CARBON FARMING SCHEME

LIFE Preparatory Project

LIFE Carbon Farming Scheme final report:

Guidance for future carbon farming schemes

Best practices for expanding carbon sequestration activities

LIFE19 PRE FI001 – SI2.828588
The Life Carbon Farming project has received funding from the LIFE Programme of the European Union

LIFE CarbonFarmingScheme

Expanding carbon sequestration activities by providing best practices and guidance for future farming schemes

The goal of the project is to identify and accelerate the development and adoption of novel incentives for carbon sequestration and the increase and maintenance of the organic carbon stock in soil and biomass in Europe. With the aim of promoting a well-functioning voluntary carbon market the project will uncover the key factors in supply and demand measures to invite the private sector to accelerate climate action. The results of the project will be fed into the development of the EU agricultural and climate policies.

Read more: www.st1.com/st1-life

Coordinator: St1

Partners: BSAG, Tyynelän tila, Luke Natural Resources Institute Finland, Puro.earth, NEOT North European Oil Trade

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The LIFE Preparatory Project

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Definitions

Additionality

Financial additionality refers to actions that the project owner would only take if they receive rewards from the mechanism. In other words, that without the mechanism rewards, the costs of the action would outweigh the benefits for the project owner.

Environmental additionality refers to whether the mechanism induces climate actions that would not have occurred in the absence of the mechanism and that lead to additional GHG reductions from atmosphere.

Baseline

A reference scenario against which a change in greenhouse gas emissions or removals is measured.

Carbon farming and carbon forestry

Nature-based practices performed in agriculture or forestry in order to sequester greenhouse gases from the atmosphere.

Compliance market

A system where a company can use carbon credits as a mechanism that contributes to reaching legally binding targets.

CRC

Carbon removal credit. A credit covering one ton of CO_2 e removed from the atmosphere and stored.

Voluntary carbon market

A market where parties such as companies and private persons can voluntarily offset their emissions by buying carbon credits. In a voluntary market, the credits cannot be used to fulfil legally binding climate targets.

Definitions

CORC

CO_2 Removal Certificates that Puro.Earth issues to net-negative carbon removal projects. CORC20 refers to a CORC issued for removal with permanence of 20 years.

AKIS

Agricultural Knowledge and innovation Systems

MVR

Monitoring, reporting and verification

Trading Pilot

Puro.Earth Trading Pilot executed on Puro.Earth platform with Soilfood's CORC20 credits during the project. The Trading Pilot consisted of new methodology development including collecting the necessary evidence of carbon removal and trading the produced CORCs in the voluntary market.

WPA1 Work package A1

WPA2 Work package A2

WPA3 Work package A3

WPA4 Work package A4

WPC3 Work package C3

Introduction

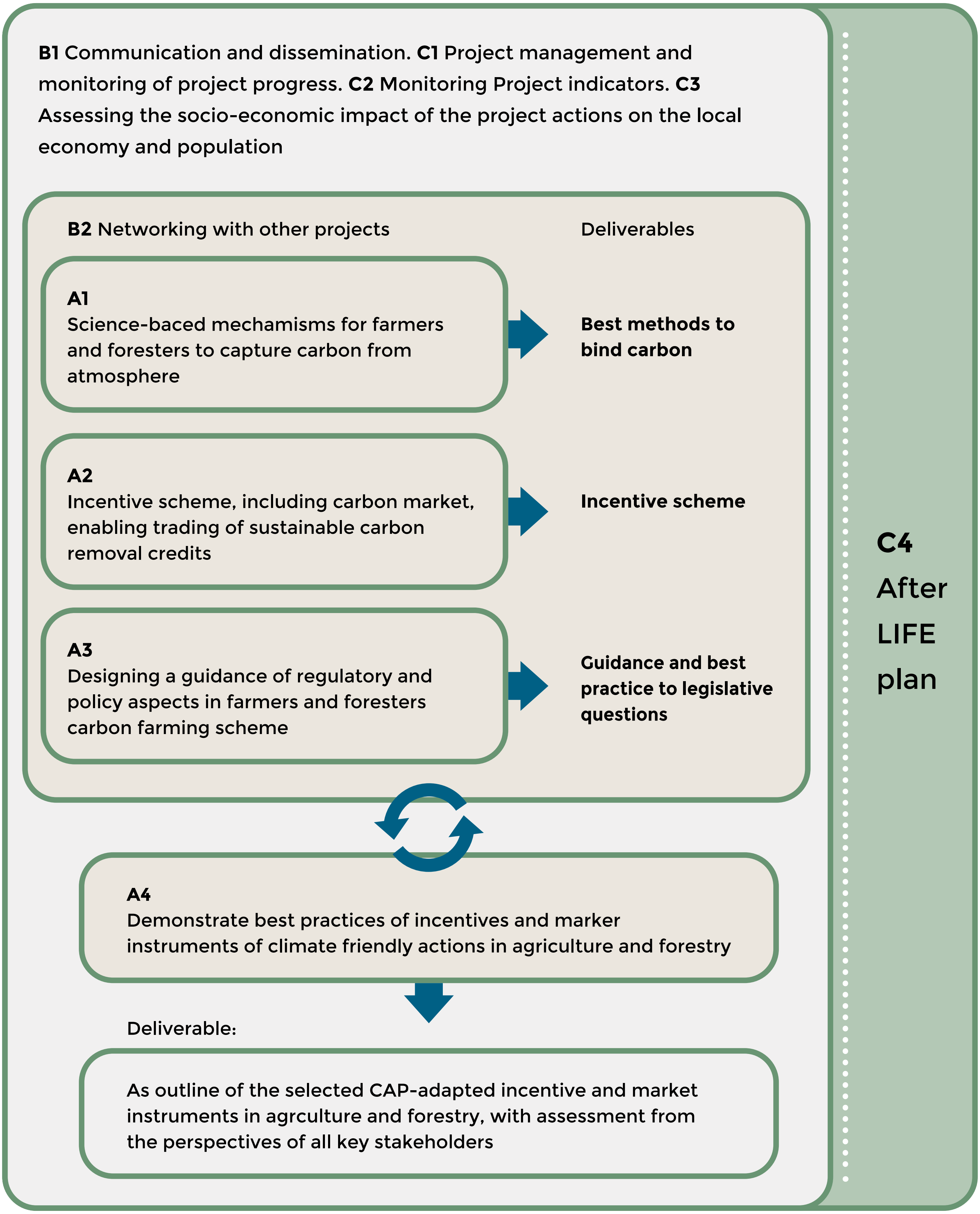
With the Climate Law, the EU and its Member States agreed to a Union-wide climate net-zero neutrality target by 2050, meaning the excess greenhouse gas emissions need to be matched by same amount of carbon removals. As a next step, the Commission is working on a regulatory framework for the certification of these carbon removals in order to ensure their accuracy and account them against the emissions.

The Commission published on 15 December 2021 the Communication on Sustainable Carbon Cycles, which presented a roadmap for next actions. As a next step, the Commission will propose by the end of 2022 a proposal for Regulation which would set certification criteria for the quality of measurement, monitoring, reporting, and verification, as well as wider environmental sustainability, such as impacts on biodiversity and the amount of energy used.

The LIFE Carbon Farming Scheme pursues the promotion of carbon sequestration activities by providing best practices and guidance for future carbon farming schemes. This report concludes the work and compiles key findings and results from the project for the framework development.

The project has demonstrated the value of carbon farming in the context of future carbon market for removals and tested its functionality in practice. The project started by analysing current voluntary and compliance market schemes, followed by research on calculation methods applied in carbon sink quantitative estimations. As a next step, the calculation methods were tested with 17 case farms and foresters in 9 different EU countries by modelling carbon sequestration potential with chosen carbon farming methods. Additionally, the project compiled a system cost analysis for setting up the carbon farming scheme and found a possible solution for incentivising both supply and demand in setting up carbon contracts for difference. During the project, a novel carbon sequestration soil amendment methodology was developed and the carbon removal credits from a Puro.Earth Trading Pilot part of the project were traded. Involving key stakeholders in the carbon market value chain, the project implemented a survey and interviews on carbon market feasibility and attractiveness. In every step of the project work the criteria, permanence, additionality, etc., have played a large role and for a regulatory framework it is clear that robust definitions are required.

The guidance gives a comprehensive summary of our project findings and raises the topics that are important to acknowledge in designing the EU carbon removals regulatory framework.



Picture 1. LIFE Carbon Farming Scheme project work plan.

1. Key messages

1.1. Addressing the knowledge gap, especially of farmers, is essential for creating an efficient certification framework for carbon removals via carbon farming

All work packages in this project emphasize the lack of information. There is a knowledge gap among farmers about new and different methods of carbon farming, as well as on the demand side which needs perspective e.g., how to claim credits with 20 years of permanence. Therefore, the essential part for a successful scheme is accurate information efficiently shared which can be extended with timely training that considers the local needs of supply side stakeholders.

The main interest for farmers is the viability of the business. There is an understanding that, in arable farming, the soil productivity, resilience to extreme weather and reduced costs of external inputs are keys to profitability. Farmers begin to see the positive correlation between environmental management and productivity of farming, including in the increased yields. Carbon sequestration and carbon market is considered a secondary aim and the fundamental requirement for the carbon market is accurate and reliable plot-level monitoring and verification.

For example, the project concluded that all carbon farming practices have the highest carbon additionality in the first 10 years upon their introduction. However, the farmers survey and interviews found that the optimal contract length for farmers is 5-10 years, meaning farmers are not keen to make longer commitments than 5 years. These inconsistencies must be overcome with sharing knowledge and creating trust between the demand and supply participants. It should be noted that the calculations and the survey approached individual carbon farming practices whereas in real life, it is meaningful to combine and implement several practices simultaneously and adopt a holistic 'carbon farming' approach.

1.2. For high quality carbon farming practices, the carbon removal certification scheme should be EU-wide

Establishing the same criteria in every Member State for each removal method from the beginning of the scheme would lead to accountability and comparability across national borders. In addition, credit transfers inside EU would not require updated rules. As found out in the market analysis of the project, all current schemes address key factors such as permanence and additionality differently. The comparability of the schemes is therefore a challenge, but it would an even bigger challenge to include all schemes in the same framework.

The project found that each carbon removal type requires its own rules or methodology to define criteria and monitoring for each carbon removal practice. An EU wide certification scheme would facilitate comparing each type of removals across countries and ensure that practices are implemented in a sensible manner – since same practice does not necessarily lead to same removal result in different climate zones. A coherent EU framework will ensure the quality of the carbon removals and methodologies. Robust and reliable comparability for removed CO_2 tons gives credibility across EU.

Transparency and reliability should be the key targets in the EU wide scheme. The reliable and transparent registry system of Carbon Removal Credits (CRC) plays a key role for the scheme to be user friendly and credible for the demand side in the value chain. The registry is also at the center of preventing double counting and double claiming. Based on the findings within the project there seems to be a need for a public centralized registry and scheme steering where a large part can consist of the information sharing responsibility and educating all the stakeholders that can join the scheme.

1.3. The Commission should develop common EU-wide rules for monitoring, reporting and verification (MRV) practices

The project found that different types of carbon removal methods need to be addressed individually and comprehensive methodologies need to be built for each of them. The certification scheme also needs a scientifically robust and comprehensive MRV system which can accommodate different nature-based carbon sequestration methods in different conditions. The project studied different aspects of the carbon criteria.

In order to build the credibility of carbon removal certificates, the criteria need to tackle the issue of the permanence of carbon removals, as well as the additionality and avoid double counting of the removals to ensure that beneficiaries do not receive double payment for the same practice.

Soil carbon accumulation and decomposition dynamics set boundaries for the permanence of carbon removals via carbon farming practices. The Trading Pilot offered 20 years of permanence, which was not a problem for farmers. Modelling and lab results indicated that roughly 20% of the share remains and is contracted to the buyer. However, for buyers it remains unclear what claim the buyer can make with the 20-year permanence.

Carbon additionality should be considered in the carbon removal certificates and is an essential feature which ensures the integrity of both payments and any credits based on the removals. The project findings include that all carbon farming practices (cover crops, green fallow, grassland area and cutting height changes, soil improvement fibres) have the highest carbon additionality compared to business as usual baseline in the first 10 years from their introduction.

The baselines are suggested to take into account relevant national, regional, or local circumstances and to ensure environmental integrity and baselines should be adapted over time in case of changes e.g., climate, climate targets, or technology. In terms of methodologies, the 'Business as usual' (comparing removals with forecasted values in a non-intervention scenario), the 'Historic emissions approach' (comparing removals with historic emissions) and the 'Benchmark Approach' (comparing removals with given benchmarks for soil carbon concentration) all fit well as an environmental baseline for carbon sinks. The 'Performance-Based Approach' (comparing similar removals in different locations) and the 'Best Available Technology Approach' (comparing removal technologies), seem to work better as a value of comparison, and not as a baseline as such. Moreover, the right choice for baseline depends to a large extent on the ambition level and expected accuracy level for carbon removals.

Double counting is a significant criterion and there are available solutions for preventing it. The methodology needs to include clear rules for this. The end-user of the credit cannot make a carbon accounting claims that the product is a carbon removal if the decoupled CO_2 removal certificate has been sold to and cancelled by another stakeholder not associated with the product.

1.4. The EU-wide certification rules need to also account for social, other environmental and sustainability impacts

A carbon farming certificate system should emphasize that carbon farming and forestry actions are implemented in a sustainable manner. The survey and farmer interviews show that farmers expect carbon farming to widely benefit farming. Multiple benefits increase motivation to continue carbon farming practices longer and maintain carbon stocks and renew contracts after the initial 5-year period. Multiple benefits include improving soil fertility, water holding capacity, yield increase and biodiversity amongst another environmental additionality. Including multiple benefits in the certificate system could also invite more stakeholders to participate in the scheme.

