complex sector (large number of farmers and diverse production systems), requiring tailored technical solutions and policies. - Adoption of Carbon Farming policies involves multiple interests and stakeholders. - Issues of knowledge brokerage between farmers and regulators, along with the need for adapted technical packages, contribute to the complexity of the sector.
Mitigation effects	Impact on food production/security. Carbon leakage and loss of competitive advantage. Impact on farmers' livelihoods.	- Challenges of increasing food production while reducing GHG emissions and adapting to climate change. - Concerns exist that mitigation efforts consistent with a 1.5 °C target may raise global food prices and heighten the risk of food insecurity. - Developing countries are particularly worried about the negative impacts of mitigation on food security, given existing food insecurity issues.

Institutional barriers	Lack of political support. Agricultural lobby. Policy coordination. Lack of institutional capacity.	- Some authors highlight a lack of political support for agricultural mitigation policies in the EU. - The absence of a strong constituency favouring reductions in agricultural GHG emissions in EU member states. - The decline in agricultural emissions in the EU until 1990 led to a perception that no mitigation measures were necessary, but this changed with a more restrictive climate policy environment.

In this context, the specific barriers to implementing CF as a business model in the Mediterranean basin can be summarized as follows:

Political barriers

There are some regulatory inconsistencies and a lack of political support between agriculture and forestry in European policies, including in the CAP. Besides farmers need more public support to adopt different new practices (i.e. agroforestry and regenerative practices) to compensate for economic losses, fund new machinery, and reward environmental benefits. Public support is also needed for enhanced training and advisory services (Bossio et al., 2020).

Socio-cultural barriers

The permanent nature of the change with legal and economic implications, the income uncertainty, and the complexity of agroforestry, which require specific knowledge and expertise on the part of farmers. Farmers have a constant need for specialized training[3].

Economic barriers

It is one of the most significant barriers in the region due to the challenge of acquiring new specialized machinery, as well as the lack of contracting services or farmers' associations able to share mechanical tools and knowledge.

Pedo-climatic barriers

Extreme summer climatic conditions create a barrier to adopting CF, particularly crop diversification due to differing pedo-environmental conditions among countries. This problem will be magnified due to the high spatial variability of SOC stocks and the small changes, which occur on a yearly basis (Lal et al., 2015). One factor that has been underestimated in Mediterranean soils, especially calcareous soils, is the interaction between SOC and SIC. This interaction influences pH, microbial activity, Ca^{2+}-SOC binding, and soil aggregation. (Sharififar et al., 2023).

Agronomical barriers

Crop diversification is hindered by climatic conditions and the lack of active markets for cover crops in some countries. Permanent soil cover and crop residue management are hampered by the need to use forage by livestock and difficulty in managing weeds and pathogens.

[3] CAMA Project Factsheet. Barriers to the adoption of Conservation Agriculture in the Mediterranean Countries. Consulted in June 2024, http://www.camamed.eu/en/pdfs/Fact_Sheets/WP2-Barriers_to_the_adoption_of_CA_in_the_Mediterranean_countries.pdf

1.4.2. Specific challenges

There are several challenges to developing a series of policies that incentivise Carbon Farming activities such as a climate change mitigation strategy.

Modelling, Reporting, and Verification (MRV)

To warrant the environmental integrity of Carbon Farming actions, it's important to be able to measure and confirm their impact. This is done through monitoring, reporting, and verification (MRV), which involves measuring emissions avoided or sequestration increase, communicating results, and ensuring their accuracy by external parties (the basic components of an MRV are described in annexe 2). A robust MRV system is vital for guaranteeing the real, additional, measurable, permanent, and environmentally sound nature of GHG mitigation and carbon removals.

Currently, a wide variety of MRV (Measurement, Reporting, and Verification) options are available on the market. However, the choice of a soil carbon assessment approach will depend on i) the purpose of the assessment, depending on the type of payment or mechanism selected, ii) resources available for investment in monitoring, and iii) the likelihood that the purpose of the assessment will evolve in the future. The World Bank (2021) published a report that developed a decision tree to support and provide advice for choosing the correct approach (Annexe 3). Moreover, it classified different monitoring approaches based on their complexity and provided an in-depth analysis of them (Table 3).

Table 3. Soil carbon MRV categories with requirements and options for improvement SOC. Source: World Bank (2021).

SOC MRV categories Purpose	Purpose	Technical requirements	Personnel requirements	Quick options for improvement of assessments
Basic	Public communication and donor reporting	Typical M&E systems, mostly based on periodic reporting of per area or head management practices without intensive data collection	Closely linked to the existing advisory and extension system	GIS-based activity data using global available land use datasets and lookup tables
Intermediate	Results-based payments	Occasional field surveys using digital data collection and central databases	Surveys were done by enumerators, and verified by field extension staff	Data collection toolkits, lookup tables, calculators or simple carbon models, development of Standard Operating Procedures for field data collection and development of sampling and monitoring plan
High-end	Carbon credit generation, high-impact carbon finance	Combination of digital field data collection and central Management Information Systems to automatize analyses and reporting	MRV staff with clear roles and responsibilities, central MRV unit, involvement of beneficiaries in monitoring	Standard Operating Procedures and QA/QC steps for all activities related to MRV, provision of continuous training and database maintenance

The monitoring component of MRV can be done through direct measurement, modelling, or a combination of both. Direct measurement offers high accuracy but at a high cost, while modelling is less expensive but comes with higher uncertainty. Effective reporting and verification are crucial for Carbon Farming, especially if it's used to generate offset credits.

This requires robust processes, including audits, secure registry systems, and long-term reporting obligations, to ensure the quality and integrity of Carbon Farming mitigation efforts.

Permanence (Long-term residence)

In order for Carbon Farming to have a positive impact on the climate, efforts to reduce greenhouse gas (GHG) levels must be permanent, meaning that the levels must remain lower over the long term. Temporary carbon storage is ineffective if the stored carbon is likely to be re-released, making long-term sequestration essential.

Permanence is a particular challenge for Carbon Farming through sequestration and storage, where carbon removed from the atmosphere is stored in biomass on agricultural land, both above and below ground. This sequestered carbon is unstable and can be released either intentionally, such as through changing cropping patterns or reintroducing tillage, or unintentionally, for example, through drought or fire that destroys agroforestry trees. This challenge is especially pronounced for soil carbon in peatlands or mineral soils due to the difficulty in monitoring permanence. In contrast, Carbon Farming actions that reduce emissions, such as improved livestock and manure management or nutrient management, offer a more reliable solution, as the GHG reductions achieved through these methods remain out of the atmosphere permanently.

Additionality

Identifying whether mitigation from Carbon Farming is additional (i.e., would not have occurred without an incentive scheme) is crucial for two reasons: i) **Cost Effectiveness:** Payments should only reward farmers for mitigation that exceeds what they would have done without financial incentives and ii) **Robust Climate Impact:** Additional mitigation is necessary to ensure that Carbon Farming offsets genuinely contribute to reducing overall emissions, rather than merely displacing them (McDonald et al., 2021).

Additionality is assessed against a baseline representing what would have happened without Carbon Farming incentives. Any mitigation beyond this baseline is considered additional. However, developing accurate baselines can be complex, costly, and time-consuming, sometimes requiring historical data that may not be available. Simplified baselines can be manipulated, resulting in non-additional mitigation.

In Europe, determining additionality is particularly challenging due to diverse CAP requirements and various agri-environment-climate incentives, which can have uncertain and evolving impacts on mitigation. This complexity makes it difficult to set realistic baselines and avoid double counting, where farmers might be paid multiple times for the same mitigation. Effective Carbon Farming mechanisms must have strict guidelines and transparent registries to track carbon credit ownership and ensure that mitigation is only recorded once, even when offset credits are traded internationally.

Co-benefits

Carbon Farming targets climate change and provides extra environmental, economic, and climate adaptation benefits. These benefits range from cost savings for farmers to public goods such as biodiversity conservation and better water quality. Leveraging natural systems like soils and trees leads to multiple benefits such as biodiversity improvement and human well-being, known as nature-based solutions. To align with the European Green Deal, it's crucial to maximize these benefits while minimizing risks. Monitoring not only the carbon impact but also biodiversity enhancement, water quality, farm resilience, and reduction of flood risk and soil erosion is essential. Policies should include measures to exclude harmful practices, regular evaluation, and comprehensive greenhouse gas monitoring to fully capture benefits and avoid significant risks.

2. Carbon Farming as a business model

Carbon Farming is an innovative approach that offers new economic prospects for farmers and foresters. By embracing sustainable practices such as regenerative agriculture, agroforestry, rotational grazing, and reforestation, they can not only diversify their income streams but also contribute to environmental conservation and improve the overall economic productivity of their land. Establishing standardized and transparent monitoring methods will be crucial in providing credibility to Carbon Farming initiatives, which, in turn, will attract more investments and support for sustainable land management practices.

2.1. Type of payments

There are three types of payments for farmers to earn money from Carbon Farming, each represents different financing possibilities and MRV needs to estimate possible soil carbon removals[4].

Action-based: Farmers are paid a set amount for carrying out specific actions, such as following certain farming practices or using particular technologies. These action-based payments are often used in the Common Agricultural Policy (CAP), such as for agri-environmental-climate payments under Pillar 2. While action-based payments are easy to implement and require less monitoring for farmers and administrators, it is uncertain how much they actually help in reducing environmental impact, as the payment is based on the action taken rather than the results achieved.

