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A system analysis of carbon farming schemes in support of the wider implementation of carbon farming in Flanders (Belgium)

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Abstract

Throughout Europe, numerous carbon farming schemes have been developed in the past decade, ranging from simple to more elaborated. Recently, schemes are increasingly being developed for the agricultural sector, with projects focusing on carbon removals (carbon sequestration) in agricultural soils and woody landscape elements, as well as focusing on reduced and/or avoided emissions at the farm level. These projects outcomes, with significant climate mitigation and adaptation potential, can be realised by altering the farm management, more specifically through the implementation of 'carbon farming practices'.

Despite the numerous carbon farming initiatives being developed, no regulatory framework exists yet, and consequently, carbon credits or certificates may be of variable quality. Therefore, in the LIFE CarbonCounts project (*LIFE20 PRE/BE/019),* we explored carbon farming schemes that have the potential to be feasible, reliable and cost efficient for Flanders, the northern region of Belgium. Flanders is a highly urbanised region, in which the agricultural sector represents approximately 50% of the open space and which is characterized by medium size farms compared to other EU countries.

We adopted a qualitative research approach: conducting in-depth interviews with stakeholders from various professional backgrounds, organizing two workshops with policy stakeholders, and extensively reviewing carbon farming schemes in Belgium (e.g. Claire, Soil Capital), our neighbouring countries (e.g. Label Bas Carbone, Stichting Nationale Koolstofmarkt, Woodland Carbon Code…) and internationally (e.g. Verified Carbon Standard, Gold Standard).

All this information was combined in a system analysis (**Chapter 2**), building on systems thinking, and subsequently we analysed the multitude of aspects (components) to be considered when developing carbon farming schemes. Specifically, we studied the relevant policy context (**Chapter 3**) and investigated different carbon farming scheme designs, with a strong focus on the governance system, guiding principles (e.g. additionality, permanence, carbon leakage…) and Monitoring, Reporting and Verification (MRV) systems, as these are the backbone of carbon farming schemes (**Chapter 4**). Besides that, we looked at the opportunities of building a geodataplatform (**Chapter 5**) and considered some emerging technologies and scientific insights that may increase the cost-efficiency of MRV systems (**Chapter 6**). On top of that, we also studied the principles of and evolutions in the Voluntary Carbon Market (**Chapter 7**), and considered the different aspects of carbon farming as a business model (**Chapter 8**). Finally, we came up with an overview of challenges and potential issues of carbon farming (**Chapter 9**).

This system analysis report will be used as a knowledge base and will be shared with various stakeholders, enabling us to collaboratively design a roadmap (to be published in an additional science-to-policy report) with recommendations for a widely accepted and more widespread implementation of carbon farming in Flanders. On top of that, we will lay the foundations of an action platform for carbon farming in Flanders.

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List of abbreviations

A6.4ERs	Paris Agreement Article 6.4 Emission Reductions
AFOLU	Agriculture, Forestry and Other Land Use
AI	Artificial Intelligence
API	Application Programming Interface
BAU-scenario	Business-as-usual scenario
BDB	Bodemkundige Dienst van België (Soil Service of Belgium)
BELAC	Belgian Association for Accreditation
CA	Corresponding Adjustment
CAP	Common Agricultural Policy (Dutch: Gemeenschappelijk Landbouwbeleid, GLB)
CCB	Climate, Community and Biodiversity standard
CDM	Clean Development Mechanism
CF	Carbon farming
CFI	Carbon Farming Initiative
COP	Conference of Parties
EC	European Commission
EJP SOIL	European Joint Programme SOIL
EOC	Effective organic carbon
ESR	Effort Sharing Regulation
ETS	Emission Trading System
F2F	Farm to Fork
FECP	Flemish Energy and Climate Plan (Dutch: Vlaams Energie- en Klimaatplan, VEKP)
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
GS	Gold Standard
GSAA	GeoSpatial Aid Application (Dutch: Verzamelaanvraag)
IALM	Imrpoved Agricultural Land Management
ICROA	International Carbon Reduction and Offset Alliance
INS	Inelastic Neutron Scattering
ISO	International Organization for Standardization
ITMOs	Internationally Transferred Mitigation Outcomes
LBC	Label Bas Carbone
LIBS	Laser Induced Breakdown Spectroscopy
LPIS	Land Parcel Identification System
LULUCF	Land Use, Land Use Change and Forestry
MRV	Monitoring, Reporting and Verification
Mt CO_2-eq/yr	Megatons of carbon dioxide equivalent per year
NDCs	Nationally Determined Contributions
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
PC	Peatland Code
REDD+	Reduced Emissions from Deforestation and Forest Degradation
RtZ	Race to Zero
SBTs	Science-Based Targets

SC	Soil Capital
SDGs	Sustainable Development Goals
SNK	Stichting Nationale Koolstofmarkt
SOC	Soil Organic Carbon
SP	South Pole
VCM	Voluntary Carbon Market
VCS	Verified Carbon Standard
VCU	Verified Carbon Unit
VNIR-SWIR	Visible-near Infrared-Shortwave Infrared
VVB	Validation and Verification Body
WCC	Woodland Carbon Code

Glossary

For an explanation of the terminology used in this document, we refer to section 1.2, Chapter 7, Chapter 8 and Appendix 1.A (Glossary)..

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1. Introduction

1.1. General context and problem statement

Since entering the Industrial Age, the concentration of greenhouse gases (CO_2 or carbon dioxide, N_2O or nitrous oxide, CH_4 or methane) in the atmosphere has risen sharply, leading to a changing climate with higher temperatures and more extreme precipitation patterns, including more frequently recurring droughts and floods (IPCC, 2022). To counter this evolution, greenhouse gas (GHG) emissions – especially those from fossil fuel use – must be drastically reduced. At the same time, CO_2 should be removed from the atmosphere by activating carbon sinks. One way to achieve this, is by storing CO_2 within the soil in the form of soil organic carbon (SOC), or in (new) above-ground or below-ground woody vegetation, for a long period of time. This transfer of carbon from the atmosphere to the soil and/or biomass is one of the cornerstones of carbon farming, which also includes sustainably reduced GHG emissions and avoided land-based CO_2 emissions (see section 1.2 for definitions). This bundled mitigation potential of carbon farming provides land managers in general, and farmers in particular, with the opportunity to make a positive contribution towards reaching a climate-neutral society. However, the adoption of carbon farming practices implies a change in management practices and in the business model for most farmers and land managers.

To quantify and valorise the efforts made by farmers and other land managers, carbon farming schemes can be developed and linked up to new and innovative or existing public funding schemes (e.g. through the Common Agricultural Policy - CAP) and/or the voluntary carbon market (VCM). This poses new opportunities for a new green business model. Although this business model can involve a win-win for the farmers and the environment, among others due to the co-benefits brought about by higher SOC levels (such as improved water retention and increased soil biodiversity), the development of carbon farming schemes, as well as the functioning of the VCM in general, has been largely unregulated to date. This, in combination with the rapidly growing demand for carbon credits/certificates (see Appendix 1.A for difference) and the need to reduce GHG emissions, could lead to a proliferation of public and/or private carbon farming scheme initiatives that do not necessarily have comparable and sufficient environmental integrity, scientific robustness or transparency. In the longer term, this could lead to a lack of trust and an overall negative perception towards all carbon farming schemes.

With this report, prepared in the context of the LIFE CarbonCounts project (see section 1.5 for more information on this project), we aim to achieve a better understanding of the different components of carbon farming schemes, and gain knowledge on the ground rules that could ensure positive impacts and reduce the risk on negative impacts. We discuss the advantages and disadvantages of different types of (existing) carbon farming schemes and highlight the different aspects to consider when developing/designing a carbon farming scheme. Throughout the report, we focus on carbon farming in the agricultural sector and the essential aspects that should be considered to enable a more widespread implementation of carbon farming in Flanders (Belgium).

In what follows, we start with an introduction to what is considered with 'carbon farming', we give an overview of how it can be implemented in practice and provide insights on its potential benefits. After that, we outline the context of the LIFE CarbonCounts project.

1.2. What is carbon farming?

1.2.1. Definition

Carbon farming is perceived differently by various actors and organizations, yet throughout this document, we will consistently refer to the definition provided by McDonald et al. (2021), which includes elements presented by COWI et al. (2021a):

> "*Carbon farming focuses on the management of carbon pools, flows and greenhouse gas fluxes at farm level, with the purpose of mitigating climate change. This involves the management of both land and livestock, all pools of carbon in soils, materials and vegetation, plus fluxes of carbon dioxide and methane, as well as nitrous oxide.*"

Besides this definition, the term 'carbon farming' is also often used to refer to a **new green business model**, that consists of incentives for farmers to implement specific farming practices that deliver a climate benefit. These incentives can come from public funds, private payments, or a combination of the two (McDonald et al., 2021). This business model aspect of carbon farming is also put forward by the European Commission (EC), in its communication on Sustainable Carbon Cycles (European Commission, 2021). In this communication, the term 'carbon farming' is also used to refer to agriculture-based as well as non-agriculture-based practices and land use changes that lead to climate mitigation. Throughout the LIFE CarbonCounts project and this report, however, we only consider carbon farming within the **agricultural sector**. Land management strategies that contribute to climate mitigation through the restoration of natural habitats (e.g. wetland and peatland rewetting), and land use changes that move the management of the land away from agriculture (e.g. afforestation of agricultural land) are therefore not considered. Schemes or practices concerning coastal wetlands, regenerative aquaculture or marine permaculture are also not considered. These too are sometimes denoted as 'carbon farming'.

In addition, we recognize the overlap between carbon farming and the concept of regenerative agriculture. **Regenerative agriculture** can be seen as an universal set of principles and practices aimed at increasing biodiversity, improving soil health and sequestering carbon (Newton et al., 2020). Although there is a clear overlap with carbon farming (the terms are sometimes incorrectly used interchangeably), carbon farming does not necessarily utilize only regenerative agriculture practices and is aimed specifically at carbon sequestration, as well as reducing and avoiding GHG emissions.

1.2.2. What type of carbon pools and greenhouse gases are considered?

In carbon farming schemes, it is important to define what **type of greenhouse gases** will be considered and from what sources (e.g. only from soils, or also from fuel use, manure storage, emissions by animals etc). Typically, method documents of carbon farming schemes focus on emissions of CO_2 or carbon dioxide, N_2O or nitrous oxide, CH_4 or methane and the potential trade-offs between these gases. In this regard, the global warming potential of CO_2 is considered as a reference, and the warming potential of other greenhouse gases is converted into the equivalent amount of CO_2 with the same warming potential over a certain period of time (**CO_2-eq**).

Regarding carbon, while developing method documents[1] for specific agricultural activities, it is important to clearly delineate the type(s) of carbon pool(s) to consider for carbon accounting. **Carbon pools**, i.e. reservoirs that exchange carbon through output and intake, typically consist of oceans, sedimentary rocks, terrestrial ecosystems and the atmosphere (FAO, 2003). In the context of carbon farming, the latter two, and their mutual interactions, are especially important. Therefore, method documents mostly consider interactions between the atmosphere, soils, above-ground woody vegetation and below-ground woody vegetation – and thus consider all agricultural activities that affect one of these sources and sinks (e.g. through the management of land/soils, crops, manure application, woody vegetation etc.).

The **choice** for the type of carbon pools and greenhouse gases to consider in a specific methodology, is often the result of a deliberate **trade-off between complexity and pragmatism**. The more carbon pools and greenhouse gases that are considered, the more complex the carbon accounting becomes. In practice, especially the process of Monitoring, Reporting and Verification may become lengthy, expensive and very complex (e.g. time-intensive and costly data collection, complex calculations for carbon accounting, high administrative burden for reporting, time-intensive verification etc.). Allowing for the exclusion of certain carbon pools or greenhouse gases with a minimal impact, or having certain carbon pools or GHG emissions to be optional, can increase the flexibility of carbon farming methodologies.

For example, the 'Methodology for Improved Agricultural Land Management' (developed for the Verified Carbon Standard (VCS) by Indigo Ag. and TerraCarbon) states that "where the increase in GHG emissions from any project emissions or leakage source, and/or decreases in carbon stocks in carbon pools, is **less than 5% of the total net anthropogenic GHG emission reductions and removals** due to the project, such sources and pools may be deemed *de minimis* and may be ignored (i.e. their value may be accounted as zero)" (TerraCarbon LLC & Indigo Ag., 2021). The methodology's approach to the inclusion or exclusion of certain carbon pools and GHG emissions is shown in Table 1 (on the next page).

Moreover, carbon farming schemes often have multiple methodologies that potentially can be combined, which leaves the decision on what type of carbon pools and greenhouse gases to consider to the project developers[2] (i.e. they can decide what methodology to use). The French domestic carbon standard (carbon farming scheme) Label Bas Carbon (LBC), for instance, has multiple methodologies, each with their specific focus on certain carbon pools and GHG emissions. The 'Méthode Grande Cultures', focuses on crop and nutrient management, and the use of fossil fuels and fertilizers, whereas the 'Méthode Haies' and the 'Méthode Plantations de Vergers' have a focus on changes in woody vegetation carbon stocks, and the 'Méthode Carbon Agri' focuses on livestock, manure and crop management.

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[1] A method document encompasses all rules, guiding principles (see section 4.2), protocols and Monitoring, Reporting and Verification processes that should be followed when implementing carbon farming projects (i.e. how to go from a project description to verified project outcomes). A method document might focus on a single carbon farming practice, or multiple. An example of a method document is the 'Improved Agricultural Land Management method by Indigo and TerraCarbon.

[2] All entities involved with the planning, implementation and reporting of a specific carbon farming project. This always includes the farmer(s) or land manager(s), and possibly further includes advisors, NGOs, consultants, governmental organizations and/or private companies.

Table 1 GHG sources included in or excluded from the project boundary in the baseline and the project scenario (TerraCarbon LLC & Indigo Ag., 2021)

Source	GHG	Included?	Justification/Explanation
SOC	CO_2	Yes	Quantified as stock change, rather than an emissions source.
Soil methanogenesis	CH_4	Optional*	
Enteric fermentation	CH_4	Yes	If livestock are present in the project or baseline scenario, CH_4 emissions from enteric fermentation must be included in the project boundary.
Manure deposition	CH_4 N_2O	Yes Yes	If livestock are present, CH_4 and N_2O emissions from manure deposition and management must be included.
Fossil fuels	CO_2	Optional*	The sources of fossil fuel emissions are vehicles (mobile sources, such as trucks, tractors, etc.) and mechanical equipment required by the agricultural land management activity.
Use of N-based fertilizers	N_2O	Yes	If in the baseline scenario the project area would have been subject to nitrogen fertilization, or If nitrogen fertilization is greater in the project scenario relative to the baseline scenario, N_2O emissions from nitrogen fertilizers must be included in the project boundary.
Use of N-fixing species	N_2O	Yes	If N-fixing species are planted in the project, N_2O emissions from N-fixing species must be included.
Woody biomass	CO_2	Optional*	Quantified as stock change, rather than an emissions source.
Biomass burning	CO_2 CH_4 N_2O	Excluded Optional* Optional*	Carbon stock decreases due to burning are accounted as a carbon stock change.
Optional* Must be included where the project activity may significantly increase emissions compared to the baseline scenario and may be included where the project activity may reduce emissions compared to the baseline scenario.			

1.2.3. What spatial scope is considered?

In practice, carbon farming techniques are implemented by farmers (and other landowners) at the scale of individual agricultural fields / parcels. However, when this implementation is coupled to a business model and carbon credits or certificates are sold, a specific project boundary has to be determined for a correct accounting of the carbon farming project[3]. This **project boundary** is **determined by a set of criteria**, detailed in the method document. These criteria pertain to specific carbon pools, greenhouse gases and spatial boundaries. Whereas the definition of carbon farming (see section 1.2.1) refers to the **farm as a whole**, some methodologies rather focus on a set of agricultural parcels. This is sometimes preferred by project developers as it provides more flexibility for the farmers. However, in order to get the full picture of GHG emissions and changes in carbon stocks, it is recommended to focus on the farm as a whole, as this could help avoiding carbon leakage (see section 4.2.3). Besides this, the type of carbon pools and greenhouse gases to be considered, further determines the project boundary, as explained in the previous section. For instance, it is possible to focus on all parcels of land, but only to consider land-based emissions and carbon stock changes in the soil.

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[3] In a carbon farming project, a landowner (or group of landowners) implement(s) carbon farming practices according to a validated project plan, developed by the project developer(s) according to a certain methodology (method document).

1.2.4. What are the outcomes of carbon farming?

To obtain a good understanding of the impact of carbon farming projects, it is important to establish the **baseline** (i.e. the business-as-usual (BAU) scenario), which assumes a continuation of pre-project agricultural management practices. Once the carbon farming practices are implemented, the project emissions and carbon stocks can be compared to the baseline, and the climate impact of the project can be calculated / quantified.

This climate impact (i.e. the **project outcomes**) consists of a combination of (1) **carbon removals** from the atmosphere and subsequent long-term storage (sequestration) in above-ground and below-ground (woody) biomass and in agricultural soils, (2) **reduced GHG emissions** compared to the baseline levels of farm GHG emissions, and/or (3) **avoided GHG emissions**, preventing (further) loss of already stored carbon (McDonald et al., 2021)[4]. The latter thus implies that a certain negative trend is occurring (consisting of CO_2 emissions from the soil to the atmosphere), thereby contribution to global warming. By implementing certain carbon farming practices, this negative trend can be reduced, stopped and even reversed. A good example of avoided emissions is the rewetting of drained (managed) peatlands[5] (due to the draining of peatlands, the peat degrades, leading to increased CO_2 emissions – however, due to rewetting, these CO_2 emissions can again decrease). Whereas avoided emissions and carbon removals in the agricultural context pertain to land and land use changes, reduced emissions mainly relate to improved processes and technological innovations at the farm level (e.g. related to the decreased use of fuel and fertilizer, the use of improved feed additives to reduce enteric emissions etc.) (see section 1.3 for other examples), although they also include land-based N_2O and CH_4 emissions.

Figure 1 illustrates the possible **project outcomes** linked to changes in **SOC stocks**. These changes are calculated as 'SOC stock in the project scenario after x years – SOC stock in the BAU after x years'. We illustrate that the climate mitigation effect can consist of carbon removals (carbon sequestration), avoided emissions or both. In **Figure 1A**, the BAU-scenario is in a steady state (see section 1.3.1), and the applied carbon farming practices cause a direct increase in the SOC stocks. The climate mitigation effect after x years therefore equals the amount of carbon sequestered after x years (carbon removal).In **Figure 1B**, the BAU-scenario has an increasing trend, and this trend can further (more rapidly) increase by implementing the carbon farming practices. Thus, the carbon sequestered since the start of the project is not solely due to the carbon farming practices. In **Figure 1C**, the BAU-scenario results in a decreasing trend, and the applied measures reduce this decreasing trend, although they cannot reverse it completely. As no carbon is sequestered here, the mitigation effect only consists of avoided (land-based) CO_2 emissions. In **Figure 1D**, the BAU-scenario follows a decreasing trend, and the applied measures convert this decreasing trend towards an increasing trend. Here, the climate mitigation effect consists of the combined impact of carbon sequestration (carbon removals) and avoided (land-based) CO_2 emissions.

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[4] Note that carbon removals and avoided emissions (CO_2) are dealt with through the Land Use, Land Use Change and Forestry (LULUCF) regulation, whereas reduced emissions – as part of the agricultural sector – are dealt with through the Effort Sharing Regulation (ESR). The latter thus also includes land-based N_2O and CH_4 emissions. See section 3.2.2.4 for more information on the ESR and LULUCF regulation.

[5] The Peatland Code (operational in the UK), is an example of a carbon farming scheme that focuses on avoiding emissions through the restoration of blanket bogs or raised bogs (both referred to as 'peatland'), and once restored, through sustainably managing these peatlands. So far, however, the Peatland Code is not linked to the application of agricultural activities (e.g. paludiculture).

Figure 1 clearly demonstrates the importance of setting the baseline in a correct way. However, it is not always possible to determine the baseline as a trend (section 4.3.2.1). Sometimes a baseline is defined as SOC measured at the start of the project, assuming the BAU scenario is at steady state. This applies for scenario A, but as illustrated by the other scenarios, this can lead to misinterpretation of the climate mitigation effect of the carbon farming project. When using a SOC measurement at the start of the project as BAU, in scenario B we would overestimate the carbon removals by the project, in scenario C we could wrongly conclude there is no climate mitigation effect and in scenario D we could underestimate the climate mitigation effect. In scenarios C and D, this is because avoided emissions cannot be detected with measurements only. Throughout this report, however, we will refer to carbon removals and avoided emissions as depicted in Figure 1.

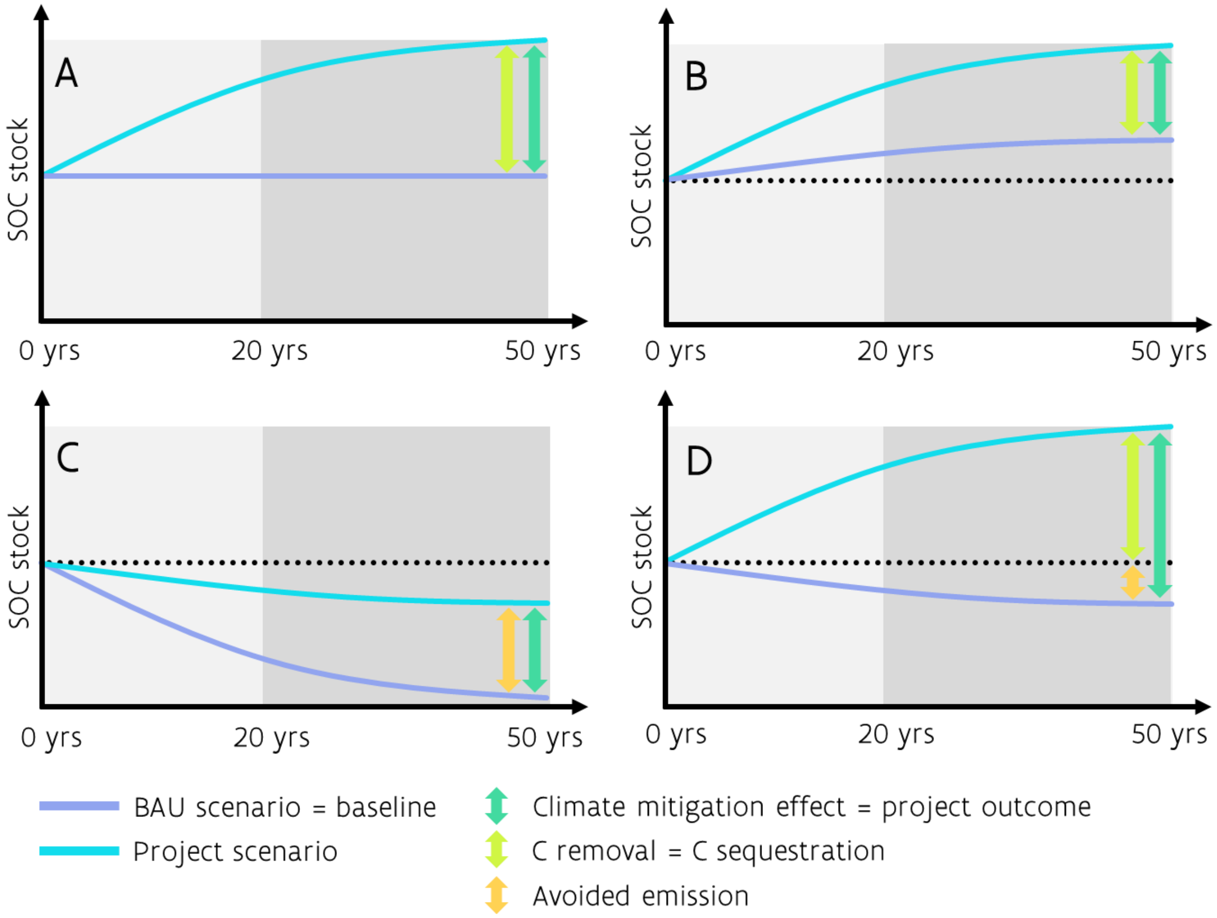

Figure 1: Theoretical evolution in Soil Organic Carbon (SOC) stocks after implementation of a carbon farming practice, as compared to the baseline or Business-As-Usual (BAU) scenario. Source: after EJP SOIL CarboSeq (2021).

1.3. Implementing carbon farming in practice

As indicated in the previous sections, carbon farming is a broad concept that pertains to different types of carbon pools and greenhouse gases, and can lead to various climate mitigation effects. On top of that, carbon farming also pertains to various types of agricultural systems (e.g. ranging from arable farming to livestock farming, mixed farming, agroforestry systems) and soil types (e.g. mineral and organic soils). This makes that there is a wide range of agricultural activities that can be considered as carbon farming practices / measures. However, these practices do not always unambiguously lead to specific project outcomes (as presented in the previous section). In what follows, we therefore provide a non-exhaustive overview of carbon farming practices, from a farm management perspective (Table 2).

Table 2: Non-exhaustive list of potential carbon farming practices (D'Hose & Ruysschaert, 2017; CLIMASOMA Final Report, 2022; European Commission, 2021b; McDonald et al., 2021). With CR = carbon removals, AE = avoided emissions, RE = reduced emissions.

Category	Carbon farming practices	Project outcomes		
		CR	AE	RE
Cropping system	• Improved crop rotations (e.g. increased share of cereals, deep rooting legumes, temporal grassland in rotation)	■	■	
	• Introduction of or longer growing period of cover crops	■	■	
	• Intercropping and undersowing (e.g. undersowing of grass in maize)	■	■	
Grassland management	• Increased grassland age	■	■	
	• Improved cultivars of grassland species or multispecies grassland	■	■	
	• Improved grassland management (e.g. grazed instead of only mown grasslands, moderate grassland management intensity…)	■	■	
Livestock management	• Optimized herd management	■	■	
	• Livestock genetics			■
	• Technologies to reduce enteric CH_4 emissions (e.g. feed additives)			■
Land use changes	• Conversion to mixed farming systems (e.g. agroforestry)	■		
	• Planting of hedges, hedgerows, woodland edges or trees	■		
	• Conversion of arable land to permanent grassland	■	■	
	• Rewetting of peat soils (e.g. from grassland to wetland)	■	■	
Tillage systems*	• No or reduced tillage (e.g. direct drilling), improved tillage		■	
Soil amendments	• Organic amendments (e.g. compost, farmyard manure, biochar, woodchips, enhanced weathering of silicate materials…)	■	■	
	• Residue retention (e.g. incorporation of straw)	■	■	
Fertilizer usage	• Reduced use of (chemical) fertilizers			■
	• Improved timing and application of (chemical) fertilizers			■
Manure management	• Improved manure management and storage			■
Nutrient management	• Improved nutrient management (e.g. leading to avoided N_2O emissions from soils)			■
Other technological innovations	• Anaerobic digestion			■
	• Microalgae cultivation			■
Other	• Paludiculture	■	■	
* Adjusted tillage systems mainly affect the carbon decomposition rate, and do not add new carbon to the soil. Moreover, the effect is not the same in different soil types / climate zones. For Flanders, the effect is uncertain.				

1.3.1. Link with soil carbon cycle

It is important to note that the climate mitigation effect of practices affecting SOC stocks is subject to the natural process of the **carbon cycle**. Carbon is added to the soil by decaying roots, root exudates, crop residues and organic manures. Soil life is converting a fraction of this carbon to soil organic matter (and the rest is released again as CO_2 to the atmosphere). After conversion as soil organic matter, carbon can be stored for longer period of time in the soil, but it is important to know that on a yearly basis also part of the soil organic matter (ca 2% but depending on the circumstances) is decomposed (mainly by soil life) again. Therefore, for carbon farming, it is important that the carbon input is always higher than the amount of carbon that is decomposed. This can be achieved by a continued implementation of the same set of carbon farming practices in the long term, or by shifting to other carbon farming practices that are able to counter the **decomposition** rate. In addition, it is also important to know that **soil carbon sequestration is not a uniform process**, but is often highest immediately after a change in land use or land management. The soil then evolves to a new **equilibrium** (steady state; see also Figure 1), which is mostly only reached after a period of 20 to 100 years, after which the SOC stock remains more or less constant. This final carbon build-up depends on a number of factors, such as the capacity of the soil to fix carbon (largely determined by its clay content), the climate – the soil temperature and moisture content determine the rate of mineralization-, the quality (stabilty) of carbon added to the soil, and the management of the soil (e.g., tillage practices, dainage).

1.3.2. Practical considerations for implementing carbon farming practices

In theory, all carbon farming practices mentioned in Table 1 could be applied in Flanders, but in practice, farmers will take a series of **strategic decisions** before deciding whether or not to incorporate specific practices in their farm management. Earlier research has demonstrated that the adoption of good soil management practices can be diverse in nature (Viaene et al., 2016; Bijttebier et al., 2015; 2018) and certainly is not only related to financial costs and revenues.

In the course of the LIFE CarbonCounts project (see sections 1.5 and 2.1), **in-depth interviews** were carried out with 27 stakeholders from 20 different organisations. During these interviews, several reasons for the adoption or non-adoption of practices were given.

Stated reasons for adoption of some practices over others were mostly based on the ease-of-introduction into the existing farm management (e.g. in relation to existing contracts or the availability of certain machinery), costs and the perceived consensus on the effectiveness of the practice to improve SOC stocks and their related co-benefits (see section 1.4.2).

Stated obstacles for the implementation of certain carbon farming practices, in particular the use of organic fertilizers and amendments, include the fear of non-compliance with the Flemish Manure Decree, which is the transposition of the European Nitrates Directive into Flemish legislation. This decree poses limits for the amount of nitrogen and phosphorus that can be applied on agricultural land and obligations for manure treatment. Nutrient leaching and run-off to ground and surface waters has been a challenge for the Flemish agricultural sector for a long time, and non-compliance might incur fines and/or sanctions. This highlights the importance for farmers to know exactly how the use of organic amendments/fertilizers may influence the phosphorus and nitrogen balance on their farms. Other obstacles include the lack of available organic amendments (e.g. farmyard manure and compost), the lack of trust in the quality of imported compost (e.g. due to the possible inclusion of plastics), price competition between biomass for energy and biomass available for the production of organic amendments, and the legal restrictions preventing woodchips/compost to be applied to agricultural soils in Flanders. In addition, farmers are concerned over the potential loss of surface area on which basic payments from the CAP are based. For example, when planting hedgerows on cropland, the surface area involved becomes ineligible for basic payments. Finally, the lack of knowledge on the effect of carbon farming practices on crop yield is also mentioned as an important obstacle.

1.4. What is the potential of carbon farming?

1.4.1. Climate mitigation potential

Carbon farming is considered a key strategic piece of the puzzle to combat climate change, and ultimately to reverse climate change (McDonald et al., 2021). This is clearly illustrated in Regulation 2021/1119 of the European Parliament and Council of 30 June 2021, which states that:

> "*The Union should aim to achieve a* ***balance between*** *anthropogenic economy-wide* ***emissions by sources and removals by sinks*** *of GHG domestically within the Union* ***by 2050*** *and, as appropriate, achieve negative emissions thereafter [...] Sinks include natural and technological solutions, as reported in the Union's GHG inventories to the UNFCCC. Carbon sinks play an essential role in the transition to climate neutrality in the Union, and in particular the* ***agriculture, forestry and land use sectors*** *make an important contribution in that context.*"

Based on a review, McDonald et al. (2021) estimate the total and additional **EU** carbon farming **mitigation potential** to be **101 - 444 Mt CO_2-eq/yr**, which would be equivalent to approximately 3% - 12 % of the EU's total annual GHG emissions[6], or approximately 26% - 114% of the EU's annual agricultural emissions[7]. These estimates are based on the implementation of multiple carbon farming techniques, including (1) peatland management, (2) agroforestry, (3) maintained and enhanced SOC on mineral soils, (4) livestock and manure management, and (5) nutrient management on croplands and grasslands. However, the authors state that there is a **large degree of uncertainty** in these estimates, based on (1) differing definitions of the potential (technical potential vs. feasibility), (2) differing research approaches (regional upscaling vs. global downscaling), (3) impact of carbon leakage and land competition on a global scale, and (4) uncertainties in measurements of results[8].