Carbon farming and forestry are local actions that aim to solve global climate challenges. The carbon removal scheme should also assess the effects on humans, biodiversity, soil, water, and air to ensure that carbon farming actions are conducted sustainably. The Environmental Impact Assessment (EIA) is a tool to assess the risks. The importance of conducting the EIA increases with the growing project area and duration.

The project results also make it clear that there is a need to address the systemic issues when proceeding with the planning and implementation of an EU wide carbon farming scheme. Some of the most pressing issues are the potential trade-offs between carbon farming and food production.

The identification of social impacts must include a strong emphasis on stakeholder engagement. The responses to identified risks and impacts, the tracking of the project developments, and the results should all be communicated to stakeholders regularly and transparently.

1.5. The administrative burden on individual farmers should be mitigated by forming larger alliances of farmers or intermediaries acting on behalf of the farmer

The different work packages identified the need for larger consortiums or alliances other than individual farmers as operators in scheme. Within the Trading Pilot, over 80% of participating farmers wanted to be involved and be represented jointly by a central party. The administrative burden of monitoring, verification and third-party validation can be an important barrier for single small or medium scale farming and forestry businesses. As the impacts often extend beyond a single business or project, the responsibility should be shared among the whole value chain.

Thus, there is a need for a link between the farmers and the system. In the current context, this intermediary link needs to be rather active due to the existing knowledge gap of the participants. The scheme should continue to build on the carbon credit programs which are being developed globally and harmonize the overall approach with the development of regenerative agricultural schemes.

It is recognized that in upcoming years, the system costs are expected to come down due to rapid technological advancements and new policy measures. The near future investment support should be targeted setting up supply chains and adaptation of required technology for monitoring and verification.

1.6. There is a necessity for economic incentives to scale up carbon removals

The total costs of different carbon sequestration practices across the value chain are relatively high, especially the incurred system cost, which indicates that economic incentives to enhance the system investments are needed.

The financing options need to be cost-effective to attract investments. The project assessed a variety of financing options to encourage carbon sequestration, including public funding and private funding through a Carbon Removal Credits (CRC) market, compliance based and voluntary carbon credit markets, action-based and result-based funding, and ex-ante and ex-post credits. Different funding schemes can be combined to create a system that brings together best features of each funding stream.

Carbon Contracts for Difference (CCfD) is an example of a combination of public and private funding through the CRC market price, which can ensure stable and predictable prices. CCfDs can provide the necessary initial push for carbon farming investments, while the share of private funding share would increase over time.

The Finnish government has proposed to introduce a carbon market to incentivise private funding flows into carbon farming. The government is planning to authorise carbon credits, introduce verification standards and create a platform for marketplace which brings together voluntary markets. This can be an inspiration for an EU-wide policy framework for carbon farming.

Increasing flexibility between sectors is a means to incentivise private funding flow to carbon farming. The development of the climate actions in different sectors is asymmetric, which leads to a situation where the most cost-efficient actions are not taken, while at the same time, the additionality with any price is decreasing in another sector. Introducing more flexibility between sectors could help solve these kinds of deadlocks and help scale faster the initiatives that lack financing and thus take too long to deliver.

1.7. Proposal of a transport sector pilot project to kick-start investments to carbon farming

The lack of demand for the carbon farming credits shows that there is little incentive for the uptake of carbon farming practices on farms, and we are seeing a delay in the scaling up carbon farming methods as a result. On the other hand, the transport sector, a major contributor to carbon emissions, is a difficult-to-decarbonise sector where the abatement cost for CO_2 reductions are high. In the short-term, the two sectors could create a symbiosis via a well-planned pilot project to scale up cost-efficient CO_2 reductions and bring climate benefits without compromising the CO_2 reduction targets for both.

The proposed pilot project foresees that a percentage of the national renewable energy in transport target would be allowed to be covered by multiplying nature-based carbon removals. The transport sector would thus create a significant boost in demand for carbon farming in the near-term.

While it is understood that the CO_2 emissions from transport have a long life-span in the atmosphere, and the nature-based CO_2 -removals may not be permanent, this mechanism is a 'step-wise' pilot project that can subsequently be adapted in the light of learning and experience. The purpose is to create incentives for carbon farming to maximise removals via enabling the over-achievement of the transport sectors usage of renewable energy to incentivise removals that would not otherwise occur.

2. Setting the standards for the EU certification framework

2.1. Comprehensive rules for each type of carbon removals

This project has evaluated the carbon criteria from various aspects. Based on the findings there is a need to categorize different carbon removal types and build comprehensive methodologies for each of them. The project studied permanence, additionality, baseline, carbon leakage and double counting. Furthermore, biodiversity to some measure as a criterion was included. The project also tested the criteria in practice within the Trading Pilot by developing a novel methodology for soil amendment carbon removal certificate and trading credits. This section presents the project findings for carbon market criteria.

2.1.1. Permanence

Permanence is a perpetual topic in discussions of carbon removals. Our project shows that there are contradictions concerning permanence between expectations from the demand side and what the supply side can offer. The Trading Pilot offered 20 years of permanence which was considered short on the demand side. On the other hand, a one-time carbon application is an easier approach for farmers, as they are not willing to make commitments longer than 5 years. In this light, there is a challenge for farmers to achieve contracts that would ensure carbon farming that is attached to farming practices and not one-time applications, such as our Trading Pilot or biochar amendment. However, the survey and farmer interviews show that farmers have a need for multiple benefits such as improving soil fertility, water holding capacity, and biodiversity, which can be seen as a suitable motivation to continue carbon farming practices longer and maintain carbon stocks and renew the contracts after a 5 years period. Maintaining soil carbon stocks requires continuous implementation of carbon farming practices.

Furthermore, permanence seems to affect the economy of carbon removal credit (CRC). The demand side finds the 52€ / t CO_2 price high for 20-year credits, but farmers expect to be paid even four times what they would earn for this 20-year CRC. However, the price level has been received well by companies interested in non-forest-based carbon removal products. In this group of products, the price of Trading Pilot's carbon removal credits is seen highly attractive.

Table 1. Project's findings on permanence.

Permanence
Soil carbon accumulation and decomposing dynamics set boundaries for permanence handling. Maintaining soil carbon stocks requires continuous implementation of carbon farming practices. **WPA1**
The Trading Pilot case demonstrates CO2 storage (20 years): In the Trading Pilot case, the 20-year permanence was not difficult for farmers in practice, because external carbon input does not require monitoring or changing practises for 20 years. The 20-year durability requires one application of the Soil Amendment product. The Yasso07 modelling result and a lab result indicated how much amended carbon remains in the soil after 20 years. Only the share (roughly 20%) that remains is contracted to the buyer as CORC20 credits. The lifetime emissions according to the LCA-assessment are deducted from the stored carbon to get the net-sequestered tonnes of carbon dioxide represented by the Puro.Earth CORC20. **WPA4**
Farmer survey and interviews showed that the optimal contract length for farmers is 5-10 years. In other words, farmers are not keen to make longer commitments than 5 years and they also expect regular yearly income. **WPA4**
Demand side findings: The Trading Pilot case showed that 20 years of permanence is short for carbon credit buyers. They had direct concerns about the price of 52€ / tCO2 which was considered to be high compared to the permanence of 20 years. Furthermore, it is unclear what claim the buyer can make with the 20-year permanence. Buyers were unclear about the 20-year durability of the carbon storage and what kind of claim it justifies. **WPA4**

2.1.2. Additionality

Carbon removals must prove to be additional to guarantee the climate integrity and added value of carbon removals. Furthermore, carbon removals paid for must be additional to the removals the farmer would have carried out regardless. Additionality is therefore a crucial criterion to fulfil in the framework of carbon removal certification. Additionality of carbon removals is required, but the terms financial additionality and regulatory additionality are also used singly. This project's findings concern mostly environmental additionality and more specifically additionality of carbon removals, which is a result of implemented or modeled carbon farming and forestry practices. However, the project has also identified that with a carefully selected baseline, it is possible to improve the financial additionality of the project (chapter 2.1.3.). This chapter's findings concern carbon additionality unless otherwise stated.

The baseline plays an important role in ensuring actual amount of additional carbon in the soil. The rules for setting accurate, measurable and credible baseline for project is in central for the scheme success. The modeling of soil organic carbon levels in case farms (WPA1) showed that it is possible to increase carbon accumulation with additional farming practices. The Trading Pilot's additionality consisted of a new method to improve the use of biomass waste stream material pulp mill sludge and instead of incineration carbon containing fibres were applied to the soil. Proving additionality requires a precise and quantifiable baseline setting and demonstrating it reliably. Setting too low or thin baseline could hinder the carbon removal and climate outcome of actions. In current standards, for example Verra Standard, baselines are updated every 6-10 years or dynamically. This periodical baseline update would also fit well for farmers' commitment expectations.

The baseline setting can also prohibit carbon leakage. In case the baseline is set too low it might be attractive to decrease the soil organic carbon content of farmlands before entering the scheme.

See section 2.1.3. below for a discussion on the different baseline options.

Table 2. The project's findings on additionality.

Additionality and baseline
The Yasso07 model was used to calculate the soil carbon stock change over time. The results show that all carbon farming practices (cover crops, green fallow, extending grassland area, grassland cutting height changes, and soil improvement fibres) have the highest carbon additionality in the first 10 years upon their introduction. **WPA1**
In the Trading Pilot, the carbon removal is achieved by increasing the soil carbon stock by adding organic matter to the farmland i.e., in the form of soil improvement fibres. A proportion of the carbon (CO_2 eq.) is stored in the soil as durable carbon compounds. **WPA4**
The Trading Pilot demonstrates eligible additional activity as: Activity that transforms biomass residues such as pulp and paper mill sludges to soil amendment products that are utilized in agriculture to improve soil quality. Without the activity the sludge would be incinerated by pulp and paper mills, releasing all the carbon contained in the organic matter into the atmosphere. The moisture content of pulp and paper mill sludges is so high (60-75 %) that they have no energy value, and other fuels are needed to aid the incineration process (Alakangas et al. 2016). **WPA4**
Financial additionality: A certification system following the Carbon Contracts for Difference (CCfD) model can provide the necessary initial push for carbon farming investments, while the balance of private funding would increase over time. For Carbon Removal Credit (CRC), any scheme should account for the 'additionality' issue and ensure that beneficiaries do not receive double payment for the same practice. **WPA2**

2.1.3. Baseline

The Paris Agreement draft suggests several options for the calculation of the baseline. It is still undecided which baseline options will be allowed in the Paris Agreement. It has been suggested that the methodology should "encourage an increase in ambition over time". The baselines are suggested to take "into account relevant national, regional or local circumstances" and possibly also "ensuring environmental integrity". The baselines suggested in the Paris Agreement are for calculating emission reductions, however, it is still unsure if they are meant to be applied also for carbon removals. The current baseline suggestions for the draft are:

1. Performance-based approach
2. An approach based on "business as usual" emissions
3. An approach based on historical emissions
4. Benchmark baseline approach, with an ambitious benchmark i.e., reference value of soil carbon concentration or biomass carbon stock.
5. Best available technology approach

Business as usual, historic emissions approach, and benchmark approach seem to fit well as an environmental baseline for carbon sinks. The other two options seem to work better as a value of comparison, and not as a baseline as such.

A common issue for all the baseline suggestions is that the following steps must be decided:

A. The locality of the baseline. In other words, if the baseline is set e.g., as EU-wide, nationally, farm level, or based on field level.

B. If the baseline is modified over time in case of changes e.g., in climate, climate targets or technology occur.

In the case of point A, the narrower the area in concern is, the fairer is the system for the farmer, as the farmer is competing against itself, instead of other farmers in the area of concern. This also leads to a situation where carbon farming is feasible in more farms, and not just in those which are closer to the baseline in their existing situation. It should be noted that often there is more potential for carbon sequestration in those areas where actions for carbon sequestration have not been implemented yet. In those farms, the expenses of the initial carbon sequestrated is also lowest, as no actions, even the most inexpensive ones have not been executed yet. The project findings suggest that the location is important in setting the baseline and in assessing by the validator.

For point B, updating the baseline over time would make sense to not to lose the ambition of climate targets and to ensure additionality is achieved at every point of time. However, in case of long projects, variation from the baseline may be greater than expected and the amount of carbon removals achieved is highly dependent on the baseline level. The project shows that farmers favor 5-10 years agreements which would naturally offer a feasible cycle for baseline updates and the raising of ambition level. Eventually, the right choice for baseline depends much on the scheme ambition level and expected measure accuracy level for carbon removals.

Below tables 3 - 7 describe the pros and cons of each type of baseline calculation and considerations relevant to their use for carbon farming based on the analysis in [OECD & IEA (2019)].

Table 3. Pros and cons of business as usual baseline.

Business-as-usual baseline: Create a future scenario for emissions/sinks in a 'business as usual' situation and for carbon farming practices. Once carbon farming practices are implemented and carbon is sequestered, the actual situation is compared to the 'business as usual' scenario.	
Advantages	• Simple baseline, which is also easy to understand by buyers. • Carbon sequestration would be concentrated on areas with the highest potential and viability for carbon sequestration.
Challenges	• Requires a lot of data. • Requires a lot of assumptions on the future.
Comments	• The destruction of carbon sinks before commissioning the program should be prevented. A way to prevent this could be e.g., prohibiting land use change retrospectively.

Table 4. Pros and cons of historic emissions baseline.