Result-based: Farmers receive a payment based on the actual impact of their efforts to reduce emissions or sequester carbon. This payment is not tied to specific actions taken, but rather to the overall outcome. However, measuring and verifying this impact is expensive and complex, which can create uncertainty for farmers, especially if prices and mitigation efforts are uncertain. On the positive side, this approach provides high environmental certainty and credibility, as it directly links a farmer's contribution to mitigating climate change to their payment. Additionally, it allows for flexibility, which can motivate farmers to develop and adapt new mitigation measures that are specific to the local environment.

Hybrid payments: Combine action- and result-based payments for farmers. This means farmers receive a guaranteed payment for implementing specific farm management actions, as well as additional payments based on the actual measured mitigation results. The upfront payments can help cover implementation costs and reduce financial risks for farmers. This hybrid model aims to increase farmer participation by lowering risks and removing financial barriers, while still allowing flexibility for farmers to implement the best actions for their farms.

2.2. Mechanisms for Carbon Farming Payments

Carbon Farming payments are made to farmers through various mechanisms, as outlined in Table 4. These mechanisms differ in who pays the farmers, the form of payment (cash or

[4] The concept of each system is based on (COWI et al., 2021; McDonald et al., 2021)

tradeable offset credits), and the required level of monitoring, reporting, and verification (MRV). The complexity and stringency of MRV impact farmers' participation costs and administrative expenses for mechanism operators (see the diagrammatic representation in annexe 4).

Table 4. Overview of the mechanisms for Carbon Farming payments. Source: COWI et al., (2021; McDonald et al., (2021)[5].

Mechanism	Description	Advantages	Disadvantages	MRV requirements	Payment
Land management practice payments	A central funder pays farmers a reward for implementing climate-Carbon Farming management actions (related to crops, soil, land use, livestock) MRV	The payments are simple to administer, generally with low MRV requirements, leading to lower costs.	Depends on public financing, which is relatively limited.	Low-medium	Cash (generally action-based; hybrid/result-based possible)
Corporate supply chains	Agri-food companies pay farmers within their own supply chain to reduce their impact on the climate, motivated by the possibility of price premiums from customers, or to meet their own company climate objectives. Also known as “insetting” or managing “scope 3 emissions”. MRV	The model can attract private funding for Carbon Farming by motivating agri-food companies. Agri-food companies' existing relationships with farmers enable them to set minimum standards and effectively encourage voluntary farmer participation.	The processes are frequently unclear. It is necessary to include the application of proven and published methodologies for quantifying and verifying the results	Low-high	Cash (generally action-based; hybrid/result-based possible) Agri-food
Voluntary carbon markets	**With intermediary** A central intermediary pays farmers for implementing mitigation measures, monitors and verifies mitigation impact, and sells offset credits to private buyers. The intermediary can be the private or public mechanism developer or a project developer. They often provide farmer training/support. MRV **Exchanged based** Farmers implement mitigation measures following approved methodologies to produce offset credits that they trade directly with buyers. A certification mechanism aims to ensure that the offset credits produced are matched by high-quality, unique climate mitigation/sequestration.	These markets link buyers seeking carbon reductions with projects or individuals offering such actions in exchange for "offset credits" representing the removal or reduction of 1 ton of CO_2-e. **With intermediary.** The credits produced are usually limited to a single type of Carbon Farming activity (not fungible). **Exchange-based.** The resulting offset credits are considered equivalent and tradeable with those from other mitigation methods like afforestation or renewable energy. Lower complexity and cost for farmers.	Most of the schemes come from forestry. **With intermediary.** The significant role and cost of intermediaries, often supported by farming consultants, make it challenging to scale up these markets. **Exchange-based.** High cost of MRV and increasing complexity. Uncertainty and risk due to the prices are determined on the market.	Medium-high (with intermediary) High (Exchanged-based)	**With intermediary** Offset certificate - non-fungible, only traded once then retired (result/hybrid/action-based) **Exchange-based** Freely tradeable offset credit (result-based) Farmers

[5] Some examples of mechanisms can be consulted in the report “Carbon Farming, Making agriculture fit for 2030”.

3. Funding options in the region

The uncertainty about funding for the setup and operating costs of Carbon Farming activities, combined with the risk of non-delivery of the expected results, deters land managers' uptake. The payment linked to carbon benefits means investing in new practices and monitoring upfront, with revenues coming later, making it unattractive for land managers. For instance, a series of public sources can support the upscale-up of Carbon Farming such as the cost associated with the MRV aspects, the improvement of infrastructure or training to ensure effective adoption of the Carbon Farming activities.

3.1. Public sources

According to the EC (2021) recommendation[6], public funding provided under the CAP and other EU programs can be utilized to support the expansion of Carbon Farming. This support could cover additional expenses associated with monitoring, reporting, and verification, and also finance pilot and research projects aimed at enhancing the effectiveness of Carbon Farming. Another potential avenue is the use of State aid, which can complement or strengthen actions supported by CAP. Public funding has the potential to significantly mitigate the risks for land managers who wish to participate in Carbon Farming schemes, thereby ensuring their involvement.

The Common Agricultural Policy 2023-2027 (CAP)

The new CAP finance can support Carbon Farming activities in various ways. This includes setting baseline standards for land management, offering contracts for specific Carbon Farming actions at different levels of climate ambition, providing upfront investment support for farm-level land use changes, offering advisory and capacity-building support for farmers, and contributing to Research and Development costs for setting up new Carbon Farming mechanisms at local, national, and EU levels through the CAP Network and the agricultural European Innovation Partnership (EIP-AGRI).

The CAP will benefit from a budget of EUR 387 billion from two main funds: the European Agricultural Guarantee Fund (EAGF) allocated EUR 291.1 billion for Pillar I and the European Agricultural Fund for Rural Development (EAFRD), including Next Generation EU funding, will make available EUR 95.5 billion for RD interventions[7].

CAP extends eligibility for Pillar 1 direct payments to include Carbon Farming practices like paludiculture and agroforestry. The updated GAEC standards set land management requirements, with penalties for non-compliance, directly impacting peatland, wetland, grassland, and SOC management. Eco-schemes, fully funded under Pillar 1, offer area-based payments for various conservation practices. Member States can also use European Agricultural Fund for Rural Development (EAFRD) co-funding under Pillar 2 for multi-annual environmental management contracts and innovative approaches to support Carbon Farming, including within Natura 2000 sites (McDonald et al., 2021). A complete analysis of the standards is shown in Table 5.

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[6] The EC published the Commission Recommendation, Assessment COM(2021) 800 final – SWD(2021) 451 final where is included a in depth analysis of Carbon Farming upscaling strategies. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021SC0450

[7] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/new-cap-202327_en

Table 5. CAP standards from 2023 for the good agricultural and environmental condition of land relevant to Carbon Farming that applies in the Mediterranean conditions. Source: European Parliament (2021) modified from McDonald et al., (2021)

Main Issue	Requirements and standards		The main objective of the standard
Main Issue Climate change (mitigation of and adaptation to) Soil	GAEC 1	Maintenance of permanent grassland based on a ratio of permanent grassland in relation to agricultural area at national, regional, sub-regional, group-of-holdings or holding level in comparison to the reference year 2018; Maximum decrease of 5% compared to the reference year	General safeguard against conversion to other agricultural uses to preserve carbon stock
	GAEC 3	Ban on burning arable stubble, except for plant health reasons.	Maintenance of soil organic matter (SOM) Minimum
Soil (protection and quality)	GAEC 6	Tillage management, reducing the risk of soil degradation and erosion, including consideration of the slope gradient.	Minimum land management reflecting site-specific conditions to limit erosion
	GAEC 7	Minimum soil cover to avoid bare soil in most sensitive periods	Protection of soils in periods that are most sensitive
	GAEC 8	Crop rotation in arable land, except for crops growing underwater	Preserve the soil potential
Biodiversity and landscape (protection and quality)	GAEC 9	[partial extract] Minimum share of agricultural area devoted to non-productive areas or features; Minimum share of at least 4% of arable land at farm level devoted to non-productive areas and features, including land lying fallow; ...; Retention of landscape features; Ban on cutting hedges and trees during the bird breeding and rearing season	Maintenance of non-productive features and areas to improve on-farm biodiversity
	GAEC 10	Ban on converting or ploughing permanent grassland designated as environmentally sensitive permanent grasslands in Natural 2000 sites	Protection of habitats and species

In rural development programs, payments are given for environmental, climate, and management efforts such as agri-environment-climate and organic farming. These payments are provided per hectare and are aimed at supporting practices that go beyond legal requirements. They apply to both agricultural and non-agricultural lands. Normally, these commitments are for multiple years, although exceptions can be made for longer or shorter periods based on specific environmental benefits. The payments are determined based on the costs incurred and income foregone. They are often part of action-based schemes but can also support result-based payment schemes for more effective climate action. These schemes allow for flexibility in achieving results and may include bonus payments for exceeding targets. Rural development interventions support tree planting, forest management, and wetland restoration. They also fund training and collaborative approaches to promote Carbon Farming. CAP programs can be combined to enhance climate effects. Member States must allocate a percentage of funds to eco-schemes and climate-related measures. The new CAP protects carbon sinks like grasslands and peatlands. However, CAP support has limitations, including eligibility for certain land types and difficulties in observing carbon impact. The administrative structure also limits the design of essential elements, such as governance and carbon registers, risking excessive administrative burdens (EC, 2021).