Moreover, the potential of carbon farming can differ significantly between regions, depending on the different opportunities, trends and obstacles, but also depending on the estimation methods used (Rodrigues et al., 2021). For **Flanders**, the mitigation potential of carbon farming – when only considering soil organic carbon – is estimated to range between **1.6% up to 12%-18%**[9] of the annual agricultural emissions, which are equal to 7.368 Mt CO_2-eq (Flanders Environment Agency, 2020).

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[6] Total EU emissions in 2019 (excluding land use, land use change and forestry, and excluding the UK) were 3637 Mt CO_2 eq (EEA, 2021b).

[7] In 2019, agricultural emissions (covering N_2O emissions from soils, manure management, and enteric fermentation but excluding soil organic carbon sequestration) amounted 389 Mt CO_2-eq/yr (EEA, 2021a).

[8] In the EJP Soil CarboSeq project, the carbon sequestration potential of agricultural soils in various regions across Europe, including Flanders, will be assessed again, using a more harmonized approach.

[9] Lower estimates resulting from unpublished ILVO research, based on a combination of feasible scenarios for the uptake of carbon farming measures. Higher estimates resulting from research by Soil Service of Belgium based on the technical potential to reach optimal SOC values in agricultural soils (Tits et al., 2020).

Based on the soil analyses commissioned by farmers to the Soil Service of Belgium, Tits et al. (2020) show that 52% of the grasslands (0-6 cm) and 50% of the arable lands (0-23 cm) have a SOC content below the optimal zone for soil fertility and hence could be employed to store more carbon. As compared to the early 1980s, with 33% of the grasslands and 16.8% of the arable lands having a SOC content below the optimal zone, the situation has drastically deteriorated over time. If these SOC percentages could be raised to the upper edge of the optimal zone in 30 years' time, 0.91 Mt CO_2-eq/yr could be sequestered in the soil (12% of annual emissions from agriculture). If this can be achieved in 20 years' time, up to 1.37 Mt CO_2-eq/yr could be sequestered in the soil (18% of annual emissions from agriculture). Although this estimated potential is significant, it is clear that besides carbon removals and avoided emissions, reduced emissions in the agricultural sector will also play an important role in reaching carbon neutrality. When it comes to the climate mitigation potential of carbon farming, we should not restrict our scope only to carbon removals, but instead take an **integrated approach** and consider all carbon farming practices (see Table 1).

1.4.2. Potential for climate adaptation and other co-benefits

Besides its important climate mitigation potential, carbon farming may also lead to climate adaptation effects and generate other co-benefits, such as the delivery of (soil) ecosystem services. However, carbon farming practices may differ significantly in the type of broader impact they provide. More technical solutions, such as feed additives to reduce enteric emissions from livestock, for example, typically do not improve ecosystem functioning at the farm level, while practices that lead to carbon sequestration in soils and biomass through the implementation of an agroforestry system, usually do have a broader impact (although differences exist between practices) (McDonald et al., 2021).

In general, an increased SOC content has a positive effect on the soil quality, increasing the biodiversity and abundance of micro-organisms, and improving plant growth through enhanced **soil fertility**. Soils with a higher organic carbon content in the top layer usually show improved resistance to erosion during extreme weather events, among other things. As a result, agricultural yields may be less affected by drought or extreme rainfall, and hence be **more stable** and thus **more climate-adaptive** over time (COWI et al., 2021b). Some argue that this aspect of climate-adaptiveness should be on the forefront in the promotion and communication about carbon farming, in order to reach a maximised societal impact (Amundson and Biardeau, 2018).

Storing carbon in biomass through planting or improved/continued management of woody landscape elements may also have additional positive effects, such as controlling run-off of water and sediments, in case the woody elements are strategically positioned in the landscape (i.e. along the contour lines). Besides that, the woody landscape elements may create shade for livestock during hot days and increase the aboveground biodiversity (Torralba et al. 2016).

These additional co-benefits of carbon farming practices are described by Baumber et al. (2019), who provide a more in-depth analysis of the provisioning, regulating, supporting and cultural ecosystem services of carbon farming, besides the economic service it provides (Figure 2). The **supporting services** are the services necessary for the delivery of all other ecosystem services. Examples are resilient and fertile soils, and improved biodiversity at the farm level. The **provisioning services** include the direct delivery of essential bio-materials, such as food and fibre, but also contain the provisioning of shelter for livestock (e.g. heat regulation by trees in agroforestry systems). The **regulating services** include processes that buffer unwanted effects (e.g.

improved pest and weed management), or facilitate desirable effects (e.g. pollination). The **cultural services** exist on the intersection between human experience (e.g. aesthetic landscape values), human health, traditions and agriculture.

To ensure that carbon farming supports the societal, environmental and economic targets of the European Green Deal, it is important to **maximize co-benefits** and **reduce risks** when designing and implementing carbon farming methodologies/payment systems. The possible valorisation of co-benefits in carbon farming schemes and voluntary carbon markets is discussed in section 8.6.

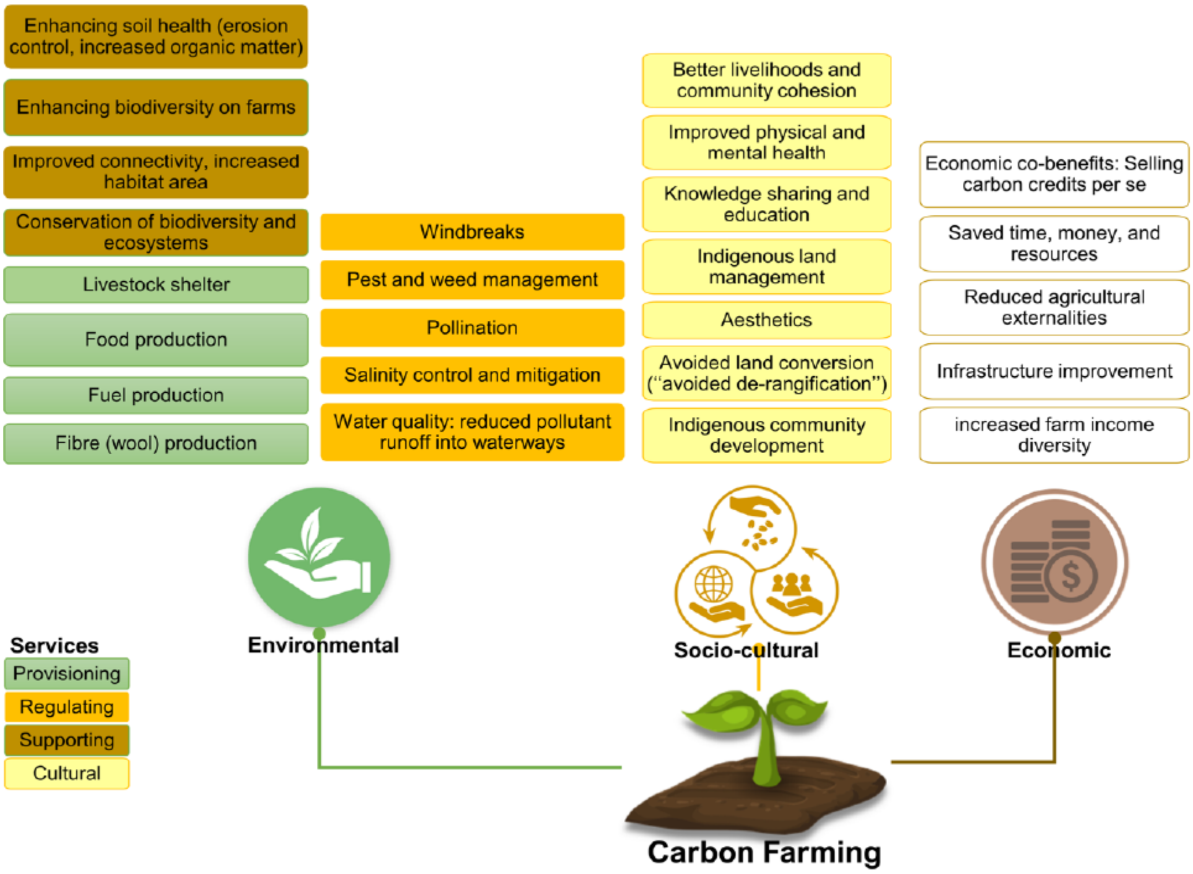

Figure 2: Potential co-benefits of carbon farming in addition to climate mitigation. Source: Baumber et al. (2019).

1.5. Context of this report: introduction to the LIFE CarbonCounts project

In the LIFE CarbonCounts project (September 2021 – February 2023), the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) and the Department of Agriculture and Fisheries (Flemish Government) joined forces to enable carbon farming in Flanders, through three objectives: (1) the development of a system analysis of carbon farming schemes and a roadmap for the stepwise implementation of carbon farming in Flanders; (2) the design, implementation and testing of a geodataplatform where farmers can simulate how much carbon is stored in soils, agroforestry and woody landscape features under business-as-usual and project scenarios; and (3) the exploration of the possibilities for a long-term action platform in Flanders (Figure 3).

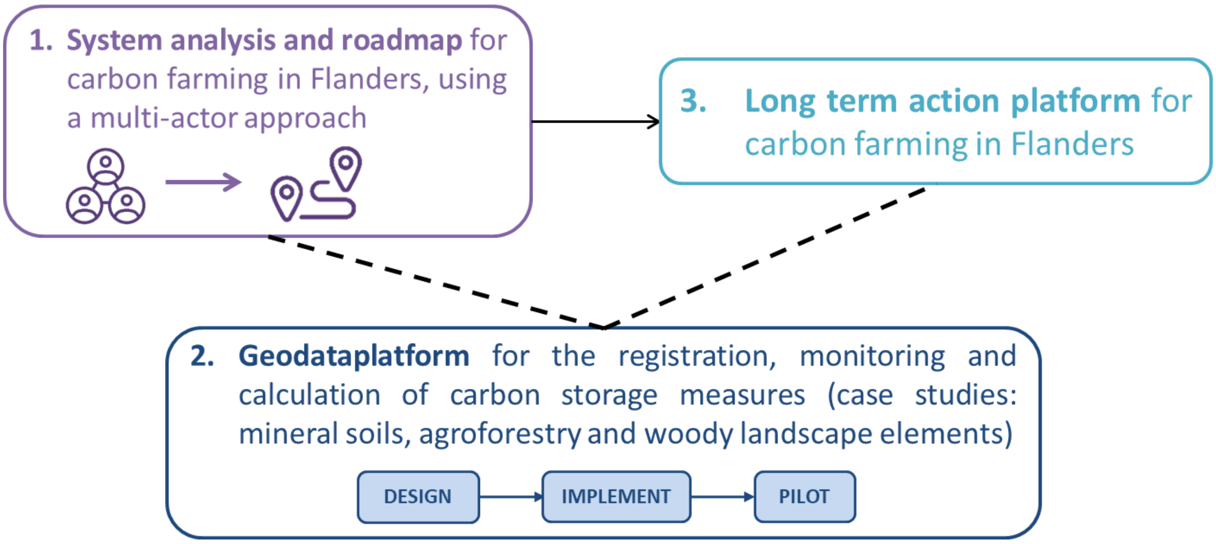

Figure 3 Objectives of the LIFE CarbonCounts project

This report, as part of the **first objective** of the project, presents a **system analysis** of the different components of carbon farming schemes and other relevant aspects to consider when stimulating carbon farming. In our system analysis, an overview is provided of the advantages, disadvantages, barriers, needs and opportunities of different types of carbon farming schemes. Our approach (methods & materials) to this report is detailed in Chapter 2.

The **second objective** of the project is to establish a **geodataplatform** that can be used by farmers to simulate and calculate the **carbon stocks** on agricultural field parcels under business-as-usual and project scenarios, by maximizing the use of readily available data. The platform informs and provides advice to farmers, but is not linked to subsidies or any form of payment linked to increased carbon stocks. However, the used calculation models are open-source, resulting in the possibility to link the platform to public and/or private carbon farming schemes to facilitate the monitoring and reporting of the project outcomes.

The novelty of the current approach consists of the **automatic linking of input data** via a 'Soil Passport' (see section 5.1.1), which is an online application providing information on the users' parcels, in which the new carbon calculation modules will be nested. In the Soil Passport (currently under development), different data inputs come together, including data made available by farmers (e.g. results from soil analyses) and by the government (e.g. crop rotations from the GeoSpatial Aid Application (GSAA) under the CAP), 'Verzamelaanvraag'), geospatial data that are readily available at the Flemish level (e.g. soil texture classes from the soil map of Flanders published in 'Databank Ondergrond Vlaanderen', the geospatial soil and subsoil data repository of Flanders) and data obtained using aerial photographs and satellite images using artificial intelligence techniques. Additionally, the farmers can use the tool to simulate other management practices by adjusting the automatic input data.

The evolution in carbon content will be calculated and simulated via a RothC-based **calculation module**, that builds upon previous carbon simulation tools developed in Flanders, the Koolstofsimulator and the Demetertool. The newly developed calculation module will not only include the carbon storage in **mineral soils**, as in previous Flemish simulation tools, but also the carbon storage by **woody landscape elements**, such as trees in agroforestry systems and hedges (based on the CARAT tool by Vanneste et al. (2022); unpublished).

To further support and implement the roadmap and geodataplatform, the **third objective** of the LIFE CarbonCounts project is to develop a **long-term action platform** for carbon farming in Flanders. Through this action platform, we aim to set up and facilitate the much-needed collaboration among various stakeholders involved in carbon farming, such as from the public sector, the private sector, research institutes, civil society organizations, farmers and advisory services. For this, we will build upon inspirational examples from other countries, such as the Carbon Action platform by the Baltic Sea Action Group, based in Finland.

2. Methodology

2.1. Data input

To come to this system analysis report, which provides an overview of the advantages, disadvantages, barriers, needs and opportunities for carbon farming (schemes), **a combination of data collection methods** was applied.

First, an inventory was made of the various organisations that work (to a small or large extent) or will work on the topic of carbon farming in Flanders (**stakeholder mapping**). A preliminary overview of the different carbon farming schemes, (research) projects and initiatives was compiled as well (**project mapping**). As carbon farming is still in its infancy (in 2022), this list was relatively limited in size. However, throughout the process of this system analysis, many organizations and companies expressed their interest in carbon farming (e.g. agrifood companies, municipalities, provinces etc.), and the topic is clearly gaining importance.

Second, based on this stakeholder and project mapping**, in-depth interviews** were carried out with 27 stakeholders from 20 different organisations in Flanders, belonging to one or more of the following categories: (i) government agency, (ii) research institute, (iii) advisory service, (iv) farmers, (v) climate consultant and/or company involved in the VCM (e.g. project developers, carbon broker) (Figure 4). The interviewees were selected using the snowball sampling method, and interviews were conducted until the point of data saturation. During the interviews, the focus was on the design and governance of carbon farming schemes, business models, different types of incentives, policies, potential pitfalls and opportunities. Particular attention was given to barriers and opportunities that are specific for the Flemish context.

Third, two interactive **policy workshops** with stakeholders from various departments of the Flemish government (including dep. of Agriculture and Fisheries, dep. of the Environment, the Forest and Nature Agency, the Flemish Land Agency, the Flemish Public Waste Agency; Figure 4), as well as from farmer organisations were organized. In the first workshop (with 21 participants), the minimal role of the Flemish government was explored. As several scenarios[10] to achieve a wider implementation of carbon farming in Flanders are still possible at this point, we discussed the minimum role that the Flemish government should play in all these scenarios, i.e. to regulate carbon farming to a minimum in order to obtain a robust and reliable system. In the second workshop (with 10 participants), the role of the government with respect to guiding principles (see section 4.2) for carbon farming schemes was discussed, further looking into the minimal role of the government. Several aspects that were dealt with during these two workshops are included in this report, although most of them will be addressed in the roadmap (see section 1.5).

Fourth, an **extensive literature review** of local to regional initiatives, and national (domestic) to international carbon farming schemes (carbon standards / carbon payment programmes) was conducted (see Appendix 1.B for an overview of the studied schemes and method documents). Here, information was collected on the governance / organizational structure and the design of

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[10] Examples of possible scenarios: public funding for carbon farming gains importance, a central government-led voluntary carbon market (farming) develops, multiple privately organized voluntary carbon (farming) markets develop, incentives other than carbon payments gain importance to promote carbon farming, the funding of broader ecosystem services gains importance, etc.

schemes, including detailed information on guiding principles, setting the baselines, monitoring, reporting and verification (as described in the various method documents).

Fifth and last, all information collected in the previous steps, was combined in this system analysis report. In section 2.2, we explain how we combined this information and came up with the structure of this report.

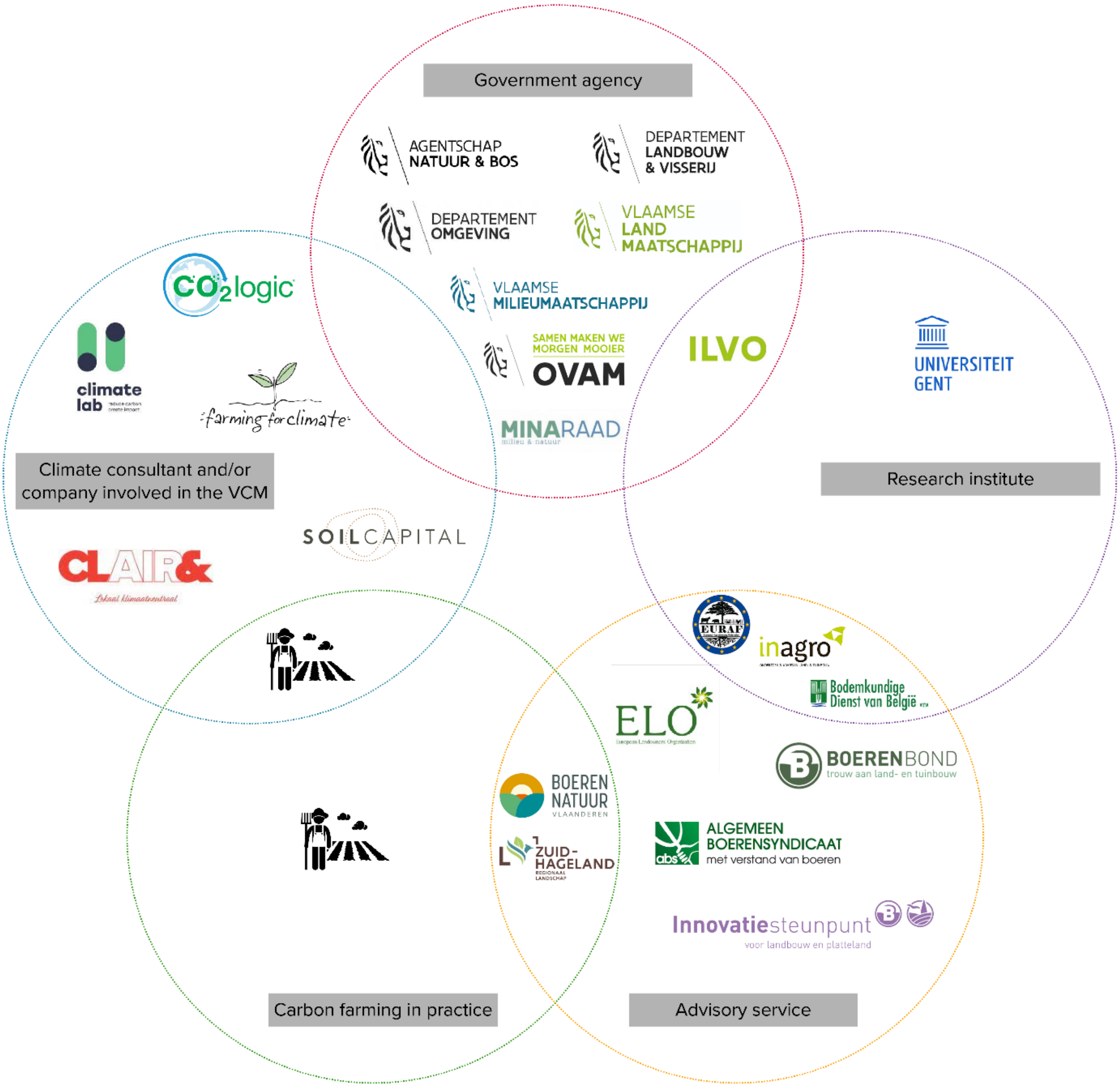

Figure 4 Overview of the stakeholders involved in the interviews and / or policy workshops. Note that the stakeholder categorization should not be considered in a rigid way (e.g. some of the companies involved in the VCM = voluntary carbon market also provide agronomic services/advice to farmers). Note also that Farming for Climate has developed a business model that goes beyond carbon sequestration alone.

Based on, among other things, this report, a step-by-step plan or **roadmap** for a wider implementation of carbon farming in Flanders will be drafted. By doing so, we will identify possible avenues for solving the identified bottlenecks, exploiting existing opportunities, and addressing the needs towards an effective and broad implementation of carbon farming in Flanders, for which an intensive collaboration between various stakeholders (from public and private sectors) will be required.

2.2. A systems approach

Based on the insights obtained during the interviews, policy workshops and literature review, it soon became clear that there is a multitude of aspects (hereafter named 'components') to be considered when aiming for a wider implementation of carbon farming. Moreover, as these aspects are strongly **interconnected**, even at different spatial scales (i.e. from a local to regional, national and international level), a systems approach to carbon farming is needed[11] (Arnold & Wade, 2015). In the words of Richmond (1994), we need to look both at the forest and the trees at the same time. By doing so, we have a greater chance of steering the entire system in the desired direction. As we gain knowledge on the individual components, we will also gain insight on their interconnections and evolving purposes.

Only by adopting a systems approach, a widely accepted form of carbon farming can be obtained. This requires **simultaneous progress on different components** of the system and **engagement of various stakeholders**, as they each may have their own interests in the matter. For example, farmers may be interested in flexible scheme designs, whereas scientists may be looking for stringent Monitoring, Reporting and Verification systems, project developers may be interested in optimizing their business model, and governmental agencies may want to connect to multiple policy objectives. Therefore, it is also important to discuss and define a **common purpose** of carbon farming as a system, by interacting with each other.

In conclusion, various components need to be thoroughly elaborated and linked to one another. Our proposal for relevant components and their linkages are detailed in Figure 5 (on the next page), and are briefly described starting on p 17. Throughout this report, Figure 5 will guide the way from one chapter to the next. It is important to note, however, that to understand the entire system and all terminology used, it may be necessary to jump from one chapter to another, to then return to the previous chapter. The various terms used in Figure 5 and its explanation, are defined in **Appendix 1.A (Glossary)**. It is recommended to consult this appendix regularly when going through this report.

A **remark** on Figure 5 is that it clearly stresses the link between carbon farming schemes and the voluntary carbon market as a new green business model for farmers. Throughout the report, our main focus is on this marketing aspect of carbon credits and/or certificates (see Appendix 1.A for difference), taking into account the rules of the voluntary carbon market, although we also recognize the importance of **public funding and incentives**.

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[11] Systems thinking typically consists of three kind of things: elements or components, interconnections and a purpose (Arnold & Wade, 2015).

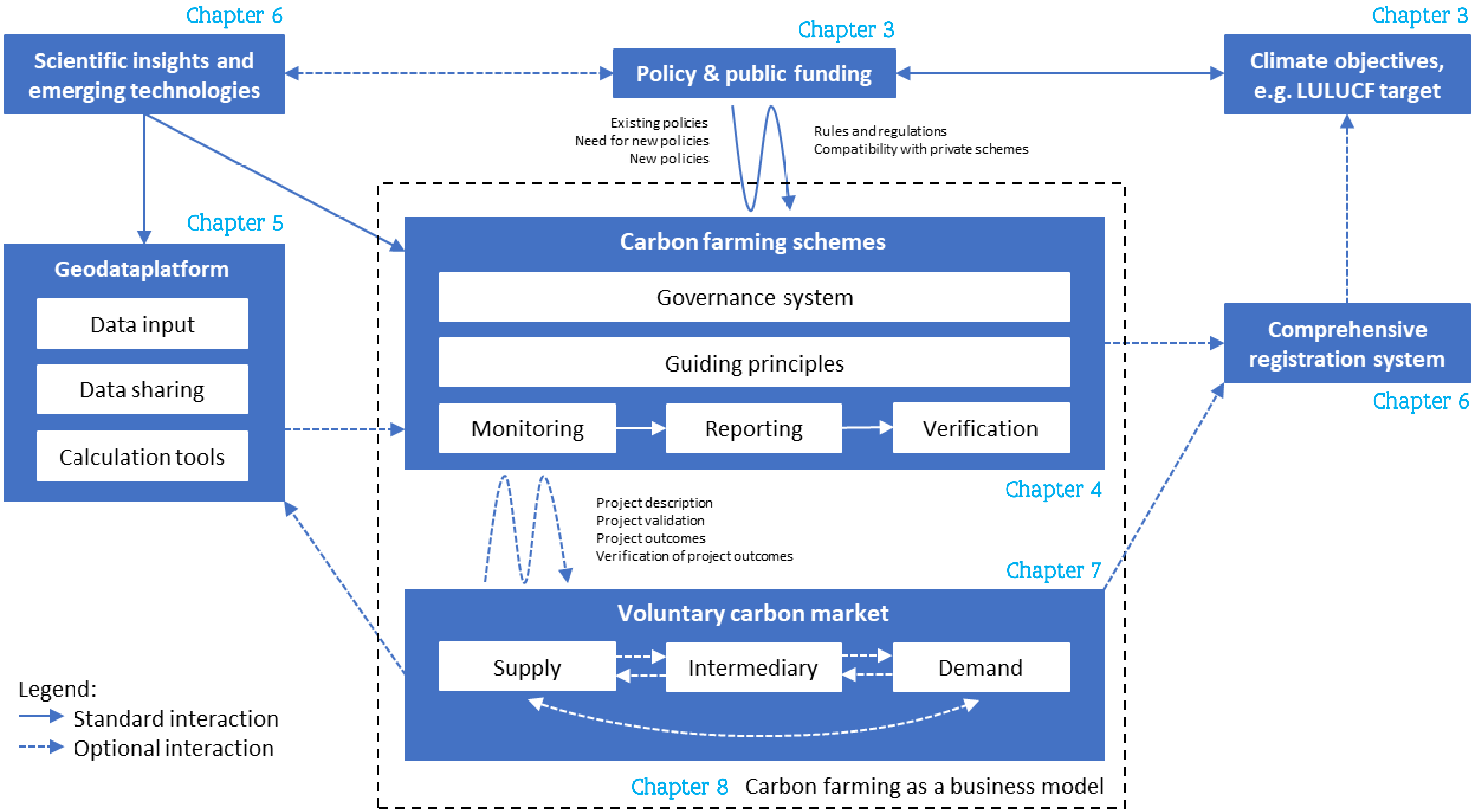

Figure 5: Different components of carbon farming schemes and the multiple aspects influencing those schemes. This figure guides the way throughout this report and contains direct cross-references to the different chapters (in light blue).

At the heart of the system are **carbon farming schemes** (Chapter 4) that set out the rules and requirements for **carbon farming projects**, in which farmers or groups of farmers can voluntarily commit themselves to apply carbon farming practices, in order to obtain climate mitigation outcomes in return for a payment via the voluntary carbon market, public funding or any other form of compensation. Central to these schemes are the governance system, the guiding principles and the Monitoring, Reporting and Verification (MRV) system.

The purpose of the **governance system** (section 4.1) is to make sure that the scheme is effective, fair and robust. In that respect, a governance structure (private, public or hybrid) is put in place, overarching rules and regulations are developed (these rules and regulations apply to all method documents developed under the carbon farming scheme – internationally also referred to as carbon standard), and procedures for putting the scheme into practice are described (a protocol, describing the stepwise approach to achieve verified carbon units).

These procedures may relate to the development of **method documents**, in which the **guiding principles** and the **MRV system** for carbon farming projects are detailed. These method documents may be tailored to specific carbon farming practices (such as in the Label Bas Carbone Méthode 'Grandes Cultures') or they may be more generic and cover a wide range of carbon farming practices (such as in the VCS 'Methodology for Improved Agricultural Land Management'). Depending on the type of carbon farming scheme or initiative (international vs. domestic vs. local), method documents may be subject to public consultation and feedback during the writing process and possible subsequent updating process. After method documents have been fully approved (e.g. validated by a scientific committee, government, external audit), they can be used by project developers.

The application of a method document in a carbon farming project, is an interactive and iterative process, starting with the submission of a **project description** (by the project developer) that is then **validated**[12] (found to be consistent with the method document and overarching rules and regulations), after which the project can be **implemented** and the climate mitigation effects can take place. These project outcomes are then **verified**, preferably by an independent third party auditor[5], after which the **verified carbon units** (equal to 1 ton of CO_2-eq) can be sold to public or private buyers operating in the **voluntary carbon market** (Chapter 7). In this voluntary carbon market, which is driven by the supply and demand of verified carbon units, different types of business models can occur (Chapter 8), of which some include intermediary actors, such as carbon brokers[13]. Some of these business models are realised within the agrifood chain (insetting), whereas others include payments from companies outside the agrifood chain (offsetting or positive contributions) (terminology explained in section 8.4).

As a cornerstone of carbon farming schemes, it is important that MRV systems are based on the latest **scientific insights** (Chapter 6) and that they are thoroughly developed with respect to data inputs, data sharing and carbon calculation tools – preferably coupled in a **Geodataplatform** (Chapter 5). For this, existing public and private **data sources**, such as data collected in the context

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[12] VCS and GS work with accredited VVBs = Validation/Verification Bodies, who assess the projects against the rules and requirements of the standard, starting from the validation of the projects.

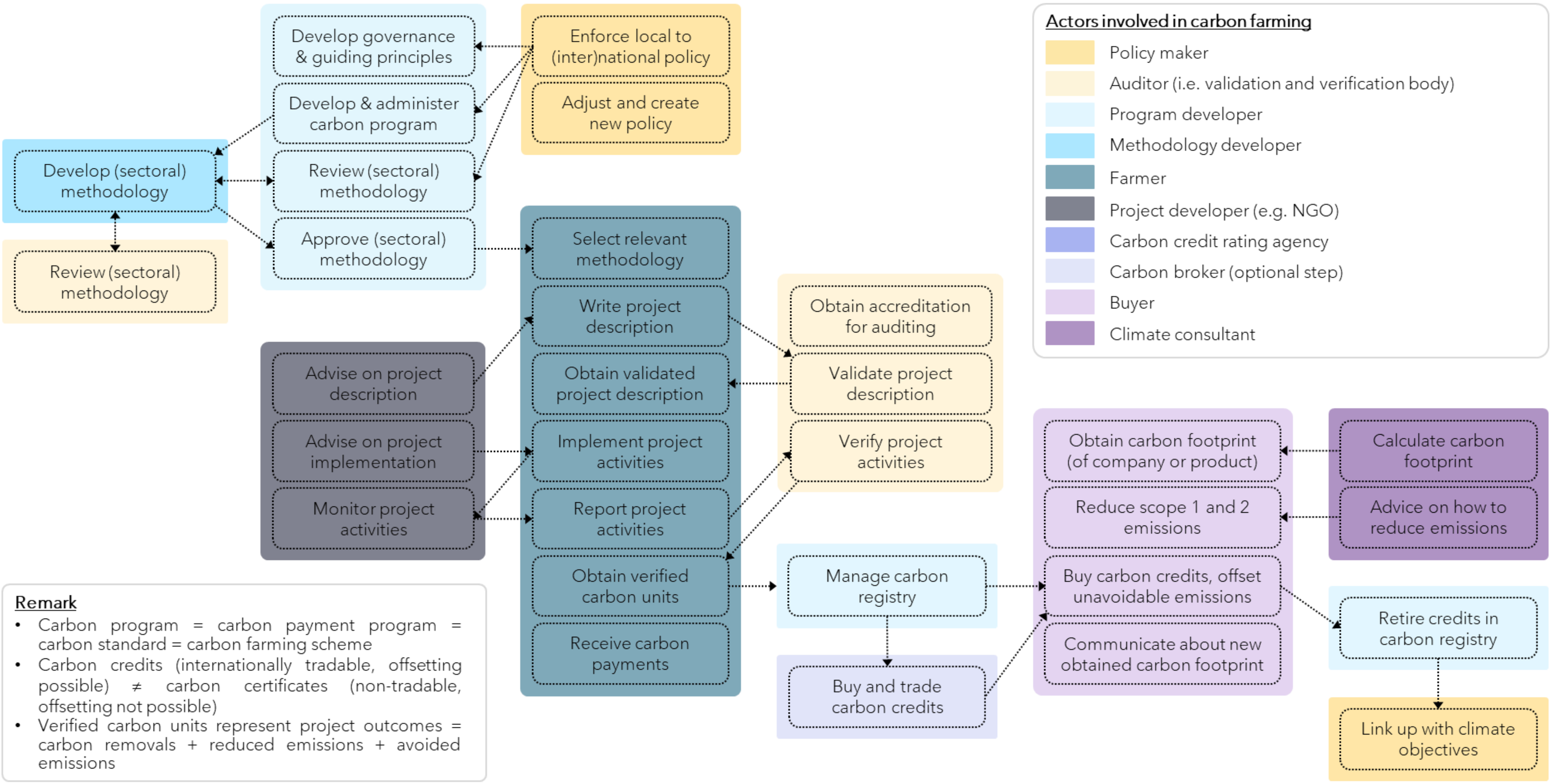
[13] Carbon brokers connect buyers and sellers in the VCM. They typically aim to have a portfolio of reputable projects, providing clients with a continuous supply of high-quality carbon credits or certificates. Additionally, they might establish and manage their own registry and aid in the marketing of project outcomes.

of the GeoSpatial Aid Application (GSAA) of the Common Agricultural Policy, should be used as much as possible and reliable **data sharing** systems should be established. This is important to facilitate the development of more automated monitoring systems, keeping the monitoring costs and administrative burden for farmers as low as possible. These data sources and data sharing systems therefore also can be coupled to a locally validated and publicly available **carbon calculation tool.** Such a calculation tool can be adapted over time, for instance when new data systems and scientific insights become available over time. In the context of such calculation tools, the General Data Protection Regulation (GDPR) should be respected and farmers should maintain the right to decide what their data are used for. In Flanders, data connections of agricultural data are possible through DjustConnect..