Historic emissions baseline: The baseline follows the historic emissions trend. The most sensible would seem to be to set the baseline according to a historic trend, not a single year.	
Advantages	• Easy to determine, only need the historical data. • EU nationwide data is available in the LULUCF inventories divided into land parcels. However, details lacking from the data varies depending on country.
Challenges	• Does not consider the development of technology or current emissions targets unless baseline is updated regularly.
Comments	• The destruction of carbon sinks before commissioning the program can be easily prevented if there is enough historic data to show the historic land use.

Table 5. Pros and cons of performance-based approach.

Performance-based approach: Evaluate the carbon removals achieved by comparing it to similar actions made elsewhere. The reference level can be set in different ways: e.g., best achieved level, best available level, or average achievements of top x %.	
Advantages	• Low administrative burden on land managers
Challenges	• Significant challenges related to reliable and accurate monitoring of actual removals. • Difficulty in controlling external factors to accurately reflect additional removals in a given location. • Does not consider the current emissions targets. • Does not consider the development of technology or current emissions targets unless baseline is updated regularly.

Table 6. Pros and cons of benchmark approach.

Benchmark approach: a type of "performance-based approach" based on ambitious reference value of soil carbon concentration or biomass carbon stock.	
Advantages	• Financial additionality (also called dependence on carbon credit income) guaranteed due to the ambitious baseline.
Challenges	• Too high of an ambition might discourage farmers to participate. • Discourages participation of farmers with land of low carbon, and highest potential on increasing the sinks. • Requires data/research on different soil types.
Comments	• Baseline is set to a level where other benefits than carbon sequestration (such as yield, nutrients or biodiversity) are in the minority. Above this level carbon sequestration is seen as purely financially additional. • CAP could encourage carbon farming until the baseline is reached, after which additional payments would be conditional on carbon removals.

Table 7. Pros and cons of the best available technology approach.

Best available technology approach: A type of "performance-based approach", where a best available technology (BAT) used as a reference. Restrictions like economic feasibility could be used when choosing the best available technology, and the best available technology could be dependent on the country and activity.	
Challenges	• The BAT list is not always up to date, as new technologies might exist but is waiting for evaluation to be able to enter the list. • The BAT list is often subjective and too static. Hard to keep updated and to **incorporate regional/local circumstances**. • BAT would work if we had overproduction of carbon sinks, and we would only want the best. However, now we should encourage also the worst to work.

2.1.4. Double-counting

Double-counting is a significant criterion and there are solutions available for preventing it. The robust registry and retirement process where CRCs are retired once used transparently are in focus but also the agreement on Article 6 of the Paris Agreement in COP26 is a step forward in term of tackling the double counting challenges. Within the project Trading Pilot, double-counting is prevented through clear rules in the methodology.

Table 8. An example of rules in Puro.Earth soil amendment methodology for double-counting.

5.6. Proof of no double-counting or double-claiming (Puro.Earth methodology)
5.6.1. A statement is needed from the CO_2 Removal Supplier that the Product or Activity in which the CO_2 is stored will not be sold or marketed as “carbon positive” if the CO_2 removal certificate associated with the use of Product (soil improvement fibres) is removed from the Product and sold to another stakeholder not associated with the Product.
5.6.2. No carbon accounting claims can be made by the end-user (user of Product; farms that use Product for soil amendment) that the Product is a carbon sink or carbon removal if the decoupled CO_2 Removal certificate has been sold to and cancelled by another stakeholder not associated with the Product.

2.1.5. Multiple benefits of carbon farming and forestry

Farmers always look at farming in a holistic manner as their livelihood depends on taking care of soil health, water management and weather resilience, which all affect farmland productivity. The survey and interviews of the project show that it is important for farmers that a future certificate system considers and includes multiple benefits in addition to carbon benefit. The Trading Pilot also indicates that carbon removal with multiple benefits is more attractive to the demand side as well. In all, a carbon farming certificate system should emphasize that carbon farming and forestry actions are implemented in a sustainable manner. Including multiple benefits to the certificate could also incentivize more participants to participate in the scheme. Furthermore, the decision makers and system designers must have a context-specific understanding of the key components of sustainability of the land productivity and farm business. Table 13 (Annex 3, chapter 3.5.) introduces multiple environmental benefits and risks that carbon farming can bring to farm as well as change in yield.

2.2. Minimum standards covering environmental and social impacts

The EU certification framework should still have minimum standards as a base requirement for stakeholders to enter the scheme, although the different types of carbon removal methods appear to need specific rules. The minimum standards concern the whole carbon farming system on the EU level, whether it consists of small private operators or is one large centrally operated system. This project investigated how different schemes have approached the environmental impacts of carbon farming or forestry projects. Additionally, in WPC3 the project analysed the socio-economic impacts of carbon farming in agriculture and forestry and developed the impact assessment model for assessing the social impacts of carbon farming.

Effects on humans, biodiversity, soil, water, and air should all be robustly assessed to ensure that actions are conducted sustainably. Environmental Impact Assessment (EIA) is a tool to assess the environmental risks and benefits of a specific project. EIA process includes biophysical, social, and other relevant effects of the proposed project. EIAs are the most known, used, and globally widespread, environmental planning and management tools and they are the only tools that are required by most countries around the world (UN Environment 2018).

Currently, environmental impact assessment (based on the EU EIA Directive or other legislation) is required only for some existing carbon farming schemes (table 9). Schemes that did not require any type of environmental impact assessment mostly seemed to assume that projects implemented based on the schemes protocol/methodology will automatically result in environmental benefits. The measurement of the impacts should nevertheless be evaluated in line with good practise.

The EIA process could also be utilized in carbon farming and forestry projects. Carbon farming and forestry projects are strongly related and dependent on the environment and it could be beneficial to conduct impact assessments before implementing specific projects e.g., projects concerning large land areas. The importance of EIA increases with the increase in the land mass and duration of the project.

Table 9. Current schemes address environmental impact assessment.

Kaindorf Ecoregion (National agriculture scheme)	No requirement for EIA.
Label Bas Carbone (National agriculture and forestry scheme)	Project apply acceptance for afforestation from local environmental authority.
Soil Enrichment protocol (National agriculture scheme)	No requirement for EIA.
NORI protocol (Private agriculture scheme)	No requirement for EIA.
Gold Standard (Global forestry and agriculture scheme)	Requires EIA in 3 cases: 1) When required by appropriate host country law. 2) When required by the CDM Executive Board. 3) May require EIA if the initial public consultation process is that environmental or social impacts are significant, and/or the sustainable development assessment matrix comprises one or more indicator scoring -1. Or the results of using a pre-screen checklist show that the environmental impacts identified in the initial stakeholder consultation or in the sustainable development matrix are significant enough to require an EIA.
Woodland Carbon Code (National forestry scheme)	Requires EIA. All projects must show that they 'do no harm' and with appropriate safe-guards ensure that any environmental impacts on the land concerned are likely to be positive.
Verra (Global forestry and agriculture scheme)	No requirement for EIA in VCS programs. In addition to the VCS program, Verra offers CCB (Climate, Community & Biodiversity) and SD Vista (Sustainable Development Verified Impact Standard) programs where an approach is detected and measure the possible positive effects of the project rather than assess negative impacts.
Registro Huella de Carbono (National forestry scheme)	No information was found.
Puro. Earth (Global carbon removal scheme, including biochar and other technology-based sequestration types)	EIA is provided as one option to demonstrate that suppliers do no significant harm to the surrounding natural environment or local communities. Other options are documentation from environmental permit or other documentation approved by Puro.Earth.

Another area for setting minimum standards concerns the social impacts of carbon farming and forestry. Analyzing impacts on people (stakeholders such as employees, farm workers, suppliers, temporary or seasonal staff, their dependents, and all individuals potentially affected in a broader community or the value chain by any business or operation) and their human rights should be considered. In line with the United Nations Guiding Principles on Business and Human Rights (UNGPs) and the recent European Commission proposal on corporate sustainability due diligence, companies are increasingly scrutinized on their sustainability and human rights performance. This also applies to companies operating in agricultural and forestry value chains and requires particularly larger companies to identify, prevent, end or mitigate any adverse impacts on human rights across their own operations, subsidiaries and value chains.

One key finding from the project analysis was that farmers/forest owners and other actors lack knowledge, firstly on the possible socio-economic impacts of carbon farming given its nascent stage, and secondly, on the salient issues and human rights risks in the increasingly more complex and international value chains. Issues such as exploitation of migrant workers and impacts to vulnerable groups are often sensitive and sometimes not obvious, and more awareness is also needed to address issues such as poor working conditions, discrimination, work safety, freedom of association, impacts on livelihoods, and cultural heritage.

What also became clear was the need to address systemic issues when proceeding with the planning and implementation of an EU level carbon farming scheme. Some of the most pressing are the potential trade-off between carbon farming and food production, accessibility of market-led carbon farming schemes considering the diversity of the EU farming landscape, equality between farmers/forest owners, as well as issues such as land grabbing and land consolidation already occurring in some parts of Europe.

Many aspects of the scheme are yet to be specified, and there are open questions regarding project type, scope, duration, location, and actor set-up (e.g., contract farming, cooperative-led, etc.). Key takeaways from WPC3 expert and stakeholder interviews are:

- It is recommended to follow up and learn from other carbon credit programs currently being developed globally, and to harmonize the overall approach vis-à-vis the development of regenerative agriculture schemes.
- It also became evident that assessing impacts, which often extend beyond a single business or project, should be the responsibility of the whole value chain, not the burden for a single small- or even medium-scale farming/forestry business.
- Furthermore, it is recommended to build collaboration arrangements and platforms at local, national and EU-level to share the burden and ensure the understanding of salient issues as well as the capacity and leverage to address them.

The following elements should be considered when designing the process, requirements, and responsibilities with regards to an impact assessment.

- The identification and assessment of social/human rights impacts must include a strong emphasis on stakeholder engagement and be followed by responding to identified risks and impacts, tracking performance, and communicating and reporting progress to stakeholders.
- The scope should include all human rights that fall under the broad categories of labor rights; civil and political rights; economic, social and cultural rights; and the protection of vulnerable individuals and groups, which requires that the assessment team has the required human rights competence.

3. Building the operations for a carbon farming carbon removal certification scheme

It is clear that carbon removal actions to become Carbon Removal Credits (CRC) requires a robust system that offers a credible process for both supply and demand side to participate carbon market. The process should transparently follow the whole value chain of CRCs which includes project validation, monitoring, verification, issuance, and retirement of CRCs. This project has been able to identify the system needs from supply and demand perspectives.

Carbon farming and forestry are local actions that aim to solve global climate challenges. Within this project, it has become clear that carbon farming schemes need to change farming practices locally, in each farm and region to achieve the wanted global effect. At the same time, farms should respond to maintaining the viability of our food and wood production, soil health, managing water supply and supporting biodiversity. Moreover, the measures of carbon farming or broader environmental benefits are local, and a greater accuracy level is obtained if carbon accounting recognizes the local agroecological conditions added with farm level information. It seems that each farm, region and climate zone must implement and adapt locally suitable carbon farming practices.

As a result of this project's different work packages, there is a need for larger consortiums or alliances than individual farmers as operator in scheme. Within the trading Trading Pilot, over 80% of participated farmers wanted to be involved and be represented jointly by the central party i.e., Soilfood. This speak for the ability to group farming or forestry businesses to ease the administrative burden on individual farmers. Verification of the CRCs requires a significant amount of information and 3rd party confirmation, which can be burdensome for individual farmers. The socio-economic review showed that impact assessment often extends beyond a single business or project and such an assessment burden is too heavy for even medium-scale farming or forestry businesses. The cost analysis showed that carbon farming will require relatively large initial land coverage in terms of hectares to make a return on investment concerning system costs. In the upcoming years, the system costs are nevertheless expected to come down due to rapid technological advancements and new policy measures. The near future investment support should be targeted setting up supply chains and adaptation of required technology for monitoring and verification.

The reliable and transparent registry system of CRCs plays a key role for the scheme to be user friendly and credible for the demand side in the value chain. The registry is also central to preventing double-counting and double-claiming.

All work packages in this project emphasize the lack of information and knowledge among farmers as well as of the demand-side needs perspective, e.g., how to claim credits with 20 years of permanence. Therefore, the essential part for a successful scheme is accurate information efficiently shared which can be extended with timely training that considers the local needs of supply-side stakeholders.

Based on the findings within the project there seems to be a need for public centralized registry and scheme steering where a large part can consist of the information sharing responsibility and educating all the stakeholders that can join the scheme. This centralized registry can be EU wide in case transactions are allowed between member states or at least it should be national in each country like is the case for the European guarantees of origin for renewable energy. Further there is a requirement for local knowhow and local central parties who can responsibly distribute the information locally, validate the projects, arrange monitoring and verification for the centralized registry which would ease the cost efficiency and minimize the work burden for individual farmers. These local actors could be either public or private operators, such as a national agency (for example Label bas Carbone) or private entities (for example Puro.Earth).

4. Proposal for a large-scale transport pilot: Using carbon credits in a transport compliance market

The LIFE Preparatory Project found that carbon farming practices have the potential to remove carbon from the atmosphere in a cost-efficient way and contribute to the EU's goal of reaching climate neutrality. However, Puro.Earth Trading Pilot as part of the LIFE Preparatory Project revealed that in the first months of the Trading Pilot (Aug-Dec 2021), there was no significant demand for the carbon farming removal credits traded on the voluntary carbon removals market, although the interest has increased during the first months in 2022. This may be partly due to the lack of a policy framework for measuring and verifying the quality of nature-based carbon removals as compared to industrial greenhouse gas emission reductions. The underlying uncertainty creates a mismatch between the supply and demand of carbon farming credits. The lack of demand for the carbon farming credits create a situation where supply side has a little incentive for the uptake of carbon farming practices on farms, and we are seeing a delay the scaling up carbon farming methods as a result.