Other EU funding sources

In EU programmes, there are additional funding sources available to cover the various costs associated with implementing Carbon Farming activities. This funding can also support pilot and research projects aimed at enhancing the efficiency of Carbon Farming and promoting collective and cooperative approaches. Table 6 shows different EU programmes and examples of funded projects regarding Carbon Farming.

Table 6. Available EU programmes for obtaining funding to develop Carbon Farming actions.

EU programme	Description	Funded projects
LIFE Programme[8]	The LIFE programme supports Carbon Farming projects, which encourage farmers to reduce their carbon footprint and increase carbon storage in vegetation and soils.	• Life Carbon Farming Scheme[9] • Life Carbon Farming[10] • Life Carbon Counts[11] • Viticase[12]
Horizon Europe[13]	The Commission supports research, development and innovation for Carbon Farming[14] mainly through Horizon Europe, notably via Cluster 6[15] (Food,	• CIRCASA[17] • MARVIC[18]

[8] https://cinea.ec.europa.eu/programmes/life_en

[9] https://www.st1.com/st1-life

[10] https://www.life-carbon-farming.eu/

[11] https://lv.vlaanderen.be/en/beleid/klimaat-milieu/energie-en-klimaat/onderzoeksproject-life-carboncounts/life-carboncounts

[12] https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE22-CCA-IT-LIFE-VitiCaSe-101113620/viticulture-for-soil-organic-carbon-sequestration

[13] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

[14] https://research-and-innovation.ec.europa.eu/research-area/agriculture-forestry-and-rural-areas_en

[15] Soil misión: https://rea.ec.europa.eu/funding-and-grants/horizon-europe-cluster-6-food-bioeconomy-natural-resources-agriculture-and-environment/soil-mission_en

[17] https://www.circasa-project.eu/

[18] https://www.project-marvic.eu/

	Bioeconomy, Natural Resources, Agriculture and Environment) and the EU Mission "A Soil Deal for Europe"[16].	• ORCaSa[19] • CREDIBLE[20] • FARMS4CLIMATE[21] • Trees4Clima[22] • MRV4SOC[23]
INTERREG[24]	The programme supports cooperation across borders through project funding. It aims to jointly tackle common challenges and find shared solutions in various fields such as health, environment, research, education, transport, sustainable energy, and more. Additionally, The Interreg EURO-MED[25] programme provides funds for projects developed and managed by public administrations, universities, and private and civil society organizations. The Programme brings together partners from 69 regions of 14 countries from the Northern shore of the Mediterranean to work towards a climate-neutral and resilient society for the benefit of its citizens.	• Carbon Farming CE[26] • Carbon Farming MED[27]
State aid	Member States might consider supporting Carbon Farming initiatives through pure national financing, i.e. State aid, to reduce net GHG emissions from the land use sector and meet targets under the LULUCF Regulation[28]. The existing instruments for the agricultural and forestry sectors are the European Union Guidelines for State aid in the agricultural and forestry sectors and in rural areas 2014 to 2020 and the agricultural block-exemption regulation[29].	

3.2. National (specific country funding sources)

Some local initiatives have been promoted by national or local governments to establish certification schemes that allow for obtaining financing to develop projects for sustainable agriculture, where Carbon Farming activities can be selected.

[16] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/soil-deal-europe_en

[19] https://irc-orcasa.eu/soil-carbon/

[20] https://www.project-credible.eu/

[21] https://www.farms4climate.eu/

[22] https://cordis.europa.eu/project/id/896512

[23] https://mrv4soc.eu/

[24] https://interreg.eu/programme/interreg-europe/

[25] https://interreg-euro-med.eu/en/

[26] https://www.interreg-central.eu/projects/carbon-farming-ce/

[27] https://carbonfarmingmed.interreg-euro-med.eu/

[28] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R0841-20230511

[29] Commission Regulation (EU) No 702/2014 of 25 June 2014 declaring certain categories of aid in the agricultural and forestry sectors and in rural areas compatible with the internal market in application of Articles 107 and 108 of the Treaty on the Functioning of the European Union (OJ L 193 of 1.7.2014, p.1).

Bosnia and Herzegovina

In Bosnia and Herzegovina, there are no specific national certification schemes or funding sources exclusively for carbon farming or sustainable agriculture similar to the Label Bas Carbone in France or the Fondo de Carbono in Spain. Bosnia and Herzegovina is working towards renewable energy integration and climate resilience through its National Energy and Climate Plan (NECP), which aims to reduce carbon emissions and increase the share of renewables in the energy mix. Although specific national certification schemes for carbon farming are not yet established, Bosnia and Herzegovina can leverage EU funding opportunities.

France

The **Label Bas Carbone**[30] (Low-Carbon label) is a French certification scheme designed to promote and recognize projects that contribute to the reduction of greenhouse gas emissions and the enhancement of carbon sequestration. It was launched by the French Ministry for the Ecological and Inclusive Transition in 2018 as part of France's broader climate policy. It aims to incentivize and reward carbon reduction projects across various sectors, including agriculture, forestry, and land use. The primary objective is to support projects that sequester carbon or reduce emissions through sustainable practices.

Greece

There is no reported policy or certification scheme.

Italy

There is no reported policy or certification scheme.

Slovenia

Slovenia does not currently have a specific, standalone national certification scheme exclusively for carbon farming. Funding for carbon farming and sustainable agriculture does not come from dedicated schemes, but rather from broader environmental and rural development programs. Various regional and national initiatives offer grants or subsidies for sustainable agricultural practices. For example, the Ministry of Agriculture, Forestry, and Food issues calls for proposals that provide diverse opportunities for securing funds, including for projects related to sustainable agriculture and potentially carbon farming.

Spain

The **Fondo de Carbono para una Economía Sostenible** (Carbon Fund for a Sustainable Economy) (FES-CO_2) (FCPJ)[31] is a national climate financing instrument designed to promote low-carbon and climate-resilient economic activity. This will help Spain meet its greenhouse gas emissions reduction targets and encourage technological development for decarbonization and climate resilience in key sectors of the economy through national actions, however, this fund normally finances projects for the capture and generation of forest carbon credits mainly.

Another local initiative was launched in 2023 for the government of Catalonia together with the Mediterranean Cooperation Alliance (MedCoopAlliance). They proposed the creation of

[30] https://label-bas-carbone.ecologie.gouv.fr/

[31] Real Decreto 1494/2011, de 24 de octubre, por el que se regula el Fondo de Carbono para una Economía Sostenible. https://www.boe.es/eli/es/rd/2011/10/24/1494/con

a **Climate Credits System**[32] to contribute to the mitigation and adaptation of forests, agricultural soils and marine and coastal ecosystems to climate change from multifunctional forest management, carbon agriculture and ecosystem restoration. These credits will offer the possibility of voluntarily offsetting the carbon footprint and water footprint of companies by investing in multifunctional and sustainable forest and cropland management in Catalonia.

3.3. Private sources

Carbon markets

Carbon markets can facilitate the development of result-based Carbon Farming schemes by providing legitimacy and longevity. These markets can be compliance-based, where carbon credits are used to meet binding emission caps, or voluntary, where targets are not regulated by public authorities. Voluntary carbon markets have proven effective for initiating Carbon Farming schemes, including soil carbon sequestration, and have numerous international examples in forestry and peatlands. While carbon markets can perpetuate these schemes, their effectiveness and long-term price stability depend on support from private or public sources. Compliance markets create demand through policies imposing emission reduction targets, and the Kyoto Protocol's mechanisms demonstrate the long-term potential for regulatory carbon markets. Article 6 of the Paris Agreement continues this with mechanisms for voluntary cooperation toward climate goals.

Voluntary carbon markets provide incentives for landowners to improve land management practices to reduce emissions or increase carbon sequestration, but they also pose the issue of double counting. Double counting can occur when the same emission reduction is claimed by multiple parties or registered under different schemes. has grown significantly since the early 1990s, but it faces challenges related to offset quality and fragmentation. Without regulatory obligations or pricing signals, firms must navigate their net-zero goals with minimal guidance[33]. Recently, Dawes et al. (2023) examined recent initiatives aimed at enhancing the functionality, transparency, and effectiveness of voluntary carbon markets, highlighting the increasing overlap between government and private sector activities.

Corporate supply chains

Corporate supply chain finance for Carbon Farming is driven by companies aiming to reduce their product's carbon footprint by incentivizing farmers in their supply chain with financial rewards to adopt Carbon Farming practices. This approach typically incurs lower MRV costs compared to carbon markets the growth of private finance for Carbon Farming is limited by concerns about the environmental robustness of Carbon Farming offset credits, issues of permanence, non-additionality, and measurement uncertainties. These challenges could be mitigated by stricter MRV standards, but the high costs and risks currently deter farmers from participating voluntarily.