After the verification of the climate mitigation outcomes, the verified carbon units can be listed in a transparent and comprehensive **registration system** (section 4.3.3.2) – managed by the governors of the carbon farming scheme or by another entity – which could be linked with the regional to national **climate objectives** in general, and the **Land Use, Land Use Change and Forestry (LULUCF) reporting** in particular (Chapter 3). This would allow for a full valorisation of the efforts made by the project developers. However, to establish this link, several challenges still need to be addressed, of which the main one is to find a solution on how to overcome the difference in spatial scale approach between the LULUCF reporting (Tier 2 approach, using country-specific data) and the local carbon farming projects often only covering a few hectares or few farm holdings (Tier 3 approach, using detailed country-specific and farm-specific data) (section 4.3.2.2 and Appendix 1.C), and hence to avoid double counting of carbon removals.

Lastly, by establishing carbon farming schemes – which should be in line with and contribute to existing **policies** (Chapter 3) – the need for updated or even new policies may raise over time, especially since carbon farming is still in its infancy to date. An example hereof, is the upcoming EU Regulatory Framework for the Certification of Carbon Removals that will need to be translated to the national/regional context (e.g. through **establishing overarching rules for carbon farming schemes**). In developing such policies, interaction between various stakeholders and policy makers at the regional, national and international levels is key. In these interactions, stressing the need for new scientific insights may lead to additional funding of research. Besides that, **public funding** also can be further shifted to carbon farming, in order for it to become an important source of funding (e.g. through the different pillars of the CAP).

To further clarify our systems approach, Figure 6 provides an overview of important activities to be performed by various actors involved in carbon farming. This reveals the extent of collaboration required to tackle the many and complex challenges / potential issues related to carbon farming, and hence to gain/retain the required trust in the concept of carbon farming and voluntary carbon markets. The various terms used in Figure 6, are explained in Appendix 1.A and the different sections of this report. After going through this report, all steps in this figure should be clear.



Remark

- Carbon program = carbon payment program = carbon standard = carbon farming scheme
- Carbon credits (internationally tradable, offsetting possible) ≠ carbon certificates (non-tradable, offsetting not possible)
- Verified carbon units represent project outcomes = carbon removals + reduced emissions + avoided emissions

Figure 6: Overview of the numerous activities to be carried out correctly by various actors involved in carbon farming schemes and projects

3. Policy context and climate objectives

In this chapter, an overview is given of the policy context and climate objectives relevant to carbon farming. The chapter is kept as concise as possible, but links to full texts, reference documents or communications are provided as needed. Given the wide diversity and broad potential impact of carbon farming, many intersections with other EU policies exist, such as the Biodiversity strategy for 2030 and the Soil strategy for 2030. For the sake of brevity, we will not go into depth on all related policies.

3.1. International policy context

3.1.1. Paris Agreement (2016)

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris on 12 December 2015 and entered into force on 4 November 2016. Its goal is **to limit global warming to well below 2°C and preferably to 1.5°C** as compared to pre-industrial levels. The Paris Agreement works on a 5-year cycle of increasingly ambitious climate actions to be carried out by the different countries. By 2020, all countries submitted their plans for climate action, known as the **Nationally Determined Contributions** (NDCs).

To better frame the efforts towards the long-term goal, the Paris Agreement further invites countries to formulate and submit long-term low GHG emission development strategies (LT-LEDS). A first long-term strategy for Flanders was approved by the end of 2019, and is discussed in section 3.3.2.

3.1.1.1. Implications of the Paris Agreement Article 6 for VCMs (2021)

One of the key outcomes of the COP26 in Glasgow (November 2021), was the conclusion of the Paris Agreement's rulebook, allowing for the full operationalisation of the Paris Agreement. The conclusion of this rulebook, amongst others, included the finalization of **Article 6**, which provides a framework for the international voluntary cooperation on emission reductions[14], in order to achieve (national) climate targets. Ever since 2015, Article 6 rules had been heavily debated, due to the complexity of the matter. By putting the Article into action, however, renewed investments in climate action may be triggered and VCMs may be boosted (see below).

Specifically, Article 6 contains two mechanisms that allow for international cooperation to achieve climate targets. The first mechanism, detailed in **Article 6.2**, includes the trade of emission reductions and carbon removals between two countries, based on the signing of a bilateral agreement. These emission reductions and removals are referred to as **Internationally Transferred Mitigation Outcomes** (ITMOs). **Article 6.4**, on the other hand, consists of the **development of a global carbon market**, overseen by a United Nations entity – referred to as the 'Supervisory Body'. In this context, (carbon farming) projects need to be registered by the Supervisory Body, and at the same time, they must be approved or 'authorized' by the host country before they can be issued as UN-recognised carbon credits. These credits moreover will be referred to **'A6.4ERs'** and will be **purchasable by countries, companies and individuals**. Remarkable is that 5% of the A6.4ERs will be given to the Adaptation Fund, which can resell the credits to generate revenues. Another 2% of

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[14] The term 'emission reductions' is used to show the way to Net-zero. However, it may include carbon removals and reduced emissions – as detailed in section 1.2.2.

the A6.4ERs automatically will be cancelled without using them. The rules of Article 6.4 – which actually are not too different from those generally used by the VCM (EY, 2021) – largely **reduce the risk of double counting**, mainly through the mechanism of **Corresponding Adjustments** (CAs) (Carbon Market Watch, 2022). With these CAs, the host country can decide whether or not to 'authorize' the transfer of mitigation outcomes to another country (Puro.Earth, 2021). If it does so, it agrees to 'uncount' the mitigation outcome from its GHG inventory, while at the same time, the 'buyer country' does the reverse and adjusts its GHG inventory in favour of the purchased mitigation outcome (Ecosystem Marketplace, 2021a). Both actions will be communicated in the countries' Biennial Transparency Reports (BTRs), which are to be commenced the latest by 2024 (Verra, 2021). At the level of companies, in particular multinationals, the risk of double counting remains largely unaddressed.

Although Article 6 **does not regulate the VCM** (i.e. voluntary carbon credits do not need to go through the Article 6 mechanism – and hence do not need CAs), it **entails important implications** that could lead to reforms in the VCM. The main adjustment to be made is that method documents will need to be compliant with the Article 6 rules. If existing crediting programs manage to achieve this and hence can obtain authorization of host countries to develop (carbon farming) projects, Article 6 can be a significant lever to further scale up the VCM (see Chapter 7). These Article 6-compliant credits will be allowed to be incorporated in the NDCs under the Paris Agreement. In this context, both VCS and Gold Standard, the two largest players on the international VCM, are currently investigating how to make their programs compliant with Article 6 (e.g. VCS investigates the development of 'Article 6 Compliant' or 'Article 6 Authorized' verified carbon units).

Another implication of Article 6 is that 'claiming' the ownership of purchased emission reductions or removals (i.e. by simple offsetting) no longer will be possible and consequently this can no longer contribute to making Net Zero claims (see Appendix 1.A - Glossary). This shifts the 'Kyoto-protocol' paradigm of offsetting emissions towards the new 'Paris Agreement' **paradigm of contributing to climate change solutions**. Two final remarks are that avoided emissions do not qualify as a basis to generate carbon credits under Article 6 (Carbon Market Watch, 2022) and that it is unclear how UN-recognized carbon credits coexist with 'unauthorized' VCM carbon credits.

3.2. EU policy context

3.2.1. EU long-term strategy for climate-neutrality by 2050 (2018)

In line with the global commitments of the Paris Agreement, in November 2018, the European Commission published a vision for a **climate-neutral European Union** (i.e. an economy with net-zero GHG emissions), covering nearly all EU key sectors and policies, and exploring pathways for the required transition. Based on this long-term strategy to be climate-neutral by 2050, EU Member States were required to develop national strategies on how to achieve the GHG emission reductions needed to meet their commitments under the Paris Agreement and EU objective. The EU long-term strategy is at the heart of the European Green Deal.

3.2.2. European Green Deal (2019)

The European Green Deal is **a package of policy initiatives and a roadmap** that aims to "transform the EU into a fair and prosperous society, with a modern, resource efficient and competitive economy where there are no net emissions of greenhouse gases by 2050 and where economic growth is decoupled from resource use." The Green Deal package therefore includes initiatives covering the climate, environment, energy, transport, industry, agriculture and sustainable finance sectors – all of which are strongly interlinked. Several of its initiatives have a direct relevance for the development of carbon farming (schemes), such as the **Farm to Fork (F2F) Strategy, EU Strategy on Adaptation to Climate Change, European Climate Law** and **Fit-for-55 package**, which are briefly described below.

3.2.2.1. Farm to Fork Strategy (2020)

The European Commission presented its Farm to Fork strategy in May 2020, as one of the key actions under the European Green Deal. Contributing to achieving climate neutrality by 2050, the strategy intends to shift the current EU food system towards a more sustainable model. Of particular relevance to carbon farming are the following objectives: (1) **reduce nutrient losses** by at least 50% while ensuring no deterioration of soil fertility – this should reduce the use of mineral fertilizers by at least 20% by 2030; (2) bring back at least 10% of the agricultural area under **high diversity landscape features** by 2030; and (3) achieve at least 25%[15] of the EU's agricultural land under **organic farming** by 2030.

3.2.2.2. EU Strategy on Adaptation to Climate Change (2021)

In February 2021, the European Commission adopted its new EU Strategy on Adaptation to Climate Change. This strategy outlines a long-term vision for the EU to become a climate-resilient society that is fully adapted to the unavoidable impacts of climate change by 2050. Of particular relevance to carbon farming are the following objectives: (1) propose **nature-based**[16] **solutions for carbon removals**, including accounting and certification in upcoming carbon farming initiatives; (2) **develop the financial aspects** of nature-based solutions and foster the development of financial approaches and products that also cover nature-based adaptation; and (3) continue to **incentivize and assist** Member States to rollout nature-based solutions through assessments, guidance, capacity building, and EU funding.

3.2.2.3. European Climate Law (2021)

As part of the European Green Deal, the European Commission proposed on 4 March 2020 the first European Climate Law, which enshrines the 2050 climate-neutrality target into law. The Climate Law thus includes the **legally binding target of net zero greenhouse gas emissions by 2050** and also covers the ambitious target of at least 55% reduction of net emissions of greenhouse gases by 2030 as compared to 1990. The European Climate Law went into effect on 29 July 2021.

3.2.2.4. 'Fit for 55' package (implementation ongoing)

In July 2021, the European Commission proposed its 'Fit for 55' package, referring to the EU's target of **reducing net GHG emissions by at least 55% by 2030**. This 'Fit for 55' package aims to translate the objectives of the Green Deal **into law**, and is a set of proposals to revise climate, energy and

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[15] This number of 25% was put into question, arguing that demand for organic farming products should be boosted for the supply side to follow. Trying to boost supply without addressing demand might be ineffective, with potential negative consequences (Example of discussion in media). The Organic Action Plan was approved by the EU Parliament by a majority vote on 3 May 2022 and did not contain this 25% target.

[16] Nature-based solutions are solutions that are inspired and supported by nature, which are cost-effective and simultaneously provide environmental, social and economic benefits and help build resilience. [...] Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services (https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en).

transport-related legislation and put new legislative initiatives to align EU laws with the EU's climate goals into place. Of particular relevance to carbon farming are the following: (1) **proposal on revision of the Effort Sharing Regulation (ESR)**; (2) **proposal on revision of the Land Use, Land Use Change and Forestry (LULUCF) regulation**; and (3) **adoption of conclusions on carbon farming** – all of which are briefly described below. Currently, the member states came to a common understanding about the ESR and LULUCF regulation, which is - at time of writing - in negotiation with the European Parliament.

The **Effort Sharing Regulation** sets binding annual GHG emissions targets for Member States in sectors that are not covered by the EU Emissions Trading System (covering electricity and heat generation, energy-intensive sectors, commercial aviation, aluminium production and production of nitric, glyoxylic acids and glyoxal) or the regulation on Land Use, Land Use Change and Forestry. With the Fit for 55 package, the Commission proposed a **revision** of the ESR regulation and meet **new targets to be achieved by 2030**. The proposal increased the EU-level GHG emissions reduction target **from 29% to 40%**, compared with 2005 levels, and updated the national targets accordingly. The calculation method for determining the national targets remained and is based on the Gross Domestic Product (GDP) per capita, with some targeted corrections to address cost-efficiency concerns. As the ESR includes the **agricultural sector**, this revision may stimulate carbon farming, as it includes emission reductions of greenhouse gases (but not carbon removals or avoided emissions as they are accounted for in the LULUCF sector).

The Commission's proposal also aims to strengthen the contribution of the **LULUCF** sector to the EU's increased overall climate ambition. Therefore, it is necessary to reverse the current declining trend of carbon removals and enhance natural carbon sinks throughout the EU. Specifically, the **revision** of the current legislation proposes to (1) set an EU-level target for **net removals of GHG of at least 310 Mt CO_2-eq by 2030**, distributed over the member states as binding targets; (2) simplify the rules on accounting and compliance and enhance monitoring; (3) extend, from 2031 onwards, the scope of the regulation to **include agriculture non-CO_2 emissions**; and (4) set an EU-level objective of **climate neutrality by 2035** for this newly combined land sector, which has been denoted as the **Agriculture, Forestry and Other Land Use (AFOLU)** sector. At time of writing, it is still uncertain if or when this AFOLU sector would come into being.

Furthermore, the **'no-debit' rule remains in place** which requires each Member State to ensure that accounted carbon emissions from land use are entirely compensated by an equivalent accounted removal of CO_2 from the atmosphere through actions in the LULUCF sector.

Additionally, on 7 April 2022, the **Agriculture and Fisheries Council** adopted **conclusions on carbon farming**, based on the Commission's communication on Sustainable Carbon Cycles, which was presented in December 2021. Relevant to carbon farming, it states:

> *"By **2028** every land manager should have access to verified emission and removal data, and carbon farming should support the achievement of the proposed **2030** net removal target of 310 Mt CO_2-eq in the land sector, as presented in July's package on delivering the European Green Deal."*

The most relevant actions proposed to tackle this challenge include: (1) the creation of an expert group on best practices and MRV methodologies; (2) mainstreaming funds for carbon farming in relevant EU policies and programmes, including the Common Agricultural Policy; (3) a study on applying the polluter-pays principle to the agriculture sector; and (4) the creation of a carbon farming group within the Climate Pact. To this end, the Commission will propose a **regulatory EU Framework for the Certification of Carbon Removals by the end of 2022**. This certification framework should ensure the transparent identification of carbon farming and industrial solutions that unambiguously remove carbon from the atmosphere.

3.2.3. Common Agricultural Policy 2023 - 2027

The **new CAP** seeks to enhance the contribution of agriculture to the EU environmental and climate goals, provide more targeted support to smaller farms and allow greater flexibility for Member States in adapting measures to local conditions. The new CAP **will apply in full in 2023** and will be designed to support the Farm to Fork and Biodiversity Strategies within the Green Deal. Income should be better targeted to farmers who need it most, and to those who contribute to the CAP green ambitions. Enhanced conditionality – which is mandatory to receive full payments – therefore will be expanded with environmental and climate-friendly farming practices and standards. The new eco-schemes and agri-environment climate measures – which are voluntary – might boost sustainable practices, including those that fall under carbon farming schemes (ELO, 2021).

In the conclusions on Carbon farming by the European Council (see above), it is indicated that the Council "*welcomes the intention to extend financial support, including from the private sector, in addition to the Common Agricultural Policy – which supports a broad range of carbon farming, carbon sequestration and other climate mitigation practices – and other public support.*" This statement seems to reflect the intention by the European policy makers to enable payments from both the CAP and private carbon farming schemes for certain practices, or at least leave the specifics to the Member States. This aspect is further explored in section 4.2.

3.3. Flemish policy context

3.3.1. Flemish Climate Strategy 2050 (2019)

In December 2019, the Flemish Government approved the Flemish Climate Strategy 2050, which was submitted to the European Commission as part of the Belgian Climate Strategy. Concerning agriculture, the 2050 climate target emphasizes the production of sufficient, safe, varied and high-quality food, the production of biomass to replace finite raw materials, sufficient qualitative space for ecosystem services, ensuring animal welfare and safety, and the contribution to a better quality of life in the environment (air, water, soil, biodiversity, etc.). Relevant to carbon farming in agriculture is the following statement:

> "*In agricultural soils, the carbon content has reached an optimum zone by 2050 and agricultural practices have evolved in such a way that the carbon content continues to increase or remains stable at a high level. This not only contributes to climate mitigation, but also makes agricultural soils more resistant to erosion and extreme weather (drought, heavy rainfall, heat, etc.) that will occur more frequently as a result of climate change.*"

Similar to European policy makers, Flanders thus attributes importance to carbon farming, and carbon storage in particular, highlighting both its mitigation and adaptation potential. The Flemish Climate Strategy 2050 also highlights some risks, including carbon leakage due to displacement of productivity (e.g. food production).

3.3.2. Flemish Energy and Climate Plan (2019, addendum 2021)

After receiving recommendations from multiple advisory bodies, the Flemish Government approved the Flemish Energy and Climate Plan (FECP) for 2021-2030, in December 2019. In November 2021, an addendum to this plan was published. The relevant aims of the FECP for carbon farming are a **35% GHG reduction** in the ESR sectors in comparison to reference year 2005, and compliance with the **no-debit rule** of the LULUCF regulation.

The specific measures taken for agriculture and the LULUCF sector are primarily focused on improving the energy-efficiency, increasing the share of renewable energy, reducing the (mineral) fertilizer usage and enteric methane emissions, improved forestry and nature development and better water management. Carbon storage in agricultural soils (a non-quantified target) and fulfilling the CAP goals on a regional level are also explicitly mentioned.

The FECP moreover announces setting up a **Flemish carbon market** as a tool towards compliance with the LULUCF regulation. The policy priorities to establish this carbon market are that it should be local, independent and voluntary, it should operate in an additional way to the ongoing policy and that it should consider co-benefits, instead of focusing on carbon only. The research priorities relevant to carbon farming are the following: (1) mapping the **potential** for negative emissions (carbon removals) in Flanders, including the opportunities for companies and services linked to the Flemish government and local authorities; (2) investigate the **realization** of a Flemish carbon market – How can a carbon market be rolled out in Flanders? Will it have the desired result in practice? How does the carbon market relate to the international framework, including the LULUCF Regulation?; (3) establish conclusive rules and reliable methods for high-quality CO_2 certificates (**toolkit**); and (4) achieve **scientific consensus in support of policy** – there is a need for scientific expertise on techniques and possibilities for CO_2 storage (e.g. soil carbon, biochar, accelerated weathering).

In November 2021, the Flemish Government published a 'vision paper', proposing an increased effort of emission reductions in all Flemish non-ETS sectors, including the agricultural sector. As a result, the **agricultural sector** will need to **reduce its emissions by an additional -0,552 Mton CO2-eq, towards a total amount of 4,97 Mton CO2-eq by 2030**, as compared to 2005. On top of the previously announced measures, the government also intends to reduce the livestock population in Flanders (including poultry, pigs and cows), by endorsing the **Global Methane Pledge** (aiming at a 30% reduction in methane emissions across energy, waste and agriculture sectors by 2030, with reference year 2020). The FECP is foreseen to be updated accordingly in 2023.

3.3.3. Other relevant policy at the local level

We conclude this chapter by referring to a survey on current policy ambitions and future soil aspirational goals (2050) in Flanders, performed by ILVO and funded by the European Joint Programme (EJP) SOIL. In this document, a comprehensive overview of policy packages that impact agricultural soils and soil management is provided (Ruysschaert and Jacob, 2021, p 10-12).

4. Carbon farming schemes

Carbon farming schemes (internationally also often referred to as carbon standards) set out the rules and requirements for carbon farming projects, in which farmers or groups of farmers can voluntarily commit themselves to apply carbon farming practices, in order to obtain climate mitigation outcomes in return for a payment via the voluntary carbon market, through public funding or any other form of compensation. Central to carbon farming schemes are the **governance system**, the **guiding principles** and the **Monitoring, Reporting and Verification** (MRV) system (as discussed successively below). As already explained in section 2.2, carbon farming schemes may include multiple method documents (targeting a specific form of carbon farming), to which overarching rules with respect to guiding principles and MRV apply.

4.1. Governance system

Governance is generally defined as "the **institutions, structures, and processes** that determine who makes **decisions**, how and for whom decisions are made, how and what **actions** are taken and by whom and to what effect. An important conceptual distinction needs to be made between governance and management: the latter refers to the resources, plans and actions that result from the functioning of governance." (Bennet & Satterfield, 2017 – also based on Lockwood, 2010).

As stated earlier in section 2.2, the purpose of a governance system in the context of carbon farming schemes is to ensure that the scheme functions in an **effective, fair and robust** manner. The relevant institutions, structures and processes therefore should be oriented towards creating and implementing the guiding principles (section 4.2) and structuring the project methodologies, of which the MRV-system (section 0) is an important part, in an efficient way. Besides the initial phase of creating and applying structures, the system of governance is also crucial to an evolving carbon farming scheme.

As different carbon farming schemes are often organized in a different way, we provide a comparison of the institutions, structures and processes involved in the governance of four different carbon farming schemes in Table 3 (i.e. Soil Capital, Label Bas Carbone, Stichting Nationale Koolstofmarkt and Verified Carbon Standard). To enable this comparison, we distinguish between a number of categories to evaluate the choices in the governance structure: (1) **distribution of responsibilities and executive power** – What internal structures exist? How are they composed? Who gets to take the final decisions in these structures?; (2) **decisions on guiding principles** – How are guiding principles established and updated? How are they applied to the carbon farming scheme?; (3) **method documents** – Who is allowed to develop and/or adapt method documents? What structures and processes are established to validate method documents?; (4) **project validation** – What structures and processes are established to validate carbon farming projects? Who is allowed to approve or disapprove projects?; (5) **management of the registry** – Is the registry managed by the governance institution itself, or is it outsourced to another party?; and (6) **fee structure** – How is the governance system itself financed? What processes and costs are involved for participants in the carbon farming scheme?

The comparison in Table 3 also allows us to contrast these governance systems visually (Figure 7). To do so, we consider whether the governance system is run by private or public actors (with different societal responsibilities and objectives), and whether decisions are made in a centralized manner (few decision makers) or a decentralized manner (many decision makers).

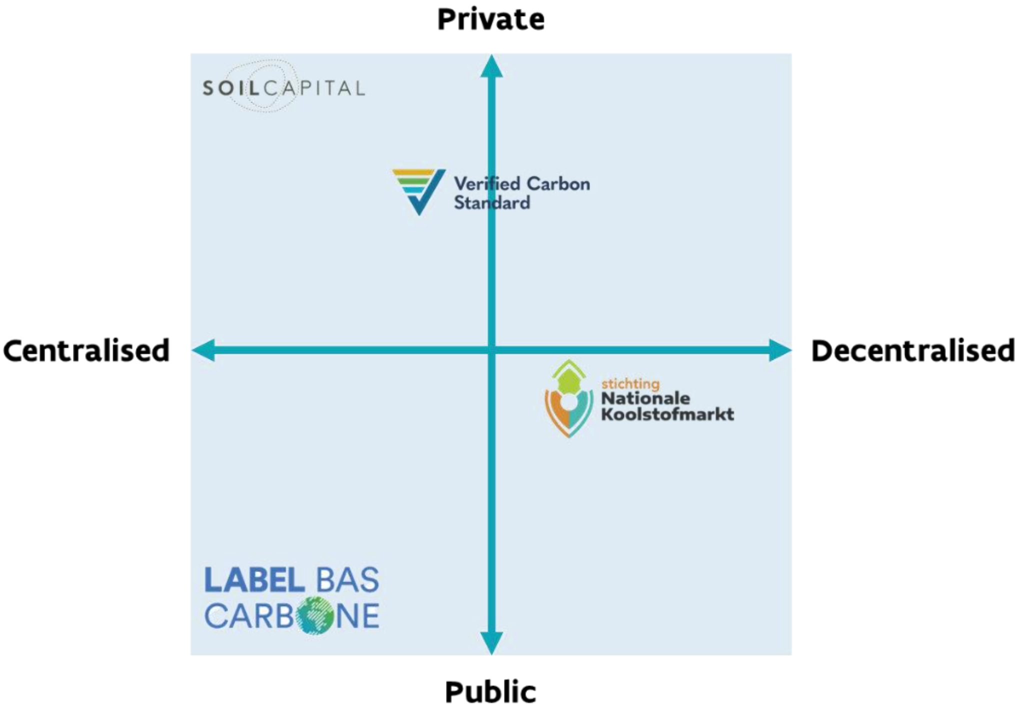

Figure 7 Comparison of the governance structure in four carbon farming schemes, based on a private-public and centralized-decentralized gradient.

Soil Capital (SC) is a private company, running its scheme in cooperation with a private partner. Decisions are made in a centralized manner. Thus, they are positioned in the upper left quadrant of Figure 7. **Stichting Nationale Koolstofmarkt (SNK)** started off as a centralized and entirely public initiative, but it has since evolved towards a more decentralized system, involving private and civil society stakeholders. As 'Staatsbosbeheer', a Dutch governmental institution, has a fixed role in the system, it remains narrowly within the public quarter of the figure. **Label Bas Carbone (LBC)**, on the other hand, is highly centralized and completely run by a public actor, as the Ministry of Ecological Transition plays a key role in almost all structures and processes involved. Therefore, LBC is placed in the bottom left quadrant. Finally, the **Verified Carbon Standard (VCS)** is positioned at the intersection of centralized and decentralized, because decisions on the framework and method documents are made with input from various stakeholders, but the managing entity, called Verra, has the final say. However, Verra does not develop or own projects directly. The VCS is considered to be private, because Verra is a non-profit organisation.

Table 3: Systems of governance driving various carbon farming schemes (with LBC = Label Bas Carbone, SNK = Stichting Nationale Koolstofmarkt, VCS = Verified Carbon Standard, SC = Soil Capital)

Governance aspect	LBC	SNK	VCS	SC
Distribution of responsibilities and executive power	• The LBC is developed by the French Ministry for Ecological Transition, with stakeholder input (°2018). • The Ministry holds all responsibilities and executive power.	• The Dutch government was strongly involved in establishing the basic structure of SNK (°2017). • Currently, private companies, civil society organisations and financing institutions are involved in SNK. • 'Staatsbosbeheer' remains the principal organizer, and the sole governmental institution involved. • Pillars of the governance system include: (1) Board of executives, (2) Committee of experts and (3) Working groups.	• The VCS (°2007) is developed and updated by Verra, a Washington based non-profit organisation. • Verra holds all responsibilities and executive power. • The multi-stakeholder group VCS Program Advisory Group advises on the VCS programme structure, but Verra has the final say.	• SC was founded as an independent agronomy firm (°2013), that developed a carbon payment programme in 2019. • SC holds all responsibilities and executive power, although it also cooperates with a private partner named South Pole), which develops and markets their carbon certificates internationally.
Decisions on guiding principles	• The Ministry defines the guiding principles in a 'National Code', and is responsible for updating this document.	• The Board of executives proposes the guiding principles. • The Committee of experts advises on these principles and collects feedback from public and private stakeholders. • The Board of executives adopts the guiding principles into the carbon farming scheme system.	• The guiding principles are established in different 'requirements' documents (e.g. the VCS Program Guide and VCS Standard).	• The guiding principles are designed by SC, based on the ISO 14064-2 norm. • Decisions on updates are made by SC, although South Pole also may have a say.
Development and validation of method documents	• Anyone is allowed to write method documents. These should consider the checklist of actions, defined in the National code. • The Ministry appoints a committee of experts (internal or external) to review the method documents. • The Ministry validates all steps.	• All participants of SNK are allowed to write method documents. • Working groups 1 and 2 advise on and validate these documents. • The Committee of experts adopts the final method documents by adding them to SNK list of approved methods.	• Anyone is allowed to write method documents, following the VCS Methodology Approval Process. • Method documents are subject to public consultation and feedback.	• SC functions both as governance institution and project developer, • SC adopts only one type of method, that complies with ISO 14064-2 (note that the method is not publicly available in a full-written method document).

Project development and validation	• Project developers write the project plans. • The Ministry validates the project plans.	• Project developers write the project plans. • SNK appoints an independent team of experts to validate these project plans.	• Project developers write a project description. • The compliance of the project with the VCS Standard and the specific method document is validated by a Validation and Verification Body.	• Farmers propose a management plan as part of their enrolment (using the 'mySoilCapital' platform). • The management plan is validated by SC.
Management of the registration system	• The Ministry recognizes project outcomes from standardized project reports and generates the carbon certificates. • The registration system is managed by the Ministry.	• The Board of executives generates the certificates. • The registration system is managed by SNK.	• Credits are issued after project validation and verification, in accordance with the VCS Registration and Issuance Process. • Verra manages a central registration system (°2020) for the transparent listing of certified projects, issued and retired units.	• SP generates the carbon certificates, and manages the registration system (including the buffer pool).
Fee structure	• The Ministry does not seem to demand any fees from participants	• Working Group 3 advises on financing, claiming and co-benefit valorisation. • Costs apply for the generation, transfer and retiring of certificates (see section 4.3.3.2.). • These costs aim to make the governance institution self-sufficient.	• Method developers receive a commission from the sale of VCUs generated using their method. • Fees apply for making an account, registering projects and issuance of Verified Carbon Units (VCU's).	• Basic plan: no yearly cost for farmers, 70% of carbon payments goes to farmers. Standard plan: farmers pay £980/yr (excl. VAT), 100% of carbon payments goes to farmers, access to advisory services through SC agronomists. • SC and SP receive a commission on the sale of carbon certificates to cover the costs of the sales, the programme and the audits.

4.2. Guiding principles

There are a number of guiding principles that should be applied in carbon farming schemes. Here, we describe the most important of these principles and how different carbon farming schemes deal with them. We consider the principles of additionality, permanence and no carbon leakage, and also consider uncertainty and risk management as an important tool to deal with non-compliance with the latter two. The principles discussed are internationally recognized by stakeholders involved in the voluntary carbon market, and thus are not specific for carbon farming projects in the agricultural sector (although they are tailored to the specific context).