On the other hand, the transport sector, a major contributor to carbon emissions, is a difficult-to-decarbonise sector and the abatement cost for CO_2 reductions in the sector are high (to illustrate this, on the German market the cost is 450 EUR per ton (Argus, March 2021). Significant research and development in the field is needed for low and zero-carbon solutions to be scaled up and become affordable enough to reach the market. At the same time, Member States need to reach the renewable energy targets in the transport sector (14% by 2030). In Finland, this target is referred to as the 'biomandate' and is set to a higher level of 19,5% (2022) and increasing to 30% (2029). At these ambitious levels the abatement cost is already high, and the availability of the feedstocks for renewable fuels are already limited. The use of high-cost bioethanol and biodiesel used today to fill the mandate could be supplemented with more cost-efficient and climate-friendly solutions.

In the short-term, the two sectors could create a symbiosis via a well-planned pilot project to scale up cost-efficient CO_2 reductions and bring climate benefits.

The proposed pilot project foresees that a limited share of the national renewable energy in transport target ('biomandate') would be allowed to be covered by multiple nature-based carbon removals. The transport sector would thus create a significant boost in demand for carbon farming in the near-term.

While it is understood the CO_2 emissions from transport have a long existence in the atmosphere, and the nature-based CO_2 -removals may not be permanent, this mechanism is a 'step-wise' pilot project that can subsequently be adapted in the light of learning and experience. The purpose is to create incentives for carbon farming to maximise removals via enabling the over-achievement of the transport sectors usage of renewable energy to incentivise removals that would not otherwise occur. As such, the pilot project can be considered as additional to what would otherwise occur.

4.1. Policy structure

4.1.1. 'Bio-tickets'

The pilot project would create credit certificates, called 'bio-tickets', that can be used to count towards a Member State's renewable energy in transport target ('biomandate').

1 bio-ticket is counted against 1 tonne of CO_2 in the greenhouse gas intensity target of the renewable energy in transport target. However, the bio-ticket would be issued on the basis of 2 tonnes of sequestrated CO_2 , thereby deliberately creating a buffer to mitigate against the risk of possible reversals of the carbon removals due to unforeseen situations. Due to the high abatement costs in the transport sector, it should be able to create a demand for the carbon farming credits.

4.1.2. National Authority

The total quantity of bio-tickets would be fixed by the National Authority, who will decide on the extent to which bio-tickets could be used to fulfil the biomandate. The flexibility will, therefore, be limited during the pilot project.

The National Authority will ensure there is no double-counting of the carbon removals. For this reason, the removals are only applicable for one sector and the Member State can decide whether removals are eligible to be counted in the LULUCF sector or the transport sector under Effort Sharing Regulation. It is for the National Authority to respect flexibilities allowed within the scope of the LULUCF and Effort Sharing Regulations.

The National Authority is also in charge of deciding the criteria of what can be certified as a 'bio-ticket'. The National Authority will identify the carbon sequestration methods that are applicable (suggested practices and proposal pilot scheme in Finland in Annex 5). The quality of the credit should be as high as possible. Bio-tickets should prioritise carbon sequestration that has multiple benefits, for example including in addition to sequestrating carbon also contributing to biodiversity and soil health. The criteria for certification need to recognise and address permanence and additionality problems of which the buffer is one feature.

The supply-side eligible participants could be limited to only include farmers covered by the Common Agricultural Policy, with additional specific and limited criteria for afforestation and reforestation practices.

Flexibility should not prevent investment in the transport sectors CO_2 reductions. The pilot is thus suitable for those Member States that are significantly exceeding the EU target under the latest Renewable Energy Directive in force. The pilot should only introduce flexibility for the short-term periods, not reducing the 2030 – 2050 reduction targets of the transport and ESR sectors.

5. Conclusions

This report summarizes the main findings and recommendations from the project activities in modelling, incentive scheme rules and governance, the piloting of nature-based carbon credits in the voluntary market, as well as farmers' perspectives and preferences. The project found out the knowledge about changes in the soil carbon stocks is currently limited and the measurement of soil carbon is evolving. As a conclusion carbon farming crediting needs to be based on modelling and not site-specific measurements. In agricultural lands carbon sequestration can be achieved with species selection or by adding carbon containing amendments to soil. In the forest sector afforestation, reforestation and the avoidance of deforestation are effective ways to increase carbon sequestration. The trading pilot showed that the supply and the demand are still far from each other in their expectations for carbon removal credits. Voluntary carbon market is not solely solution to increase carbon farming activities because willingness to pay on the demand side is unsure.

This report contributes to the common European discussion about carbon farming and carbon markets.

Annexes

Annex 1. WPA1 summary and deliverables

1. Potential in soil carbon and challenging verification

In the framework of the LIFE project, WPA1 by LUKE completed reports on " Draft report on calculation methods to be applied in estimating quantitatively agricultural and forest carbon sinks and their stability " and "Action A1 Science-based mechanisms for farmers and foresters to capture carbon from the atmosphere", available on the LIFE project website. The latter report addresses practical research examining the case farms in the EU, comparing the current cultivation methods with carbon-smart techniques. The research assesses how changes in farming practices can affect soil carbon stocks on EU farms and forests.

1.1. Existing approaches for assessing soil carbon stock changes

WPA1 aim to show the scope for potential climate impact when changing farming and forestry practices towards carbon farming and long-term carbon (C) sequestration. To be able to scale the impact it is needed to address the statistics around agriculture and forest sequestration potential. In the modeling calculations carried out in WPA1 the addition to carbon stock was achieved through different carbon farming methods: adding soil improvement fibres (Pulp mill sludge lime-stabilized, Pulp mill sludge (Composted), and Zero Fibre), changing the grass cutting height, adding cover crops, green fallow of grassland to the cultivation cycle or theoretically increasing the soil productivity, resulting increases in yields by 10% or 15%. According to our modeling exercise, the carbon farming practices increased soil carbon stocks at the highest 16.3 t CO_2e (4.44 t C/ha) during the 10-year simulation period, which is 0.4 t C ha/yr.

The highest carbon additionality was achieved with the use of soil improvement fibres. The calculated total C inputs at the farm are lower if nutrient fibres are used instead of manure. In farms, the sole use of zero fibres causes a decrease in carbon stocks due to the lack of adding nutrients at all. The combination of nutrient fibres and manure could be implemented, but the usages and the amounts of the products are farm specific, hence such a combination was not considered in the calculations. The case of change in grass cutting height has shown a positive effect on the growth pace which in turn affects positively the soil's carbon content (e.g., farm in Finland). Based on the farmers' feedback on the results, related to grass cutting heights, less than 50% of harvesting heights are the most realistic in a sense of sustainable and smart farming. Comparing all the carbon farming practice results, such as soil improvement fibres, annual carbon additions are lower but improvement in e.g., biodiversity (not assessed in this study) can be more beneficial than just adding fibres. Therefore, the combination of different methods would provide the best outcomes for the agricultural farms.

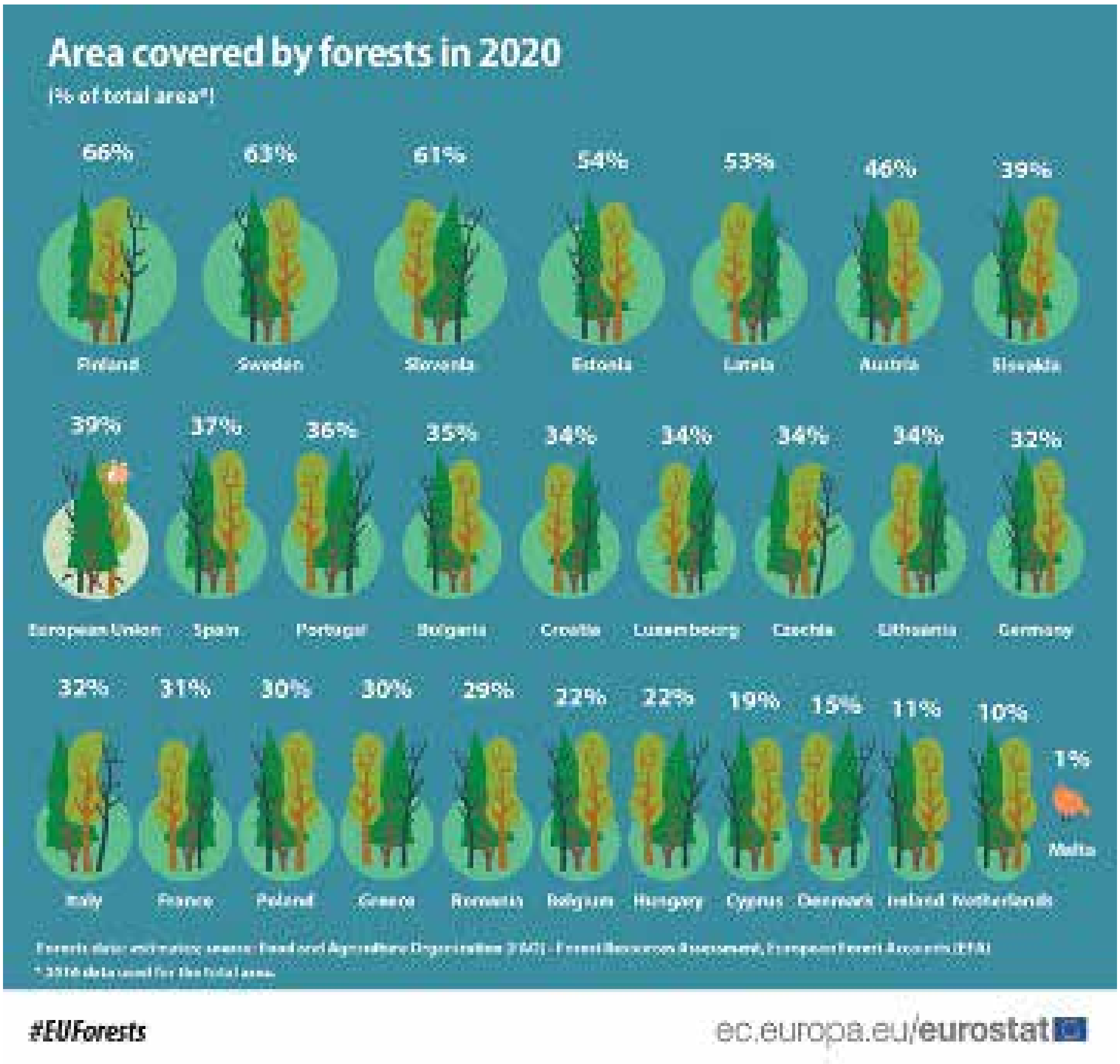
The Yasso07 models' function tends to an equilibrium point and over time achieves stability. As in our calculations, all carbon farming practices have the highest carbon accumulation in the first 10 years upon their introduction. After this period, the sequestration slowly evens out, as the new equilibrium point for the specific practice is approaching. This is based on that there is an upper limit of soil stable carbon storage, which is referred to as soil organic carbon (SOC) steady state (Hassink 1997, Six et al. 2002, Stewart et al. 2007, Chen et al. 2018). The Yasso model and our calculations behave the same way as Smith et al. (1997) and West and Post (2002) describe, where the continuous use of carbon farming practices increases soil carbon storage to levels following a sigmoid curve, reaching a maximum rate 5–10 years after initiating the practices and continuing the increase in carbon accumulation until reaching the new level of equilibrium, usually after 15–100 years. Maintaining soil carbon stocks requires continuous implementation of carbon farming practices and new methods should be adapted after equilibrium of one method is achieved if the purpose is to continue to build the soil carbon stock.

The means available to increase carbon sequestration in the forest sector are afforestation and reforestation, and the avoidance of deforestation. Also, the use of genetically improved seedling material and establishment of the new forest stands dense enough can increase the carbon accumulation in the long run (Sedjo & Sohngen 2012). In areas with low nitrogen deposition (North Europe), nitrogen fertilization can be used to increase the carbon sequestration with a quick response on annual biomass accumulation and litter deposition (Mäkipää et al. 1998). In the estimation of the forest carbon accumulation, the determination of the baseline describing the additionality can be challenging. The response of forests and soil carbon stocks to land-use changes and global warming is critical, and accurate data is essential to quantify these dynamics.

1.2. European-wide carbon sequestration potential

Based on our calculations where one carbon farming method was introduced to a farm, the highest carbon sequestration potential would be 280 Mt CO_2 e/year if every farm in the EU would start using this method. The potential could be higher in the case of using multiple carbon farming methods at the same time. This number is based on our modeling work and the statistics around agriculture and forest sequestration potential. Based on FAOSTAT 2022, there is 187 million ha (2020) of agricultural land in Europe.

Approximately, 5% of the world's forests, a total of 182 million hectares, is in the EU, which is 42 % of the total land area in the EU (European commission forestry 2021). The forests are divided between the member states as shown in Picture 2. The growing stocks of timber in EU-27's forests totaled an estimated 28.4 G m3 and annual growth of 840 M m3 (Eurostat 2020).



Picture 1. Distribution of forest land area in the EU (182 million ha in total) (Eurostat 2022).

1.3. Verification of carbon accumulation

Carbon trading could enable carrying out mitigation actions cost-effectively, simultaneously financing climate-smart development. Income from carbon trading acts as a financial incentive for farmers to adopt practices that enhance the synergy of food security, climate change mitigation, and sustainable development. In comparison to other mitigation practices, such as reforestation or the cultivation of bioenergy crops, carbon sequestration through carbon farming does not compete with food production. Long-term co-benefits encourage smallholders to maintain and increase the soil carbon stock further.