[32] https://govern.cat/salapremsa/notes-premsa/567122/govern-crea-sistema-credits-climatics-catalunya-potenciar-labsorcio-del-co2-que-semet-latmosfera

[33] Dawes et al. (2023) examined recent initiatives aimed at enhancing the functionality, transparency, and effectiveness of voluntary carbon markets, highlighting the increasing overlap between government and private sector activities. They focused on analysing the schemes to suggest recommendations for its inclusion in a future U.S. policy.

4. The present legal status of Carbon Farming in the EU.

The current policy and legislative landscape surrounding soils is strikingly underdeveloped. A patchwork of EU and national environmental and sectoral laws and policies touches on soil matters, but there is no overarching, coherent legal framework. In the absence of European legislation focused on soil, many soil threats remain unregulated and many soil functions unmonitored, leading the European Environmental Agency (and many others) to conclude that "the absence of suitable soil legislation at the European level contributes to the continuous degradation of many soils within Europe"[34]. Regarding Carbon Farming a specific policy package supporting and enhancing Carbon Farming did not exist in the EU until just recently, even though scientists have extensively researched the potential of soil carbon stock from soil and climate perspectives for a long time.

4.1. Background and policy development on Carbon Farming in the EU.

The timeline of Carbon Farming policy development comprises diverse EU regulations that began with the signing of the European Climate Law[35] (2021) aimed to legally bind the EU to become climate neutral by 2050. Afterwards, the Commission adopted a communication document regarding Sustainable Carbon Cycles[36] that highlighted the importance of adopting Carbon Farming as a successful and attractive business model, at the same time the "Technical Guidance Handbook – setting up and implementing result-based Carbon Farming mechanisms in the EU" was published (COWI et al., 2021) which explored the key issues, trade-offs and design options to support a widespread adoption of Carbon Farming initiatives in the EU. Both documents were focused on: (i) promoting Carbon Farming activities under the EU-wide funding schemes such as the CAP, (ii) standardizing MRV methodologies to provide a clear and reliable framework for Carbon Farming, and (iii) providing adequate knowledge, and data management and tailored advisory services to land managers.

Likewise, the EU has two regulations governing greenhouse gas (GHG) emissions and removals in the agricultural sector: the Effort Sharing Regulation (ESR) (Regulation (EU) 2018/842)[37] and the LULUCF Regulation (Regulation (EU) 2018/841)[38]. The ESR sets annual emission reduction targets for member states, while the LULUCF Regulation applies to emissions and removals in specific land sectors. These regulations complement each other, allowing member states to use net removal quantities from the LULUCF sector to comply with the ESR and vice versa. Currently, carbon farming is not explicitly defined under either the ESR or the LULUCF Regulation. Nevertheless, both regulations may indirectly support farmers in adopting climate-smart agriculture practices. However, neither the ESR nor the LULUCF regulation directly regulates specific farming practices to achieve their objectives.

[34] Extracted from (European Environmental Agency, 2020).

[35] European Climate Law, 2021. http://data.europa.eu/eli/reg/2021/1119/oj

[36] https://climate.ec.europa.eu/document/download/d3529f84-0f18-40ee-ab72-124ba786fb5a_en

[37] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A555%3AFIN

[38] https://eur-lex.europa.eu/eli/reg/2023/839/oj

4.2. The recent EU Carbon Removals and Carbon Farming Certification (CRCF) Regulation

The Carbon Removal Certification Proposal (it was the tittle of the first version) aims to accelerate the deployment of high-quality carbon removals and prevent greenwashing by setting requirements for certification, third-party verification, and registry functioning. It screens out low-quality carbon removals and aims to build trust with stakeholders. In April 2024 the European Parliament adopted the provisional agreement on the Carbon Removals and Carbon Farming (CRCF) Regulation. The framework will help the EU achieve climate neutrality by certifying carbon removals and carbon farming, ensuring they are transparent, trusted, and free from greenwashing. This initiative will also create new business opportunities (see timeline in Fig. 3).

Figure 3. Timeline of EU Carbon Removals and Carbon Farming Certification Regulation. Source: own elaboration with data from https://tracker.carbongap.org/policy/crcf/ (Consulted on June 2024)

Key elements of the framework include[39]:

Carbon Farming: Involves activities like restoring forests and soils, avoiding soil emissions, rewetting peatlands, efficient fertilizer use, and other innovative farming practices.

Industrial Carbon Removals: Includes techniques like bioenergy with carbon capture and storage, and direct air carbon capture and storage.

Binding Carbon in Long-Lasting Products: Covers using materials like wood-based construction materials or biochar.

The regulation will enhance the EU's ability to quantify, monitor, and verify these carbon removals' authenticity. It establishes rules for recognizing certification schemes that comply with the EU framework and sets criteria to ensure high-quality, transparent, and credible carbon removal certifications.

[39] European Comission, 2024 (February). Commission welcomes political agreement on EU-wide certification scheme for carbon removals [Press release]. https://ec.europa.eu/commission/presscorner/detail/en/ip_24_885.

Certified carbon removals offer new economic opportunities by enabling monetization through private schemes and public sector support and providing commercial advantages for businesses with eco-friendly practices. Carbon farming introduces new business models for farmers and foresters, benefiting biodiversity. The regulation promotes using long-lasting bio-based building products to retain carbon for extended periods, encouraging sustainable building techniques. Additionally, it unlocks innovative financing options, such as impact finance and result-based public support, rewarding carbon removers and farmers based on certified removals and emissions reductions.

For Carbon Farming and soil emissions reductions, the new regulation proposes to include the following specific activities:

1. Rewetting and restoring peatlands and wetlands to reduce carbon oxidation and increase carbon sequestration.
2. Agroforestry and mixed farming, integrating trees or shrubs with crop and/or livestock management.
3. Implementing soil protection measures like catch crops, cover crops, conservation tillage, and hedgerows.
4. Reforestation respecting ecological principles for biodiversity and sustainable forest management.
5. Improving fertiliser use efficiency to cut nitrous oxide emissions.

According to the new CRCF Carbon Farming activities can provide a **temporary net carbon removal benefit** or a **net soil emission reduction benefit**, which shall be quantified using the formulas in annexe 5.

One of the first tasks carried out by the EU for developing the CRCF was to form the Expert Group on Carbon, which aims to advise the Commission on developing tailored EU certification methodologies. With around 70 members from various backgrounds, including national authorities, businesses, NGOs, and research institutions, it ensures a broad representation of stakeholders[40]. The expert group develops biannual meetings and public workshops to discuss progress on the different topics covered by the regulation.

The first outcomes of the Expert Group about Carbon Farming were published by van Baren et al. 2023). They reviewed the different certification methodologies for Carbon Farming putting special emphasis on the QU.A.L.ITY criteria[41]. The main input of this report was the review originating from a survey conducted through the EU Survey website in April / May 2023 and the identification of best practices that will be applied once the proposal for a Certification Framework for Carbon Removals. The report includes a classification of the methodologies according to their development stage (under development, available but not yet applied, applied on a pilot scale and applied at scale). For Carbon Farming there were reported 52 methodologies for agricultural land management, 24 for forest management and 6 for peatland. The geographical scope shows most of the methodologies (54) have an international scope while the others focus on a specific country or are developed at a country level and intended to be upscaled to the international level.

[40] Expert Group on Carbon Removasls. https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming_en#carbon-removals-and-carbon-farming-in-a-nutshell. Consulted June 2024.

[41] QU.A.L.ITY criteria was a proposal of the EC to sets out the rules for the independent verification of carbon removals, as well as rules to recognise certification schemes that can be used to demonstrate compliance with the EU framework. The criteria was based in 1) **Qu**antification: Carbon removal activities need to be measured accurately and deliver unambiguous benefits for the climate; 2) **A**dditionality: Carbon removal activities need to go beyond existing practices and what is required by law; 3) **L**ong-term storage: Certificates are linked to the duration of carbon storage so as to ensure permanent storage; 4) Sustainabil**ity**: Carbon removal activities must preserve or contribute to sustainability objectives such as climate change adaptation, circular economy, water and marine resources, and biodiversity. Currently, the criteria was modified and the acronym is no longer used.

The majority of the national methodologies have been designed in Mediterranean countries such as France (12), Spain (7) and Italy (6). Finally, the authors made a selection of these methodologies for a more detailed assessment related to the specific criteria of the CRCF.

4.3. Discussion and recommendations of the European Commission and other EU projects for ensuring Carbon Farming Activities.

In the framework of the ORCASA project, Batjes et al. (2023) developed a review of the global diversity in application contexts, ecosystems, frameworks, methodologies, and tools used for MRV of SOC and GHG changes. Recognizing the need for a consistent and scalable MRV system, a novel framework was developed, building on previous influential work. This framework details the individual components of MRV, emphasizing the importance of uncertainty assessment. Analysis showed a fairly uniform distribution of MRVs without clear clusters. Future efforts could involve stakeholder workshops to refine key characteristics of MRV methodologies.