4.2.1. Additionality

It is internationally accepted that emission reductions and/or carbon removals through carbon farming projects must be 'additional'. This means that the generated reductions and/or removals **would not have occurred under the 'business-as-usual' scenario**, i.e. without the carbon finance or incentive. Additionality thus ensures that no payments are made for improvements that would have occurred anyway, and therefore helps to achieve the intended emission reductions, avoided emissions and/or carbon removals in a more cost-effective way.

4.2.1.1. Approaches to demonstrate additionality

As the voluntary carbon market is not regulated, different carbon farming schemes often adopt a different approach to determine additionality. Mostly, they adopt a combination (or pre-determined sequence) of approaches ('tests') to reach the **most objective assessment.** However, it is nearly impossible to determine additionality with complete certainty, as this always involves a future prediction of the business-as-usual scenario (Climate Change Authority, 2020).

The most commonly applied test to determine additionality is the '**legal test**', which checks for 'regulatory additionality'. This means that the adoption of a specific carbon farming practice cannot be required by law or regulation at any policy level. If, however, this is the case, the practice is considered ineligible. Although the legal test is relatively straightforward and reliable, it is not sufficient to determine additionality per se and therefore it should always be used in combination with another test (Climate Change Authority, 2020).

Another frequently used test to demonstrate additionality is the '**financial test**'. This test tries to prove that the carbon finance – irrespective of the type or source of finance – is strictly necessary to implement the practice. This can be proven, for example, by demonstrating that the project is not financially attractive or even not financially viable without the carbon finance (CDM, 2004). Although the principle of financial additionality is relatively simple, it can be difficult to test it in practice, as this requires specific knowledge of the investment environment (Climate Change Authority, 2020). It may also lead to a somewhat subjective assessment and for this reason, SNK decided not to work with the financial additionality test for instance (SNK, 2021).

A specific form of demonstrating financial additionality, is by working with the '**contribution of carbon finance test**'. This test indicates whether or not the carbon finance covers a certain percentage of the total investment cost, and consequently can be considered significant. The Woodland Carbon Code (WCC), for example, adopts the requirement of a minimum contribution of carbon finance of 15% of the planting and establishment costs up to the 10th year of the project to determine additionality (WCC, 2019).

Another test that is often used to demonstrate additionality is the '**barrier test**'. For this test, scheme developers must demonstrate that the carbon farming scheme and its associated carbon financing will help to overcome existing obstacles in order to implement a certain carbon farming practice. These barriers may be related to a lack of knowledge, public perceptions, cultural practices, risks, technological innovations, land tenure rights, land use practices, institutional aspects, and others. Solutions to address such barriers may be as 'simple' as rolling out an information campaign or developing a demonstration programme.

Most carbon farming schemes adopt an **individual project-by-project approach** to demonstrate additionality, even though this can be time consuming and can increase transaction costs. In response, some carbon farming schemes (e.g. the Australian Carbon Farming Initiative; Thamo & Pannell, 2016) choose not to determine additionality at the project level and instead adopt a more standardized approach by working with a so-called '**positive list**'. This is a list of carbon farming practices that are automatically considered eligible for implementation within a certain region or country (the area of application is determined by the scheme developer). Practices may be included on such a list because they have low levels of adoption in a certain region, are not the least cost option, but have multiple other benefits or have no revenue streams at all besides potential carbon finance (VCS, 2013). To compile and justify such a positive list, quantitative indicators may be used. Besides reducing the transaction costs, the advantage of working with a positive list, is that it provides opportunities to promote specific practices and hence can help to accelerate the implementation rate of these practices. Working with a positive list thus can be seen as a **standardized form** of testing additionality (e.g. referred to as 'Standardized Methods' by VCS; VCS, 2013). As implementation rates and investment environments may evolve over time, it is necessary to frequently reassess an update positive lists.

An alternative approach to avoid project-by-project additionality assessments, is to work with a **'common practice test'**. Here, the regional or national level of adoption of a certain practice or a combination of practices is set against a predetermined threshold, often 20%. In case the level of adoption is below this threshold, the practice is considered additional. To use the common practice test, regional or national data on implementation rates should be available (e.g. based on census or other government data, peer-reviewed literature, research data, reports or assessments by industry associations). When implementation rates exceed the set threshold, the practice is no longer considered to be additional.

To comply with the Improved Agricultural Land Management (IALM) method of VCS, for example, project proponents must demonstrate regulatory surplus (similar to legal additionality) and apply the barrier and common practice tests. Here, the common practice test – for which a threshold of 20% must be applied (following the Clean Development Mechanism (CDM)[17] threshold) – pertains to the adoption rate of the three (or more) predominant proposed carbon farming practices. For this, the weighted average adoption rate is calculated by considering the proposed area of implementation. Practices with regional adoption rates higher than 20% therefore can be considered eligible when combined with practices with regional adoption rates below 20%, as long as the weighted averaged adoption rate remains below 20%.

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[17] See The Clean Development Mechanism | UNFCCC for more information on the CDM.

Table 4 Overview of the types of additionality tests applied in different carbon farming schemes (with CDM = Clean Development Mechanism, LBC = Label Bas Carbone, SNK = Stichting Nationale Koolstofmarkt, WCC = Woodland Carbon Code, CFI = Carbon Farming Initiative, VCS = Verified Carbon Standard, GS = Gold Standard).

	CDM	LBC	SNK	WCC	CFI	VCS	GS
Legal test	X	X	X	X	X	X	X
Financial test	X	X		X			X
Contribution of carbon finance test				X			*
Common practice test	X	X	X			X	(X)
Barrier test	X	X		X		X	(X)
Positive list					X	(X)	(X)
Other	*						

* ‘First-of-its-kind’ test (the practice is automatically considered additional if it is the first-of-its-kind) and identification of alternatives to the project activity consistent with mandatory laws and regulations.
* Gold Standard projects must demonstrate the ‘ongoing financial need’ to implement a certain practice. However, there is no threshold defined for the contribution of carbon finance.

For Gold Standard (GS) projects in the agricultural sector, project proponents can choose between different options to demonstrate additionality. Either they use the CDM tool for additionality demonstration, they work with a positive list (only allowed under certain conditions) or apply the common practice test (referred to as the level of ‘activity penetration’). In case of using the CDM tool, a step-wise approach must be applied: (1) first-of-its-kind test (if positive: additionality is demonstrated, if negative: apply next steps), (2) investment test (demonstrate the need for carbon finance), (3) barrier test, and (4) common practice test.

4.2.1.2. First movers disadvantage

An important drawback of strict adherence to the principle of additionality is that farmers who already pay much attention to carbon removals (carbon sequestration), avoided emissions and/or emission reductions – the so-called first movers – are possibly not eligible to participate in carbon farming schemes (as the principle of additionality hinders the payment for activities already occurring in the business-as-usual scenario). This may be discouraging for these farmers as their efforts are not valorised and they have to bear all investment costs themselves. Even though first movers are expected to be fully convinced of the multiple benefits of carbon farming, in some cases, the sense of injustice due to ineligibility may lead to unfavourable consequences, such as the undoing of efforts made[18]. Obviously, this is not the impact carbon farming schemes are aiming for. Furthermore, the exclusion of first movers also may lead to the loss of **soil health ambassadors**, who are very important to show the way to other farmers.

Therefore, it is worthwhile reconsidering the eligibility of first movers participation in carbon farming schemes. This can be done, for example, by applying the common practice test (at regional level) and setting a fair threshold.

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[18] Note that in some carbon farming schemes (1) it is indicated that certain land use changes cannot have occurred in the past 5 years, or that (2) a historical look-back period of three to five years is applied to determine the baseline (business-as-usual scenario). Both aspects hinder the eligibility of first movers in case of the undoing of efforts made.

4.2.1.3. Additionality assessments in practice

In practice in Flanders, we see that carbon farming schemes often adopt a more pragmatic approach to determine additionality and mainly look at the **historical management** of the agricultural fields within the project boundary. If a specific practice has not been implemented in the past three to five years, for example, the practice automatically is considered additional. As the adoption of new practices by the farmer or land manager is at the core of the assessment, this type of additionality can be considered a form of '**behavioural additionality**' (Meyers, 1999) (and this pragmatic approach could be referred to as the '**carbon farming practice test**'). For this approach, data can be collected through farmer consultation (declaration on honour) or by consulting the GeoSpatial Aid Application ('Verzamelaanvraag'). Different schemes adopt this approach because it is straightforward and it does not require a detailed analysis, which strongly reduces the administrative burden and transaction costs. The latter is very important in the Flemish context, as farms are of relatively small size and high transaction costs may undermine the financial incentive for implementing carbon farming practices.

In the **absence of a clear regulatory framework**, we also observe that it is now up to the managers of the private carbon farming schemes to determine **whether** participation in a carbon farming scheme **can be combined** with the CAP Pillar 1-funded **eco-schemes** (or pre eco-schemes), in which farmers may participate on a voluntary basis in Flanders. For these eco-schemes, farmers can receive 40 up to 100 euro per hectare if they grow crops and cover crops that lead to inputs of effective organic carbon[19] (EOC) above a certain threshold level (dLV, 2022). Although no one is interested in double funding, it is especially in the interest of public funding agencies to set clear rules on the combined participation in eco-schemes and private carbon farming schemes.

4.2.2. Permanence

In the context of carbon farming projects, permanence indicates the **sustained climate mitigation effect** of the three possible project outcomes of carbon farming (i.e. carbon removals, emission reductions and avoided emissions) **in the long term**. In theory, the achieved climate mitigation effects should be sustained as long as possible, ideally forever. In practice, specifically for projects in the agricultural sector, ensuring permanence requires a good design of carbon farming schemes, but also requires some pragmatism. Both the **project duration** and the **post-project period** should be considered.

If the climate mitigation effects are lost at some point in time, we refer to this as a the '**loss of permanence**' or '**non-permanence**'. There are several ways to handle the risk of non-permanence, as discussed in section 4.2.4. Besides the loss of permanence, a carbon farming project may also cause other unintended emissions, this is referred to as 'carbon leakage', which is discussed in section 4.2.3.

4.2.2.1. Potential ways of losing permanence

Loss of permanence can occur for several reasons, including the **(1)** interruption or cancellation of efforts, **(2)** the introduction of actions with a negative impact on project outcomes, or due to **(3)** external factors over which the farmer has no control.

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[19] The effective organic carbon is the carbon that remains in the soil one year after application to the soil.

First, in order to achieve permanence, it is important **not to interrupt or cancel the efforts done**. This has different implications for the three types of project outcomes. For carbon removals, this implies that the sequestered carbon should be maintained in the soil (e.g. under cropland or grassland) and/or in the woody biomass (e.g. trees or hedgerows). This requires **a continuous implementation of carbon farming practices**. If the farming practices change, this may cause an increase in soil carbon decomposition or decrease of carbon inputs, and this may result in net carbon emissions from the soil (Rimhanen et al., 2022). Achieving permanence in agricultural soils could therefore consist of reaching an agreed-upon optimal SOC content, and balancing the rate of SOC breakdown and SOC build-up once that optimal content is reached. What that optimal content might be for the various soil types / textures and carbon farming practices involved, will need to be discussed at length. Maintaining carbon stocks in woody biomass also implies that a proper management of the woody landscape elements is required, in order to promote growth and avoid degradation (e.g. keeping an agroforestry system healthy). For reduced emissions, the measures taken should be maintained over time (e.g. reduction in mineral fertilizer usage, reduction in fossil fuel usage), whereas for avoided emissions, the measures taken should be maintained for as long as necessary for the carbon pool to reach a new, stable, and reduced new steady-state emission profile (e.g. restoration of peatlands; also see Figure 1 in section 1.2.4).

The interruption or cancellation of efforts may have **different causes**, and could occur during or after a carbon farming project. Some examples include: (1) the land manager loses trust in the viability of the applied measures (e.g. because of a short-term yield loss), and stops participating in the carbon farming scheme, reverting back to conventional practices; (2) after carbon payments received during the project duration, the applied measures are no longer economically viable for a farmer; and (3) the farm or land is sold, and the new land manager does no longer apply the introduced measures and hence loses the obtained climate benefits.

In this context, different types of carbon farming practices seem to have a different level of risk on the interruption or cancelation of efforts made (i.e. they have a **different risk profile**). Practices that require less effort to maintain, that are cheaper to maintain or result in earlier or more straightforward (co-)benefits, likely will be more resistant to cancellation, and thus will be less at risk of losing permanence. Planting an agroforestry system (carbon removals), for example, can be considered less risky for losing permanence as the high initial investment costs for agroforestry systems (which only become profitable over time), will not be undone easily as this would be very cost-ineffective. On the other hand, adopting multiple carbon farming practices at once during a carbon farming project (e.g. adapting new crop rotations, including intercropping, converting cropland to permanent grassland and modifying the timing and application of fertilizers), may be more risky. Throughout the project, the farmer may benefit from advisors and communication with peers, whereas when the project ends, continuing all of these practices on his/her own may prove to be too much to handle.

This highlights that **challenges** for achieving permanence in the agricultural sector occur at the intersection of **strategic, economic and social factors**, setting it apart from other nature-based solutions (e.g. afforestation or reforestation), which are particularly prone to external (natural) factors. This implies that policy decisions on carbon farming should involve a tailor-made approach for carbon farming projects in the agricultural sector.

Second, farmers may implement new activities that have a negative impact on the achieved project outcomes, especially carbon removals (carbon sequestration) and avoided emissions, as certain actions can quickly undo the slow process of increasing carbon stocks in the soil. For example, intensive tillage deteriorates the soil structure and weakens the soil aggregates, causing them to be susceptible to decay (Zheng et al., 2018). The SOC bound to the soil aggregates then becomes available to soil microbial metabolic activity, and can easily be lost to the atmosphere in the form of CO_2 emissions (Humberto et al., 2004).

Third, **external factors** may also lead to the non-permanence of project outcomes. These external factors may be of anthropogenic or non-anthropogenic origin, and may be attributed to local factors (e.g. vandalism), global trends (e.g. distortion or disruption of market functioning due to global pandemics, war…), climate change (e.g. higher temperatures, more frequent and longer periods of drought and natural disasters (e.g. flooding, burning…).

4.2.2.2. Handling permanence in practice

As the voluntary carbon market is not regulated, there are no obligations for carbon farming schemes to put systems in place for handling the loss of permanence. Despite this, several carbon farming schemes do implement such systems to increase trust in the market. This is mostly achieved by building some form of **risk management** into the design of the carbon farming scheme. In section 4.2.4.3, the most prominent of these systems are demonstrated through examples from existing carbon farming schemes. These systems include, but are not limited to: buffer accounts, eligibility criteria, long-term contracts, additional result-based rewards for long-term retention, stakeholder buy-in, development of other long-term markets, transfer of land to non-commercial ownership, permanent restrictions for future land use (COWI et al., 2021a).

Another proposed action is to work with **offset ratios**. These ratios help to transform the obtained climate mitigation effects into carbon certificates or credits (see Appendix 1.A for difference), by taking into account the contract duration of the carbon farming project. The number of generated credits or certificates is then simply multiplied by the offset ratio. The longer the duration of the project's contract length, the higher the offset ratio will be and thus the higher the number of carbon certificates or credits that can be sold. In fact, the offset ratio thus is a **discounting method** that corrects for short contract lengths. This can be seen as a pragmatic approach to handling permanence (Ollikainen et al., unpublished).

Besides having risk mechanisms in place, it can be especially important to stress to farmers that carbon farming practices should be economically viable without carbon payments by the end of the project's duration. In that regard, it is necessary to already maximize the potential gains during the project, for instance by applying the most cost-effective practices (i.e. the practices that can achieve certain climate benefits at the lowest cost).

Though not exclusive to Flanders, a particular challenge to achieve permanence in our region is related to **land rights and access to land**. Sale, leasing or swapping of agricultural lands are all common practice. However, currently, there is no mechanism to transfer carbon farming contracts from one party to another, nor are there any obligations to maintain previously elevated carbon stocks in parcels of agricultural land. In addition, in 2016, the average age of a Flemish farm manager[20] was 56 years. In the same year, only 13% of the farm managers had a presumed successor. In the largest farms, this percentage increased to about 25%, so the problem of no clear

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[20] The farm manager is the person responsible for the day-to-day operation of the farm (choice of production method, sowing date, etc.). This is also is the person legally and economically responsible for the farm.

succession chiefly occurs on smaller farms (Vermeyen, 2019). When discussing the upscaling of carbon farming in our region, these demographics and land tenure issues clearly should be top of mind. The question then arises whether we should target younger farmers early in their career to ensure a long and consistent application or whether we should develop contracts that are linked to a parcel of land and hence can be transferred between owners.

4.2.3. Carbon leakage

Carbon leakage is the (unintended) **spatial shift** of GHG emissions **and/or the shift in other types of GHG emissions** within or outside the spatial scope of the project **due to trade-offs** (e.g. due to emissions in other carbon pools or emission types, see section 1.2.2) occurring due to the implementation of carbon farming practices. As a result, the climate mitigation effect of the project is reduced. In the most extreme cases, the project even may cause a net increase in GHG emissions due to the local or non-local forms of carbon leakage.

4.2.3.1. Types of Carbon Leakage

As mentioned, carbon leakage may occur because of several reasons. To explain these reasons, we refer to Figure 8, and provide some examples below.

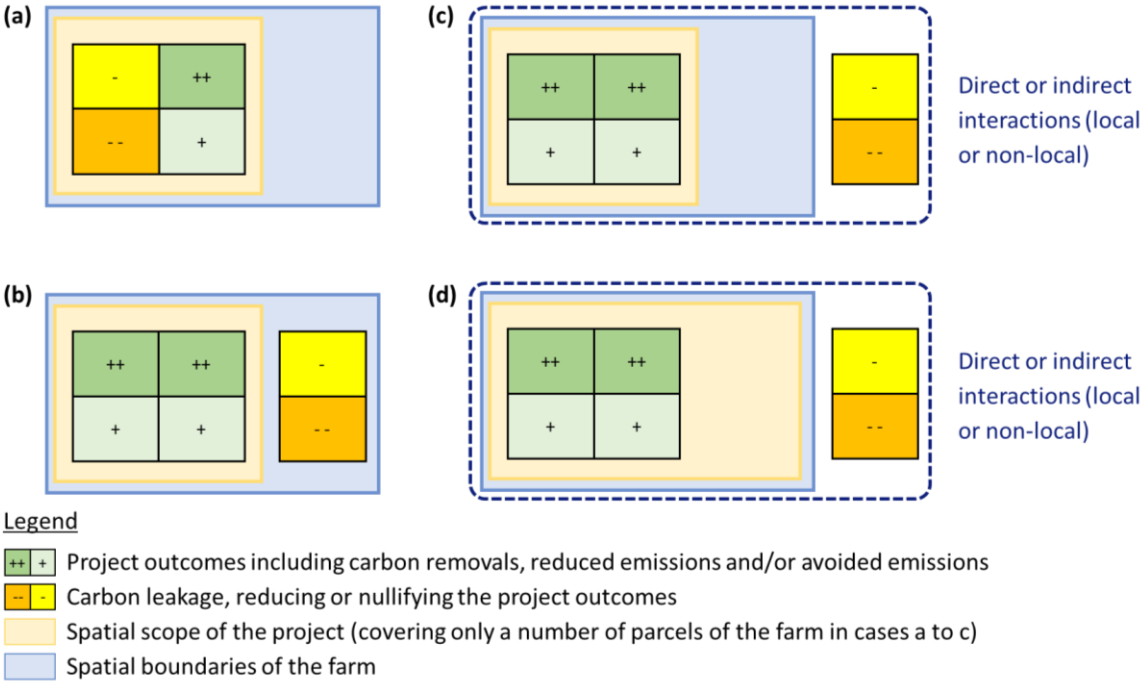

Figure 8 Conceptual overview of the different types of carbon leakage that may occur in carbon farming projects in the agricultural sector: (a) within the spatial scope, (b) outside of the spatial scope of the project but within the farm boundaries, (c) outside of the spatial scope of the project and outside of the farm boundaries (local or non-local leakage), (d) outside of the spatial scope of the project and outside of the farm boundaries (local or non-local leakage) even though the spatial scope of the project is equal to the farm boundaries.

First, carbon leakage may occur **within the spatial scope of the project** (**Figure 8a**). This mainly occurs due to unintended trade-offs, in the form of non-CO_2 emissions (released from the land). A farmer, for example, may grow cover crops, increasing the soil organic carbon content, but also increasing the risk on N_2O emissions that might partly offset the climate mitigation impact of the cover crops.

Second, carbon leakage may occur outside the spatial scope of the project, but within the farm boundary (**Figure 8b**). This especially may occur when not all parcels of land are incorporated in the project boundary. A farmer, for example, may concentrate all carbon farming practices on parcels of cropland that are inside the spatial scope of the project, such as application of compost, adapted crop rotations and the implementation of cover crops, leading to an increased soil organic carbon content. At the same time, the farmer, for several reasons, might decrease the carbon input by crops or organic amendments and intensify tillage on other parcels that are outside the scope of the project, leading to a decreasing soil carbon content there. This decrease in soil organic carbon content outside of the project area then reduces the overall impact of the carbon farming project. Another example, is adding more temporary grassland in a crop rotation as an effective measure to increase soil organic carbon on arable land inside the scope of the project, but at the same time converting permanent grasslands to arable land on parcels outside the project scope, leading to a net loss of soil carbon at the farm level.

Third, carbon leakage also may occur outside of the spatial scope of the project, and outside of the farm boundary. This may occur both when the spatial scope of the project covers only a few parcels of the farm (**Figure 8c**) and when the spatial scope of the project covers all parcels of the farm (**Figure 8d**). A farmer, for example, may start a series of carbon farming practices at the farm. All cropland and grassland are involved, and the farmer also aims to reduce the fossil fuel usage of machines through reduced tillage methods. At the local scale, the project achieves a climate mitigation effect through increased soil organic carbon in the soil, and a reduction in the direct emissions. However, this farm may import all organic soil amendments (such as straw, woodchips, organic manure…) from another farm in the same region (**local**) or possibly from another country (**non-local**). The GHG emissions associated with harvesting, transporting and storing these imported amendments reduce the impact of the project. Also, the other farm may suffer from a decrease in the soil organic carbon content as organic fertilisers and amendments are no longer available at that farm.

Another example of non-local carbon leakage may be a shift in agricultural production towards regions with less sustainable agricultural processes (higher GHG emissions per unit produced) or even to regions where forests are converted to agricultural land. This may be caused by increased costs that go along with more sustainable production locally or by decreases in productivity by carbon farming practices.

4.2.3.2. Handling Carbon Leakage in practice

The examples in the previous section highlight the risk on different types of carbon leakage, which is especially high when not including all parcels or farm operations within the spatial scope of the project. When restricting the project boundary to only a number of farm plots or to a small selection of farm operations, you may be ignorant of the **total emission profile of the farm**. This **may lead to overestimating the climate mitigation effects** of a project, and thus lead to a loss in capital efficiency towards tackling climate change. On the other hand, when adding an increased complexity to carbon farming schemes in order to tackle carbon leakage, this may quickly raise the costs of the system (e.g. due to the monitoring costs, development of new tools, administrative costs, costs of audits…), also leading to a loss in capital efficiency. More complex carbon farming schemes moreover may also be less attractive to farmers, who put high value on flexible schemes, which they can gradually apply to larger parts of their farm.

A **well-thought** determination of the **project's scope** (project boundary) is thus essential to avoid unintended impacts. Handling carbon leakage also requires a good coordination between the carbon farming scheme design (section 4.2.4.3) and the MRV design (section 4.3). However, when accounting for carbon leakage, it is also important to draw the line somewhere, not to make the system overly complicated. In that regard, it is important to **determine when carbon leakage is significant**. Table 5 gives an overview of how different carbon farming systems attempt to tackle the latter.

Table 5: Determination of carbon leakage significance, according to various carbon farming systems.

LBC	SNK	WCC	VCS
• An assessment of the risk of carbon leakage should be conducted. It must be demonstrated that this risk is 'low'.	• For all sources / sinks, it is not mandatory to demonstrate that not counting these emission sources contributes to a conservative estimate of the GHG impact of the project. • Sources / sinks can be left out when their combined share is < 5% of the total CO_2 sequestered, and thus can be considered not significant.	• Domestic carbon leakage is not significant if it accounts to < 5% of the carbon sequestered in the project, during the project's lifetime. • If international carbon leakage occurs, an individual assessment of the resulting GHG emissions must take place.	• Where the increase in GHG emissions from any project emissions or leakage source, and/or decreases in carbon stocks in carbon pools, is < 5 % of the total net GHG emission reductions and removals due to the project, such sources and pools may be deemed *de minimis* and may be ignored (i.e., their value may be accounted as zero).

WCC, VCS and SNK thus apply a **'de minimis' approach**, based on a **5% threshold**. VCS and SNK apply this threshold to all carbon sources and pools. LBC requires an individual assessment, leveraging the central role of the government towards a tailor-made approach for every type of methodology. In all cases, certain calculations and assessments have to be made in order to assure that carbon leakage is properly taken into account when it occurs.

As an example, we also looked into the Soil Organic Carbon Framework methodology by Gold Standard[21], which aims to avoid carbon leakage by (1) defining a minimum set of parameters to be considered in the projects (such as changes in agrochemical inputs, hydrology, crop-related inputs, technical management of crops and crop management activities); (2) banning projects on wetlands and in forests – as land use changes may lead to net carbon emissions and by (3) not allowing projects that incur a decrease in crop revenues or in agricultural productivity – **projects should be set up to maintain yields** (within the normal range of variation) **or increase yields**. For the latter, which is referred to as avoiding '**market leakage**', yield reductions should be tracked by comparing the current yields with those of the past five years, considering the lowest yields in the project area. If a reduction in yield is detected, it is assumed that the lost production capacity will have to be made up for on land outside the project area. Emissions caused by such a shift therefore must be accounted for as leakage (by deducting them from the project outcomes), unless the project owner can provide evidence that the yield reductions are caused by factors unrelated to the project activity, for example due to weather conditions.

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[21] This document provides the guiding principles to quantify changes in GHG emissions and SOC stocks through the adoption of various agricultural practices. Eligible activities can achieve avoidance of emissions as well as sequestration of carbon in the soil.

In conclusion, tackling carbon leakage thus requires a **thorough knowledge** of the processes involved, in order to **foresee risks**. The goal is also to avoid complex calculations wherever possible, for example by having **clear guiding principles for project eligibility**. When calculations are unavoidable, they should follow a clear formula and require as little extra data as possible (on top of the data already collected in the carbon farming scheme, e.g. for monitoring).

Currently, **in Flanders**, some carbon farming project developers do not account for carbon leakage, preferring to keep the methodologies simple. The most prominent reasons for this seem to be that (1) the barrier of entry for farmers increases when they cannot enroll with just a few parcels of their land; (2) even though a system at the farm level is more robust than one at the parcel level, the preference is to keep things simple for the initial phase of projects - by fostering farmer engagement, knowledge and experience can be gained; (3) there is trust in the farmers as they would not (purposely) work against their own self-interest by decreasing the SOC content in parcels of land not incorporated in the project, for instance; and (4) the risk of carbon leakage is reduced when the farmers entering a carbon farming scheme are convinced of the merits of increased soil carbon content, for example, and thus understand the basics of a good soil health.

4.2.4. Uncertainty and risk management

Risks in carbon farming schemes refer to processes that might lead to outcomes that contradict the intentions of the carbon farming scheme (e.g. a net increase in GHG emissions, degradation of biodiversity, etc.). **Uncertainties** in carbon farming schemes might lead to a difference between the real impact of a carbon farming project and the attempt to quantify that real impact.

As demonstrated in the sections on additionality, permanence and carbon leakage, uncertainties and risks are often highly project-specific. However, some general approaches and principles can be applied to tackle these challenges, and will be explored next.

4.2.4.1. Types of uncertainty

One of the most prominent reasons for uncertainty to arise, is due to the method used to **measure** (measurement uncertainty) and/or **model** (model structure or model input uncertainty) the **baseline and project outcomes** (especially linked to soil organic carbon stocks and hence to carbon removals and avoided emissions). Accounting for these types of uncertainty in the design of carbon farming schemes can make them more scientifically robust.

- Measurement uncertainty

When measuring carbon stocks in the soil through soil sampling, uncertainty is inherent, as capturing all variation requires an unfeasible number of soil samples to be taken. Therefore, **soil sampling protocols** are designed to attain a certain **pragmatic level of accuracy**. Another source of uncertainty occurs when soil sampling protocols are not followed properly, reducing the accuracy and representativeness of the measurements. Both these uncertainties will carry on into the analysis of the samples (i.e. **error propagation**).

- Model structure uncertainty

In order to reliably predict the outcome of carbon farming schemes, various models can be used. The model choice will, among others, depend on the type of carbon farming practices and specific conditions that the model can be used for (e.g. subsoil or not, organic or mineral soils) and the feasibility of obtaining the needed input data. Next, the model should be **calibrated** and **validated for the (regional) context** in which it will be used.

To guarantee transparency of the model accuracy, certain carbon farming schemes or standards formulate a **basic set of criteria**, which must be fulfilled. For example, the VCS methodology for Improved Agricultural Land Management states that models must (1) be publicly available from a reputable source (though not necessarily free of charge); (2) be shown in peer-reviewed scientific studies to successfully simulate changes in SOC and/or other GHG; (3) be able to support the repetition of model simulations by having stable software and clear version histories; and (4) be validated with robust datasets and procedures – for which VCS proposes its own methodology.

Calibrated and validated models moreover can only be used for the conditions in which they have been developed and tested. For example, the LBC 'Méthode Haies'[22] employs a customized model based on empirical input data from experiments in the north western part of France ('Région Grand-Ouest'), combined with values from literature. The model is thus trained to be accurate in that specific region. When the model is used outside of the Grand-Ouest, the increased uncertainty is translated into withholding 5-50% of the carbon certificates obtained through the method.

- Model input uncertainty

As mentioned, the modelling results strongly depend on the quality and accuracy of the input data. This quality may be variable for several reasons.

First, when using regional estimates as input data instead of project specific data, the uncertainty is higher due to **local deviations from regional estimates**. When using (simplified) generalized values for model inputs, **conservative estimates** always have to be used in order not to overestimate the climate mitigation effects. Therefore, it is important to distinguish between an accurate project-scale variable and one that is representative for a larger region. For example, the growth rate of trees in an agroforestry system may vary according to the species used, local soil type, regional weather conditions and management practices. However, when applying conservatively estimated growth rates, these should be applicable to a wider region.

Second, uncertainties also can occur due to the **practical implementation of carbon farming practices**, which may differ between farms and regions. This difference may be due to the use of specific machinery, existing farm management habits, the way farmers deal with landscape characteristics (such as steeper slopes), and the farmer's ability to learn and apply new practices in an effective manner. An example is the intensity of the seedbed preparation which might impact soil carbon turnover and residues remaining at the soil surface. In order to be sure that practices are implemented in a way that is agreed upon, field visits could be organised or field evidence (e.g. through geotagged photos) could be obtained.

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[22] This method quantifies the carbon sequestration of planting and/or sustainable managing hedgerows (the traditional French 'bocage' systems).

Third, the outcome of the **combined implementation of several carbon farming practices** – either implemented within the same method or in different methods – may be difficult to predict. To avoid confusion, some carbon farming schemes (such as LBC), have an obligatory section in their method documents that indicates what other project types the method is compatible with. For example, the LBC 'Méthode Plantation de Vergers'[23] mentions that it can be combined with other LBC methods that already exist or are under preparation. Specifically, this method can be combined with the 'Méthode Boisement'[24], 'Méthode Haies' and 'Méthode Agroforestry' (currently under preparation). However, in practice, these methods are only compatible when applied to different parcels, where they do not interfere with each other's calculations at the farm level. When combining methods, no adjustments for beneficial or detrimental interaction effects are taken into account yet for the individual calculations.

These shortcomings are also present in other carbon farming schemes. Combinations of practices are either not discussed, or estimations of their combined effect are limited to the question whether these practices are reinforcing or reducing each other's impact. Often, the precise **interaction effect** – whether positive or negative – is **unknown** due to the **lack of scientific data from field experiments**. For reasons of cost, many long-term field experiments only have simple designs and neglect the potentially interesting combination of treatments (e.g. no-till combined with the use of cover crops) (CLIMASOMA final report, 2022).