Carbon calculators are important tools to assess CO_2 emissions. Carbon calculators are common and most of them are emission counters like carbon footprint calculators (Mulrow et al. 2019), which cover mainly topics of household consumption, transportation, and lifestyle. Other calculators are invented to calculate the carbon sequestration potential and GHG emissions in the agriculture and forestry sector, models are used to calculate the stock and flow of carbon in forest ecosystems and wood products. The soil carbon models are used mainly to compare and evaluate the change of carbon stock in the soil (Tuomi et al. 2011), as we indicated in our WPA1 study with the Yasso07 model. In the aspect of relocating and storing carbon, these models are more suitable. Different modeling tools and carbon calculators are listed in Table 10.

Table 10. List of common carbon footprint calculators, the carbon sequestration potential calculators in agriculture and forestry, and soil carbon models that compare and evaluate the change of carbon stock in the soil.

C footprint calculators	CoolClimate Calculator, WWF Footprint Calculator, CarbonFootprint, UN carbon footprint calculator, Conservation International Carbon Footprint Calculator, EPA Carbon Footprint Calculator, etc.
C calculators in agriculture	Solagro, Huella de carbono, CLAM, Farm Carbon Calculator, Agro Climate, Agro-Chain Greenhouse Gas Emissions (ACE), Agriculture, Forestry, Other Land Use (AFOLU) Carbon Calculator, SLU Odlingsperspektiv, ICBM, etc.
C calculators in forestry	Barkley Forest, Simosol, The Forest Sector Carbon Calculator, Agriculture, Forestry, Other Land Use (AFOLU) Carbon Calculator, Motti, etc.
Soil C models	Century (Parton et al. 1987, Parton et al. 1992), CoupModel (Jansson and Karlberg 2004), Q-model (Rolff and Ågren 1999), ROMUL (Chertov et al. 2001), RothC (Coleman and Jenkinson 2005), DECOMP (Wallman et al. 2006), Yasso07 (Liski et al. 2005, Tuomi et al. 2009, Tuomi et al. 2011), etc.

Different calculators can generate varying results. The variation may be due to different calculation methods or emission factors. Commonly, the calculators lack the level of transparency needed to understand variations. There is a need for improving consistency and transparency among the different calculators (Padgett et al. 2008). It is good to consider the problems arising from the delineation of the system, as well as possible negative environmental impacts outside production or elsewhere. Transparency in calculation and counters is very important, i.e., what methods and estimates have been utilized.

As listed earlier, every calculator and modeling tool requires a bit different preliminary information depending on the wanted outcome. Some of the models describe the soil carbon cycle at a rather detailed level, and such information is not always available, making it hard to apply models on large geographical scales or at even a national level (Tuomi et al. 2011). From a carbon farming point of view, a comparison of the different results between different models would give the best possible overall picture of the different modeling methods in different soils and climate conditions.

In the forestry sector, the monitoring is based on field observations acquired in natural forest inventories, but in some cases on national forest soil inventories. Some of the EU Member States are exploring integrated soil observation in their forest monitoring, although the capacity to retrieve coherent and harmonized forest-related information across the EU has not yet been explored (COM 2021). The LiDAR systems have been used for measuring the height and vertical structures of forests and unite with the carbon stock field measurements (Osama et al. 2003, Giri and Mandla 2017). NASA/USGS Landsat is working on a new carbon monitoring method for forests building on the Landsat-based Global Forest Change product and Landsat-based global mangrove maps to create the study's improved global maps of forest coverage and carbon fluxes (Streiff (NASA) 2021). The reliability of modeling is based on empirical measuring and the reliability increases as the used area gets larger.

In the future, satellite data could potentially be used for carbon trade monitoring. The satellite data can be used to estimate ground biomass, seasonal productivity, and carbon sequestration (Tripathi et al. 2010). The remote sensing technology can be carried out at a global scale, and therefore, observe vegetation and carbon cycle (Tripathi et al. 2010). Forests, peatlands, and wetlands are already monitored via remote sensing methods. Remote sensing methods could be a way to monitor and manage carbon sequestration at agricultural farms. In 2019 Indigo announced the Terraton Initiative that is a long-term objective to capture CO_2 from the atmosphere into agricultural soils by providing real-time information and agronomic support to farmers during the growing season (Sulla-Menashe (NASA) 2019).

1.4. The state of the art

WPA1 study includes interviews with farms that collected the information for Yasso soil carbon calculations, and conversation and feedback on the calculations and how farmers felt and thought about carbon farming. In the beginning, the interviews with farmers entailed preliminary information of the farm's cultivation routines and methods but also communication and questions that give a better overall idea of how the farm worked and what are the farmer's values in farming. Farmers were interested in learning climate-smart farming practices and getting ideas to improve soil health for better yields and stability. Increasing farmers' awareness and knowledge of climate-smart methods and communication with scientists related to sustainable farming were considered important. Farmers highlighted the topics regarding the production of quality food supplies and meeting the expected yields. Farmers did not support the idea of their farms being compensation for emissions from industrialized companies. This was considered to increase risks for potential carbon leakages, resulting, in the end, no real mitigation.

Effective actions on climate change must be a major goal in the EU and globally. Education and communication have a major part in it, including farmers, politicians, lawmakers/authorities, and other stakeholders. The best means to mitigate climate change at the national level is to reduce already existing carbon emissions and avoid expanding agricultural land area and increase reforestation. Also, cultivation methods that help to increase carbon accumulation in soil are important.

Annex 2. WPA2 and WPA3 summary and deliverables

2. Report on the incentive scheme

In the framework of the LIFE project, North European Oil Trade Oy (NEOT) completed a WPA2 reports on “Analysis of the market demand mechanisms and the demand potential for land-based carbon credits” and “Incentive scheme to encourage foresters and farmers to adopt agricultural practices enforcing removal of CO_2 from the atmosphere”. St1 have completed a report on “Review of risk assessment and policy aspects for best practices.”, available on the LIFE project website. Based on a cost analysis, the report outlined an approach for building an incentive scheme for nature-based carbon removals to rapidly scale up nature-based carbon sequestration.

2.1. Cost analysis of carbon farming and carbon forestry

The cost analysis covered three different categories of carbon farming practices – soil improvements, forest fertilization, afforestation, and reforestation. Based on the data collected from different LIFE Carbon Farming Scheme collaborators (Natural Resources Institute, Tyynelä farm) and operators (Green Carbon, South Pole, Puro, Soilfood), the analysis determined the costs of implementing the carbon farming practices, the transaction costs of the support scheme, and program-based costs.

The total costs of different carbon sequestration practices across the value chain are relatively high. Annual total costs range from 10 000 € to 19 600 € and total costs of the twenty-year program period range from 199 000 € to 393 000 €. The differences stem mainly from investment costs which relate to the type and the cycle of the instrument.

Compared to the instrument costs, there are high system costs which cover validation, verification, registering, and trading. Additionally, the programs will require relatively large initial land coverage in terms of hectares in order for the CO_2 prices per ton to make return of investment with respect to system costs. In upcoming years, the system costs are expected to come down due to rapid technological advancements in technological innovations[1] and new policy measures.

Table 11. Summary table of system, total and annual costs, and lower and upper limits of carbon sequestration scheme by category

	Validation of project	Cost of actions to enhance carbon sequenstration	TC	System verification	Register	CRC trade	Total costs	Averange annual cost
Organic soil improvement materials in agriculture	Simple: 60 000 € Complex: 120 000 €	192 €/ha - 887 €/ha	16€/ha - 267 €/ha	40 000 € - 120 000 €	10 000 € - 20 000 €	120 000 €	230 208 € - 381 153 €	11 510 € - 19 058 €
Forest fertilization	Simple: 60 000 € Complex: 120 000 €	9 000 €/ha - 10 000 €/ha	90 €/ha - 1 000 €/ha	2 € - 40 €	10 000 € - 20 000 €	120 000 €	199 092 € - 271 040 €	9 955 € - 13 552 €
Afforestation/ reforestation	Simple: 60 000 € Complex: 120 000 €	2 350 €/ha	23,5 €/ha - 235 €/ha	40 000 € - 120 000 €	10 000 € - 20 000 €	120 000 €	232 374 € - 382 585 €	11 619 € - 19 129 €

Therefore, economic incentives to enhance the system investments are needed. The results of the study show, that all support instruments should be based on the following guidelines to minimize market distortions and form an effective policy regime:

- Fixed term with phase-out
- Targeted on infrastructure and investments
- Support levels defined on the cost-benefit basis
- Result-based as opposed to action based

Investment support and grants targeted to setting up supply chains, especially outside the farm gate (e.g., machinery required, but not utilized in current operations), and adaptation of required technology in verification and monitoring are needed.

Given the estimated break-even price levels calculated in the report, the current high levels of CO_2 price in the ETS mechanism could cover the instrument costs, and even form profit in the program period.

[1] E.g., Field Observatory by MULTA consortium. Carbon sequestration on farmland and the factors that affect it, can now be monitored in real time on the new Field Observatory website. https://www.fieldobservatory.org/en/online-field-data/ and LANDMARC Horizon 2020 consortiums Earth observation techniques and models to assess the impact of potential Land Based Mitigation Technologies. https://www.landmarc2020.eu/landmarc-tools

2.2. Options for funding and incentive schemes

The financing options need to be cost-effective to attract investments. The report assessed variety of financing options to encourage carbon sequestration, including public funding and private funding through Carbon Removal Credits (CRC) market, compliance based and voluntary carbon credit markets, action-based and result-based funding, and ex ante and ex post -credits.

Different funding schemes can be combined to create a system that brings together the best features of each funding stream. Carbon Contracts for Difference (CCfD) is an example of a combination of public and private funding through the CRC market price, which can ensure stable and predictable prices.

Carbon contracts for difference lower the investment risks and therefore investment costs, and give an incentive for investing (e.g., when the low price of CRC is not incentivizing for more actions). Carbon contracts for difference are an answer to the following two problems:

- Uncertain price level of the final product (e.g., price of CRC), and
- The price level of the final product is too low regarding repayment of the investment.

CCfDs can provide the necessary initial push for carbon farming investments, while the balance of private funding would increase over time. For CRC, any scheme should account for the 'additionality' issue and ensure that beneficiaries do not receive double payment for the same practice.

Creating a compliance market for CRCs would bring carbon removals into line with other emission reduction measures. Bringing carbon removals into the same marketplace with emission reductions would allow to evaluate carbon removals in comparison with emission reductions, which would allow for the most cost-effective measures to be taken to achieve the climate goals. As discussed in the market analysis in Carbon Farming Scheme 2020a, this would not mean that carbon removals become equal alternatives for emission reductions in reaching the net-zero target. The Climate Law includes a limit for the use of carbon removals in fulfilling climate targets to ensure all possible emission reductions are obtained. Another example is the Californian cap-and-trade program which sets a limit of 8 % for offsets, while the rest of the obligation must be fulfilled with other means. Climate targets can even be made more ambitious if carbon removals are accepted as a mean to fulfil part of the targets

Annex 3. WPA4 summary and deli-verables

3. Report on the stakeholders' perspectives

In the framework of the LIFE project, BSAG completed reports on "Key considerations for the future carbon farming incentive scheme based on stakeholder perspectives" and "Analysis of the impact of carbon farming practices on biodiversity, including aspects of impact on nutrient leaching and climate resilience", available on [the LIFE project website](). These reports present the outcomes of WPA4 work: the online surveys, farmer interviews, and test trading of soil amendment carbon credits run by Puro.Earth and carbon farming impact analysis. The stakeholder perspective report indicates that demand and supply expectations are still quite apart but there are common interests that can ease the way forward and create opportunities for a win-win carbon farming scheme in the future. The impact analysis gives overview the multiple benefits and risks associated carbon farming practices.

3.1. Carbon as a key component for productivity and sustainability

Among the interviewed farmers, there were three types of gaps related to the notion of 'carbon farming'. First, initially farmers may shrug off the whole idea of carbon farming as nothing new. When carbon farming is just presented as a list of good practices, like minimum tillage or green cover, instead of a systematic approach, it is easy to ignore. Thus, we may go wrong and achieve nothing if carbon farming is promoted just through good practices. Furthermore, this overlaps with existing standards, like e.g., organic farming, and may lead some farmers to believe that they are already carbon farmers or even better than carbon farmers if they are farming organic. Existing definitions and standards for regenerative farming in U.S. and Australia offer valid examples and references for the European definition of carbon farming that can be implemented e.g., as an add-on to the organic farming standard and adapted to different production systems and contexts.

Second, there are gaps in farmers' awareness about carbon as a key component which maintains life above and underground. Carbon plays a critical role in soil structure and the nutrient cycling between the soil and the plants. Carbon enables biodiversity underground and carbon farming is expected to benefit biodiversity above the ground. But failing to understand the strong link between soil carbon and productivity compromises the ground for making the win-win case for biodiversity and carbon.

Thirdly - and this is more of a gap on the side of the carbon market interest – for the farmer, it is never about just carbon or nitrogen or no-till or catch crops. For the farmer, it is about the farm and livelihood, about the soil health and weather proofness. New sources of extra income can help, but in the end, it is a question about the sustainability of their core business that matters. When designing incentive systems for agriculture and forestry, decision makers must have a context-specific understanding of the key components of sustainability of the land productivity and farm business. Incentive and market system should respond to a multitude of objectives and should not compromise the viability of productive agriculture or cause unintended structural disruption in the production systems in any country or region.

3.2. Advisory services, skills and learning

There is a big disparity in the availability, thematic scope and quality of agricultural advisory services for the farmers around Europe. Many interviewed farmers state the lack of advice, support and knowledge as the key barrier to the adoption of new practices. This is one of the fundamental aspects in the transition to more sustainable agricultural systems. The need for information, advice, low risk -pilot projects and peer-support is the greatest in the transition when one is learning something new and testing the viability of alternative crop rotations or cultivation systems. Furthermore, overall, sustainable, or regenerative, production systems, which are less dependent on external imported and fossil-based inputs (fertilizers, pesticides, energy), are – in exchange – more knowledge-intensive, requiring more human and intellectual input. This calls for more attention on the whole AKIS – Agricultural Knowledge and Innovation Systems – involving research, extension agents, advisors and peer-groups, supported by data, intelligence and shared platforms.