On November 2023 the consortium of the MARVIC project published recommendations on 8 key points[42] regarding baselines. These recommendations were based on the amended version of the CRCF of 11/10/2023[43]. The document critiqued the approach to baseline propositions and suggested the adoption of a different approach. The eight points of attention proposed were:

1. Clarify what is a standardized baseline.
2. Give the possibility to use either specific or standardized baselines according to the carbon farming situation of the farm.
3. Carry out multi-year baselines to consider interannual climate and management variability, which has a strong impact on the agricultural climate balance.
4. Calculate the baseline on the perimeter of the entire farm to avoid leakage between fields within a farm.
5. Limit the diversity of types of carbon certificates.
6. Express all credits in the same unit (ton CO2-eq).
7. Standardize the baseline approach for the calculation of $GHG_{associated}$.
8. Clarify the situation where $GHG_{associated}$ is negative.

Some of these points have been modified in the new CRCF agreement.

The CREDIBLE project has developed a Focus Groups that generates periodic outcomes such as key messages, tensions and opportunities for advancing carbon farming in the EU. Recently, each focus group have developed a series of expert reports Recently, each focus group has developed a series of expert reports that are in the public consultation stage that cover different topics regarding the adoption of Carbon Farming, the implementation of MRVs and the certification process. The reports are[44]:

1. How to identify and promote best carbon farming practices.

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[42] The document can be consulted on https://www.project-marvic.eu/resources (cosulted in June 2024)

[43] This is a previous version of the CRCF agreement and it is no longer valid.

[44] The reports are available in the project's website https://www.project-credible.eu/consultations.

2. Supporting positive synergies between carbon farming, food production and biodiversity.
3. Developing fit-for-region carbon farming approaches.
4. Minimum requirements to ensure carbon delivers sustainability benefits.
5. The issue of scale for the carbon certification framework.
6. An effective policy mix for scaling up carbon farming.
7. How to harmonise public and private datasets for mapping and monitoring soil carbon dynamics.
8. Proximal sensing and digitalisation for carbon farming.
9. Earth observation for the monitoring, reporting, and verification of carbon farming.
10. How long-term monitoring sites could support robust MRV systems.

During the 4th Meeting of the Carbon Removals Expert Group (April 2024)[45] was developed the discussion of preliminary findings of the Technical Assessment Papers on Agriculture (agroforestry, soil organic carbon) where the outcomes were grouped in three blocks and the major findings were:

1. **Definition of carbon farming activities**
    - Inclusion of agroforestry in the agricultural land methodology (rather than in forestry methodology).
    - Preference of focus group for inclusion of biochar under the methodology for agricultural land management.
    - Criteria-based approach was preferred to a specific list of eligible practices.
    - Potential trade-offs should be prevented by the minimum sustainability criteria and the potential lower effectiveness of a practice should be reflected in the quantification methodology.
    - The carbon pools should be defined at a minimum sampling depth of 30 cm, but in the case of no/reduced tillage also look at the subsoil.
2. **Quantification, Baseline and Additionality**
    - Hybrid approach combining soil sampling, modelling, and remote sensing, in line with CIRCASA recommendations.
    - Set out criteria on transparency and accuracy of measurements rather than imposing forward-specific measurement techniques.
    - Direct emissions: based on IPCC guidance.
    - Express uncertainty at the level of a project (i.e. a group of operators).
    - Tiered approach: use a default uncertainty factor with a higher discount, and a lower discount can be used if the uncertainty is proven lower.
    - A hybrid approach with different types of data (national, regional, local and activity-specific data) to be incorporated in the standardised baseline.
    - The reference period of 3-5 years covers the start and end of crop rotation.
    - Quantification approach of activity and baseline should be comparable.
    - Low trust in financial additionality tests, in carbon farming non-financial barriers are more important.
    - Allow public co-funding and sharing of financial risks.
3. **Storage, Monitoring and Liability and Sustainability**
    - Short activity period (e.g. 5 years).
    - No consensus on whether the monitoring period should be the same or longer than the activity period.

[45] The recording of the session and the documents are available in https://climate.ec.europa.eu/news-your-voice/events/4th-eu-carbon-removals-expert-group-meeting-2024-04-15_en (consulted in June 2024).

- Liability mechanisms and incentives should take into account a longer monitoring period.
- Use a buffer pool approach, possibly combined with other mechanisms (e.g. insurance products).
- Use a negative list of practices that risk harming the sustainability objectives.
- Avoid metrics that imply additional data collection.
- Quantitative assessment can be applied in case no additional data collection is needed.
- Combination of on-farm data collection, remote sensing (e.g. crop diversity, landscape features, agro-ecological practices), and modelling (nutrient/sediment run-off, surface and groundwater withdrawals).

5. Conclusions

1. Carbon Farming is a new and innovative business model that encourages farmers to integrate activities that deliver a climate benefit such as climate change mitigation and adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity.
2. This new model has a wide range of applications in the Mediterranean basin because it is one of the most important areas to develop agriculture worldwide. However, the effectiveness of Carbon Farming activities largely depends on environmental characteristics (climate and soil) and their proper implementation in region-specific sites.
3. Regenerative agriculture and agroforestry practices represent the greatest carbon removal potential for the Mediterranean region; however, it is necessary to highlight that to achieve these results it is necessary to carry out holistic management of all carbon pools in the soil, materials, and vegetation, also integrating the flows of CO2 and methane.
4. In order to incentivize Carbon Farming activities in the region, it's important to explore different payment models such as ecosystem services payments, cap-and-trade systems, and carbon offset programs. When designing and expanding these payment structures, it's vital to thoroughly evaluate the opportunities and risks involved.
5. It is necessary to develop appropriate monitoring, reporting, and verification (MRV) models for the region, specifically in quantifying SOC stocks in semiarid climate zones and considering the region's soil diversity.
6. The Carbon Removals and Carbon Farming (CRCF) provisional agreement has the capability to establish a regulatory framework that provides certainty, reliability, and transparency for certifying carbon removal. This will also create new business opportunities. Therefore, it is highly recommended for the project to continue discussions on the certification schemes that will be validated by this regulation.

6. References

Aguilera, E., Lassaletta, L., Gattinger, A., Gimeno, B.S., 2013. Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: A meta-analysis. Agric. Ecosyst. Environ. 168, 25–36. https://doi.org/https://doi.org/10.1016/j.agee.2013.02.003

Álvaro-Fuentes, J., Plaza-Bonilla, D., Arrúe, J.L., Lampurlanés, J., Cantero-Martínez, C., 2014. Soil organic carbon storage in a no-tillage chronosequence under Mediterranean conditions. Plant Soil 376, 31–41. https://doi.org/10.1007/s11104-012-1167-x

Andrés, P., Doblas-Miranda, E., Rovira, P., Bonmatí, A., Ribas, À., Mattana, S., Romanyà, J., 2022. Agricultural Potential in Carbon Sequestration. Humus Content L. Used Agric. CO2 Storage 655–699.

Batjes, N.H., Ceschia, E., Heuvelink, G.B.M., Demenois, J., Le Maire, G., Cardinael, R., Arias Navarro, C., van Egmond, F., 2023. International review of current MRV initiatives for soil carbon stock change assessment and associated methodologies 122.

Bossio, D.A., Cook-Patton, S.C., Ellis, P.W., Fargione, J., Sanderman, J., Smith, P., Wood, S., Zomer, R.J., von Unger, M., Emmer, I.M., Griscom, B.W., 2020. The role of soil carbon in natural climate solutions. Nat. Sustain. 3, 391–398. https://doi.org/10.1038/s41893-020-0491-z

Bumbiere, K., Diaz Sanchez, F.A., Pubule, J., Blumberga, D., 2022. Development and Assessment of Carbon Farming Solutions. Environ. Clim. Technol. 26, 898–916. https://doi.org/10.2478/rtuect-2022-0068

Burgess, P.J., Rosati, A., 2018. Advances in European agroforestry: results from the AGFORWARD project. Agrofor. Syst. 92, 801–810. https://doi.org/10.1007/s10457-018-0261-3

Carbocert, 2020. Guía de buenas prácticas agrarias Carbocert "Secuestro de carbono y mejora de los suelos en cultivos agrícolas mediterráneos."

Carranca, C., Pedra, F., Madeira, M., 2022. Enhancing Carbon Sequestration in Mediterranean Agroforestry Systems: A Review. Agric. 12, 1–16. https://doi.org/10.3390/agriculture12101598

COWI, Ecologic Institute, IEEP, 2021. Technical Guidance Handbook - Setting up and implementing result-based carbon farming mechanisms in the EU.

COWI, Ecologic Institute, IEEP, 2020. Analytical Support for the Operationalisation of an EU Carbon Farming InitiativeCLIMA/C.3/ETU/2018/007Lessons learned from existing result-based carbon farming schemes and barriers & solutions for implementation within the EU 1–260.

Dawes, A., McGready, C., Majkut, J., 2023. Voluntary Carbon Markets A Review of Global Initiatives and Evolving Models.

De Rosa, D., Ballabio, C., Lugato, E., Fasiolo, M., Jones, A., Panagos, P., 2024. Soil organic carbon stocks in European croplands and grasslands: How much have we lost in the past decade? Glob. Chang. Biol. 30, 1–15. https://doi.org/10.1111/gcb.16992

del Pozo, A., Brunel-Saldias, N., Engler, A., Ortega-Farias, S., Acevedo-Opazo, C., Lobos, G.A., Jara-Rojas, R., Molina-Montenegro, M.A., 2019. Climate change impacts and adaptation strategies of agriculture in Mediterranean-climate regions (MCRs). Sustain. 11, 1–16. https://doi.org/10.3390/su11102769

Domínguez, I.P., Fellmann, T., Witzke, P., Weiss, F., Hristov, J., Himics, M., Barreiro-Hurlé, J., Gómez-Barbero, M., Leip, A., Fellmann, T., 2020. Economic assessment of GHG mitigation policy options for EU agriculture: A closer look at mitigation options and regional mitigation costs. https://doi.org/10.2760/4668

Don, A., Seidel, F., J, L., Kätterer, T., Martin, M., Pellerin, S., Emde, D., Seitz, D., Chenu, C., 2023.