- Uncertainty related to project integrity

Additionally, uncertainty may occur due to the improper implementation of guiding principles, method documents or validation / verification. Even when a certain methodology is scientifically robust, things can still go wrong in the implementation phase. For example, the methodology may not fit the proposed project due to an improper validation of the project (e.g. when not done by a third-party auditor) or a project may not perform (all) of the requirements of the methodology. In the latter case, the verification of project results still needs to occur, preferably by an independent third-party auditor. If the verification is not thoroughly done, an under- or overestimation of the project impact may occur.

4.2.4.2. Trade-off between costs and accuracy

Trying to minimize the level of uncertainty, by strongly increasing the number of required soil samples for example, clearly comes at a cost. This results in the **constant trade-off between costs** of the MRV system (section 4.3) **and the potential revenues** that a farmer may derive for implementing certain carbon farming practices. In other words, increasing the accuracy of the MRV system directly impacts the profitability of the carbon farming scheme, and could potentially make the scheme less attractive for participants if the costs or administrative burden become too high (Köhl et al., 2020).

In Flanders, the **average farm size** is **small to medium**, even though it has increased significantly over time. The Belgian National Inventory Report (1990 – 2019) mentions that the number of Belgian agricultural and horticultural businesses dropped by 42% between 2000 and 2019, while the agricultural area remained the same. Despite this size increase, the average Flemish farm size was about **27 hectares** in 2020 (Statistiek Vlaanderen), which is well below that of neighbouring

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[23] This method quantifies the carbon sequestration of planting perennial fruit crops (orchard) on agricultural land not currently used for this purpose.

[24] This method quantifies the carbon sequestration of converting non-forest land into forest land.

countries. In the same year, the average area of cultivated land was 34 hectares for farms in the Netherlands (StatLine) and 69 hectares for farms in France (Agreste).

Although higher levels of accuracy come at a cost, they also contribute to making a robust MRV system, which preferably also should be automated, reliable, flexible and cheap to operate. Having such a MRV system may increase the **buyer trust** (as it ensures that the credits or certificates are matched by real, additional emission reductions or carbon storage) and hence increase the demand. On the contrary, McDonald et al. (2021) highlight that **farmer uptake is crucial** for the scheme to achieve a sufficient scale to create impact. Scheme designers therefore should try to **minimize transaction costs borne by farmers** and increase the likelihood of uptake. These transaction costs can be reduced **directly**, for example, by letting the scheme cover the soil sampling costs (partly), or **indirectly** by spending more money up-front and simplify the scheme for farmers. The trade-off between up-front set-up costs and lower farmer transaction costs, however, always needs to be balanced and well-informed.

One way to do this is to work iteratively, starting with relatively low set-up costs and a less robust scheme, and then progressively invest in the scheme to decrease transaction costs, while maintaining a reasonable level of accuracy.

Optimizing the collaboration between research institutes, policy makers and private actors in the voluntary carbon market may also trigger a reduction of costs through a more balanced sharing of research and development costs when working towards a regionally adapted and scientifically robust carbon farming scheme. An iterative feedback-loop between **science, policy and practice** could facilitate this process (Figure 9).

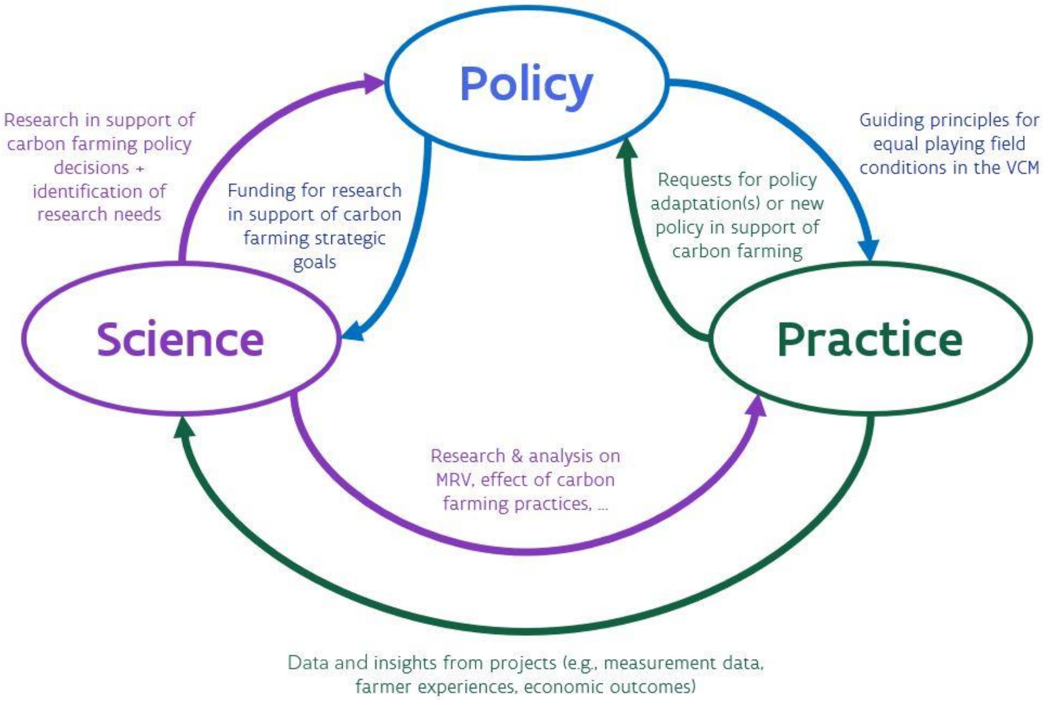

Figure 9: Scenario for collaboration between science, policy and practice towards robust carbon farming schemes.

Examples of entities in the science group are research institutes, living labs and universities. The policy group, on the other hand, consists of governments at different levels (local, regional, national, EU), whereas the practice group includes project developers such as advisors, NGOs, farmers. Some organisations, such as civil society organisations, hover between these categories.

The strategic options to tackle the challenge of reducing MRV costs, specifically those borne by farmers, will be further explored in the roadmap following this system analysis report.

4.2.4.3. Risk management

- Risk management through carbon farming scheme design

As described above, the risk of overestimating the climate mitigation effect can have several causes, such as by uncertainties in measuring or modelling the baseline and project outcomes, by risks of carbon leakage or risks of non-permanence. Different carbon farming schemes handle risks in different ways, and adopt a scheme-specific form of risk management (see Table 6 on the next page, as well as sections 4.2.2.2 and 4.2.3.2).

Table 6: Risk management practices in a selection of public and private carbon farming schemes.

Label Bas Carbone	Stichting Nationale Koolstofmarkt	Woodland Carbon Code	Verified Carbon Standard	Gold Standard
• Certificates can be withheld based on risk assessments for specific methodologies. • Each method chooses a certain level of deduction, depending on the assessed risks, and withholds a certain percentage of the certificates issued (at least 10% for all methods). • LBC applies this method to address the following risks: - Risk of non-permanence - Risk of overestimating emission reductions and carbon removals (e.g. due to parameter uncertainties, uncertainties in determining the baseline, uncertainties in the verification process). • Each method should include an assessment of the risk of carbon leakage. It should be demonstrated that the risk is low.	• Risk management is mandatory for each methodology. • Risk estimates regarding project outcomes should be approved by SNK. Proper measures to handle the significant risks need to be formulated. • When ex-ante certificates are issued, a safety buffer of 15% of the 5-year project outcomes is applicable. • Based on annual monitoring, project parties can estimate whether they remain within the buffer range or whether measures must be taken to improve project performance. Even if one remains within the safety margin of the buffer, it may be wise to take these measures. • After 5 years, the buffer certificates are released and can be sold on the market.	• The communal buffer pool and written commitments manage risks. • Land managers are asked to: - Identify risks and develop appropriate mitigation strategies in the project plan. - Contribute to the WCC Buffer (holding 20% of the credits). - Replant or re-supply in case of projects with harvesting. - Replant in case forest is lost - Adjust the management to achieve long-term goals (contractual obligation). - Inform the (potential) future land managers about the commitment to WCC and the relevant carbon contracts. • Corrective actions must be taken if the planting rates, tree growth rates and carbon sequestration rates do not meet the predicted and validated amounts. • Significant carbon leakage should be tracked. If leakage is considered significant, it should be quantified and accounted for.	• For quantification method 1, uncertainties are estimated using (1) an analytical calculation of error propagation, considering model input uncertainties and model prediction errors; and (2) Monte Carlo simulations. • For quantification method 2, uncertainties related to links with baseline control sites are taken into account. • For AFOLU projects, the number of credits to be assigned to the pooled buffer is calculated by multiplying the non-permanence risk rating with the net carbon removals (not the emission reductions). • The VCS AFOLU Non-Permanence Risk Tool helps estimating the risk of non-permanence. • A deduction must be applied to account for carbon leakage (e.g. due to N_2O emissions) and other uncertainties (calculated using specific formulae).	• Project proponents must use a precision of 20% of the mean at the 90% confidence level as the criteria for accuracy. • Uncertainties of input data should be known from estimates based on statistical sampling or measurements, or from published values or IPCC guidelines. • An uncertainty deduction must be applied if compliance with the 20% at 90% confidence level cannot be obtained: - 20% to 30% uncertainty: 50% deduction. - 30% to 40% uncertainty: 75% deduction. - 40% to 50% uncertainty: 100% deduction. • The uncertainty deductions shall always be used in the most conservative way.

A common pattern is that most schemes require a risk analysis and hence a risk mitigation plan, in which the project developers should explain how they will handle risks in practice. Commonly used ways of handling risks include **buffer accounts** (i.e. a certain percentage of the carbon credits/certificates (e.g. 20%) is only released after a certain amount of time (e.g. 10 years) in order to account for the event of non-permanence – these credits/certificates cannot be sold during this period), **strict eligibility criteria** (e.g. all parcels of land have to be included to be eligible to enter the carbon farming scheme), **long-term contracts** (e.g. contracts of at least 10 years), **offset ratios** (as explained in section 4.2.2.2), additional result-based rewards for long-term retention, stakeholder buy-in, development of other long-term markets, transfer of land to non-commercial ownership, permanent restrictions for future land use. In addition, another commonly used way of handling risks is to have a conservative estimation of the climate mitigation effect.

➢ Risk management through actor involvement

Besides this risk management incorporated in the scheme design, different **actors** active in the voluntary carbon market can work towards **increasing trust** in the project outcomes by reducing uncertainties and managing risk.

For example: (1) **farmers** may work to preserve their best interests by maintaining soil fertility through optimizing the soil carbon management, preventing soil erosion and/or avoiding overgrazing of grasslands, or by anticipating and preparing for weather extremities; (2) for **project developers** the goal can be to have a good reputation for long-term success and to achieve this by providing guidance and consultancy to farmers, or by having and communicating a clear strategic vision (e.g. increasing the area of land under regenerative farming); (3) **carbon brokers** may select reputable projects in order to buy and consequently sell high-quality credits or certificates (managed in a transparent registry), or they may establish their own buffer reserve to provide clients with a steady supply of high-quality credits or certificates; (4) **carbon credit rating agencies** may check for robust schemes, and provide insights to buyers by performing independent audits and providing quality ratings, or may include evaluations of co-benefits; and (5) **buyers** may want to be associated with supporting high-quality projects by reputable actors when communicating their positive contribution to a carbon farming scheme since the reputation of the project developers can reflect on the buyer.

Sometimes actors take on several of these roles simultaneously. For example, an organization such as Soil Capital functions as project developer as well as carbon broker. Specifically, they set up projects with farmers according to their methodology, guide them, and buy carbon certificates from them. These certificates are then sold to buyers, and a certain buffer pool is managed to hedge against loss of permanence and other risks.

Research institutions can increase scientific robustness of carbon farming schemes by putting forward new methodologies and compiling scientific consensus on the impact of carbon farming practices in their region. (Local) **governments** can stimulate open-sourcing of pilot project data, and provide the required data-infrastructure (see section 5.1) to increase transparency and trust in regional carbon farming initiatives. Furthermore, any actor in the VCM can contribute to the development of platforms and lines of communication between the public and private sector to discuss guiding principles and rules, and connect farmers into Communities-of-Practice for the implementation of different carbon farming practices in various circumstances.

4.3. Monitoring, Reporting and Verification

To ensure that carbon farming projects have a real and positive impact on the climate, it is essential to demonstrate this impact. A well-developed and reliable monitoring, reporting and verification (MRV) system is therefore of paramount importance. Here, **monitoring** (section 4.3.2) refers to the measuring and/or modelling of project outcomes, for which different types of emissions and removals are set against the baseline (business-as-usual scenario) at regular time steps. This requires knowledge of the baseline and subsequently measuring and/or modelling of the project outcomes. **Reporting** (section 4.3.3) refers to the process of communicating the monitored results, whereas **verification** (section 4.3.4) consists of the confirmation that the reported results are truthful and accurate. During the verification step, a check is performed on whether or not all rules and requirements of the carbon farming scheme have been respected.

Robust MRV systems thus help to ensure that project outcomes have **environmental integrity**, are correct, **additional**, **measurable** and **permanent**, deal with potential carbon leakage and avoid double counting (McDonald et al., 2021). A good MRV system hence is the basis for the generation of high-quality and comparable carbon credits or certificates (see Appendix 1.A for difference).

4.3.1. MRV approach in carbon farming schemes

As part of the project description, a **monitoring plan** typically is drawn up by the project developers (e.g. a combination of agricultural experts, advisors, NGOs, farmers and/or land managers). This plan details the data and parameters that remain the same throughout the project and the data and parameters that will be collected and monitored throughout the crediting (project) period. The plan mentions how and how often the different parameters will be monitored, and what data will be necessary to do this in a reliable way. Quantification methods, and measurement and modelling procedures are also detailed in the plan. After **validation** of the project description, the monitoring plan forms the basis for the **monitoring reports** that need to be submitted by the project developer to the scheme owner on a regular basis throughout the project (mostly yearly). In these monitoring reports, an overview is given of the generated project outcomes (i.e. the total amount of estimated removals, avoided emissions and emission reductions), based on the different parameters monitored. In case of carbon leakage, the amount of leakage is deducted from the total amount of removals, avoided emissions and emission reductions. After **verification**, the project outcomes result in the issuance of carbon credits or certificates (see Appendix 1.A for difference) (Figure 10). The verification, and often also the project validation, is done by an independent third-party auditor, in international standards often referred to as the **'Validation and Verification Body' (VVB).**

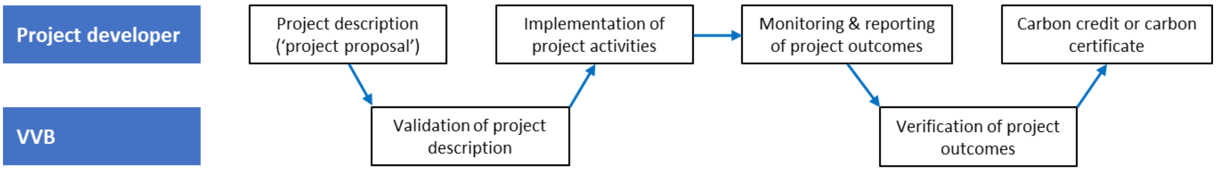

Figure 10: Overview of the different steps to be undertaken by the project developers and the Validation and Verification Body (VVB) to come to verified project outcomes.

4.3.2. Monitoring

4.3.2.1. Establishing the baseline (with focus on SOC)

In order to calculate the climate mitigation effect (carbon removals and/or avoided emissions) of the carbon farming project after x years, we ideally know what the SOC stock would have been after x years under the business as usual scenario (**BAU trend**) (see Figure 1). This can be done by **modelling** the BAU scenario, so that we understand the BAU trend, or this can be done by **measuring or estimating** carbon stocks under the BAU scenario. If a measuring or estimation method is used, different spatial approaches can be used (see below).

In practice, however, the BAU *trend* is not always known, and instead, a **point measurement in time** can serve as a reference. This can be the case when a measure and re-measure quantification approach is applied. Here, the project outcomes are calculated as the difference in carbon stocks between the two measurement moments. It is then assumed that the business as usual is in steady state and stocks would not have changed under BAU, but in practice that is mostly not the case. Therefore, when an increase in soil carbon stocks is measured, it is not sure if this can be solely attributed to the carbon farming practices.

- Different spatial approaches to determine the baseline

Different spatial approaches exist to determine the baseline (i.e. adopting a local project-by-project approach, using certain reference plots or using an average regional trend as baseline). These approaches differ mainly in terms of accuracy and hence in terms of costs.

First, the baseline can be determined specifically for the **project area** (i.e. for the field parcels included in the project boundary), based on in situ measurements and/or local estimates. This project-by-project approach is the most accurate (most specific) but also the most costly and time-consuming approach.

Second, the baseline also can be determined in a so-called '**baseline control site**'. This is a site located outside of the project area, with comparable characteristics in terms of soil texture, topography and climate, and where similar agricultural management practices are implemented as in the business-as-usual scenario of the project area. The baseline control site can be managed by different actors, such as by an individual farmer, the carbon farming scheme / carbon standard managing entity or by a research institute, as long as all activities and outcomes are systematically monitored. The advantage of working with a baseline control site is that it can serve to determine the baseline for multiple project areas at once, whether located nearby or further away. This strongly reduces the costs to determine the baseline.

Third, the baseline can also be determined at the regional level, based on regional statistics or trends (e.g. SOC stocks in mineral soils are decreasing with X kg per ha per year in region Y). Working with such a **regional performance benchmark** is the cheapest and least time-consuming approach, but it also is the least accurate. Despite this drawback, the regional approach provides the opportunity to reward all farmers who do better than the reference situation (provided that guiding principles are taken into account), which may lead to the inclusion of first movers.

However, when applying regional performance benchmarks for SOC in combination with result-based payments[25], where the baseline *trend* is not known, farmers may be overpaid or underpaid with respect to their actual project outcomes (Figure 11). If the regional baseline is below the actual baseline (Figure 11a), farmers will receive a payment that is higher than the payment they would have received based on the actual improvement. In case these farmers know their actual baseline, they may benefit from the **information asymmetry** between them and the scheme designers, as the measured project results would be above the baseline (regional performance benchmark) anyway (i.e. the **adverse selection**). On the contrary, if the regional baseline is above the actual baseline (Figure 11b), farmers will receive a payment that is lower than the payment they would have received based on the actual improvement. For these farmers, working with a regional performance benchmark appears disadvantageous and these farmers may be less inclined to participate in the scheme if they know their actual baseline (McDonald et al., 2021).

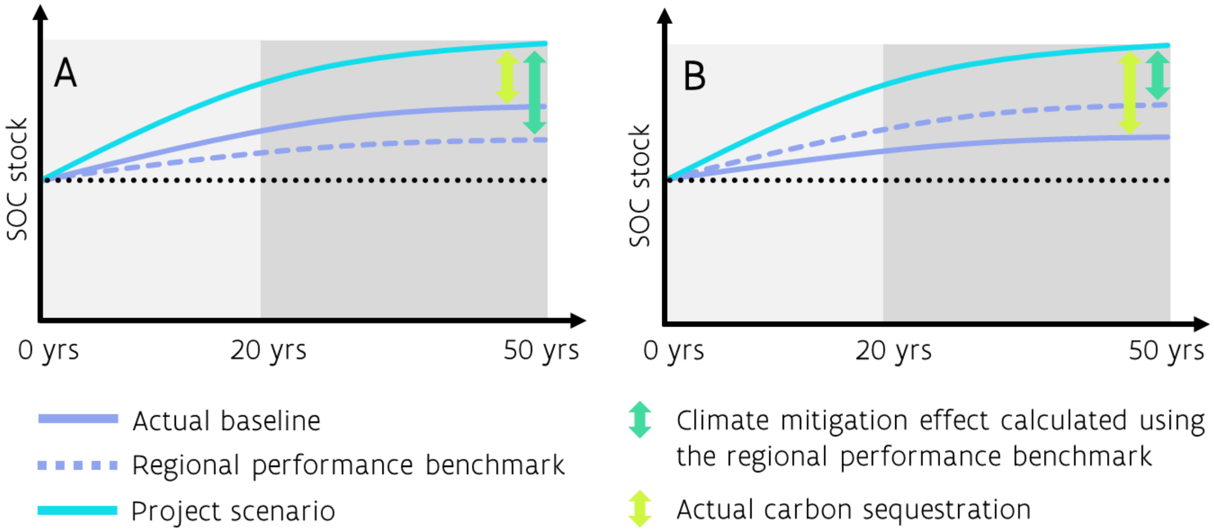

Figure 11 Working with a regional performance benchmark (baseline) leads to a beneficial situation for farmers with an actual baseline above the regional performance benchmark (A), and a disadvantageous situation for farmers with an actual baseline below the regional performance benchmark (B) (adapted from Figure 1).

4.3.2.2. Quantification methods (with focus on SOC)

To monitor and hence quantify the project outcomes, different methods can be applied, ranging from relatively simple to very complicated methods. The choice for the right method highly depends on the **payment type** that will be applied (section 8.1) and cost-accuracy considerations. Considering this, a wide variety of (combinations of) methods exists (**Table 7**). Therefore, we do not provide a comprehensive overview of different options but point out the most common monitoring approaches and our main points of concern.

For **activity-based payments**[26], the data needs depend on how the project outcomes are estimated. This method of estimation depends on the level of accuracy of the available data, and can be done according to the following pathways, with different levels of complexity: (1) using the default

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[25] With result-based payments, farmers receive a payment at the end of the project based on the actual impact of the implemented (combination of) carbon farming practice(s) (section 8.1).

[26] With activity-based payments, farmers receive a payment based on the estimated impact of the implemented (combination of) carbon farming practice(s). The payment is mostly done on a yearly basis (section 8.1).

emission factors[27] (e.g. provided by IPCC; **low-accuracy; Tier 1 approach**), (2) using regional or national emission factors reflecting local pedo-climatic and farm characteristics (**medium-accuracy; Tier 2 approach**), and (3) using model simulations based on locally calibrated and validated models (**high-accuracy; Tier 3 approach**) (Peter et al., 2016; see 1.C for more information on Tier levels). For the Tier 1 and 2 approach, emission factors are typically derived from long-term field experiments, but for Tier 2 these long term field experiments are representative for the area (these long-term field experiments can then also be used as baseline control sites). Emission factors derived from long term field experiments can be relative (SOC/SOC_{BAU}) or can reflect actual annual changes (ton C/ha/yr; ($SOC-SOCb_{BAU}$/years).

When using emission factors (Tier 1 or Tier 2), the monitoring is relatively simple and mainly consists of checking whether the carbon farming activities have been (properly) implemented, in accordance with the project description. This requires linking different data sources (i.e. to collect '**activity data**'), consisting of (1) qualitative information provided by the farmer or land manager via a signed attestation or during a consultation (e.g. information on tillage, organic amendments, fertilizer application, irrigation…) and/or (2) invoices of purchased materials (e.g. seeds) or contract work, (3) geotagged photos (e.g. to prove what type of crops are growing, to prove whether crop residues have been left on the field and non-inversion tillage has been applied), (4) data submitted to the GeoSpatial Aid Application as part of the Integrated Administration and Control System of the CAP (e.g. crop types, see section 4.3.4 for links), and/or (5) time series of remote sensing images. The latter can be used for different purposes, such as checking whether or not farmland has been ploughed or to estimate the approximate sowing date of specific crops (e.g. for cover crops the biomass and thus, the amount of carbon that returns to the soil, is depending on the sowing date and the growing period) (see section 6.1).

When using locally calibrated and validated models for SOC estimates (e.g. RothC), besides activity data (for instance with a **historical review period of three to five years**), other data are also required, such as initial SOC measurements, soil texture (clay content), bulk density and weather or climate data.

For purely **result-based payments**, measurements (e.g. soil samples) are taken at the beginning (baseline) and end of the project (i.e. **measure and re-measure**). To carry out the measurements, locally (or internationally) approved (soil sampling) protocols have to be used. For the sake of model improvements, the measured results could be used to optimize the local calibration and validation of the models.

For **hybrid payment systems**, a combination of activity-based and result-based monitoring methods is applied. Here, activity data (Tier 1 and Tier 2) and other data in case of model-based estimates (Tier 3), as well as measurements at the end of the project duration are used. Unless emission factors are used, the hybrid approach always allows optimization of the models used.

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[27] An emission factor is a coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions (IPCC Glossary, CHAPTER 1 (ipcc.ch))

Table 7 Overview of the required input data for monitoring approaches for activity-based and result-based carbon farming schemes (hybrid schemes adopt a combination of the two approaches)

Required data	Activity-based		Result-based
	Tier 1 / Tier 2	Tier 3	
Activity data	Yes	Yes	No*
Model input data	No	Yes	No*
Initial SOC measurement	No*	Yes	Yes
Final SOC measurement	No	No*	Yes
Monitoring approach	Monitoring of activity data + application of emission factors	Monitoring of activity data + measure and model	Measure and re-measure

* For Tier 1 / Tier 2 approaches, no initial SOC measurements are required in case of actual annual emission factors (expressed as ton C per ha per year). However, for relative emission factors, initial SOC measurements are required or an estimation of SOC of the BAU scenario.

* For Tier 3 approaches, a final SOC measurement is strictly not necessary. However, for local model improvements, it can be interesting to collect these final measurements.

* For result-based schemes, it is not strictly necessary to collect activity data or other model input data. However, for the sake of local model improvements, it can be interesting to collect these data, in order to be linked to the SOC measurements.

The **frequency** of monitoring depends on the type of input data. Whereas management or activity data can easily be monitored on a yearly basis, re-measurements (especially SOC re-measurements) should only be performed after a minimal amount of time (e.g. after five years) as carbon sequestration is a long-term process and there is always an uncertainty associated with soil sample analysis.

International carbon standards, such as VCS and Gold Standard, allow the project developers to decide what monitoring method to apply. They can choose between the 'measure and model' or 'measure and re-measure' quantification methods. Whereas VCS favours the use of the 'measure and model' approach[28], Gold Standard seems to recommend the 'measure and re-measure' way of working, which they consider the most accurate approach. For project developers, data availability, modelling capacity and monitoring costs will play a crucial role in choosing the monitoring method.

Domestic standards and local carbon farming initiatives often specifically determine the monitoring method that project developers should apply. In the LBC Grandes Cultures methodology, the 'measure and model' approach is proposed, whereas in the SNK methodology for Permanent Grasslands, a 'measure and model and re-measure' (hybrid) approach is applied. In Flanders, Soil Capital adopts an activity-based approach, using the Cool Farm Tool. Although no final measurements are required to receive the payment, Soil Capital takes a final measurement for methodology improvement.

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[28] The VCS Methodology for Improved Agricultural Land Management mentions to 'measure and re-measure' "where models are unavailable or have not yet been validated or parameterized for a particular region, crop or practice". This indicates the preference for the use of models.

4.3.3. Reporting

4.3.3.1. Process of reporting

In the context of MRV systems, the least attention is usually paid to the reporting of project outcomes, as it mainly consists of the project developers **communicating the monitoring results to the owners of the carbon farming scheme or standard**, often on a yearly basis. This communication details what has been done and what impact has been generated so far, taking into account all information provided in the project description (e.g. on monitoring methods). The reporting is thus a relatively straightforward process, that does not require new scientific insights. However, it is still an important step in obtaining verified project outcomes.

In the monitoring report, information should be included on the implementation status of the (new and continued) project activities and the possible deviations from the project description. These deviations may relate to project activities as well as to monitoring methods. In both cases, the impact of the deviations should be assessed and described, and it should be explained why these deviations occurred (e.g. due to internal or external factors affecting the project).

In the monitoring report, information on the different parameters monitored should be provided. This can include information on emission reductions, avoided emissions and carbon removals, as well as on potential sources of carbon leakage. If leakage occurs, this should be described in detail, as should be the risk of non-permanence. As a result, an accurate overview of the baseline and project emissions should be attained. Based on this information, the net GHG reductions and removals can be calculated and reported.

Finally, the monitoring approach should be detailed, indicating who performed what type of monitoring tasks and why. On top of that, it should be indicated whether or not the required level of confidence was reached, and potentially what amount of credits / certificates should be attributed to the buffer pool[29].

4.3.3.2. Linking up with a comprehensive registration system

The reporting mostly remains an internal process between the project developers and the owner of the carbon farming scheme or standard. However, if this reporting (and later also the verification) could be linked to a comprehensive registration system, it could play a significant role in **improving the transparency of carbon farming schemes**.

In such a registration system, the expected project outcomes could be detailed from the start, i.e. from the point of validation of the project description (prior to any project outcomes). From then onwards, the **status of the carbon units** could be modified from **'expected'** or **'pending'** to **'verified'** and eventually **'retired'**. Retired carbon units refer to units that have been **'claimed'** and hence are taken off the voluntary carbon market (McKinsey & Company, 2021). Having such information stored in an accessible registration system, could help **avoiding double claims** ('double counting') and **double payments** as unique tracking numbers are assigned to carbon farming projects, which in turn could increase the reliability of the system. The registration system obviously would be most valuable when used by all public and private carbon farming schemes in a certain region or

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[29] A buffer pool, or buffer account, is a potential tool for addressing the risk of permanence loss at the CF project level. A buffer pool is created by withholding payments for a certain percentage of credits / certificates across all projects within one or multiple CF schemes. The specific percentage to set, and the rules on how this buffer pool is used, are a part of the CF scheme design.

country. If more than one private initiative is operating in a certain region, it would be useful for governments to manage the registration system, or at least to be directly involved. This moreover would facilitate **linking up to the LULUCF accounting**.

Managing the registration system clearly would require a long-term commitment and considerable efforts on the part of the responsible organisation. Therefore, it is important to have a reliable entity with sufficient capacity in place to manage the registration system. This either can be done by a governmental actor or a private company. In France, for example, it is the Ministry for Ecological Transition which manages the registration system, as LBC is fully government-led. In the UK, on the other hand, it is S&P Global (a private company) that manages the UK Land Carbon Registry, containing carbon units from the Woodland Carbon Code and Peatland Code.

The costs for managing the registry either can be covered by the government or through participant fees. SNK, for example, covers the registry costs by taking € 0.25 each time a certificate is created or processed, and by receiving a yearly fee of € 500 from the users with an account in the registry (SNK, 2022). Fees for opening user accounts and for the listing or transferring of carbon units also apply for the UK Land Carbon Registry (WCC, 2016).

An example of a well-developed registration system is the **Verra Registry**, which serves multiple purposes. First, project developers (referred to as 'project proponents') can **submit and manage their projects** via their user accounts. They can also **directly report** and upload all necessary project documents via the registry (thus including the monitoring reports). After submitting these documents, the Verra Registry team checks the documents for completeness and subsequently sends them to internal (Verra team) and external reviewers (VVB's). After approval of the documents, the status of the carbon units can be updated. Project developers can get an overview of their projects and the status of the carbon units through their account. Via the registry, project developers can also pay the required fees (e.g. for audit costs etc.) using the Verra billing service. Next to project developers, **account holders** also include traders and brokers who are involved in **buying and selling credits**, and 'end users' who are simply interested in **offsetting** (i.e. 'retiring' carbon credits). Individuals are not eligible to hold an account. Via the Verra Registry, carbon **credits can be transferred** (traded) between account holders. This transfer depends on bilateral agreements between the two parties involved, and does not involve Verra. As much as possible, Verra remains impartial and uninvolved in the market, and only facilitates all administrative aspects.

For many registration systems employed in the VCM, it is unclear what type of technology is underpinning the registration system. From the available information, it seems that most registry managers set up a centrally controlled relational database, that operates either internationally (e.g. the Verra Registry) or within a certain region or country (e.g. the LBC registry), through which different types of manual operations (e.g. transferring or retiring of credits) can be performed.

4.3.4. Verification

Verification refers to the ability of external parties to **check the truthfulness and accuracy** of the monitored and reported project outcomes, which can result in high-quality carbon certificates or credits.. A proper verification ensures that the project is implemented according to its proposed methodology and guiding principles, and that the project outcomes are reported accurately. In the context of MRV design, the verification step thus requires that the monitoring and reporting are done in a coherent and transparent way.