3.3. Carbon vs multiple benefits

The third point above discussed the need to change the focus from carbon to the overall environmental, climatic and social benefits. Nature-based carbon sequestration and agricultural and forestry carbon sinks cannot be vacuumed out of the natural system or the local communities. It is imperative that large scale nature-based carbon sequestration happens within the boundaries of sustainability of each local context, each production system and value chain, and do not risk negative or uncontrollable consequences globally. The farm level is an appropriate context to verify that the carbon sequestering activities are sustainable and bring about other private and public benefits as well. Admittedly, in some cases, this scale is too small or negligible, but that makes only a stronger case that the individual carbon projects, methodologies or incentive schemes need to meet equally high criteria. The difficulty, however, is exactly in the fact that agriculture is local, biodiversity is local, and the socio-economic context is local. No management measure has the same effect across different locations or regions. For agriculture, this means that each farm, each region, must find, implement and adapt most suitable management practices to reach set, measurable targets based on principles and guidelines of carbon farming. This further stresses the need to develop the structures for information, knowledge and learning.

3.4. Dialogues and shared goal

The average farmer, however, environmentally aware, has barely heard about the carbon market and considered the possibility of getting paid to sequester atmospheric CO_2 . This means that the farmers, in general, are still oblivious to the complexities of the carbon market and the, potentially fundamental, changes it may bring to their position as land managers and food producers. We need open dialogue with farmers and a broader society about what is the desired path and state we are aiming for. Participating farmers in planning and designing of carbon farming schemes help to establish appropriate and reliable models and engage farmers.

Table 12. Key findings with respect to the carbon markets from stakeholder survey.

Aspects of voluntary CS contracts	**Supply survey**	**Farm interviews**	**Test trading**	**Aggregated findings** in this study (project activity A4)
Price / expected income to farm	30-100€/ha/a per activity	At a minimum expect risk free cost coverage and annual payment.	16€/ha/a (Price set by seller was 52€/tCO2 net stored for 20 years and it is shared 33% farm, 33% fibre, 33% Process)	Price demand by the seller is higher than expected and higher than the current nature-based carbon market
Permanence and durability of the carbon storage	5-10 years preferred contract length max. 10 years	preference for 1–5-year contracts	20 years (based on the methodology for soil improvers)	Supply and demand are far apart
Willingness to participate (both supply and demand)	high interest	modestly interested	Buyers waiting and confused, fear of greenwashing label	Participants are hesitating, not strongly "incentivized"
Must-have-terms in contract	Integrity and co-benefits	Flexibility, low bureaucracy	Liability of re-emissions should be on the seller, in this case, the farmers	High contrast between supply and demand on contract terms rigidity
Preferred Additional criteria or co-benefits (environment, social, socio-economic)	Co-benefits are important: Agronomical (farmers) and biodiversity (buyers)	Farm productivity, synergies with resilience to weather and climate	Prefer credits from their own country	There is potential for win-win-win incentives

3.5. Summary of carbon farming impact analysis

The report "Analysis of the impact of carbon farming practices on biodiversity, including aspects of impact on nutrient leaching and climate resilience" has defined "carbon farming" as integrated regenerative agriculture, and which is the holistic approach to food production that strengthens the ecosystem while producing food and increasing soil carbon stocks (Hagelberg et al. 2020). This widens the definition more holistic than carbon farming being just one action sequestering greenhouse gases from atmosphere. This paragraph uses carbon farming as above-described holistic approach. The following table concludes findings of this report and gives an overview of multiple benefits or possible risks associated with carbon farming.

Table 13. Table of the effects of common carbon farming practices on biodiversity, water quality and N20 emissions. The sources consist of meta-analyses, review articles or large-scale modelling studies. + = positive impact, 0 = neutral impact and - = negative impact.

Practice	Biodiversity			Water quality			N_2O		
No / reduced tillage	+ 3	0 12	- 3	+ 1		- 15			- 8,17,18
Mulching / residue retention	+ 14			+ 11		- 1			- 7
Cover crops / green manure	+ 12,13,14,19	0 19		+ 1,8,9, 11,15,19	0 19		+ 17,19		
Agroforestry	+ 4,5,6			+ 6,8			+ 17,19	0 8,10	
Organic fertilizers / soil amendments	+ 2,12,14			+ 1			+ 8		- 21
Biochar				+ 8			+ 8,17,18		
Perennial leys	+ 19			+ 19		- 19	+ 19		
Regenerative grazing	+ 20	0 20,22	- 20				+ 23		

References:

1. Olin, S., Lindeskog, M., Pugh, T. A. M., Schurgers, G., Wårlind, D., Mishurov, M., Zaehle, S., Stocker, B. D., Smith, B., and Arneth, A.: Soil carbon management in large-scale Earth system modelling: implications for crop yields and nitrogen leaching, Earth Syst. Dynam., 6, 745–768, https://doi.org/10.5194/esd-6-745-2015, 2015.

2. Hannula, Silja & Morriën, Elly. (2022). Will fungi solve the carbon dilemma?. Geoderma. 413. 115767. 10.1016/j.geoderma.2022.115767. 3. van Capelle, Christine & Schrader, Stefan & Brunotte, Joachim. (2012). Tillage-induced changes in the functional diversity of soil biota – A review with a focus on German data. European Journal of Soil Biology. 50. 165–181. 10.1016/j.ejsobi.2012.02.005.

4. Udawatta, Ranjith & Rankoth, Lalith & Jose, Shibu. (2019). Agroforestry and Biodiversity. Sustainability. 11. 2879. 10.3390/su11102879. 5. Torralba, Mario & Fagerholm, Nora & Burgess, Paul & Moreno, Gerardo & Plieninger, Tobias. (2016). Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agriculture, Ecosystems & Environment. 230. 150-161. 10.1016/j.agee.2016.06.002.

6. Tsonkova, P., Böhm, C., Quinkenstein, A. et al. Ecological benefits provided by alley cropping systems for production of woody biomass in the temperate region: a review. Agroforest Syst 85, 133–152 (2012). https://doi.org/10.1007/s10457-012-9494-8

7. Zhao, Xin & Liu, Bingyang & Liu, Shengli & Qi, Jianying & Xing, Wang & pu, Chao & Li, Shuai Shuai & Zhang, Xiong Zhi &

Yang, Xiao Guang & Lal, Rattan & Chen, Fu & Zhang, Hailin. (2020). Sustaining crop production in China's cropland by crop residue retention: A meta analysis. Land Degradation and Development. 31. 10.1002/ldr.3492.

8. Almaraz, Maya & Wong, Michelle & Geoghegan, Emily & Houlton, Benjamin. (2021). A review of carbon farming impacts on nitrogen cycling, retention, and loss. Annals of the New York Academy of Sciences. 1505. 10.1111/nyas.14690.

9. Valkama, Elena & Lemola, Riitta & Känkänen, Hannu & Turtola, Eila. (2015). Meta-analysis of the effects of undersown catch crops on nitrogen leaching loss and grain yields in the Nordic countries. Agriculture Ecosystems & Environment. 203. 93-101. 10.1016/j.agee.2015.01.023.

10. Kim, Dong Gill & Kirschbaum, Miko & Beedy, Tracy. (2016). Carbon sequestration and net emissions of CH4 and N2O under agroforestry: Synthesizing available data and suggestions for future studies. Agriculture, Ecosystems & Environment. 226. 65-78. 10.1016/j.agee.2016.04.011.

11. Quemada, M. & Baranski, Marcin & Lange, M.N.J. & Vallejo, A. & Cooper, Julia. (2013). Meta-analysis of strategies to control nitrate leaching in irrigated agricultural systems and their effects on crop yield. Agriculture, Ecosystems & Environment. 174. 1–10. 10.1016/j.agee.2013.04.018.

12. Puissant, Jérémy & Villenave, Cécile & Chauvin, Camille & Plassard, Claude & Blanchart, Eric & Trap, Jean & Blanchart, Eric. (2021). Quantification of the global impact of agricultural practices on soil nematodes: A meta-analysis. Soil Biology and Biochemistry. 10.1016/j.soilbio.2021.108383.

13. Kim, Nakian & Zabaloy, María & Guan, Kaiyu & Villamil, María. (2020). Do cover crops benefit soil microbiome? A meta-analysis of current research. Soil Biology and Biochemistry. 142. 107701. 10.1016/j.soilbio.2019.107701.

14. Liu, Ting & Chen, Xiaoyun & Hu, Feng & Ran, Wei & Shen, Qirong & Li, Huixin & Whalen, Joann. (2016). Carbon-rich organic fertilizers to increase soil biodiversity: Evidence from a meta-analysis of nematode communities. Agriculture Ecosystems & Environment. 232. 199-207. 10.1016/j.agee.2016.07.015.

15. Abdalla, M. & Hastings, Astley & Cheng, Kun & Yue, Qian & Chadwick, Dave & Espenberg, Mikk & Truu, Jaak & Rees, Bob & Smith, Pete. (2019). A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. Global Change Biology. 25. 10.1111/gcb.14644.

16. Huang, Yawen & Ren, Wei & Wang, Lixin & Hui, Dafeng & Grove, John & Yang, Xiaojuan & Tao, Bo & Goff, Ben. (2018). Greenhouse gas emissions and crop yield in no-tillage systems: A meta-analysis. Agriculture, Ecosystems and Environment. 268. 144-153. 10.1016/j.agee.2018.09.002.

17. Guenet, Bertrand & Gabrielle, Benoît & Chenu, Claire & Arrouays, Dominique & Balesdent, Jerome & Bernoux, Martial & Bruni, Elisa & Caliman, Jean-Pierre & Cardinael, Rémi & Chen, Songchao & Ciais, Philippe & Desbois, Dominique & Fouché, Julien & Frank, Stefan & Hénault, Catherine & Lugato, Emanuele & Naipal, Victoria & Nesme, Thomas & Obersteiner, Michael & Zhou, Feng. (2021). Can N2O emissions offset the benefits from soil organic carbon storage?. Global Change Biology. 27. 237-256. 10.1111/gcb.15342.

18. Zhang, Qi & Xiao, Jing & Xue, Jianhui & Zhang, Lang. (2020). Quantifying the Effects of Biochar Application on Greenhouse Gas Emissions from Agricultural Soils: A Global Meta-Analysis. Sustainability. 12. 3436. 10.3390/su12083436.

19. Hyvönen, Terho & Heliölä, Janne & Koikkalainen, Kauko & Kuussaari, Mikko & Lemola, Riitta & Miettinen, Antti & Rankinen, Katri & Lång, Kristiina & Turtola, Eila. (2020). Maatalouden ympäristötoimenpiteiden ympäristö- ja kustannustehokkuus (MYTTEHO): Loppuraportti.

20. Morris, Craig. (2021). How Biodiversity-Friendly Is Regenerative Grazing?. Frontiers in Ecology and Evolution. 23. 9:816374.. 10.3389/fevo.2021.816374.

21. Zhou, Minghua & Zhu, Bo & Wang, Shijie & Zhu, Xinyu & Vereecken, Harry & Brüggemann, Nicolas. (2017). Stimulation of N2 O emission by manure application to agricultural soils may largely offset carbon benefits: a global meta-analysis. Global change biology. 23. 10.1111/gcb.13648.

22. McDonald, Sarah & Lawrence, Rachel & Kendall, Liam & Rader, Romina. (2019). Ecological, biophysical and production effects of incorporating rest into grazing regimes: A global meta analysis. Journal of Applied Ecology. 56. 10.1111/1365-2664.13496.

23. Gomez-Casanovas, Nuria & Blanc-Betes, Elena & Moore, Caitlin & Bernacchi, Carl & Kantola, I. & DeLucia, Evan. (2021). A review of transformative strategies for climate mitigation by grasslands. Science of The Total Environment. 799. 149466. 10.1016/j.scitotenv.2021.149466.

Annex 4. Trading Pilot summary

4.1. Market Trading Pilot

The test trading was performed with Soil Amendment projects and resulting CORC20 credits on Puro.earth platform. Along with the EU LIFE duration three projects were identified and selected to be verified according to the Soil Amendment requirements Puro.earth Soil amendments carbon removal methodology.

Applying soil improvement fibres is one-time external input of organic carbon to agricultural soils. Soil improvement fibres contain only moderate amounts of nutrients and are low in harmful substances. The maximum application rate according to nutrient and cadmium limitations varies typically from 35-50 wet tons per hectare. Application can be done every 3-5 years. Part of the carbon that fibres include remains stable and is stored for at least 20 years. The average application of 40 tons per hectare of soil improvement fibres include around 5 tons of organic carbon from which the amount of stable organic carbon is 1-1.4 tons depending on the composition of the fibre material. Soil improvement fibres in the Finnish project Soilfood are produced from pulp and paper mill side streams which otherwise would be incinerated.

The 20-year permanence requires one application of soil improvement fibre and the Yasso-modelling result and lab result indicate how much of that remains in the soil after 20 years. Only the stabile carbon share is contracted to the buyer as credits. The lifetime emissions according to the LCA-assessment are deducted from the stored carbon to get the net-sequestered tonnes of carbon dioxide. From the average application of 40 tons per hectare, that means approximately 5 tons of CO_2 per hectare removed from the atmosphere which equals 5 CORCs.

The revenue from sold credits is divided equally between the industrial supplier of the side-stream material, the processing company (Soilfood) and the farmers who apply the soil improvement fibre in their fields. This kind of profit distribution is needed to incentivize all actors in the value chain.