Carbon sequestration in soils and climate change mitigation – Definitions and pitfalls (Opinion paper)). Submitt. Glob. Chang. Biol. https://doi.org/10.1111/gcb.16983

Drexler, S., Gensior, A., Don, A., 2021. Carbon sequestration in hedgerow biomass and soil in the temperate climate zone. Reg. Environ. Chang. 21, 74. https://doi.org/10.1007/s10113-021-01798-8

EEA-UNEP, M.A.P., 2014. Horizon 2020 Mediterranean Report: Israel, EEA Technical Report.

European-Environmental-Agency, 2020. The European environment-state and outlook 2020. Knowledge for transition to a sustainable Europe, European Environmental Agency. https://doi.org/10.15196/TS600305

FAO-ITPS, 2020. Gsoc MRV Protocol. A protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes.

FAO, 2021. V3 - Recarbonizing global soils - A technical manual of recommended management practices: cropland, grassland, integrated systems and farming, Recarbonizing global soils: A technical manual of recommended sustainable soil management.

Francaviglia, R., Ledda, L., Farina, R., 2018. Organic Carbon and Ecosystem Services in Agricultural Soils of the Mediterranean Basin. Springer International Publishing. https://doi.org/10.1007/978-3-319-90309-5_6

He, L., Zhang, A., Wang, X., Li, J., Hussain, Q., 2019. Effects of different tillage practices on the carbon footprint of wheat and maize production in the Loess Plateau of China. J. Clean. Prod. 234, 297–305. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.06.161

Joffre, R., Rambal, S., 2001. Mediterranean Ecosystems, in: ELS. https://doi.org/https://doi.org/10.1038/npg.els.0003196

Jordon, M.W., Willis, K.J., Bürkner, P.C., Haddaway, N.R., Smith, P., Petrokofsky, G., 2022. Temperate Regenerative Agriculture practices increase soil carbon but not crop yield—a meta-analysis. Environ. Res. Lett. 17. https://doi.org/10.1088/1748-9326/ac8609

Kay, S., Rega, C., Moreno, G., den Herder, M., Palma, J.H.N., Borek, R., Crous-Duran, J., Freese, D., Giannitsopoulos, M., Graves, A., Jäger, M., Lamersdorf, N., Memedemin, D., Mosquera-Losada, R., Pantera, A., Paracchini, M.L., Paris, P., Roces-Díaz, J. V., Rolo, V., Rosati, A., Sandor, M., Smith, J., Szerencsits, E., Varga, A., Viaud, V., Wawer, R., Burgess, P.J., Herzog, F., 2019. Agroforestry creates carbon sinks whilst enhancing the environment in agricultural landscapes in Europe. Land use policy 83, 581–593. https://doi.org/10.1016/j.landusepol.2019.02.025

Lal, R., 2020. Soil and Fertilizers Managing the Environmental Footprint, First edit. ed. CRC Press, Boca Raton, FL.

Lal, R., Negassa, W., Lorenz, K., 2015. Carbon sequestration in soil. Curr. Opin. Environ. Sustain. 15, 79–86. https://doi.org/https://doi.org/10.1016/j.cosust.2015.09.002

Lugato, E., Leip, A., Jones, A., 2018. Mitigation potential of soil carbon management overestimated by neglecting N2O emissions. Nat. Clim. Chang. 8, 219–223. https://doi.org/10.1038/s41558-018-0087-z

McDonald, H., Frelih-Larsen, A., Keenleyside, C., Lóránt, A., Duin, L., Andersen, S.P., Costa, G., Aubert, G., Hiller, N., 2021. Carbon farming, Making agriculture fit for 2030. European Parliamentary Research Service.

Pagella, T., Kmoch, L., Leudeling, E., Mulia, R., ..., 2014. Agroforestry from Mediterranean Partner Countries: Report on possible technology transfer from Mediterranean Partner countries to European countries. ... Eur. Cranf. ....

Pardo, G., del Prado, A., Martínez-Mena, M., Bustamante, M.A., Martín, J.A.R., Álvaro-Fuentes, J., Moral, R., 2017. Orchard and horticulture systems in Spanish Mediterranean coastal areas: Is there a real possibility to contribute to C sequestration? Agric. Ecosyst. Environ. 238, 153–167. https://doi.org/https://doi.org/10.1016/j.agee.2016.09.034

Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A., Doelman, J., Emmet-Booth, J., Engelmann, J., Fricko, O., Frischmann, C., Funk, J., Grassi, G., Griscom, B., Havlik, P., Hanssen, S., Humpenöder, F., Landholm, D., Lomax, G., Lehmann, J., Mesnildrey, L., Nabuurs, G.J., Popp, A., Rivard, C., Sanderman, J., Sohngen, B., Smith, P., Stehfest, E., Woolf, D., Lawrence, D., 2021. Land-based measures to mitigate climate change: Potential and feasibility by country. Glob. Chang. Biol. 27, 6025–6058. https://doi.org/10.1111/gcb.15873

Schillinger, W.F., Schofstoll, S.E., Alldredge, J.R., 2008. Available water and wheat grain yield relations in a Mediterranean climate. F. Crop. Res. 109, 45–49. https://doi.org/10.1016/j.fcr.2008.06.008

Scott, J., 2024. Climate Change Economics: Carbon Capitalism, Regenerative Agriculture, Urban Farming & Beyond [WWW Document]. 2024. URL https://envirotechaccelerator.org/climate-change-economics-carbon/

Sharififar, A., Minasny, B., Arrouays, D., Boulonne, L., Chevallier, T., van Deventer, P., Field, D.J., Gomez, C., Jang, H.-J., Jeon, S.-H., Koch, J., McBratney, A.B., Malone, B.P., Marchant, B.P., Martin, M.P., Monger, C., Munera-Echeverri, J.-L., Padarian, J., Pfeiffer, M., Richer-de-Forges, A.C., Saby, N.P.A., Singh, K., Song, X.-D., Zamanian, K., Zhang, G.-L., van Zijl, G., 2023. Chapter Four - Soil inorganic carbon, the other and equally important soil carbon pool: Distribution, controlling factors, and the impact of climate change, in: Sparks, D.L.B.T.-A. in A. (Ed.), . Academic Press, pp. 165–231. https://doi.org/https://doi.org/10.1016/bs.agron.2022.11.005

Smith, P., Soussana, J.F., Angers, D., Schipper, L., Chenu, C., Rasse, D.P., Batjes, N.H., van Egmond, F., McNeill, S., Kuhnert, M., Arias-Navarro, C., Olesen, J.E., Chirinda, N., Fornara, D., Wollenberg, E., Álvaro-Fuentes, J., Sanz-Cobena, A., Klumpp, K., 2020. How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. Glob. Chang. Biol. 26, 219–241. https://doi.org/10.1111/gcb.14815

Teague, W.R., Apfelbaum, S., Lal, R., Kreuter, U.P., Rowntree, J., Davies, C.A., Conser, R., Rasmussen, M., Hatfeld, J., Wang, T., Wang, F., Byck, P., 2016. The role of ruminants in reducing agriculture's carbon footprint in North America. J. Soil Water Conserv. 71, 156–164. https://doi.org/10.2489/jswc.71.2.156

van Baren, S., Arets, E., Dankers, C., Peter Lesschen, J., Sybenga, J., Demmendal-Wit, F., Karsch, P., 2023. Review of certification methodologies for carbon farming-survey results and first assessment of coverage of the QU.A.L.ITY criteria.

Van Hoof, S., 2023. Climate Change Mitigation in Agriculture: Barriers to the Adoption of Carbon Farming Policies in the EU. Sustain. 15. https://doi.org/10.3390/su151310452

Villat, J., Nicholas, K.A., 2023. Quantifying soil carbon sequestration from regenerative agricultural practices in crops and vineyards. Front. Sustain. Food Syst. 7, 1–12. https://doi.org/10.3389/fsufs.2023.1234108

World Bank, 2021. Soil Organic Carbon MRV Sourcebook for Agricultural Landscapes, Soil Organic Carbon MRV Sourcebook for Agricultural Landscapes. https://doi.org/10.1596/35923

Zdruli, P., 2014. Land resources of the Mediterranean: Status, pressures, trends and impacts on future regional development. L. Degrad. Dev. 25, 373–384. https://doi.org/10.1002/ldr.2150

7. Annexes

7.1. Annexe 1 - "Carbon sequestration" and related terms

The Policy Brief of the EJP Soil Programme published on December 2023 mentioned "A recent study shows that even in scientific publications on the subject, technical terms are not always used correctly. This result is illustrated by an analysis of 100, recent, international publications, the majority of which misused terms surrounding C and climate change. It is not just a matter of quibbling over words - imprecise wording can lead to inflated expectations of measures. climate protection". Don et al., (2023) defined different terms for improving and clarifying definitions around carbon (C) sequestration in soils (see the image below).