4.3.4.1. Procedure for verification

To verify carbon farming projects and their project outcomes, specific procedures need to be followed. These procedures are mostly detailed in several documents at the '**scheme level**' or the '**standard level**', and then still need to be translated to the specific methodology used. For example, the ISO 14064[30] standard specifies the following procedure for verification: (1) pre-engagement activities – agree with client on certain parameters, such as the level of assurance, criteria and scope; (2) selection of verification team; (3) verification planning including a strategic analysis, risk assessment, identification of the need for site visits, planning of site visits etc.; (4) execution of verification activities; and (5) completion of verification activities including the evaluation of the GHG statement, conclusions and verification report. In this case, the ISO standard thus defines all requirements and steps involved, but it does not go into the specifics that may be required to verify MRV-related steps in a carbon farming scheme in the agricultural sector. It also does not specify how to handle administrative documents on a farm basis or how to handle reports based on remote sensing data. Elaboration on these aspects therefore is required from the carbon farming scheme developers.

Similarly, the requirements for verification outlined in the LBC, SNK, WCC, VCS and GS carbon farming schemes will still need to be **translated to** verification at the **project level** (Table 8).

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[30] This standard consists of 3 parts, each one detailing guiding principles and requirements. ISO14064-1: designing, developing, managing and reporting GHG-inventories at the organization-level. ISO14064-2: determining baselines, monitoring, quantifying and reporting GHG emissions, reductions and removals at the project level. ISO14064-3: Process for verification and/or validation of projects.

Table 8: Examples of verification guidelines at the carbon farming scheme level

Label Bas Carbone	Stichting Nationale Koolstofmarkt	Woodland Carbon Code	Verified Carbon Standard	Gold Standard
• Different types of audits are allowed and can be offered by the methods. • Audit of compulsory documents: these include the examination of invoices, bills or other elements that demonstrate the reality of the work carried out, the measures taken and the effectiveness of the emission reductions. • Additional site visits: applicable if required by the methodology. A visit may include direct measurements, field checks, etc. The relevance of such an additional check should be justified by the method, in the context of the objectives and mitigation levers used. • To guide the audit and ensure a certain uniformity among the different labelled LBC projects, each method has a list with the main elements to be audited.	• There are three options for the level of verification. Projects following the same methodology might be bundled, so verification costs only apply once. • Reasonable assurance: 'everything' needs to be checked and has to be correct. This option provides 95% reliability and is the most expensive (> € 10,000). • **Limited assurance (i.e. the minimal SNK requirement)**: verification with a limited level of certainty. This level is common for Corporate Social Responsibility & Sustainability Reports. Costs are € 5000 to € 10,000. • Report of specific verification: SNK itself determines whether the verification results of the monitoring report provide sufficient certainty for issuing certificates. This option is the least detailed and cheapest (up to € 5000). • To receive annual certificates, the annual verification of project outcomes is required.	• Verification is the periodic evaluation of the project against the requirements of the WCC by a UK Accreditation Service accredited body. • Verification verifies how much carbon sequestration has taken place, as well as ongoing compliance with the UK Forestry Standard. It checks whether statements about predicted or actual carbon sequestration are correct: - In year 5, with a 'limited level of assurance' - From year 15, with 'reasonable assurance' for standard projects, and with 'limited level of assurance' for small projects. • After year 15, self-evaluation is possible under certain conditions.	• Validation & Verification Bodies (VVBs) assess projects against the Program rules and requirements of the applied methodology. • VVBs have 3 main roles: (1) they validate projects, (2) verify GHG emission reductions and removals, (3) assess methodology elements (methodology approval process). • The VCS Validation and Verification Manual details the procedure. It largely follows ISO 14064-3. • The VVB and its client must come to agreement on the objectives, scope, criteria, level of assurance and materiality of the validation or verification assessment. • The procedure includes (1) a pre-validation assessment, (2) key validation and verification requirements, (3) key elements of the verification and validation process.	• Project developers choose an auditor from the list of accredited VVBs, based on the project type and certification pathway. • Validation & Verification Bodies (VVBs) conduct third-party assessments to provide independent confirmation that projects are in line with Gold Standard Requirements. This includes a desk review and a field visit. • After the third-party verification, the GS-associated auditing firm SustainCERT does a performance review (i.e. it checks the documentation and requests clarifications and resolutions of corrective actions where required). • The performance review results in performance certification. SustainCERT certifies adherence to safeguards and stakeholder inclusivity, and climate & sustainable developments achieved.

4.3.4.2. Auditor requirements

Currently, there is a broad (international) consensus that the verification of carbon farming projects should be performed by an **independent third party**, such as an auditing firm or an executive branch of the government (COWI et al., 2020, 2021a). This need was also highlighted during our interviews with stakeholders and policy workshops in Flanders. In this context, auditors should be considered as independent entities who carry out verifications to check the truthfulness of the reported emission reductions and the correct application of the quantification methods to calculate the baseline as well as project emissions.

Being 'independent' implies that the auditing party was not involved in the monitoring and reporting steps, nor directly benefits from the project outcomes (e.g. through involvement with market actors). However, due to cost considerations, some projects deviate from this criterion (see section 4.3.4.4). What entities qualify as an auditor also differs between various carbon farming schemes. A few examples are given in Table 9.

A common element in these examples is the fact that **auditors need to be accredited** and possibly need to comply with a number of additional requirements. The accreditation needs to apply for the region in which the carbon farming scheme operates (i.e. often within the regional or national boundary). Besides the requirement to be accredited to perform audits in the specific sectoral scope of the carbon farming project (e.g. soil carbon sequestration, agroforestry, paludiculture in the agricultural sector), an auditor also needs to have knowledge of the specific methodology, the guidelines and the framework that may apply (e.g. ISO standards, EU framework for the certification of carbon removals…). When planning to scale up the voluntary carbon market, the need for **capacity building** in the form of diverse and competent **auditors** should not be forgotten.

Table 9: Eligibility criteria for third-party auditors in a selection of carbon farming schemes

Label Bas Carbone	Stichting Nationale Koolstofmarkt	Woodland Carbon Code	Verified Carbon Standard	Gold Standard
• The auditor must be competent in the (sectoral) field of the project, accredited for the project area, operate independently of the project, and comply with the below specifications. • The auditor must be accredited for the Technical Reference Center for Air Pollution and Climate Change (CITEPA), Joint Implementation (JI), Clean Development Mechanism (CDM), EU-ETS, Verra, Program for the Endorsement of Forest Certification (PEFC), Forest Stewardship Council (FSC), Label Rouge, Protected Designation of Origin or Protected Geographical Indication (PDO or PGI), organic farming, High Environmental Value label (HVE), Product Conformity Label (CCP); or must be accredited by the French Accreditation Committee (COFRAC). • If the auditor's organisation is not in the above list, his/her competence needs to be demonstrated.	• The auditors must be accredited by the Dutch Accreditation Council. • For verification at the level of 'limited assurance', the auditor must have demonstrated knowledge of: - ISO 14064-2[31] and ISO 14064-3[32]. - SNK, its objectives, methods and procedures. - National climate policy and climate accounting. - European, regional and local policies relevant to assessing additionality of the project. • Additionally, the auditor: - Must have an appeals and complaints procedure (which project parties can use in the event of a disagreement on the verification). - May not have any prejudices or conflict of interest with the project or project developers. - Must perform a SNK trial audit satisfactorily.	• Auditors must be accredited by the UK Accreditation Service. • Currently, Organic Farmers & Growers' and Soil Association are accredited to verify WCC projects.	• VVBs are qualified, independent third parties, accredited to work in a specific sectoral scope by a VCS-recognized accreditation body. • Currently, more than 20 VVBs are approved under the VCS Program.	• VVBs typically are auditing companies with ample experience in GHG validation & verification, and are accredited by an accreditation body under one of the accreditation schemes recognized by Gold Standard. • VVBs needs to complete a VVB exam and attend regular trainings, hosted by SustainCERT.

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[31] Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements

[32] Specification with guidance for the verification and validation of greenhouse gas statements

4.3.4.3. Method certification

Besides the accreditation of auditors, **methodologies** also need to be **approved or certified by** some governing entity. In practice, the methodology approval process for international carbon standards (e.g. VCS or Gold Standard) is done by organizing an internal review, a public consultation round and an external review by a VVB, after which the methodology is approved by the standard. The standard in turn can be certified or endorsed by the International Carbon Reduction & Offset Alliance (ICROA)[33] Accreditation Programme. In the VCM, projects from ICROA-certified carbon farming schemes are recognized to generate **internationally tradeable carbon credits** (see definition of carbon credits in 1.A).

Carbon farming methodologies are also often certified via the International Organization for Standardization (ISO). Specifically, **ISO 14064** for quantifying and reporting GHG emissions is often used (e.g. by locally active project developers Soil Capital or Claire). Alternatively, a local or national government might design and endorse their own custom carbon farming scheme (e.g. Label Bas Carbone, Woodland Carbon Code). At time of writing this report, project outcomes from ISO-accredited or publicly designed and endorsed carbon farming schemes are not recognized to generate internationally tradeable carbon credits in the VCM. Instead, they indicate their project outcomes in terms such as **carbon certificates or carbon units.**

Schemes currently active in Flanders, such as Claire, seem to prefer the ISO 14064 standard, through which a custom-made methodology can be constructed. Reasons to work with the ISO 14064 standard are that (1) the costs of getting ISO 14064-certified are manageable; (2) the ISO 14064 standard is seen as more appropriate versus existing carbon standards with internal auditing schemes (ISO 14064 is the overarching international standard with independent external auditing structures); and (3) there is some hope that ISO 14064 will be accepted in the future to generate carbon credits instead of carbon certificates only. Obtaining any ISO-certification requires an initial audit by an external party. ISO itself does not perform certification activities. To maintain certification over time, yearly surveillance audits need to be done. As for Belgium, auditing firms for ISO 14064 certification are accredited by the Belgian Association for Accreditation (BELAC). Some examples of auditing firms with a BELAC-accreditation for ISO 14064 are Vinçotte, Belgian Quality Association, SGS Belgium and Bureau Veritas.

Designing a complete (and certified) methodology incurs high initial costs, which are often difficult to cover for new carbon farming schemes. These pilot schemes therefore initially focus on pragmatic decisions to get some experimental projects running, while taking the first steps towards developing a methodology that could be certified later on.

4.3.4.4. Cost considerations

Verification is an essential step to generate and sell carbon certificates or credits on the voluntary carbon market. However, verification comes at a cost, which potentially decreases the revenues for the seller. To manage these costs, **varying levels of thoroughness in the verification procedure**

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[33] ICROA is the International Carbon Reduction & Offset Alliance, ICROA representing the interests of service providers in promoting emissions reductions and offsetting to the highest standards of environmental integrity and in support of the Paris Agreement. ICROA provides an Accreditation Programme and supports organisations through advocacy and action-oriented activities aimed at advancing best practice in the Voluntary Carbon Market (VCM). More info: https://www.icroa.org/

can be requested (see section 4.3.4). However, guidelines at the framework or standard level also still need to be translated to the project level. Depending on the specific type of methodology used, this may incur a difference in verification costs. For example, the SNK methodologies for Permanent Grasslands and peatlands (ValutaVoorVeen) require the 'limited assurance' verification level, although in practice this may incur different costs. The Permanent Grassland methodology requires the verification of (1) the project validation; (2) remote sensing data (e.g. time-series of NDVI values); (3) adherence to soil sampling protocols and results (at the start and end of the project). The ValutaVoorVeen[34] methodology, on the other hand, requires verification of (1) the project validation; (2) groundwater table time-series data; (3) when combined with agricultural activities, additional verification requirements include the periodical check of (3a) reports of site visits, or compilations of satellite imagery to check for tillage activities; (3b) project's adherence to plant residue sampling protocol and results.

At first glance, verification costs in the SNK methodology ValutaVoorVeen are likely to be higher than those for Permanent Grasslands. However, in terms of the scheme profitability, the income also needs to be considered (peatland restoration typically involves a significant mitigation potential).

Besides setting a level of thoroughness for the verification and fine-tuning the methodology, some carbon farming schemes allow for deviations on the independence of auditors in order to **reduce costs**: (1) the organization that performs the monitoring is also allowed to perform the audit in MoorFutures projects (COWI et al., 2021b); (2) the validation and verification can be carried out by the same third-party (e.g. MoorFutures, Peatland Code, VCS, Gold Standard); (3) SNK limits the price of project validation (max. € 1500), which is carried out by a SNK-assigned committee of experts; and (4) in the LBC 'Méthode Haies', periodic audits are combined with the provision of advice to the farmers – this requires additional knowledge from the auditors. By having a single actor who performs multiple tasks, the MRV-process becomes more cost-efficient. However, an increased centralization may also enhance the risk on fraudulent practices and reduce the trust from buyers. On the other hand, to maximize the buyer trust and ensure high-quality credits, the CDM requires a separate step for the approval of designated verifiers, for example.

Carbon farming schemes thus should carefully consider the requirements that are associated with the desired manner of selling project outcomes and should **adjust** their **verification strategies** accordingly.

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[34] "ValutavoorVeen" projects result in avoided CO_2 emissions by raising the groundwater level in peatlands and bogs - whether or not they are in agricultural use - by raising the groundwater level. This method can be applied in different situations and with different measures.

5. Geodataplatform

Monitoring, reporting and verification can be a costly and time-consuming process. If we want to enable carbon farming on a larger area (many field parcels), costs and administrative burden should be kept to a minimum. This can (partly) be achieved by making smart use of already available (georeferenced) data and through the automatization of calculations by a geospatial data infrastructure, also called 'geodataplatform' in this report. A geodataplatform can be developed for different purposes. Here, we focus on the development and use of a platform that allows the calculation and simulation of carbon stocks in agricultural parcels.

5.1. Aspects of a geodataplatform for carbon calculations

In order to implement a geospatial data infrastructure to **register, monitor and calculate the effect of carbon farming projects**, a ready-to-use and scientifically validated geodataplatform could be established. Here, we focus on the different aspects necessary to establish such a geodataplatform and describe what is being done to develop this sort of platform in Flanders. It should be noted that we focus on the development of a geodataplatform for which the land manager is the primary user.

To set up a geodataplatform, **four main aspects** are needed. First, an **accessible platform** should be used, through which the land manager can consult information on his/her parcels and decision-making advice on carbon farming practices. Second, the platform should contain **datasets** (from various sources) on all the parameters required. Third, **proper data connections** between the platform and other data sources should be set up. Fourth and last, the platform should implement a module that allows to **simulate the carbon stored** at the parcel, based on the available data and a scientifically validated **calculation model**. Once the geodataplatform is set up, the collected data and carbon simulation module can eventually be connected with public or private carbon farming schemes or to the national GHG inventory.

5.1.1. Accessible platform

Below, we describe some examples of geodataplatforms that are used in the context of carbon farming. Some of these platforms focus only on carbon farming, whereas in other cases, a carbon simulation module is connected to an already existing geodataplatform.

The **Dutch** website Farmmaps.be is a geospatial data infrastructure in which a carbon tool has been implemented. On this website, land managers can consult data of all their parcels. These data are either collected automatically from public databases (e.g. soil type, parcel size and elevation) or uploaded by the user from different resources. On the website, different applications can be activated, of which the **SoilC tool** is one (Lesschen et al. 2020). This tool helps land managers to get insights in the organic carbon stocks of their parcels and can simulate temporal changes based on different land management practices. To calculate the carbon stocks, the user should provide information about the parcels and management practices, such as crop rotation schemes, clay percentage and addition of organic manure. Additionally, the user can define alternative management scenarios, and the tool will model the expected effect on soil organic carbon for the parcel so that the user can identify the best carbon farming strategies.

Another tool to estimate organic carbon stocks at the agricultural parcel level, is the Cool Farm Tool, set up by the **Cool Farm Alliance**, an industry platform helping farmers to reduce their environmental impact (Cool Farm Alliance, 2021). In this tool, the user should add detailed farm data, including information on crop rotations, manure and transport. The Cool Farm Tool is not directly linked to a geospatial data infrastructure and thus is solely based on the data provided by the user. It calculates the GHG emissions based on different farm practices and gives insights in the total amount of emissions at the farm level. The carbon stock changes are visualized in such a way that the impact of specific land management practices on SOC stocks can be identified.

Another example that is not linked to a geospatial infrastructure, but focuses on farm emissions and carbon sequestrations, is the **Carbon Calculator** from the independent Farm Carbon Toolkit. Here, the users can 'create' their own farm by adding farm and parcel details. This includes information on crop rotations, manure input, livestock, used materials and waste information. The tool calculates total emissions from the farm and, additionally, shows a carbon balance, visualising the sources of carbon emissions and sequestration.

In **Flanders**, a geospatial data infrastructure, called **Bodempaspoort** ('Soil Passport'), is currently being developed. On this platform, the land managers can login via a secured governmental identification system (ItsMe), and visualize data of their own parcels and other parcels they have access to. The Bodempaspoort is developed to bring soil and soil-related (e.g. crop relevant) data of agricultural field parcels together (such as data on nutrients, soil type, crop rotation and erosion class) in one accessible tool. By bringing these data together, the Bodempaspoort aims to inform farmers about (the evolution of) different soil and soil-related parameters on their parcels, in order to help them to reach healthy soil conditions. Additionally, the Bodempaspoort will integrate newly developed digital decision support tools, such as the **Koolstoftool** ('Carbon Tool') which is currently being developed within the LIFE CarbonCounts project. In this tool, the carbon stocks of the parcel are simulated over time, based on the current farm practices, and graphically represented for the user. The user also will be able to create project scenarios and compare the expected carbon stock changes on their parcels. The end goal is for farmers to be able to identify the best practices for their parcels to increase the carbon stocks in mineral soils, agroforestry systems and woody landscape features.

5.1.2. Data

To be able to calculate the carbon storage in field parcels under business-as-usual and potential project scenarios, it is key to work with correct data. These can be provided by the user who fills in all the necessary information him/herself, or by linking the system with already existing trusted (validated) data sources. The latter will ensure data correctness and decrease the efforts from the user and hence also decrease the administrative burden. It is, however, important that the data sources are checked for accuracy before implementing the data connection. Additionally, the user should be informed about the origin of the data and privacy of certain data needs to be ensured. When the user can fill in all, or additional data, he/she should be informed in general terms of how the data provided will affect the result.

In Flanders the data in the Bodempaspoort, will be retrieved from different sources, such as **governmental data**, **public data** and **farmer-owned data**.

5.1.2.1. Governmental data

Examples of available governmental data at the agricultural field parcel level are data on crops and cover crops grown, yearly registered by farmers in the Geospatial Aid Application (GSAA;

Verzamelaanvraag) and the size and shape of field parcels yearly registered in the Land Parcel Identification System (LPIS; Landbouwpercelen identificatiesysteem).

5.1.2.2. Public data

Several soil and crop characteristics are publicly available at (governmental) organizations. By using geotagged data and LPIS, average values of the field parcels can be retrieved from the publicly available sources. In Flanders, publicly available spatial soil-related data and maps are collected and stored by 'Databank Ondergrond Vlaanderen' ('Database (Sub)soil Flanders'), such as soil maps with information on the soil texture.

Another public data source that can be used, are satellite and aerial images that are freely available (section 6.1). An example here is the use of the Normalized Difference Vegetation Index (NDVI) derived from Sentinel satellite images to fit growth curves of crops on specific parcels and to identify the crops cultivated on a certain parcel, or to compare crop growth on neighbouring parcels. In Flanders, this information is freely available on geopunt.be. On top of that, a geodataplatform can develop tools to analyse the available data into useful information. Within the Bodempaspoort, for example, aerial images are analysed using Artificial Intelligence (AI) systems to detect woody landscape features on agricultural parcels. This information can be used to calculate the stored carbon for each parcel, including the carbon stored by woody landscape features.

5.1.2.3. Farmer-owned data

Besides the data described above, the farmer can opt to add data that are not publicly available, such as data from soil analyses and organic amendments applied on their parcels. Important here is to implement appropriate privacy regulations, to ensure correct handling of the data shared by the farmer within the tool.

5.1.3. Data connections

Once the necessary data have been identified, it is key to retrieve all the data together in a single platform where they can be consulted and visualized. As for any step in this process, it is crucial to ensure privacy for the farmers and their privately owned data.

In the Bodempaspoort developed in Flanders, the data connection with the databases containing results of soil lab analyses, will only be created if the owner (land manager) gives consent to use the data. This will be done using a platform to share private data among several players, i.e. DJustConnect, developed by ILVO. For the Bodempaspoort, DJustConnect connections will be set up to link the data from soil sample analyses with the Bodempaspoort. Additionally, the Bodempaspoort and thus the Koolstoftool are directly linked with the GSAA application of the Flemish Department for Agriculture and Fisheries, allowing a direct transfer of information on crop rotations from the GSAA to the Koolstoftool.

In the Dutch platform Farmmaps, the user can link his/her account to already existing accounts of other consultancy tools. An example is a connection with Dacom, a farm management system. By setting up this connection, all information stored in the Dacom account, such as cropping schemes and use of fertilizers and manure, will be directly downloaded to the Farmmaps account.

To enable simulation of temporal changes in carbon stocks it also necessary to use climatological data. For example, climate is an important factor in the turnover of soil organic carbon. The geodataplatform could connect with meteorological stations or soil moisture sensors present on or near the parcel of interest.

The crop yield also influences the organic carbon stocks on the parcel. To track this, for example, satellite images can be analysed and connected with vegetation growth models to estimate crop yields. If the image analyses are directly implemented into the geodataplatform, the results can be directly used and shared through the platform.

5.1.4. Calculation tool

Once the required information has been collected at the parcel level, it can be used to simulate future carbon stocks, and thus to identify possible changes between the business-as-usual and project scenarios. To ensure the quality of the results, the calculation model used should be scientifically validated and regularly updated considering new scientific insights when needed. For Flanders, we aim to develop an open-source calculation model, which creates the advantage that both public or private carbon farming schemes can consult and use the same model.

One of the most widely used carbon calculation models is the **RothC model** (Coleman and Jenkinson, 2014), which was originally developed to simulate temporal changes in SOC stocks. This model has often been used in (international) research initiatives, such as in the EJP Soil project CarboSeq and to develop the FarmMaps Soil-C tool (Lesschen et al., 2020).

Furthermore, the Koolstoftool (see above) is based on RothC. First, the RothC model was adapted for the Belgian situation within the development of the Koolstofsimulator (UGent and BDB, 2011), which was then further refined in the Demetertool (https://www.vlm.be/nl/projecten/Europeseprojecten/Demeter/Demetertool), before being applied to the Koolstoftool.

The CARAT-tool (Vanneste et al., 2022; unpublished) is also based on the RothC model for SOC simulations in agroforestry systems. It employs a tree-species specific leaf litter degradation model as input for the RothC model, enabling a calculation of the effect leaf litter has on SOC within the agroforestry system. The integration of various calculation tools under development is a work in progress.

The RothC model makes use of climate data and of parcel data, including information on soil characteristics, crop rotations and manure applications. Although the model can simulate most crop rotations and management practices in Flanders, further improvements will continuously be needed. For example, the model currently cannot simulate non-inversion tillage practices, crop mixtures or soil amendments such as woodchips. Besides that, further research will be needed to obtain data on carbon inputs and carbon stability from new crops.

In order to build full trust in the calculation models, it is important to increase the level of transparency by documenting the models, the used input data and the model performance.

5.2. Application of a geodataplatform in carbon farming schemes

Once a geodataplatform is established, it can be used in carbon farming schemes, by different users or organizations in different ways.

5.2.1. Geodataplatform as a tool for farmers

A geodataplatform with the characteristics discussed above can deliver insights that can help farmers in improving their soil and crop management. Moreover, an easily accessible geodataplatform may help farmers to shift towards a more data-driven approach, and allow them to determine whether joining a carbon payment programme is feasible/rewarding.

5.2.2. Using the calculation model

While the geodataplatform itself will be accessible for farmers via the Bodempaspoort, the calculation model optimised to be used in the platform can play a role in carbon farming schemes on its own. If the model code is open source, other organisations can use the same model to calculate soil organic carbon stocks. This can result in a more harmonized voluntary carbon market. Additionally, alternative carbon farming schemes can use the developed code. Using this open-source and scientifically validated model, ensures that calculations of sequestered carbon are transparent, improving the credibility of the carbon farming schemes, both for farmers, credit buyers and governmental organisations.

For example, the model behind the Flemish Koolstoftool, will also be used by another tool that is currently being developed within the Klimrek project, which is a collaboration between ILVO, Boerenbond (Belgian Farmers Union) and VITO (Flemish Institute for Technological Research). Klimrek develops a tool, the Klimaatscan ('Climate Scan'), that calculates the climate impact of agricultural activities, at the level of the farm. The purpose of the Klimaatscan is that a trained consultant can use the results of the climate scan to suggest measures tailored to the context of the farm, to increase its ecological and economical sustainability. For the calculation of the effect of management practices on soil organic carbon, the calculation model of the Koolstoftool will be used, but in this case using detailed farm-specific data that are collected via the Klimaatscan.

6. Scientific insights and emerging technologies

The different components of carbon farming schemes are not static. As shown in Figure 5 (section 2.2), new scientific insights and emerging technologies flow into carbon farming schemes directly, or indirectly. In this section, we highlight some emerging technologies that are expected to impact carbon farming scheme design and functioning in the next few years, and those which have the potential to enable the application of carbon farming schemes on larger areas reducing costs and administrative burden.

6.1. Remote Sensing

In the context of carbon farming schemes, remotely sensed data can assist the **monitoring process** and facilitate the **verification step**. The reason why remote sensing is increasingly being used for such purposes, is that it allows monitoring **large areas** at once, in a non-invasive way, and from an objective point of view (e.g. scientifically proven thresholds can be applied to support conclusions). Especially in areas that are difficult to access, remote sensing proves to be a great asset, but also in easily accessible areas, it can strongly increase the **time efficiency** of the monitoring process, for example, by limiting the number of field visits required. Even when parcels of agricultural land are scattered throughout the landscape, they can easily be monitored. Additionally, when considering a large number of parcels, imagery captured using remote sensing approaches – whether or not combined with other spatially-explicit data – may also be used to determine the **spatial biophysical heterogeneity** within the project area and even within parcels. Based on this information, additional (field-based) data could be requested for specific parcels. On top of that, time-series of remotely sensed data allow to **monitor changes** in agricultural fields over time, which helps to take into account natural fluctuations in certain parameters (e.g. crop growth). Although remote sensing data with the highest spatial resolutions are mostly not free of charge (and often even quite expensive), **open source data** increasingly prove to be valuable. Compared to Landsat 8/9 images[35], the European Union's Copernicus Sentinel-2 data have a much improved spatial resolution (i.e. a resolution of 10 m x 10 m instead of 30 m x 30 m) and temporal resolution (i.e. a revisiting time of 5 days instead of 16 days), which is very promising.

For monitoring and verification processes, remote sensing data can be used to identify sowing and harvesting dates and hence to **determine growing periods of crops**, which is very relevant information, as crops need to develop properly to have a significant and positive impact on carbon inputs to soils and thus on SOC. This is possible by calculating vegetation indices, such as the Normalized Difference Vegetation Index (NDVI)[36] at different moments in the season, which allows to spatially detect active vegetation when applying a certain threshold (often NDVI > 0.3) (Tucker, 1979). Thus, NDVI data and data from other vegetation indices can be used to verify whether certain crops (e.g. cover crops) have been sown and how they develop. They also can be used to check for **year-round vegetation coverage**. In the case of permanent grasslands, a sudden large drop in NDVI values, for instance, could indicate tillage activities and therefore a breach of the agreements made. Besides that, remote sensing images also can be used to detect and monitor **woody**

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[35] The NASA/USGS Landsat Program provides the longest continuous space-based record of the Earth's surface. The first Landsat satellite was launched in 1972.

[36] The NDVI is calculated as the normalized difference between the near infrared and visible red spectral bands. It allows to distinguish active from inactive vegetation, as green vegetation chlorophyll absorbs red light for photosynthesis and reflects near infrared wave lengths (Tucker, 1979)

landscape elements, which is useful to monitor and verify the set-up of agroforestry systems or planting of hedgerows. However, this application requires a higher spatial resolution than is available from the open source remote sensing data and substantial computational power to analyse images. The analysis could be based on the combination of image processing algorithms (i.e. image segmentation and object-based image analysis techniques (e.g. using eCognition) with machine learning algorithms (e.g. Random Forest). Finally, remote sensing images can also be used to check for non-permanence due to **natural disasters**, such as flooding or burning. For this, the Burned Area Index (Chuvieco et al., 2002) or the Normalized Difference Water Index – in combination with the NDVI – (Tarpanelli, 2022) can be used.

From these examples, it is clear that imagery captured using remote sensing is especially useful to monitor and verify **activity data**, including the (correct) implementation of carbon farming practices. Particularly when combined with additional field evidence (e.g. from geotagged photos) or specific crop growth models, remote sensing technologies hold a large potential to speed up and automate monitoring and verification processes. Another way in which remote sensing data could be useful, is by **incorporating** them **into SOC models** as input data (supplementing data obtained from soil samples), as remotely sensed covariates may help to remove noise and hence to reduce the modelling variability (Schillaci et al., 2017).

However, the use of optical remote sensing also has its **limitations.** For instance, data acquisition by optical remote sensing is limited to only **cloud-free** days. This, can reduce the data availability for the calculation of vegetation indices time series. Although this can be a problem, it probably will not limit the monitoring possibilities due to high temporal resolution of current optical sensors in orbit. For instance, Sentinel-2 images have a recurrence interval of 5 days, while most parameters do not require to be monitored with that level of temporal precision. Another challenge is that certain conditions (e.g. soil moisture levels), may alter spectral signatures locally and lead to difficulties in interpreting the results of certain spectral indices. Additionally, the spectral signatures from the soil may **interfere with atmospheric absorptions** (even after atmospheric corrections), or may be unclear due to **mixed pixels**, containing more than one land use (e.g. pixels at the edge of the field can include cropland as well as hedgerows or trees). Also, in order to link up field data with remote sensing data, the latter need to be perfectly georeferenced, requiring thorough **geometric corrections** (Angelopoulou et al., 2019).

Remote sensing is a rapidly evolving field that receives much scientific attention worldwide and it is expected that the range of applications in the context of carbon farming will continue to expand, most likely with an increasing level of accuracy. One of the applications currently being investigated, is the possibility to **predict SOC levels in agricultural fields** using remote sensing data (i.e. based on **soil reflectance spectroscopy**[37]). Although some studies manage to obtain reasonable results for estimating SOC levels in the topsoil – including with the freely available Sentinel-2 satellite images (e.g. Gholizadeh et al., 2018, Castaldi et al., 2019), it is challenging **to monitor SOC changes** over time, as high levels of uncertainty remain. Especially in fields with low SOC levels, predictions from remote sensing images are not yet the most accurate. As the fields of remote

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[37] The SOC content impacts the top soil's spectral reflectance as (1) soil organic matter and SOC typically absorb the Visible Near Infrared and Shortwave Infrared (VNIR & SWIR) portions of the electromagnetic spectrum (England & Viscarra Rossel, 2018) – resulting in high correlations with Sentinel-2 bands B4, B5, B11 and B12 (Gholizadeh et al., 2018); and (2) soils with higher SOC contents appear to be darker in the visible spectrum (Angelopoulou et al., 2019). Therefore, it is interesting to combine the visible and NIR ranges in measuring instruments, as they provide complementary information (England & Viscarra Rossel, 2018).

sensing, machine learning and advanced regression analytics will further evolve, it may become possible to monitor SOC changes in the future, even though interference with factors such as the presence of vegetation (residues), soil moisture[38] and terrain roughness may continue to complicate the matter. The arrival of the German hyperspectral Environmental Mapping and Analysis Program (**EnMAP**), Hyperspectral Precursor of the Application Mission (PRISMA), and Copernicus Hyperspectral imaging Mission for the environment (CHIME) are promising in this regard, as it will lead to unprecedented data streams of high temporal (4 days recurrence interval) and spectral resolutions, especially across the VNIR-SWIR spectral range (Angelopoulou et al., 2019).

Besides spaceborne remote sensing images, airborne remote sensing images and low altitude remote sensing platforms (e.g. from **drones**) may also be used in the monitoring and verification process, although this probably would increase the costs in comparison to orbital imagery rather than decrease them.