The project from Finland listed their Soil Amendments credits in August 2021. The prices were set at approximately 50 euros per tCO_2 stored for 20 years by credit seller i.e., Soilfood. The interest was high and resulted in many views but led to only a few trade transactions. The test trading period has only been 7 months. At a completed trade the ownership of the Soil Amendment credits is transferred to the Puro Registry. In a voluntary market, the buyer has the freedom to decide when and how to claim the CO_2 removal represented by the carbon credits. That process is called retirement and retired credits can no longer be traded or change ownership. The retirements are available in the Registry (Puro.earth | Registry)

The main concerns and confusion on the demand side were related to the claim and retirements. Buyers were unclear about the 20-year durability of the carbon storage and the kind of claim it justifies.

The farmers' consent to participate was received digitally by the project proponent, the party that centrally managed the logistics and processing of the Soil Amendment materials. Over 80% of the farmers wanted to participate and be represented jointly by the central party.

Soil amendment carbon removal experiences from 2022 onwards
Soilfood, the soil amendment fibre processing company On the market side, interest in Soilfood's carbon removals has increased from the beginning of 2022 and there are indications that demand will continue to grow at an accelerating pace during this spring. The price level of carbon removals from soil improvement fibres has been received well by companies interested in non-forest-based carbon removal products. In this group of products, the price of Soilfood's carbon removal credits is seen as highly attractive. Farmers have reacted positively to the idea of receiving additional income from carbon removal sales and they are expecting results on the progress of sales of the credits. From the farmers using soil improving products 90 % agreed to participate in the Trading Pilot representing 97,5 % of delivered soil improver tons. The price level of Soilfood's carbon removal credits did not raise questions among farmers, as the revenue model has been communicated to them clearly and transparently during the whole process. Overall, the revenue model used in Soilfood's carbon removal sales makes it even more profitable for farmers to use Soil Improvement Fibres, giving them an incentive to participate in the selling of their carbon removals. Soilfood Ltd is a Finnish circular economy company founded in 2015 that creates a sustainable food chain by processing industry side streams into fertilizers and soil amendments for agriculture.

Soil amendment carbon removal experiences from 2022 onwards

Tyynelä farm:

In Finland, there is decades of experience trialling soil improvement fibres in agriculture and horticulture. At the Tyynelä farm, a partner of this project, soil improvement fibres have been in trials since 2011 and the methods of using them have been developed at the farm. At the farm´s six-year crop rotation composted nutrient fibre is applied at the rate of 50 t/ha (40% dry matter) in late June just before terminating 2-year leguminous multi-species green manure ley with 3-4 shallow (up to 10 cm) minimum tillage passes. Shallow tillage incorporates soil improvement fibre to the soil with large amount of plant residue from the ley to feed the microbes. This creates stabile aggregates that sequester carbon and decrease nutrient leakage. The procedure is followed by the establishment of winter oilseed rape crop.

Because soil improvement fibres are high in carbon to nitrogen ratio, they immobilize soil nitrogen for 1-2 weeks after the application. Therefore, soil improvement fibres are best used when terminating green manure crops, or before winter crops. Also, prior to spring sown pulse crops, they are suitable but avoiding soil compaction during the transport and application should be considered.

Limiting factor of wide utilisation of soil improvement fibres is the cost. Rewarding carbon sequestration of fibres enables more extensive utilisation for the farmers.

Picture 2. Soil improvement fibre application on ley.

Annex 5. Suggested carbon management practices for pilot

In discussing different carbon management practices, it should be taken into account that carbon sequestration MRV based on soil sampling or modelling is not yet reliable or feasible for accurate assessment. Therefore, the results of the suggested practices that will be monitored are based on proxies of carbon sequestration based on scientific literature. The proposed methods are known to have reliable carbon sequestration results and are already used in other schemes (Mathiu et al. 2021).

During the proposed national pilot period (until 2030) the carbon sequestration MRV methodologies are considered to reach appropriate accuracy to monitor soil carbon stock changes directly. Therefore, the end of the pilot will enable truly additional market-driven soil carbon sequestration leaving multi-beneficial practice- and proxy-based schemes for the CAP. Pilot produces ready-for-use model to introduce result based multi beneficial schemes on CAP period beginning 2030.

In addition, the duration of the pledge of the carbon management practices are critical regarding the operator´s willingness to participate. Low threshold and short commitment periods increase participation to the pilot. However, this is contrary to soil carbon permanence, which is therefore ensured in the pilot by crediting with the use of buffer.

Below the different suggested carbon management practices for the pilot, the proxies for monitoring per different practices, the approximate costs and methodologies for monitoring are presented.

5.1. Practices for mineral soils

Cover crops in annual crop production

a. Cover cropping carbon credits are accrued when the CAP-subsidized level of cover crops is exceeded with a defined crop cover index monitored with Sentinel-satellite (or similar) in September or October. The defined crop cover index should be met also in the CAP-subsidized area.

b. Sink 1 CO_2 t/ha/yr according to Poeplau & Don (2015).

c. Cost approximately 30-50 €/ha.

d. Monitoring by satellites.

Adaptive multi-paddock grazing

a. Intensive rotational grazing where ruminants are short period (1-2 days) in the ley parcel and eats half of the biomass at a time. Ley has a recovery period of 15-30 days.

b. Sink even 16 t CO_2 /ha/yr according to Stanley (2018) and Teague (2016).

c. Additional costs compared to conventional grazing 50-100 €/ha in the establishment year.

d. Monitoring by bookkeeping, GPS-tracking of animals and satellite.

Organic soil amendments

a. Using organic soil amendments such as biochar or soil improvement fibres, which are already piloted in the project.

b. The sink depends on the application rate and decomposition of the material. The sink is for example 4-10 t CO_2 /ha/yr per application with at least 20 years of permanence.

c. Cost depends on the application rate and the product.
Renumeration according to market price.

d. Monitoring by receipts.

5.2. Organic soil practices

Paludiculture

a. High water level culture with crops such as willow, cattail or cranberry.

b. Emission reduction 20-35 t CO_2 /ha/yr according to Kekkonen et al. (2019).

c. Establishment cost approximately 1000 €/ha according to Miettinen et al. 2020.

d. Monitoring by satellites and controlling

Wetland restoration

a. Permanent water level rising to the natural level.

b. Emission reduction 20-35 t CO_2 /ha/yr according to Kekkonen et al. (2019).

c. Establishment costs approximately 1400 €/ha, according to Hiilipörssi.

d. Monitoring by satellites and controlling.

Afforestation and reforestation

a. To establish new forests in areas where no trees are growing now for various reasons.

b. Sink size depends on site type, climatic conditions and stand age. The annual growth rate i.e., sink increases via the stand age during the first decades reaching values > 10 m3 ha-1 yr-1 (1m3 is c. 1 t of CO_2) of stem wood and leveling of slowly after that. In addition to stem wood, branches and roots also accumulate carbon.

c. Forest establishment cost approximately 2350 €/ha according to WP2 cost analysis.

d. The survival and growth are measured by field surveys.

Annex 6. Proposed pilot scheme in Finland

The mechanism for the pilot scheme could look like this, based on the example of Finland and its biomandate.

- The transport sector biomandate law is updated by introducing a new "flexible sub mandate". The biomandate target in Finland, which exceeds the level required by the EU's renewable energy Directive, could be partially fulfilled under the pilot scheme by the use of a new flexibility. In this scheme overall biomandate target would be increased correspondingly to the flexibility being allowed.
- The Finnish Ministry of Environment establishes bio-tickets, incentivising the market players to uptake high quality carbon farming practices.
- The sequestrated carbon removals need to be certified in a reliable and transparent way. This is key to the pilot in order to build trust between the market players and with stakeholders (such as environmental NGOs). The Ministry will set the methodologies applicable for measurement, reporting and verification of the carbon removals, with the possibility to delegate over-sight of the pilot project to reputable offsetting schemes such as that run by Gold Standard. Once verified, the National Authority will issue the farmers with a corresponding quantity of bio-tickets at a rate of 1 bio-ticket for every 2 tonnes of sequestrated carbon, as described above.
- The farmer or an intermediary acting on behalf of the farmer would place the ticket on the market to obtain the highest price available, with proceeds (net of transaction costs) being returned to the farmer. The trading can take place via auctions, on designated markets or 'over-the counter', as is normal practice in other markets. This could be done via existing voluntary market platforms, such as Puro.Earth.
- If the scheme attracts enough suppliers, the monetisation of bio-tickets will incentivise the farmers to compete for quality sequestration cost-effectively.
- Transport companies will purchase the bio-tickets at competitive prices. The companies are able to register the bio-tickets in the national registry, where they can surrender the tickets for compliance purposes with respect to obligations under the renewable energy in transport targets ('biomandate'). Surrendering of the ticket will cancel the bio-ticket.
- To continue fulfilling the carbon targets, the companies will return to the market to acquire more, incentivising farmers to consistently implement carbon farming methodologies.
- The pilot scheme should simultaneously lead to a robust information sharing platform and educating stakeholders as this need was identified within the project.

References

Abdalla, M. & Hastings, Astley & Cheng, Kun & Yue, Qian & Chadwick, Dave & Espenberg, Mikk & Truu, Jaak & Rees, Bob & Smith, Pete. (2019). A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. Global Change Biology. 25. 10.1111/gcb.14644.

Almaraz, Maya & Wong, Michelle & Geoghegan, Emily & Houlton, Benjamin. (2021). A review of carbon farming impacts on nitrogen cycling, retention, and loss. Annals of the New York Academy of Sciences. 1505. 10.1111/nyas.14690.

Argus Biofuels Daily international market prices and commentary. Issue 22-58. Thu 24 March 2022. Argus Media group

Arvanitopoulos, Theodoros & Garsous, Grégoire & Agnolucci, Paolo. (2021). Carbon Leakage and Agriculture: A Literature Review on Emissions Mitigation Policies, OECD Food, Agriculture and Fisheries Working Papers, No. 169. 10.1787/9247f1e7-en.

Batjes, N. and Sombroek, W. 1997. Possibilities for carbon sequestration in tropical and subtropical soils. Glob. Chang. Biol., 3. 161-173

Castellano, Michael & Archontoulis, Sotirios & Helmers, Matthew & Poffenbarger, Hanna & Six, J.. (2019). Sustainable intensification of agricultural drainage. Nature Sustainability. 2. 914-921. 10.1038/s41893-019-0393-0.

Chen, S., Martin, M.P., Saby, N.P.A., Walter, C., Angers, D.A., and Arrouays, D. 2018. Fine resolution map of top- and subsoil carbon sequestration potential in France, Science of The Total Environment, Volume 630. 389-400, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2018.02.209

Chertov, O.G. Komarov, A.S. Nadporozhskaya, M. Bykhovets, S.S., and Zudin, S. L. 2001. ROMUL – a model of forest soil organic matter dynamics as a substantial tool for forest ecosystem modeling. Ecological Modelling, 138. 289-308

COM. 2021. COMMISSION STAFF WORKING DOCUMENT Sustainable carbon cycles for a 2050 climate-neutral EU, Technical Assessment, Accompanying the Communication from the Commission to the European Parliament and the Council Sustainable Carbon Cycles. https://ec.europa.eu/clima/system/files/2021-12/swd_2021_451_parts_1_to_3_en_0.pdf

Coleman, D.C. and Jenkinson D.S. 2005. RothC-26.3 A Model for Turnover of Carbon in Soil. Model Description and Windows Users Guide. IACR-Rothamsted, Harpenden, U.K. 45.

COWI, Ecologic Institute and IEEP (2021) Technical Guidance Handbook - setting up and implementing result-based carbon farming mechanisms in the EU Report to the European Commission, DG Climate Action, under Contract No. CLIMA/C.3/ETU/2018/007. COWI, Kongens Lyngby.

Dignac, M.F., Derrien, D., Barré, P., Barot, S., Cécillon, L., Chenu, C. and Basile-Doelsch, I. 2017. Increasing soil carbon storage: mechanisms, effects of agricultural practices and proxies: a review. Agron. Sustain. Dev., 37. 14

European Commission forestry. 2021. EU forestry explained. https://ec.europa.eu/info/food-farming-fisheries/forestry/forestry-explained_en#relatedlinks

European Commission environment. 2021. New EU Forest strategy for 2030, To improve the quantity and quality of EU forests. Forest strategy (europa.eu)

European parliament. 2021. Greenhouse gas emissions by country and sector (infographic). Greenhouse gas emissions by country and sector (infographic) | News | European Parliament (europa.eu)

Eurostat Statistics Explained. 2020. Forest, forestry, and logging statistics. Forests, forestry and logging - Statistics Explained (europa.eu)

Eurostat Statistics Explained. 2022. Land area covered by forest. 39% of the EU is covered with forests - Products Eurostat News - Eurostat (europa.eu)

FAOSTAT. 2022. Food and agriculture organization of the United Nations. https://www.fao.org/faostat/en/#data

FAO. 2021. Sate of the World's Forests 2020. https://www.fao.org/state-of-forests/en/

FAO. 2020. Land use in agriculture by the numbers. https://www.fao.org/sustainability/news/detail/en/c/1274219/

Friedlingstein. 2021. Distribution of fossil fuel CO_2 emissions worldwide in 2020, by select country. Global Carbon Project. Source link, globalcarbonatlas.org. https://www.statista.com/statistics/271748/the-largest-emitters-of-CO2 -in-the-world/

Giri, R and Mandla, V. 2017. STUDY AND EVALUATION OF CARBON SEQUESTRATION USING REMOTE SENSING AND GIS: A REVIEW ON VARIOUS TECHNIQUES. International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 4. 287-300 Article ID: IJCIET_08_04_035. Available online at http://iaeme.com/Home/issue/IJCIET?Volume=8&Issue=4

Guenet, Bertrand & Gabrielle, Benoît & Chenu, Claire & Arrouays, Dominique & Balesdent, Jerome & Bernoux, Martial & Bruni, Elisa & Caliman, Jean-Pierre & Cardinael, Rémi & Chen, Songchao & Ciais, Philippe & Desbois, Dominique & Fouché, Julien & Frank, Stefan & Hénault, Catherine & Lugato, Emanuele & Naipal, Victoria & Nesme, Thomas & Obersteiner, Michael & Zhou, Feng. (2021). Can N2O emissions offset the benefits from soil organic carbon storage?. Global Change Biology. 27. 237-256. 10.1111/gcb.15342.