Term	Definition
C sequestration in soils	Process of transferring C from the atmosphere into the soil through plants or other organisms, which is retained as soil organic carbon resulting in a global C stock increase of the soil (based on IPCC, 2001; Olson et al., 2014)
SOC loss mitigation	An anthropogenic intervention to reduce SOC losses compared to a business-as-usual scenario
Negative emission	Net removal of CO_2-equivalents of greenhouse gases from the atmosphere
Climate change mitigation	An anthropogenic intervention that reduces the sources or enhance the sinks of greenhouse gases (based on IPCC, 2021)
SOC storage	The size of the SOC pool (i.e., SOC stock or SOC content)
SOC accrual	An increase in SOC stock at a given unit of land, starting from an initial SOC stock or compared to a business-as-usual value (does not always result in climate change mitigation or C sequestration in soils)

Figure 4. Proposed definitions of key terms.

7.2. Annexe 2 – Components of a Monitoring, Reporting, and Verification (MRV) framework.

A MRV protocol according to (FAO-ITPS, 2020) involves a series of step-by-step stages and sub-protocols to assess changes in SOC and GHG emissions or removals through sustainable soil management (SSM) practices. The FAO-ITPS protocol proposed six stages for developing a correct assessment:

1. **Applicability Conditions (S1):** Intended to verify that the project and activities meet the requirements for this methodology to be applicable.
2. **Boundaries (S2)**: The project's spatial and temporal boundaries.
3. **Baseline and Intervention Scenarios (S3):** Indicating historic and projected relevant activity data for the different areas to be assessed.

4. **Additionality Assessment (S4):** Perform a preliminary assessment of the additionality of projected practices, using SOC modelling and standardized methodologies.
5. **Monitoring (S5):** Implement monitoring of the practices, with general methodologies.
6. **Reporting (S6):** indicating performed activities, soil sampling results and modelling estimates.

Later as an output of the CIRCASA project, Smith et al. (2020) proposed to create building blocks MRV for croplands and provided a methodological basis for the ground monitoring, modelling and verification of SOC stock changes. Implementing the MRV system requires integrating various datasets (e.g., model inputs, calibration data) with different models (e.g., empirical, soil process, crop models) within a spatial data infrastructure (SDI). This SDI handles database management, computing, decision support, and MRV result distribution (Figure 5).

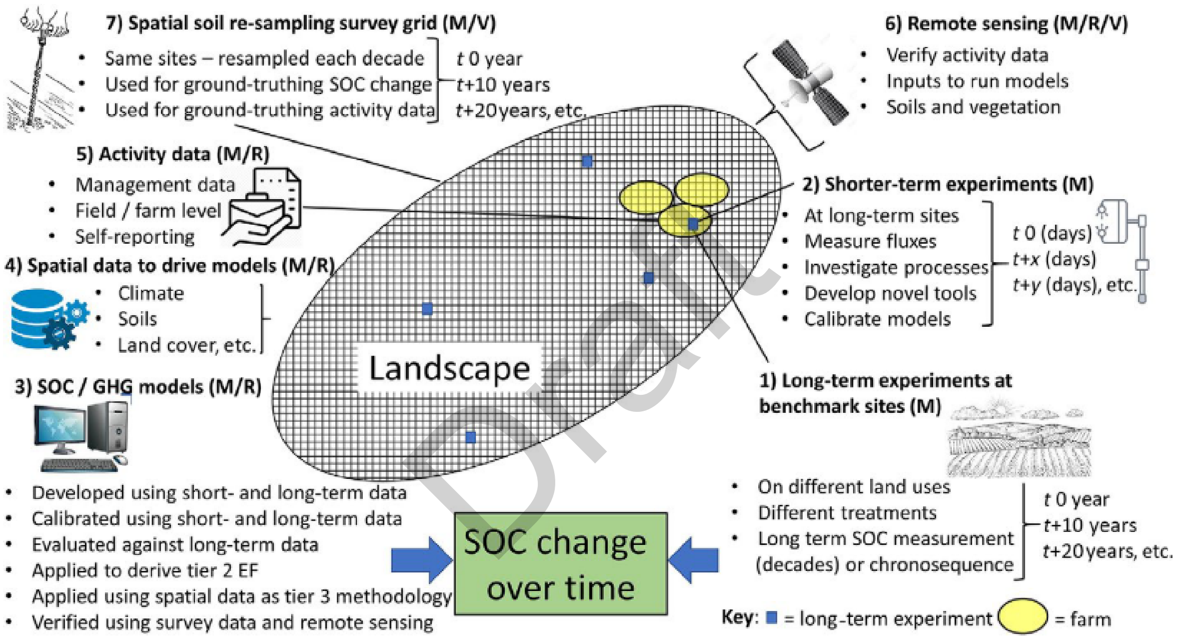


Figure 5. Components of a soil measurement/monitoring, reporting and verification framework according to Smith et al. (2020). The caps letters in the brackets indicate the different blocks of contribution: measurement/monitoring (M), reporting (R) or verification (V).

The latest approach presented by the ORCASA project (a continuation of CIRCASA) stated that the approach of the MRV greenhouse gas emissions and carbon sequestration activities depends on the size of the area being monitored, the availability and accuracy of input data (e.g., climate, remote sensing, soil properties, or activity data), sampling and measurement protocols, monitoring frequency, the scale of interest (e.g., farm/plot level, landscape level, subnational, national, and international), and the specific purposes (e.g., carbon farming, insetting, CAP, NDCs). Based on this approximation they defined a MRV framework composed of three components (see Figure 6). An important thing is that the individual parts that can be combined to create the MRV itself. A comprehensive analysis of the strengths and limitations of this approach can be found in the report published by Batjes et al. (2023).

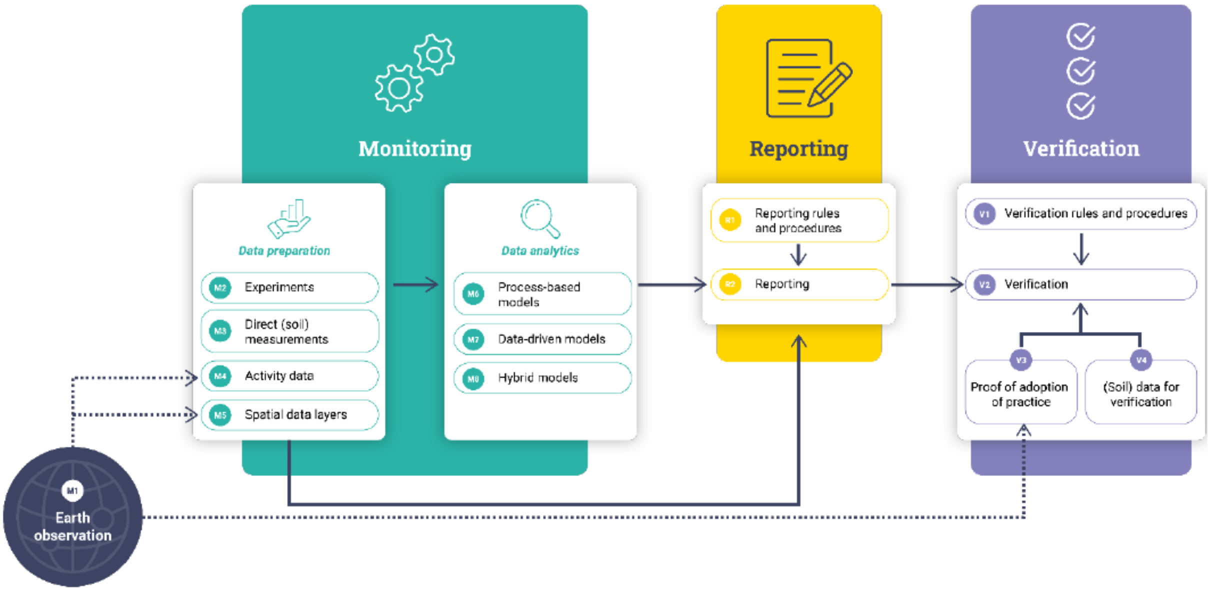
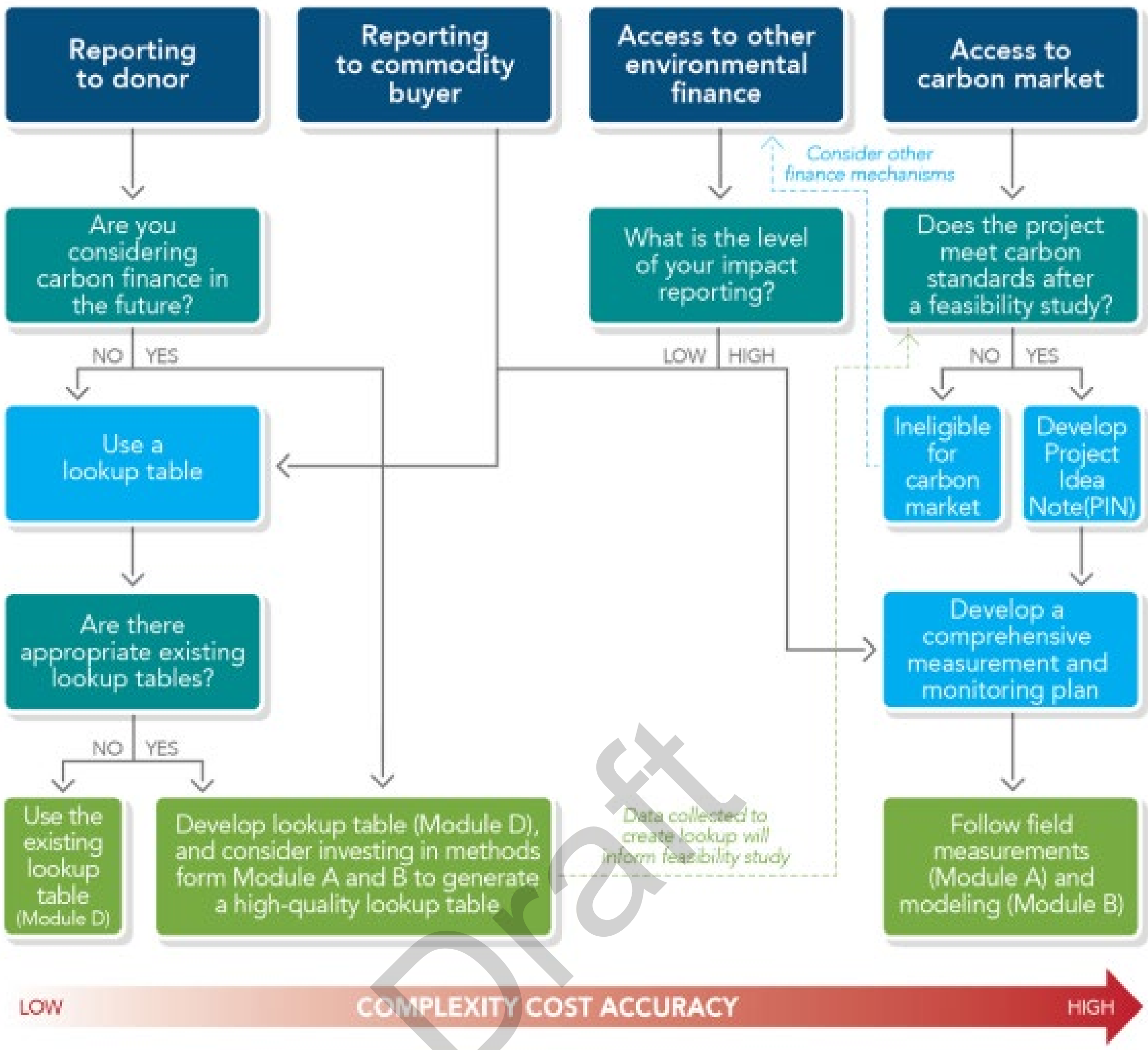