6.2. Proximal Sensing

Next to sensors attached to satellites or drones, sensors that are in close proximity to the field (at max. 2 m distance), can also be used to predict SOC levels based on the principles of soil reflectance spectroscopy, which are described in the footnote on the previous page (Angelopoulou et al., 2020). These sensors can either be mounted on agricultural vehicles or can be incorporated into hand-held devices. This is referred to as **proximal sensing spectroscopy**.

Visible-Near Infrared and Shortwave Infrared (**VNIR-SWIR) spectroscopy** appears to be the most suitable proximal sensing method for estimating SOC content (England & Viscarra Rossel, 2018). Although several studies managed to obtain good predictions, laboratory spectroscopy often still performs better, as it is not influenced by the soil-to-sensor distance and angle, gravels or straws, vegetation, and changes in the illumination conditions (Angelopoulou et al., 2020). With proximal sensing spectroscopy, results are especially less satisfactory when there is little in-field variation in SOC and when field conditions are sub-optimal to measure the spectral reflectance (e.g. when soils are moist) (England & Viscarra Rossel, 2018).

Just like remote sensing-based spectroscopy, the potential of VNIR-SWIR spectroscopy to predict SOC content strongly depends on the type of multivariate calibration techniques used (Angelopoulou et al., 2020). In general, machine learning algorithms seem to outperform the frequently used linear approaches (e.g. Partial Least Squares Regression) due to the existence of non-linear relationships between spectra and soil variables (i.e, SOC) (Gholizadeh et al., 2013).

Similar to remote sensing-based spectroscopy, the field of proximal sensing spectroscopy is rapidly evolving and it is anticipated that new developments will result in accuracy improvements. It is also a promising alternative for conventional soil sample analyses as well as for laboratory soil spectroscopy (which requires sieving, grinding and drying), because it has the potential to be **cheaper** (although most accurate portable VNIR-SWIR spectrometers are still quite expensive; England & Viscarra Rossel, 2018) and many more measurements can be done across space and time. It also has the advantage of being **non-destructive**, which has the benefit that soil samples could be stored in archives for verification purposes, using spectroscopy based on the use of lab instruments (England & Viscarra Rossel, 2018).

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[38] Due to strong water absorptions in the medium-wave infrared (mid-IR), absorptions due to other constituents may be masked or deformed, decreasing the potential for predicting SOC using the mid-IR, even though it has stronger and more distinctive absorptions than the NIR (England & Viscarra Rossel, 2018).

However, soil spectra are sensitive to scanning conditions which profoundly influence measured spectra and derived models. Therefore, there is a **need** for **standardized and procedural guidelines** to ensure robust measurements and accurate reporting and verification, which is particularly important when linking financial incentives to carbon sequestration (England & Viscarra Rossel, 2018; Angelopoulou et al., 2020; Gholizadeh et al., 2021). Additionally, there is a strong need for the development of **spectral libraries** that keep record of spectral data, soil analytical data, and metadata. With these spectral libraries, reliable calibration models can be developed, tailored to the local or regional context, and model validations can be done. Both steps are crucial to improve spectroscopic modeling and hence to build reliable monitoring methods for soil carbon sequestration (England & Viscarra Rossel, 2018). Some also argue that there is a need for **integrated multi-sensor approaches** for estimating SOC stocks, and simultaneously taking bulk density and gravel occurrence into account (England & Viscarra Rossel, 2018). This, for example, is possible using the Soil Condition Analysis System (SCANS), which combines an automated soil core system (including a vis-NIR spectrometer) and statistical analytics across landscapes (Viscarra Rossel et al., 2017).

In addition to VNIR-SWIR spectroscopy, other proximal sensing techniques exist as well. **Laser-Induced Breakdown Spectroscopy** (LIBS), for instance, uses atomic emission spectroscopy. With this technique, a focused laser pulse heats the surface of the soil sample to break the chemical bonds and vaporises them, generating a high-temperature plasma on the surface of the sample. The resulting emission spectrum is then analyzed using a spectrometer. Different LIBS peak intensities can be used to identify different soil elements and their concentrations. LIBS measurements are rapid, and relatively accurate, although they require soil sample preparations and lose accuracy in wet conditions. Another method is based on **Inelastic Neutron Scattering (INS)**, which involves spectroscopy of gamma rays induced by fast and thermal neutrons interacting with the nuclei of soil elements. This allows to study the elemental composition of the soil, and to determine SOC. INS allows to measure to a depth of 30-50 cm and to process large volumes in a short period of time. Sample preparations are not required. Although this technology appears useful, it is not yet sufficiently developed, the equipment is expensive, and there are concerns around the safe use of fast neutron generators in farms (England & Viscarra Rossel, 2018).

The Improved Agricultural Land Management method by VCS is one of the few methods that allows using INS, LIBS, and mid-IR and VNIR-SWIR spectroscopy to predict SOC stocks. However, this is only possible on the condition that there is sufficient evidence for the scientific progress in calibrating and validating measurements, and that uncertainties are well-described.

6.3. Innovative registration and trading systems

To address the issues mentioned in section 4.3.3.2, various companies (e.g. Biodiversity & Ecosystem Futures (USA, °2020), Veritree (USA, °2017) and Nori (USA, °2017)), organisations (Climate Chain Coalition, The European Commission Digital Strategy department, the Cambridge Centre for Carbon Credits) and scientific papers (e.g. Hartmann and Thomas, (2020), Van Wassenaer et al., (2021)) propose the use of **blockchain or distributed ledger technologies** in the VCM.

As arguments in favour of adoption, Van Wassenaer et al., (2021) mention the (1) decentralization and consensus mechanisms to ensure immutability of records; (2) smart contracts[39] to ensure automatic transactions; and (3) redundancy and technical transparency to enable audit trails of permits, certifications and transactions. In addition, Mike Davies, director of Biodiversity & Ecosystem Futures LLC, mentions that it is possible to build a peer-to-peer marketplace on top of a blockchain-based registry, allowing **buyers and sellers** of project outcomes to **interact directly**. When linked, transactions in such a marketplace would automatically update the registry. Interoperability with existing registries could be achieved through an Application Programming Interface (API) with an existing blockchain-infrastructure.

An example of an energy-efficient modular open-source blockchain framework, is 'Hyperledger Fabric', built by the Linux Foundation and commercialised by IBM. Several organisations have already used this framework to build **decentralized marketplaces or MRV-systems**, such as Energy Blockchain Labs and Interwork Alliance. There are also open-source initiatives, such as the Hyperledger Carbon Accounting and Neutrality Working Group.

It should be noted, however, that most of the examples found through simple internet searches have a focus on carbon credits from forestry (REDD+) projects, ETS and energy trading. **Nori** is the only example that we have found of a blockchain-based voluntary carbon offset registry, focusing on certificates generated from carbon sequestration in the agricultural sector. Furthermore, projects differ significantly in how they bring the value of carbon certificates/credits to a blockchain-based platform, such as tokenization of certificates/credits, or using a custom cryptocurrency. A further analysis of this subject is out of scope for this report.

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[39] Defined as a piece of computerized transaction protocol that satisfies contractual conditions such as payment terms, confidentiality or enforcement, reduces exceptions and minimizes the need for trusted intermediaries (Van Wassenaer et al., 2021).

7. The Voluntary Carbon Market (VCM)

7.1. Terminology

The topic of carbon farming, situated in the wider context of Voluntary Carbon Market (VCM), is characterized by a large amount of complex terminology, which is often used in an ambiguous way. To obtain a common understanding and communicate in a clear way, it is of great importance to harmonize the language we use. In the context of this report, we refer to several definitions put forward by the UN-backed Race to Zero Expert Peer Review Group (RtZ EPRG), i.e. **net zero, carbon neutrality, climate positive / carbon negative, offsetting, insetting, compensation, science-based and Paris-aligned** (Appendix 1.A). Besides these definitions, we also use the following definitions adopted in the GHG Protocol[40] (WBCSD & WRI, 2004):

- **Scope 1 direct GHG emissions.** Direct GHG emissions occur from sources that are owned or controlled by the company (or farm), for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment.
- **Scope 2 electricity indirect GHG emissions.** Scope 2 accounts for GHG emissions from the generation of purchased electricity, consumed by the company (or farm). Purchased electricity is defined as electricity that is purchased or brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.
- **Scope 3 other indirect GHG emissions.** Scope 3 is an optional reporting category that accounts for all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Some examples of scope 3 activities at the farm level are extraction and production of purchased materials (e.g. animal feed, additives, seeds…); transportation of purchased fuels; and use of sold products (e.g. crops) and services. Scope 3 emissions of food (processing) companies / companies within the agrifood chain, include the emissions generated from the primary production of agricultural products and thus the emissions of the farms from which they purchase.

In addition to this, we distinguish between **carbon credits** and **carbon certificates** (as defined in Appendix 1.A). Both carbon credits and carbon certificates represent the removal, avoidance or reduction of 1 ton of CO_2-eq, although they **differ in the way they can be used** after purchasing. Carbon credits – mostly issued by an international carbon standard accredited or endorsed by ICROA[41] – allow companies to offset their emissions (take it into account in their carbon accounting) and hence to declare carbon neutrality in case they manage to balance their emissions

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[40] The Greenhouse Gas Protocol Initiative is a multi-stakeholder partnership of businesses, non-governmental organizations (NGOs), governments, and others convened by the World Resources Institute (WRI), a U.S.-based environmental NGO, and the World Business Council for Sustainable Development (WBCSD), a Geneva-based coalition of 170 international companies. Launched in 1998, the Initiative's mission is to develop internationally accepted greenhouse gas (GHG) accounting and reporting standards for business and to promote their broad adoption.

[41] ICROA is the International Carbon Reduction & Offset Alliance, representing the interests of service providers in promoting emissions reductions and offsetting to the highest standards of environmental integrity and in support of the Paris Agreement. ICROA provides an Accreditation Programme and supports organizations through advocacy and action-oriented activities aimed at advancing best practice in the Voluntary Carbon Market (VCM). More info: https://www.icroa.org/

and reductions/removals over time. The term 'credit' indicates the buyer is essentially purchasing an emission allowance. Carbon credits can be traded internationally on the VCM, which is not the case for carbon certificates. The latter are mostly issued in the context of regional initiatives or domestic standards, and should be viewed as a 'contribution' towards reaching climate objectives, rather than as an offsetting instrument (also see the 'Kyoto Protocol to Paris Agreement' paradigm shift, as described in section 3.1.1.1).

This is the case for LBC in France, for example, where companies cannot claim carbon neutrality after financially contributing to LBC projects. Instead, they can only claim to have made a positive contribution. Clear rules on how to communicate on project outcomes are therefore required, highlighting the need for an overarching governance structure and advice on such issues. Internationally, the **debate** on how and when '**offsetting claims**' are allowed is ongoing, which is also why a climate consultancy company such as CO2logic is working towards a new label that could promote positive contributions, besides its existing 'CO_2 Neutral' label.

7.2. State of affairs

7.2.1. Functioning of the VCM

The voluntary carbon market (covering carbon credits as well as carbon certificates) provides financing for climate mitigation projects that are complementary to governments' initiatives to mitigate climate change, or that contribute to them, such as in case of the large-scale Jurisdictional REDD+ Program[42]. In other words, the VCM largely operates **outside of regulated or mandatory carbon pricing instruments**, such as the EU ETS, and creates opportunities for private actors to finance, **on a voluntary basis**, activities that lead to climate mitigation, either in their own country or elsewhere. Contrary to what the name may suggest, there is no single or centralized voluntary carbon market (Climate Focus, 2021).

In the VCM, the supply and demand for **carbon credits** – representing 1 ton of CO_2-eq[43] that has been removed, avoided or reduced – is matched. Whereas the supply of carbon credits mostly originates from the Global South, the demand mainly arises from the Global North. To overcome this geographical mismatch, carbon credits can be **traded across boundaries**, for instance with the support of intermediaries such as carbon brokers, who market the credits to the final users (Climate Focus, 2021). In order to avoid double counting of mitigation outcomes (by the host country and the country of the buyer), with **Article 6 of the Paris Agreement rulebook,** the international community is committed to overcome this issue by making agreements (i.e. **Corresponding Adjustments**) between the host country and the country of the buyer (see section 3.1.1.1). In the VCM, the adoption of Article 6 could lead to the development of 'adjusted' and 'non-

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[42] As embedded in the 2015 Paris Agreement, REDD+ (Reducing Emissions from Deforestation and Forest Degradation) implementation focuses on jurisdictional scales (subnational to national scales) as part of the Nationally Determined Contributions for climate change mitigation. The aim is that subnational governments take leadership in developing jurisdictional approaches to REDD+ through the integration of policies and market-related measures in a holistic way (Wunder et al., 2020). In 2012, VCS, for example, established the **VCS Jurisdictional and Nested REDD+ (JNR) Framework**., as the world's first accounting and verification framework for jurisdictional REDD+ programs and nested programs. The program was designed to catalyze high-impact forest conservation activities that produce important co-benefits for local communities, while also supporting governments in reaching their long-term climate goals (https://verra.org/project/jurisdictional-and-nested-redd-framework/).

[43] The global warming potential of any GHG mostly is converted into the reference GHG potential of CO_2.

adjusted' carbon credits, which do or do not allow the claiming of mitigation outcomes. Major international standards, such as VCS and Gold Standard, are currently investigating the need for such developments (VCS, 2021; Gold Standard, 2021).

In contrast to the geographical mismatch between the supply and demand for carbon credits, the trading of **carbon certificates** is dominantly organized within the boundaries of a certain region or country. This overcomes the complexities linked to the international trade of mitigation outcomes (e.g. double counting), although within countries, there are also no rules on how to transfer mitigation outcomes between different sectors (e.g. under the ESR and LULUCF regulations). Here, several uncertainties remain, which leads to the need for clear rules on the communication and claiming of carbon farming project outcomes.

7.2.2. Evolutions in the VCM (with a focus on carbon credits[44])

International compliance markets still cover more GHG emissions than the VCM (Climate Focus, 2021), although the **VCM** has **grown significantly** since 2017, with traded volumes of carbon offsets (i.e. carbon credits) **hitting records in 2021** (i.e. 239 Mt CO_2-eq from January till August 2021[45]) and market transactions exceeding the value of $1 billion by the end of 2021 (Ecosystem Marketplace, 2021b). Geographically, most of these credits (56%) originated from projects in Asia, 22% from projects in Latin America & Caribbean, 15% from projects in Africa, 6% from North America and less than 1% from projects in Europe and Oceania. According to project types, most credits were from Forestry and Land Use projects (45%), followed by Renewable Energy projects (42%). Projects in **Agriculture** made up **less than 1%** of the total number of credits issued (Donofrio et al., 2021), although these credits are relatively new on the market. Both VCS and Gold Standard – the two largest international standards – only came up with methodologies for agricultural projects by 2020. Therefore, the share of credits from agricultural projects is expected to grow over time.

In addition to the observed market growth, the demand for carbon credits could further increase by a **factor of 15 or more** by **2030** and by a **factor of up to 100** by **2050**. However, although there is a great untapped potential supply of carbon credits, several challenges could prevent this supply from reaching the market as the market is characterized by low liquidity, scarce financing, inadequate risk-management services and limited data availability (McKinsey & Company, 2021). It is also possible that the supply of credits is not sufficient to meet the rapidly growing demand (Climate Focus, 2021). Reasons for purchasing carbon credits vary among buyers, but mostly consist of one or more of the following reasons: (i) contribution to climate goals, (ii) differentiation from competitors, (iii) building of branding recognition, (iv) defining and marketing of climate-friendly or even 'carbon neutral' products (Climate Focus, 2021).

While there are many benefits of the VCM, it is important to note that the VCM nets out emissions and it does not reduce emissions overall. Therefore, it does not provide a solution to climate change on its own and hence it should be seen as a supplementary measure only.

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[44] In this section, we focus on the evolution in the voluntary carbon market linked to carbon credits, as these still make up the largest share of the VCM, and data are more easily accessible than for carbon certificates.

[45] This equals about 3.5 times the GHG emissions in Flanders in 2020 (for 2020 emissions in Flanders, see https://www.vmm.be/klimaat/broeikasgasemissies-per-sector).

8. Carbon farming as a business model

8.1. Payment type

Payments for carbon credits or carbon certificates obtained through (voluntary) carbon farming schemes can take many forms, although in most cases, a payment occurs for the climate mitigation impact (i.e. the amount of CO_2-eq that is reduced, avoided or removed). Payments covering the true implementation cost of carbon farming practices – which are often higher than the amount paid based on the achieved climate mitigation – also occur, though rather in more 'informal' schemes. In these informal schemes, payments-in-kind also occur from time to time (e.g. in the form of a free lease of land or the free use of compost).

Depending on whether emission reductions, avoided emissions and removals are actually measured in the field, payments can be made in three ways (activity-based, result-based or hybrid; see sections 4.3.2.1 and 4.3.2.2).

First, in **activity-based schemes**, payments are made for implementing specific agricultural management practices, based on the assumption that the implementation of these practices will lead to a certain amount of emission reductions and/or removals. This assumption is most often supported by the use of emission factors (Tier 1 or Tier 2) and/or the use of different types of calculation models (Tier 3).

Second, **result-based schemes**, provide payments based on the actual emission reductions and removals. The path to reach these results is less fixed than in activity-based schemes (i.e. the farmer is free to choose how to achieve the envisioned results and does not necessarily need to specify the type of carbon farming practices that will be implemented).

Third, **hybrid schemes** combine elements of activity-based and result-based schemes. Mostly, activity-based payments are made throughout the project (e.g. on a yearly basis), whereas result-based payments may be made at the end of the project, depending on the obtained results.

Each payment type has its own **advantages and challenges** (Table 10). The balance between the cost and accuracy of the MRV system is often the determining factor to choose which payment type to use. Another consideration might be practice-specific, such as applying a large portion of the payment on an activity-basis at the project's start because of high costs in the start-up phase (e.g. for an agroforestry system). Besides that, result-based schemes are currently still in its infancy, while activity-based schemes have the potential for a fast implementation at larger scale (ELO, 2021).

Table 10: Advantages and challenges of activity-based and result-based payments in carbon farming schemes

	Activity-based	Result-based
Advantages	- Low monitoring requirements for Tier 1 and Tier 2 approaches - Guaranteed payments and more informed view on return on investment - Upfront payments (after year 1) may cover implementation costs and financial risks - Simple governance and service infrastructure required for Tier 1 and Tier 2 approaches	- Flexibility to implement different carbon farming practices tailored to the local context - Actual mitigation impact is certain (quantifiable and verifiable) - High credibility, targeted use of relevant funds (clear link between impact and payment)
Challenges	- High monitoring requirements for Tier 3 approaches. - Actual mitigation impact is uncertain, buyers bear the risk of uncertain impact - Strong governance system and service infrastructure required for Tier 3 approaches	- No guaranteed payments (risk of non-delivery), farmers bear the risk of uncertain impact, e.g., due to climate change - No upfront payment (financial barrier) - Costly - Strong advisory support required due to high flexibility to implement carbon farming practices
Sources: McDonald et al. (2021), ELO (2021), COWI et al. (2021), European Commission (2021) and own input		

8.2. Timing of payments

Depending on the *type* of payment, the *timing* of payments for carbon certificates or credits may differ. Whereas activity-based payments are mostly on a yearly basis, result-based payments mostly only occur after a certain number of years (e.g. after 5 years), as carbon sequestration is a long-term process that definitely cannot be reliably measured after 1 year (due to measurement uncertainties). If the carbon farming scheme works with a buffer system to deal with risks, some payments even occur several years after project completion – which leads to long-term financial incentives. In the case of Soil Capital, for example, buffer certificates (i.e. 20% of the total amount of generated certificates) are released (and hence paid) 10 years after the initial generation.

In the examples so far, all payments occur *after* the emission reductions or removals have taken place (e.g. even in case of activity-based payments, payments are done after the estimated amount of carbon has been stored). This is often referred to as **ex-post** certificates or credits. **Ex-ante** certificates or credits, on the other hand, consists of payments that are done *before* any climate benefits have occurred.

Ex-ante payments are often done in afforestation or reforestation projects in the Global South, as these demand high upfront costs that could hinder the development of the projects. Plan-Vivo, an international carbon standard active in the Global South (focusing on community benefits), offers the opportunity to work with ex-ante certificates, for example, on the condition that sufficient evidence is provided that the benefits will be obtained in the future.

8.3. Price

Similar to the EU ETS (a compliance market) – in which 1 ton of CO_2 was priced at € 68 on 17 October 2022 (https://ember-climate.org/data/data-tools/carbon-price-viewer/) – the price of carbon credits or certificates on the voluntary carbon market is **primarily driven by supply and demand**, and thus fluctuates over time. Reaching a market equilibrium is challenging because carbon credits or certificates on the voluntary carbon market are highly heterogeneous as they vary in project category and type, quality, region of origin, co-benefits etc. Volumes of specific types of carbon certificates or credits therefore can be highly dependent on a small number of projects and thus can be very variable over time. This makes their pricing less straightforward and hence difficult to predict. The latter leads to unfavourable conditions for investors who like to get involved in the voluntary carbon market (McKinsey & Company, 2021). Based on information from the Verra registry, for example, tech-based carbon credits were priced at € 2 to € 3 per ton CO_2 in October 2022, whereas credits from AFOLU projects were priced at € 8 to € 9 per ton CO_2 (https://carboncredits.com/carbon-prices-today/). Besides that, also within the AFOLU category, prices differ a lot. Projects in agriculture are sold at a lower price than afforestation or reforestation projects, for instance (Donofrio et al, 2021).

As compared to the relatively **low price** of internationally tradable **carbon credits**, the price on European domestic or local voluntary carbon markets for **carbon certificates** is **high**. This is mainly because of the higher costs for project development, among other reasons due to the relatively small scale of carbon farming projects (Cevallos et al., 2019; JIN Climate and Sustainability, 2022). For instance, LBC certificates are sold at € 20 to € 50 per ton CO_2 with an average price of € 40 per ton CO_2, whereas WCC carbon units are sold at € 6 to € 17 per ton CO_2. In regional initiatives, prices reach even higher values, ranging from at least € 27.5/ton CO_2 (Soil Capital in Belgium/UK/France) to € 52/ton CO_2 (Puro.Earth in Finland), € 60/ton CO_2 (Claire in Belgium) and even € 100/ton CO_2 (Go2Positive in the Netherlands) for projects in the agricultural sector. Sometimes the supply of carbon certificates runs out, which is currently the case for the MoorFutures projects (as of 4/08/2022). Low supply and high demand is likely to drive up prices.

Even though carbon prices in Europe are high, local carbon farming projects and their co-benefits are very tangible, which plays to their advantage and may convince companies to contribute to the decarbonization of their own region. However, in Flanders, for example, the potential for local carbon removals is limited, meaning the local supply is unlikely to ever meet the local demand. Therefore, local contributions are often combined with international offsetting. This also helps to keep the costs manageable.

Whereas low carbon prices may lead to cost-efficient emission reductions, these prices also should be high enough to provide sufficient financial incentives for project developers or for sustainable maintenance of different projects (Gold Standard, 2016).

8.4. Type of business model

In addition to governance systems, guiding principles and MRV systems, carbon farming schemes differ according to the type of business model they apply, and more specifically according to the **type of product, type of funding and source of funding** they comprise (Figure 12).

First, project outcomes can be sold together with the agricultural products for which the carbon farming practices were applied, to different private actors within the agrifood chain (i.e. **insetting**). This may consist of raw material processors paying a **price premium**[46] to farmers for successfully implementing carbon farming practices, which leads to reduced scope 3 emissions for the processor, and hence contributes to an overall more sustainable product – which the processor may communicate about in marketing efforts. Insetting may also be promoted by retailers who want to focus on selling more climate-friendly or possibly even carbon neutral products, for which communication (and marketing) on product labelling may be used. In this way, it is the consumer

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[46] A price premium is an increased price per production unit (e.g. per liter of milk or per kg of meat produced).

who ultimately pays for the generated climate benefits. Alternatively, consumers may also directly pay for the carbon farmed products through short-chain marketing (e.g. via the local farmers' market or the farm shop).

Second, project outcomes achieved via carbon farming are often sold as stand-alone products, as a form of payment for climate mitigation and other ecosystem services (i.e. **offsetting** through carbon credits and **positive contributions** through carbon certificates). For this, both public and private funding sources can be employed. Direct **public funding** mainly consists of subsidies via the CAP, including subsidies via eco-schemes or rural development measures (such as the Flemish Agricultural Investment Fund - VLIF). Besides that, local or regional governments may also be involved in a direct way, e.g. through local subsidy regulations. Public funding is mostly linked to positive contributions, and aims at achieving various policy objectives. **Private funding**, on the other hand, may come from different actors, such as private companies, citizens or carbon brokers, although the latter often do not take ownership of the carbon credits/certificates and only focus on matching supply and demand (Carbonfund, 2020). For private companies, the motivation to buy carbon credits, is mostly related to the voluntary decision to offset the company's remaining emissions, which they cannot reduce themselves. This could be in order to reach their Science Based Targets[47] (SBTs). When buying carbon certificates, the motivation shifts to a 'contribution' mindset, in which the decarbonization of the region is an important driver.

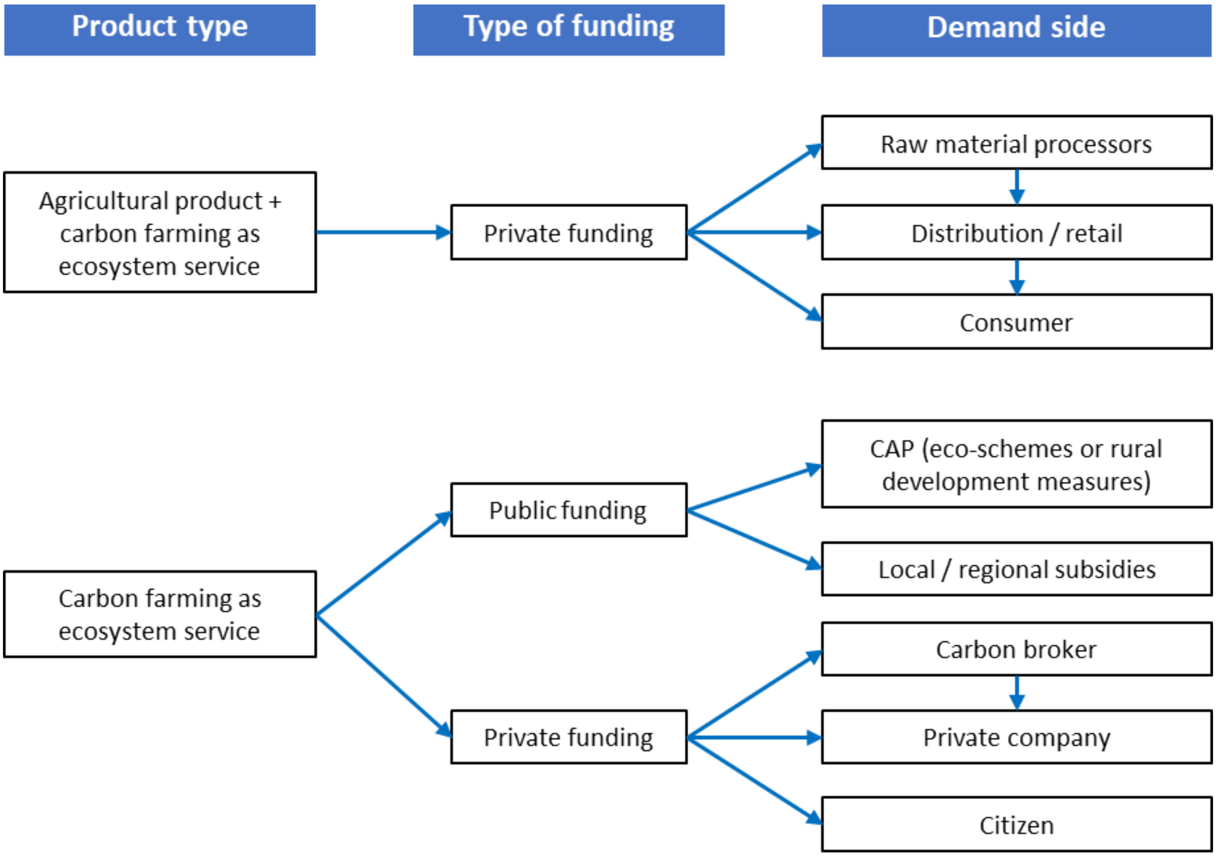

Figure 12: Overview of the different types of business models for carbon farming (Source: Interreg Carbon Farming, 2021 and own insights from different public and private carbon farming schemes)

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[47] SBTs show a clear path to reduce emissions in line with the goals of the Paris Agreement. The targets are based on the latest science, and aim to limit global warming to well-below 2°C, with serious efforts to limit warming to 1.5°C (the goal is net-zero by 2050). If all companies worldwide would commit to the SBTs, global climate goals would be achieved. For more detailed information, see https://sciencebasedtargets.org/.

8.5. Business models in practice

In contrast to other countries such as France and the Netherlands, large-scale carbon farming schemes do not yet exist in Belgium, although several pilot initiatives are emerging and two private carbon farming schemes are implemented already (but not yet on a large scale, by mid-October 2022).

The pilot initiatives are mostly funded by (local) (research) projects and consist of rather informal partnerships between farmers, a research institute and a local organisation, such as a local government, non-governmental organisation, civil society organisation and/or retailer (e.g. Landbouwers Koolstofbouwers, Koolstofboeren, carbon farming in Beernem). These initiatives mainly aim at **gaining experience** in the implementation and actual impact of carbon farming techniques, as well as how to pay farmers for this type of ecosystem service. In practice, a variety of payment types is used, ranging from payments-in-kind (e.g. the free use of a land parcel or the free supply of organic amendments such as compost) to payments for agricultural advisory services, lump sum payments (covering the implementation costs) or activity-based payments. Whereas most of the initiatives are exploratory and focus on the supply side, in some of the initiatives the obtained mitigation effects serve to compensate the emissions from the vehicle fleet of a specific municipality or province, for example.

Besides these pilot initiatives, which may scale up in the long run, two more developed carbon farming schemes exist in Flanders. One of these initiatives is '**Claire**' (https://www.claire-co2.com/) – short for 'Clean Air' – which aims to accelerate the climate transition by matching the supply of and demand for carbon certificates. Claire adopts a hybrid payment system for the involved farmers, combining activity-based payments with a top-up fee if the measured amount of carbon sequestered is higher than expected at the end of the project (at year 6). Farmers currently receive a minimum price of € 60 for each ton CO_2 that they reduce or remove. They are, however, allowed to negotiate this price based on their unique selling point, and depending on the evolution in the VCM, the minimum price also may increase over time. The other carbon farming scheme is '**Soil Capital**' (https://soilcapital.com/), which mainly operates in the Walloon Region, but is now also entering the Flemish region. Besides Belgium, the scheme is also active in the UK and France. Soil Capital adopts activity-based payments for different types of regenerative practices, and pays at least £23 (i.e. ± € 27) per ton CO_2. Depending on the market situation, this price can increase over time. For the development and marketing (selling & trading) of carbon certificates, Soil Capital cooperates with South Pole, a major player in climate strategies and solutions in Europe. Whereas so far, farmers receive 100% of the sales price and no fees need to be paid to Claire, farmers receive a minimum of 70% of the sales price and pay a £980 fee (± € 1150, excl. VAT) on a yearly basis to Soil Capital. The latter implicitly requires a minimum area of ± 50 hectares to benefit from the carbon farming scheme.

8.6. Valorisation of co-benefits

As indicated in section 1.4.2, the implementation of carbon farming practices may generate multiple co-benefits, although very often, these benefits are not (directly) valorised in carbon farming schemes. Some carbon farming schemes even do not at all take co-benefits into account. However, many other schemes do incorporate them and request a premium price for carbon certificates or credits that generate high-quality co-benefits. These co-benefits associated with a certificate are sometimes only based on theoretical assumptions and consequently are only reported to occur.

Alternatively they may be fully verified based on qualitative (or even quantitative) assessments. Co-benefits may be part of the carbon farming scheme itself, or they may be certified by a coupled certification programme.