Hagelberg, E., Wikström, U., Joona, J. & Mattila, T. (2020). Regenerative agriculture: the new direction of food production. Baltic Sea Action Group.

Hannula, Silja & Morriën, Elly. (2022). Will fungi solve the carbon dilemma?. Geoderma. 413. 115767. 10.1016/j.geoderma.2022.115767.

Harris, N.L., Gibbs, D.A., Baccini, A. et al. 2021. Global maps of twenty-first century forest carbon fluxes. Nat. Clim. Chang. 11. 234–240. https://doi.org/10.1038/s41558-020-00976-6

Hassink J. 1997. The capacity of soils to preserve organic C and N by their association with clay and silt particles. Plant Soil, 191. 77-87

Hiilipörssi Oy. https://hiiliporssi.fi/

Huang, Yawen & Ren, Wei & Wang, Lixin & Hui, Dafeng & Grove, John & Yang, Xiaojuan & Tao, Bo & Goff, Ben. (2018). Greenhouse gas emissions and crop yield in no-tillage systems: A meta-analysis. Agriculture, Ecosystems and Environment. 268. 144-153. 10.1016/j.agee.2018.09.002.

Hyvönen, Terho & Heliölä, Janne & Koikkalainen, Kauko & Kuussaari, Mikko & Lemola, Riitta & Miettinen, Antti & Rankinen, Katri & Lång, Kristiina & Turtola, Eila. (2020). Maatalouden ympäristötoimenpiteiden ympäristö- ja kustannustehokkuus (MYTTEHO): Loppuraportti. Report number: Luonnonvara- ja biotalouden tutkimus 12/2020. Affiliation: Natural Resources Institute Finland (Luke).

Jansson, P. and Karlberg, L. 2004. COUP Manual. Coupled Heat and Mass Transfer Model for Soil-plant-atmosphere Systems. Stockholm, Sweden, 445.

Kekkonen et al. (2019) Mapping of cultivated organic soils for targeting greenhouse gas mitigation, Carbon Management, 10:2, 115-126.

Kim, Nakian & Zabaloy, María & Guan, Kaiyu & Villamil, María. (2020). Do cover crops benefit soil microbiome? A meta-analysis of current research. Soil Biology and Biochemistry. 142. 107701. 10.1016/j.soilbio.2019.107701.

Lin, Brenda & Macfadyen, Sarina & Renwick, Anna & Cunningham, Saul & Schellhorn, Nancy. (2013). Maximizing the Environmental Benefits of Carbon Farming through Ecosystem Service Delivery. BioScience. 63. 793-803. 10.1525/bio.2013.63.10.6.

Liski, J. Palosuo, T. Peltoniemi, M., and Sievänen, R. 2005. Carbon and decomposition model Yasso for forest soils. Ecological Modelling, 189. 168-182

Liu, Ting & Chen, Xiaoyun & Hu, Feng & Ran, Wei & Shen, Qirong & Li, Huixin & Whalen, Joann. (2016). Carbon-rich organic fertilizers to increase soil biodiversity: Evidence from a meta-analysis of nematode communities. Agriculture Ecosystems & Environment. 232. 199-207. 10.1016/j.agee.2016.07.015.

Mathieu Nogues, Mirabelle Husson, Grousset Paul, Suzanne Reynders, Jean-Francois Soussana.

Framework of possible business models for the implementation of a carbon demonstrator: Territorial

demonstrators of soil carbon sequestration.. [Rapport Technique] INRAE; LISIS; NATAÏS. 2021. hal-03327011

Miettinen, A., Koikkalainen, K., Silvan, N. & Lehtonen, H. (2020). Kosteikkoviljelyn päätuote turvepellolla on päästövähennys. Käytännön maamies 10/2020, s. 36-38

Minasny, B., Malone, B.P., McBratney, A.B., Angers, D.A., Arrouays, D., Chambers, A., and Winowiecki, L. 2017. Soil carbon 4 per mille. Geoderma, 292. 59-86.

Moreno, Gerardo & Gonzalez-Bornay, Guillermo & Pulido, Fernando & López-Díaz, María Lourdes & Bertomeu, Manuel & Juárez, Enrique & Díaz, Mario. (2015). Exploring the causes of high biodiversity of Iberian dehesas: the importance of wood pastures and marginal habitats. Agroforestry Systems. 90. 10.1007/s10457-015-9817-7.

Morris, Craig. (2021). How Biodiversity-Friendly Is Regenerative Grazing?. Frontiers in Ecology and Evolution. 23. 9:816374.. 10.3389/fevo.2021.816374.

Mulrow, J., Machaj, K., Deanes, J., and Derrible, S. 2019. The state of carbon footprint calculators: An evaluation of calculator design and user interaction features. Sustainable Production and Consumption, Volume 18. 33-40.

OEDC & IEA. 2019. Designing the Article 6.4 mechanism: assessing selected baseline approaches and their implications. Climate Change Expert Group. Paper No. 2019(5). Available at: https://www.oecd.org/environment/cc/Designing-the-Article-6-4-mechanismassessing-selected-baseline-approaches-and-their-implications.pdf

Olin, S., Lindeskog, M., Pugh, T. A. M., Schurgers, G., Wårlind, D., Mishurov, M., Zaehle, S., Stocker, B. D., Smith, B., and Arneth, A. (2015). Soil carbon management in large-scale Earth system modelling: implications for crop yields and nitrogen leaching, Earth Syst. Dynam., 6, 745–768.

Padgett, J.P., Steinemann, A.C., Clarke, J.H., and Vandenbergh, M.P. 2008. A comparison of carbon calculators. Environmental Impact Assessment Review, Volume 28, Issues 2–3. 106-115.

Parton, W.J. Schimel, D. S. Colem, C.V., and Ojima, D. S. 1987. Analysis of factors controlling soil organic matter levels in Great Plains grasslands. Soil Science Society of America Journal, 51. 1173-1179. https://acsess.onlinelibrary.wiley.com/doi/abs/10.2136/sssaj1987.03615995005100050015x

Parton,W. P. McKeown, B. Kirchner, V., and Ojima, D.S. 1992. CENTURY User's Manual NREL Publication, Colorado State University, Fort Collins, Colorado, U.S. (1992).

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G.P., and Smith, P. 2016. Climate-smart soils. Nature, 532. 49-57

Poeplau and Don (2015) Carbon Sequestration in Agricultural Soils via Cultivation of Cover Crops—A Meta-Analysis. Agriculture, Ecosystems & Environment, 200, 33-41.

Puissant, Jérémy & Villenave, Cécile & Chauvin, Camille & Plassard, Claude & Blanchart, Eric & Trap, Jean & Blanchart, Eric. (2021). Quantification of the global impact of agricultural practices on soil nematodes: A meta-analysis. Soil Biology and Biochemistry. 10.1016/j.soilbio.2021.108383.

Quemada, M. & Baranski, Marcin & Lange, M.N.J. & Vallejo, A. & Cooper, Julia. (2013). Meta-analysis of strategies to control nitrate leaching in irrigated agricultural systems and their effects on crop yield. Agriculture, Ecosystems & Environment. 174. 1–10. 10.1016/j.agee.2013.04.018.

Rolff, C. and Ågren G. I. 1999.Predicting effects of different harvesting intensities with a model of nitrogen limited forest growth. Ecological Modelling, 118. 193-211.

Schils, R., Kuikman, P., Liski, J., van Oijen, M., Smith, P., Webb, J., Alm, J., Somogyi, Z., van den Akker, J., Billett, M., Emmett, B., Evans, C., Lindner, M., Palosuo, T., Bellamy, P., Alm, J., Jandl R., and Hiederer, R. 2008. Review of Existing Information on the Interrelations between Soil and Climate Change (CLIMSOIL) – Final Report

Six, J., Conant, R., Paul, E.A., and Paustian, K. 2002. Stabilization mechanisms of soil organic matter: implications for c-saturation of soils. Plant Soil, 241. 155-176

Sulla-Menashe, D. 2019. Using NASA's Harmonized Landsat Sentinel-2 Product to Give Farmers Real-Time Crop Health Information. Using NASA's Harmonized Landsat Sentinel-2 Product to Give Farmers Real-Time Crop Health Information | Landsat Science

Smith, P., Fang, C., Julian, C.F., Dawson, J.C., and Moncrieff J.B. 2008. Impact of Global Warming on Soil Organic Carbon, Advances in Agronomy, Volume 97, 1-43.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., and Romanenkov, V. 2008. Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences. Volume 363, Issue 1492. https://doi.org/10.1098/rstb.2007.2184

Smith, P., Powlson, D., Glendining, M., and Smith, J.O. 1997. Potential for carbon sequestration in European soils: Preliminary estimates for five scenarios using results from long term experiments. Global Change Biology, 3(1). 67-79.

Stanley et al. (2018) Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in

Midwestern USA beef finishing systems. Agricultural Systems 162, 249–258.

Stewart, C.E., Paustian, K., Conant, R.T., Plante, A.F., and Six, J. 2007. Soil carbon saturation: concept, evidence and evaluation. Biogeochemistry, 86. 19-31.

Streiff, L. 2021. NASA Satellites Help Quantify Forests' Impacts on Global Carbon Budget. https://www.nasa.gov/feature/goddard/2021/nasa-satellites-help-quantify-forests-impacts-on-the-global-carbon-budget

Teague et al. (2016) The role of ruminants in reducing agriculture's carbon footprint in North

America. Journal of Soil and Water Conservation 71, 156-164

Torralba, Mario & Fagerholm, Nora & Burgess, Paul & Moreno, Gerardo & Plieninger, Tobias. (2016). Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agriculture, Ecosystems & Environment. 230. 150-161. 10.1016/j.agee.2016.06.002.

Tripathi, S., Maurya, A., and Soni, P. 2010. Calculating carbon sequestration using remote sensing and GIS. Geospatial world. Remote Sensing & GIS Lab, MGCGV, Chitrakoot, Satna, Madhya Pradesh, India

Tsonkova, P., Böhm, C., Quinkenstein, A. et al. Ecological benefits provided by alley cropping systems for production of woody biomass in the temperate region: a review. Agroforest Syst 85, 133–152 (2012). https://doi.org/10.1007/s10457-012-9494-8.

Tuomi, M. Rasinmäki, J. Repo, A. Vanhala, P. and LIski, J. 2011. Soil carbon model Yasso07 graphical user interface. Environmental Modelling & Software. Elsevier, Volume 26, Issue 11. 1358-1362. https://doi.org/10.1016/j.envsoft.2011.05.009

Tuomi M., Thum T., Järvinen H., Fronzek S., Berg B., armon M., Trofymow J. A., Sevanto S., and Lisk J. 2009. Leaf litter decomposition—Estimates of global variability based on Yasso07 model. Ecological Modelling 220. Issue 23. 3362 – 3371. doi:10.1016/j.ecolmodel.2009.05.016

Wallman, P. Belyazid, S. Svensson, M.G.E. and Svendrup, H. 2006.
DECOMP – a semi-mechanistic model of litter decomposition.
Environmental Modelling and Software, 21. 33-44.

Verra standard, Updates to VCS Program Released 20 January 2022
https://verra.org/vcs-program-updates-released/

West, T. O., and Post, W. M., 2002. Soil organic carbon sequestration rates by tillage and crop rotation. Soil Science Society of America Journal, 66(6), 1930-1946.

Wiesmeier, M., Hübner, R., Spörlein, P., Hangen, E., Reischl, A., Schilling, B., and Kögel-Knabner, I. 2014. Carbon sequestration potential of soils in southeast Germany derived from stable soil organic carbon saturation. Glob. Chang. Biol., 20. 653-665.

Zhao, Xin & Liu, Bingyang & Liu, Shengli & Qi, Jianying & Xing, Wang & pu, Chao & Li, Shuai Shuai & Zhang, Xiong Zhi & Yang, Xiao Guang & Lal, Rattan & Chen, Fu & Zhang, Hailin. (2020). Sustaining crop production in China's cropland by crop residue retention: A meta analysis. Land Degradation and Development. 31. 10.1002/ldr.3492.

Udawatta, Ranjith & Rankoth, Lalith & Jose, Shibu. (2019). Agroforestry and Biodiversity. Sustainability. 11. 2879. 10.3390/su11102879.

Yang, Yali & Xie, Hongtu & Mao, Zhun & Bao, Xuelian & He, Hongbo & Zhang, Xudong & Liang, Chao. (2022). Fungi determine increased soil organic carbon more than bacteria through their necromass inputs in conservation tillage croplands. Soil Biology and Biochemistry. 167. 108587. 10.1016/j.soilbio.2022.108587.

Sedjo, R. & Sohngen, B. 2012. Carbon Sequestration in Forests and Soils. Annual review of resource economics 4: 127-144.

Mäkipää, R., Karjalainen, T., Pussinen, A. & Kukkola, M. 1998. Effects of nitrogen fertilization on carbon accumulation in boreal forests: Model computations compared with the results of long-term fertilization experiments. Chemosphere 36: 1155-1160