Figure 6. Schematic representation of components, building blocks, and information flow for a generic, scalable MRV system proposed by the ORCASA project. Source: Batjes et al. (2023).

7.3. Annexe 3 – Decision-making tree for choosing a soil carbon assessment approach.

Decision tree of monitoring approaches on Carbon sequestration or removal projects

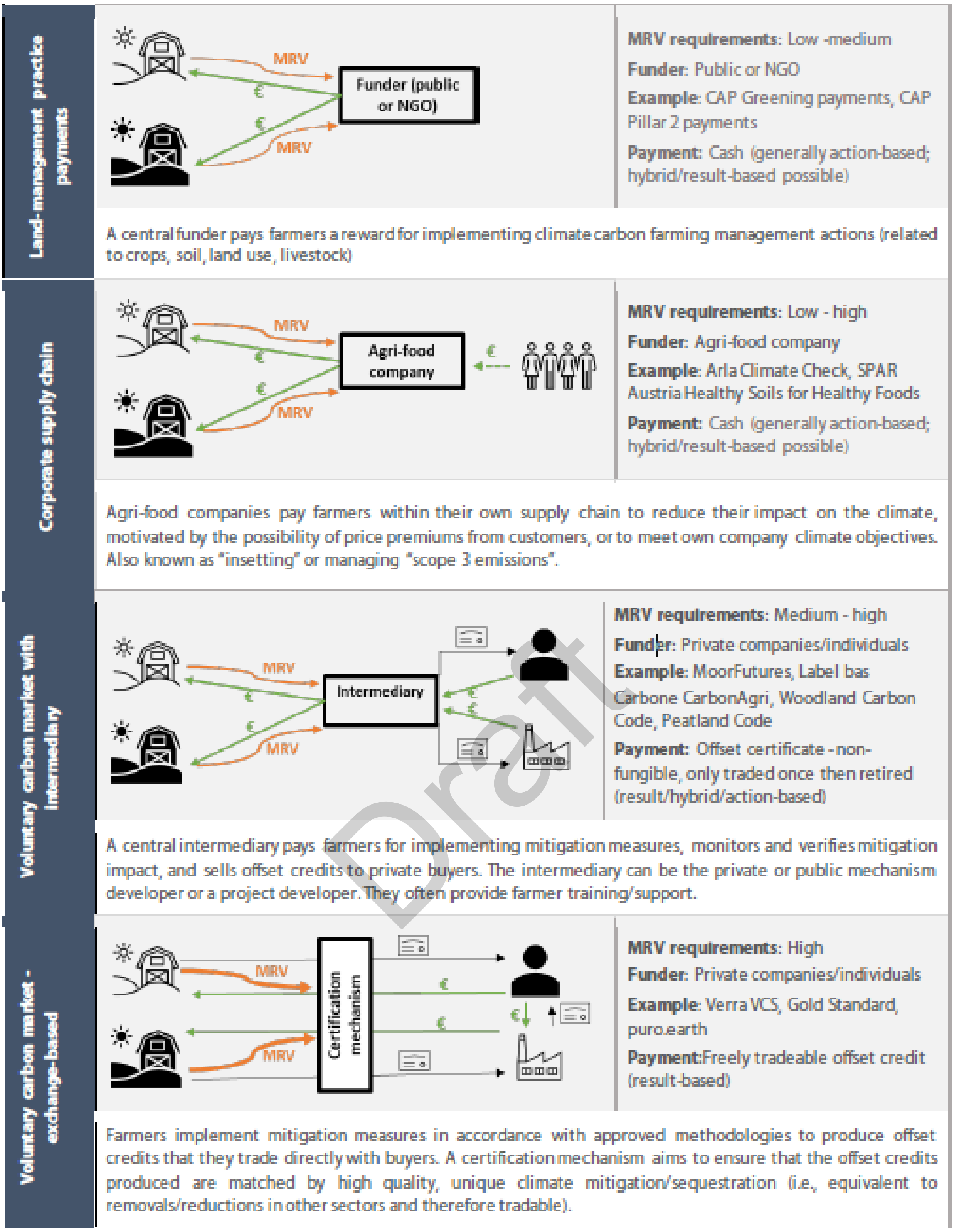
“Despite the different levels of accuracy of these options and thus the uncertainty associated with the soil carbon estimates they generate, all data, methods, and calculations need to meet the required level of quality and detail laid out by the carbon finance or reporting framework followed, and in any case must align at minimum with basic requirements set forth by the IPCC Guidelines on general guidance and reporting of GHG inventories, adopted by NDCs and Biennial update Reports (BURs) to the UNFCCC.”



Source: World Bank (2021)

7.4. Annexe 4 – Models for Carbon Farming mechanisms

Diagrammatic representations and examples of different models for Carbon Farming payments.



Source: McDonald et al., (2021)

7.5. Annexe 5 – Quantification of temporary net carbon removal benefit and net soil emission reduction benefit in the CRCF agreement.

According to Chapter 2, article 4 of the CRCF agreement Carbon Farming activities can provide a:

$$\boldsymbol{Temporary\ net\ carbon\ removal\ benefit = CRbaseline - CRtotal - GHGassociated > 0}$$

Equation 1.

Where:

(a) $CR_{baseline}$ is the carbon removal under the baseline,

(b) CR_{total} is the total carbon removal of the activity,

(c) $GHG_{associated}$ is the increase in direct and indirect greenhouse gas emissions, over the entire lifecycle of the activity which are due to its implementation, including indirect land use change, calculated, where applicable, in accordance with protocols set forth in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and any further refinement.

Or can provide a **net soil emission reduction benefit,** quantified with the equation 2.

$$\boldsymbol{Net\ soil\ emission\ reduction\ benefit = LSEbaseline - LSEtotal + ASEbaseline - ASEtotal - GHGassociated > 0}$$

Where:

(a) $LSE_{baseline}$ are the LULUCF soil emissions under the baseline;

(b) LSE_{total} are the total LULUCF soil emissions of the activity;

(c) $ASE_{baseline}$ are the agricultural soil emissions under the baseline;

(d) ASE_{total} are the total agricultural soil emissions of the activity.

(e) Not included in the agreement.

(f)Not included in the agreement.

(g) $GHG_{associated}$ is the increase in direct and indirect greenhouse gas emissions, over the entire lifecycle of the activity which are due to its implementation, including indirect land use change, calculated, where applicable, in accordance with protocols set forth in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and any further refinement.