The Gold Standard, for example, takes co-benefits into account by requiring a contribution to at least three Sustainable Development Goals (SDGs), one of which must be SDG 13 on Climate Action. These contributions must be demonstrated using the SDG impact tool, aiming to quantify the co-benefits in a consistent and comparable way. As Gold Standard tries to more closely mirror the social cost of carbon and the economic value provided in additional impacts, the price of Gold Standard carbon credits varies between projects (from 11 to 47 USD per ton CO_2), depending on the quality, type, size and geographical location of those projects (Gold Standard, 2016).

Verra, on the other hand, allows the valorisation of co-benefits by providing the opportunity for projects to be double certified. The VCS can be combined with the Climate, Community and Biodiversity Standard (CCB) or the W+ Standard for example. Whereas the CCB identifies projects that address climate change, support local communities and smallholders, and conserve biodiversity, the W+ Standard quantifies women's empowerment in different domains. Like the Gold Standard, carbon credits generated by projects with co-benefits may attract higher prices on the market, although these prices also strongly depend on the total quantity of high-quality carbon credits on the VCM (e.g. S&P Global, 2022).

9. Challenges and potential issues

9.1. Narrow focus on carbon

As farmers become involved in carbon farming schemes and are paid for every ton of CO_2-eq that they reduce, avoid or remove, there is a risk that these farmers will develop a narrow focus on carbon and will start '**managing to the metric**', i.e. implement carbon farming practices with the sole purpose of increasing the amount of carbon captured or stored, or GHG emissions reduced, while losing track of the bigger picture.

In the context of agroforestry, for example, it is possible that the rationale would shift towards biomass production and hence carbon storage per se, rather than focusing on stimulating resilience to extreme weather events, improving pest control or generating additional income from the trees. Such narrow focuses would be detrimental as carbon farming provides the opportunity to trigger a **systemic transition** towards a more sustainable type of farming. Therefore, it is important that farmers view carbon farming in a **holistic way** and are well-aware of its full potential. Carbon farming scheme advisors thus have an important role to play to convey their message in a broad way, which moreover could contribute to the wider societal acceptance of carbon farming.

Besides that, it is also important to mention that it is important to maintain the production function of agricultural fields and not to produce crops (biomass) purely for the sake of carbon storage (through incorporation in the soil) or to convert agricultural lands into forests. Both examples would lead to carbon leakage, in the form of market leakage (section 4.2.3.2).

It is also important to recognize that carbon farming *can have* numerous co-benefits, but that it is unwise to assume that these co-benefits automatically occur when implementing any type of carbon farming practice. A monoclonal plantation of poplars, for example, does not have the same positive impact on above-ground biodiversity as planting certain woody landscape elements. Similarly, incorporating biochar in the soil does not have the same stimulating impact on the soil microbial activity as adding organic amendments, such as compost. As each carbon farming practice has its own pros and cons, it is essential to have a good **understanding** of their **impact on carbon and the environment**. This is also crucial in order to optimize advice on what type of carbon farming practices (and combinations thereof) to promote in certain environmental conditions.

9.2. Overestimation of the potential of carbon farming

As indicated above, to understand the full mitigation potential of carbon farming, the combined efforts of emission reductions, avoided emissions and carbon removals should be studied. So far, in Flanders, the main focus has been on the mitigation potential of carbon sequestration in agricultural soils, which appears to be relatively limited (i.e. maximum 18% of the GHG emissions from the agricultural sector – section 1.4.1). This stresses the need not to focus on carbon removals (carbon sequestration) alone, but rather to investigate the broad range of carbon farming possibilities. Farmers who sequester carbon in the soil and generate carbon certificates from this, still need to invest in other climate actions to reduce their own climate footprint in order to reach the various climate objectives for the agricultural sector (Chapter 3).

Carbon farming is often referred to as a ‘new green business model’. However, it is important to note that the revenues from carbon farming are very variable due to the local carbon farming potential (e.g. avoided emissions on peatlands vs. carbon sequestration on mineral soils), local costs (labour costs, input costs, land prices (to rent or buy), etc.) and the difference in prices paid per ton CO_2-eq. In most carbon farming schemes, farmers are not eligible to re-enter the scheme after the first project contract has ended, as the baseline for a new contract would consider the carbon farming practices that were implemented in the first contract, and the new project activities may not be considered additional (as payments cannot be done for what is already done under the (new) business-as-usual scenario).

As the financial incentives thus mostly are situated in the short-term, the revenues from carbon farming should be viewed as a means to counter the potential short-term negative impact of carbon farming (e.g. yield penalties), prior to benefiting from improved soil health in the long-term. In that regard, it makes sense that financial incentives are situated in the short term, and carbon payments therefore should be viewed as facilitators for systemic change.

9.3. Greenwashing (as a barrier)

Voluntary carbon markets are often – rightly or wrongly – associated with greenwashing, as some (multinational) corporations buy carbon credits to offset emissions rather than that they actively reduce their own emissions. This type of offsetting does not contribute to net GHG emission reductions and therefore it should always be avoided. This can be done by adopting an approach similar to that of CO2 logic, for example, where the quantification and subsequent reduction of own emissions is mandatory prior to offsetting. As reductions cannot be realised all at once, it is important for companies to set out a **clear long-term reduction path**. This can be done by committing to the international Science Based Targets initiative, which collectively guides the way to Net Zero, while considering the latest scientific insights. Greenwashing can also be avoided by developing **clear rules on how to communicate about reaching specific climate targets**, such as CO_2 neutrality. In all cases, it should be clear how these targets have been reached (e.g. what is the share of own emission reductions as compared to offsets). Whereas offsetting (within a Net Zero trajectory) can take up a large share of the CO_2 neutral claim at the start of the trajectory, this proportion should drastically decline over time.

Although the risk of greenwashing is a serious and real problem, it also should not be used as an indisputable barrier against the development of carbon farming projects. This would lead to the loss of a huge untapped potential of agronomic solutions for climate mitigation globally, with a potential broader impact on climate adaptation and biodiversity. In the USA, for example, over 200 NGOs have signed a letter against the development of a carbon farming initiative, mainly due to the fear of widespread greenwashing. Also in Europe, different NGOs (e.g. Via Campesina, Greenpeace) oppose the development of a certification framework for carbon removals. Whereas these NGOs raise multiple valid points of concern (e.g. greenwashing from the farmers’ side should also be avoided), it seems that carbon farming schemes and voluntary carbon markets will (continue to) develop anyhow. Therefore, it is important to steer the debate towards a constructive and problem-solving way, and hence to focus on how carbon farming schemes can become as robust and environmentally sound as possible.

9.4. Linking up carbon farming projects to the LULUCF reporting

From a governmental perspective, full valorisation of the efforts made by carbon farmers towards climate objectives, needs incorporating their climate mitigation impact into the LULUCF accounting. However, considering the **current Tier 1 to Tier 2 approach** for this LULUCF accounting (indicating relatively low levels of accuracy (i.e. a coarse spatial approach) for the estimation of GHG emissions and removals), several steps still need to be taken to achieve the desired harmonisation. A first step would be linking up with a comprehensive registration system, to record all verified carbon units produced by public and private carbon farming initiatives, and developing clear guidelines on what type of carbon farming projects to include (e.g. depending on the level of uncertainty). A full-fledged Tier 3 approach would also be needed to overcome double counting due to the potential mismatch of data flows.

As the LULUCF sector might evolve into the AFOLU sector. over time (merging the agricultural sector and the land sector), selling carbon credits from carbon farming could entail a problem for the agricultural sector, as this sector is also entailed to reach its own climate objectives, and the sectoral climate mitigation potential is not limitless. When farmers sell emission reductions and/or removals to companies outside of the agricultural sector, these mitigation outcomes can no longer be attributed to the AFOLU sector. In that respect, it could make sense to promote the trade of carbon credits within the agricultural sector. This problem does not occur with carbon certificates, as it consists of a positive contribution rather than offsetting.

9.5. Risks of a poor carbon farming scheme design

9.5.1. For farmers

Farmers, who deliver the project outcomes, may be prone to multiple – mainly financial – risks related to carbon farming. First, if carbon farming schemes are purely result-based, it is uncertain for the farmer how much revenue he/she might obtain at the end of the project. Although a revenue estimation can be made at the start of the project, many external factors can influence the outcome (e.g. extreme weather events). Although the results may deviate both in the positive and negative direction, the risk of no return on investment is purely borne by the farmer. Second, if the carbon payments are fully subject to market forces, the revenues from carbon farming may be uncertain in the long run, although several carbon farming schemes currently promise a minimum payment per ton CO_2 at the start of the project. Third, when the climate benefits are sold within the agrifood chain (i.e. insetting), this could lead to price premiums for the agricultural products. However, there is a risk for farmers that carbon farming will become the new standard method of production, without compensation for the additional efforts.

9.5.2. For buyers

If carbon farming schemes are properly designed, buyers of carbon certificates are generally not exposed to financial risks. If this is not the case, the main risks for buyers relate to **double funding**, the **funding of inefficient projects** and the **funding of project outcomes that are highly uncertain**. Private companies could fund actions or results that already have been funded by public funding (e.g. from the CAP), whereas they could also fund projects that already have been funded by other private companies if the farmers participate in multiple schemes at the same time. Both types of double funding could be avoided through the development of a transparent and comprehensive registration system, in which all carbon farming initiatives have to participate. On the other hand, the funding of outcomes that are highly uncertain, can be reduced by a simple but critical evaluation of the carbon farming scheme. It could be good to look, for example, at the type of carbon farming practices that are eligible in the scheme. Many existing carbon farming schemes involve the implementation of cover crops and no-till as a practice. However, in Flanders, cover crops hardly can be considered additional and the impact of no-till also is rather uncertain (which is not uniformly the case for other regions). Another way of evaluating the carbon farming schemes, is to look at the way risks (e.g. on non-permanence or carbon leakage) are managed.

Buyers might cooperate with regional governments and intermediaries in the voluntary carbon market (e.g. rating agencies, portfolio managers, project developers) to distinguish high-quality project outcomes from lower-quality ones. Another way to avoid buying 'hot air' is to only invest in result-based schemes, as these schemes have a higher level of certainty to generate real climate benefits (the other side of the medal here, is the risk borne by the farmers).

9.6. Limitations of the principle of additionality

One of the main challenges linked to the principle of additionality, is that the first movers/ early adopters are not eligible to enter carbon farming schemes, as they already have implemented carbon farming practices for multiple years. This may be highly discouraging as farmers who did not take care of their soils in the past will now be paid to implement good practices, whereas those who did, will not be paid at all. This even may lead to unintended negative outcomes. The principle of additionality also hinders that the permanence of project outcomes (e.g. soil organic carbon stocks) can be fully assured in the long run. However, several options exist to overcome these limitations. Examples are working with a regional baseline or adopting a 'common practice' test to determine additionality (e.g. applying a threshold of 20% adoption in a region). Additionally, allowing farmers to re-enter the carbon farming scheme once or twice after the termination of the first project cycle and adopting longer project durations also could be the way to go, as these options provide financial incentives in the long-term.

10. Conclusions

Carbon farming is a broad concept, leading to **confusion regarding definitions**, scope of application and communication on its potential benefits and pitfalls. Our system analysis works towards clarification of the concept of carbon farming, in order to achieve efficient collaboration in upscaling public and private carbon farming initiatives in Flanders. When making decisions concerning carbon farming, a **systems approach** should be employed. Otherwise, one risks decisions that are incompatible with the broader context of carbon farming schemes, which could for example lead to counter-productive legislation (e.g. carbon tunnel-vision), non-cost-effective MRV systems or the spread of non-science-based methodologies (e.g. based on inaccurate estimates of carbon farming practice impacts).

We have proposed **a conceptual framework**, consisting of distinct components, in which to view the upscaling Flemish carbon market. At the heart of the system are **carbon farming schemes** (Chapter 4) which set out the rules and requirements for carbon farming projects. Central to these schemes are the governance system, the guiding principles and the MRV system. **Governance** consists of the institutions, structures, and processes that drive the decision making. By exploring different carbon farming schemes, we have found interesting differences in governance systems, based on the distribution of responsibilities and executive power, decisions on guiding principles, validation of method documents, project validation, management of the registry and fee structure. The **guiding principles** that structure most carbon farming schemes are related to additionality, permanence, carbon leakage and management of uncertainties and risks. By performing our system analysis, we have encountered a broad consensus on some aspects of these guiding principles (e.g. usage of the legal additionality test), as well as significant differences for others (e.g. handling permanence). It is likely that consensus on guiding principles will still need to be orchestrated at the regional level, despite the upcoming **EU regulatory framework for the certification of carbon removals**. Knowing that priorities and interests can differ significantly among stakeholders in the VCM, thorough collaboration between science, policy and practice will be required to attain widely accepted and robust guiding principles in Flanders.

In order to attain comparable and reliable monitoring and reporting of project outcomes with acceptable cost and limited administrative burden in a regional VCM led by various private and/or public actors, a well-thought and efficient **MRV system** that can be adapted to the latest scientific insights and makes optimal use of available data, is essential. In our analysis, we have underlined the importance of considering **monitoring, reporting and verifying as clearly distinct processes**, and explored their role in the broader context of carbon farming schemes. We have found that stakeholders tend to mainly focus on monitoring, which can be problematic, as all three processes are very much interlinked. Specifically, there is a high interdependency between the guiding principles, the MRV system (design and cost) and carbon farming as a business model (profitability). Decisions in either of these components tend to have cascading effects in the others. Finally, we can conclude that **the one perfect MRV system does not exist**. There will always be a need to adapt to regional conditions. Several aspects of MRV systems are specifically a governmental concern, such as decisions on what entities may be eligible to be independent auditors, or the desired flow of data towards a centrally managed, transparent and comprehensive registration system (section 4.3.3.2), which could be linked with the regional to national climate objectives in general, and the LULUCF reporting in particular (Chapter 3). To this end, a **geodataplatform** (Chapter 5) could be employed as a step-up towards a central registry, data hub and platform for hosting specific carbon farming calculation modules. This geodataplatform should be accessible, open source, based on reliable data and robust data-connections.

Carbon farming scheme functioning is subject to existing legislation but can also lead to updated policies or the creation of new **policies** (Chapter 3). Article 6 of the Paris Agreement particularly has important implications for VCM functioning. Specifically, it includes the trade of emission reductions and removals between two countries (Article 6.2), and consists of the **development of a global carbon market**, overseen by a United Nations entity (Article 6.4). In this context, (carbon farming) projects must be approved or 'authorized' by the host country before they can be issued as UN-recognised carbon credit system. This aims to **reduce the risk of double counting**, through the mechanism of **Corresponding Adjustments**. Carbon farming method documents will ultimately need to be adjusted in order to generate 'Article 6 Compliant' or 'Article 6 Authorized' project outcomes. Due to its broad nature, various strategic European and Flemish policy goals have important implications for carbon farming. At the European level, we highlight the long-term strategy for climate neutrality in 2050, the European Green Deal and the upcoming new Common Agricultural policy (2023 – 2027). At the Flemish level, upscaling carbon farming is anchored in the FECP (2021-2030). In order to reach the proposed policy goals, regional experience, validated methodologies, collaboration and infrastructure will be required.

Carbon farming schemes interact with the **voluntary carbon market** (Chapter 7) through development and execution of projects, leading to (validated and verified) project outcomes, which are then traded according to the laws of supply and demand. Market research shows the largest supply originates in the Global South, while demand is mainly located in the Global North. The share of agricultural projects in the VCM currently is very small (1%), but the entire VCM is expected to grow significantly. In our system analysis, we have put forward several definitions and terminology from literature and our own work, to **attain a shared understanding** with our regional stakeholders. In order to retain trust in the growing VCM, we underline the importance of rules regarding **claiming and communicating** about purchased project outcomes.

Structuring the VCM in **business models** (Chapter 8) is essential for successful scaling. Our research focus involved business models for the agricultural context in Flanders. Once again, a systems approach is essential, as payment type, timing of payments and price setting all need to be attuned to the regional costs (such as implementation costs and MRV costs). Good design of a carbon farming business model can decrease the risk of non-permanence, attain a better distribution of risks between farmers and other parties involved in a carbon farming scheme, lower barriers for adoption of practices with high initial costs, etc. Designing a perfect system is rather difficult, indicating the need for an iterative approach. The progression from pilot projects to more formalised projects in Flanders seems to be ongoing. We make an important distinction between **offsetting** and **insetting**, as two separate types of business models, each having their own characteristics and challenges. Many insetting schemes are not transparent in this early phase, prompting a need for further research on this type of business model. All business models we have investigated are oriented towards valorising climate mitigation outcomes. Co-benefits are sometimes 'bundled' in the transaction of project outcomes, often leading to a price premium.

Finally, new **scientific insights and emerging technologies** (Chapter 0) could alter carbon farming scheme functioning and make monitoring more feasible on larger areas or with higher accuracy. Our discussion on remote sensing, proximal sensing and innovative registration and trading systems aims to illustrate the need to think ahead when designing carbon farming schemes and accompanying MRV systems.

10.1. Next steps

This system analysis will function as a knowledge-base for stakeholders in the efforts of upscaling carbon farming in Flanders. The next step consists of using the system analysis report as a reference in drafting a roadmap as part of the LIFE CarbonCounts project. This roadmap will include: (1) practical implications of the required minimal role of the government, (2) defining favourable pathways for upscaling of the Flemish VCM, (3) lists of priorities, (4) possible solutions to challenges and potential issues.

As a final part of the LIFE CarbonCounts project, we aim to streamline the required collaboration between science, policy and practice into a regional action platform for carbon farming, by outlining the governance structure of such a platform and by bringing together relevant stakeholders.

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Appendices

A. Glossary

Carbon certificate	Carbon certificates equal 1 ton CO_2-eq that has been removed, avoided or reduced through the implementation of carbon farming practices, which preferably has been verified by an independent auditor. Carbon certificates do not allow companies to offset their emissions (use it in their carbon accounting) and declare itself carbon neutral. Carbon certificates allow companies to contribute to the decarbonization of their region/country (and make a positive contribution). Carbon certificates can be realized through local, regional or national/domestic carbon farming schemes or initiatives (e.g. Claire, Soil Capital, Label Bas Carbone, Stichting Nationale Koolstofmarkt). Contrary to carbon credits, carbon certificates cannot be traded internationally (own definition).
Carbon credit	Carbon credits equal 1 ton CO_2-eq that has been removed, avoided or reduced through the implementation of carbon farming practices, which preferably has been verified by an independent auditor. Carbon credits allow companies to offset their emissions (use it in their carbon accounting) and declare themselves carbon neutral. Carbon credits are realized through international carbon standards (e.g. Verified Carbon Standard, Gold Standard) endorsed by ICROA = the International Carbon Reduction & Offset Alliance. Contrary to carbon certificates, carbon credits can be traded internationally (own definition).
Carbon unit	The term 'carbon unit' – equal to 1 ton CO_2-eq – is often used by domestic or international carbon standards to indicate the status of project outcomes. Throughout this process, carbon units can have the status 'expected or pending' (after validation of the project plan and the expected project outcomes are estimated), 'verified' (after the verification step) and 'retired' (after the carbon unit has been claimed in the carbon accounting of the buyer) (own definition).
Carbon Farming	Carbon farming focuses on the management of carbon pools, flows and greenhouse gas fluxes at farm level, with the purpose of mitigating climate change. This involves the management of both land and livestock, all pools of carbon in soils, materials and vegetation, plus fluxes of carbon dioxide and methane, as well as nitrous oxide (McDonald et al., 2021).
Carbon farming as a business model	Carbon farming is a new green business model, through which farmers can receive a payment for the implementation of carbon farming practices that lead to carbon removals, avoided emissions and emission reductions. Carbon farming business models can differ with respect to the source of funding (public funding vs. private funding – within or outside the agrifood chain), type of funding (measure-based vs. hybrid vs. result-based), timing of funding, price setting and the way in which the project outcomes can be used for claiming (carbon certificates vs. carbon credits – offsetting vs. insetting vs. positive contributions) (own definition).
Carbon farming project	Carbon farming practice(s) implemented by a land manager (or group of land managers) according to a validated project plan, developed by the project developer(s) using a certain methodology or method document (own definition).
Carbon farming schemes	A carbon farming scheme sets out the rules and requirements for carbon farming projects, enabling the valorisation of implemented carbon farming practices. Central to carbon farming schemes are the governance system, the guiding principles and the MRV-system (own definition).
Carbon neutral(ity)	Referring to the <u>world as a whole</u>, the IPCC defines carbon neutrality as: *"Net zero CO_2 emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period"*. Race to Zero considers <u>individual actors</u> to be carbon neutral when: *"CO_2 emissions attributable to an actor are fully compensated by CO_2 reductions or removals exclusively claimed by the actor, such that the actor's net contribution to global CO_2 emissions is zero, irrespective of the time period or the relative magnitude of emissions and removals involved"*. <u>Remark</u>: These definitions are not the same as the Race to Zero definition does not require 'like for like' balancing: i.e. a source of emissions and a sink of emissions cancelling each other out

	in terms of global warming potential, timescale of effects and durability of carbon storage (Race to Zero, 2021).
Carbon Pool	Reservoirs of carbon that exchange carbon through output and intake, typically consisting of oceans, sedimentary rocks, terrestrial ecosystems and the atmosphere (FAO, 2003).
Climate objectives	The operational targets for climate mitigation and adaptation resulting from all climate change-related legislation, such as the Paris Agreement, EU policy (e.g. long-term strategy for climate-neutrality, Green Deal) and regional policy (own definition).
Climate positive / carbon negative	When an actor's greenhouse gas reductions / carbon removals, internal and external, exceed its emissions and any removals are "like for like" (see definition carbon neutrality). Must be specified over a declared time period, and whether removals and emissions are cumulative or represent only the time period specified (Race to Zero, 2021).
Compensation	Reducing GHG emissions, or increasing GHG removals through activities outside of an actor's emissions inventory, in order to compensate for GHG emissions such that an actor's net contribution to global emissions is reduced. Compensation claims are only valid under a rigorous set of conditions, including that the reductions/removals involved are additional, not over-estimated, and exclusively claimed. <-> This includes offsetting, but also all other activities an actor makes outside its value chain that contribute to net zero (Race to Zero, 2021).
Comprehensive registration system	A registration system serves to record the project outcomes of in their various stages (see definition of carbon units). Having such information stored in an accessible registration system, could help avoiding double claims ('double counting') and double payments, as unique tracking numbers are assigned to carbon farming projects, which in turn could increase the reliability of the system. The registration system obviously would be most valuable when used by all public and private carbon farming schemes in a certain region or country (own definition).
Emission factor	An emission factor is a coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions (IPCC Glossary, CHAPTER 1 (ipcc.ch))
Geodataplatform	A geodataplatform is defined as an accessible geospatial data infrastructure, to which different georeferenced data sources (public and/or private) are linked through automated data connections, based on which carbon simulations for specific carbon farming practices (e.g. agroforestry, arable farming) at specific parcels of land can be done using (open source) calculation models (own definition).
Governance system	Governance consists of the institutions, structures, and processes that drive the decision making within a carbon farming scheme. The purpose of a governance system in the context of carbon farming schemes is to ensure that the scheme functions in an effective, fair and robust manner (own definition).
Guiding principles	The guiding principles that structure ('guide') carbon farming schemes are related to the internationally recognized criteria of additionality, permanence, carbon leakage and management of uncertainties and risks. Formulating these guiding principles requires giving an interpretation and application of these criteria (own definition).
Insetting	Insetting occurs when project outcomes are purchased by agrifood companies (within the value chain), which aim to reduce their scope 3 emissions (see section 7.1). This mostly occurs through the payment of price premiums (a higher price per production unit), rather than through the payment for carbon certificates / credits as such (own definition). Insetting claims are only valid under a rigorous set of conditions, including that the reductions and removals involved are additional, not over-estimated, and exclusively claimed. Further, insetting can only be used to claim net zero status to the extent it is "like for like" (see definition carbon neutrality) with any residual emissions (Race to Zero, 2021).
Method document	Method documents encompass all rules, guiding principles, protocols and MRV processes that should be followed when implementing carbon farming projects. A method document might focus on a single carbon farming practice, or multiple. We specifically refer to those documents

	designed for projects in the agricultural sector. An example of a method document is the Improved Agricultural Land Management method by Indigo and TerraCarbon (own definition).
MRV-system	An MRV-system consists of three distinct, but correlated, processes: **monitoring, reporting and verification.** • **Monitoring:** The process of quantifying the net climate mitigation impact of a carbon farming project. Monitoring consists of all necessary steps (e.g. measurements and modelling) in establishing a baseline or business-as-usual scenario, and comparing an project scenario to this baseline. • **Reporting:** The process of communicating monitoring results between project developers and the owners of a carbon farming scheme, often on a yearly basis. Reporting typically details project progress and generated impact, using data generated during the monitoring process. Reporting can include the flow of data towards a registry. • **Verification:** Verification refers to the ability of external parties to check the truthfulness and accuracy of the monitored and reported project outcomes. A proper verification ensures that the project is implemented according to its proposed methodology and guiding principles, and that the project outcomes are reported accurately. We distinguish two levels of verification (giving rise to two specific processes): o Project verification: project developers need to provide data and documents to prove the veracity of the net climate mitigation impact calculated. o External verification: External verifiers carry out random and/or scheduled checks to ensure that the supporting data and documents provided by the project developers are not biased or fraudulent (e.g. output from Farm Management Systems, bills given as proof for expenses made, etc.) (own definition).
Net Zero	Referring to the world as a whole, the IPCC defines net zero as: When anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period. Race to Zero considers individual actors to have reached a state of net zero when: An actor reduces its emissions following science-based pathways, with any remaining GHG emissions attributable to that actor being fully neutralized by like-for-like removals (e.g. permanent removals for fossil carbon emissions) exclusively claimed by that actor, either within the value chain or through purchase of valid offset credits (Race to Zero, 2021).
Offsetting	Reducing GHG emissions (including through avoided emissions), or increasing GHG removals through activities external to an actor, in order to compensate for GHG emissions, such that an actor's net contribution to global emissions is reduced. Offsetting is typically arranged through a marketplace for carbon credits or other exchange mechanism. Offsetting claims are only valid under a rigorous set of conditions, including that the reductions/removals involved are additional, not over-estimated, and exclusively claimed. Further, offsetting can only be used to claim net zero status to the extent it is "like for like" (see definition carbon neutrality) with any residual emissions (Race to Zero, 2021).
Paris-aligned	Targets are considered 'Paris-aligned' if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement – limiting global warming to well-below 2°C above pre-industrial levels and pursuing efforts to limit warming to 1.5°C, with no or low overshoot. Specifically, Paris-aligned mitigation targets are the same as science-based targets (Race to Zero, 2021).
Policies	In our systems approach, we consider policies to encompass laws, regulations or incentives from local and regional governments, and the system of guidelines that underpins decisions on these. Policies originating from other institutions are also considered, consisting of agreed-upon voluntary practices (Race to Zero, 2021).
Project developers	All entities involved with the planning, implementation and reporting of a specific carbon farming project. This always includes the farmer(s) or land manager(s), and possibly further includes advisors, NGOs, consultants, governmental organizations and/or private companies. (own definition)

Project outcomes	Project outcomes are typically calculated by comparing the project emissions to the baseline (i.e. the business-as-usual scenario). For functional purposes in the context of carbon farming projects, we distinguish (1) carbon removals, (2) reduced emissions and (3) avoided emissions (section 1.2.4) (own definition).
Science-based	Targets are considered 'science-based' if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement – limiting global warming to well-below 2°C above pre-industrial levels and pursuing efforts to limit warming to 1.5°C, with no or low overshoot. Science-based mitigation targets are therefore the same as 'Paris-aligned' targets (Race to Zero, 2021).
Scientific insights and emerging technologies	New scientific insights and emerging technologies flow into carbon farming schemes directly or indirectly, depending on how these insights interact with the concept of carbon farming. Innovations in remote sensing, for example, might have a significant impact on the monitoring process in carbon farming schemes (own definition).
Voluntary carbon market : demand side	The demand side of the voluntary carbon market consists of entities (e.g. companies, organisations, (local) governments, etc.) who are interested in financing project outcomes on a voluntary basis (no legal requirement to do so). In the context of the Paris Agreement, this financing should be viewed as a 'contribution' towards climate mitigation and adaptation. How the demand side of the market is defined, is essential for societal acceptance and trust in the market functioning (own definition).
Voluntary carbon market : intermediaries	Intermediaries in the voluntary carbon market serve various functions, between the supply and demand sides, such as facilitating the trade of project outcomes (e.g. marketplace operators), providing information on projects to the demand side (e.g. project rating agencies), or providing services to enhance carbon farming scheme functioning (e.g. carbon farming project portfolio management, carbon financing) or registry services (own definition).
Voluntary carbon market : supply side	*In the context of this project, we only consider suppliers from carbon farming in the agricultural sector.* The suppliers in the voluntary carbon market provide climate mitigation and adaptation outcomes through the implementation of carbon farming projects. These outcomes might be offered to the market as a qualitative result, a number of carbon certificates or carbon credits (representing 1 ton CO_2-eq each), or another form (own definition).

B. Overview of the studied carbon payment programs

	Label Bas Carbone	Stichting Nationale Koolstofmarkt	Verified Carbon Standard	Gold Standard	Soil Capital	Claire
Area of operation	France	Netherlands	Worldwide (> 80 countries)	Worldwide (> 90 countries)	Belgium, France, UK	Belgium
Program development and administration	French Ministry of Ecological Transition	Stichting Nationale Koolstofmarkt*	Verra	Gold Standard (for the Global Goals)*	Soil Capital*	Claire*
Carbon standard or carbon payment program	Label Bas Carbone		Verified Carbon Standard			
Methodologies	E.g. Méthode Grande Cultures, Méthode Haies, Méthode Plantations de Vergers	E.g. Blijvend grasland op minerale gronden, CO_2-vastlegging in de bodem op minerale landbouwgronden	E.g. VM0042 Improved Agricultural Land Management	E.g. Soil Organic Carbon Framework Methodology	(no fully written method documents)	(no fully written method documents)
Registration system	LBC Registry	SNK Registry	Verra Registry	Gold Standard Impact Registry	/	/
Verified Carbon Units	Carbon certificates (non tradable)	Carbon certificates (non tradable)	Carbon Credits: Verified Carbon Units (internationally tradable)	Carbon Credits: Verified Carbon Units (internationally tradable)	Carbon certificates (non tradable)	Carbon certificates (non tradable)

* The organisation that develops and administers the carbon standard or carbon payment program, was created for the sake of that particular carbon standard.

C. IPCC Guidelines for National GHG Inventories: Tier levels

Based on the IPCC document "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories"[48] (p. 32), we refer to the following definitions:

Tier refers to a description of the overall complexity of a methodology and its data requirements. Higher tier methods are generally more complex and data-intensive than lower tier methods. The guidance for each category should contain at least a Tier 1 method, and in many cases there will be a Tier 2 and Tier 3. The general expectation is that Tier 2 and Tier 3 methods will both be consistent with good practice guidance for key sources, although in some cases Tier 3 will be preferred, for example with methane from coal mines where Tier 1 is a global default value, Tier 2 basin specific and Tier 3 mine specific.

Tier 1 approaches are simple methods that can be applied by all countries in all circumstances. Default values for the emission factors and any other parameters needed must be supplied (see below for documentation needed).

Tier 2 methods should in principle follow the same methodological approach as Tier 1, but allow for higher resolution country specific emissions factors and activity data. In some categories, this may not be the case. These methods should better replicate the parameters affecting the emissions. Country specific emission factors are needed and possibly more parameters will also be needed.

Tier 3 methods give flexibility either for country specific methods including modelling or direct measurement approaches, or for a higher level of disaggregation, or both. This is a more complex method, often involving a model. This will replicate many features of nation emissions and require specific parameters for each country.

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[48] https://www.ipcc.ch/site/assets/uploads/2021/09/13_adopted_outline_methodology_report_guideline.pdf

D. Overview of hyperlinks

Flemish Environmental Agency	https://www.vmm.be/klimaat/broeikasgasemissies-per-sector/uitstoot-bkg-sector-evolutie
Bodempaspoort	https://ilvo.vlaanderen.be/en/news/bodempaspoort-als-nieuwe-tool-om-landbouwpercelen-duurzamer-te-managen
verzamelaanvraag	https://lv.vlaanderen.be/nl/bedrijfsvoering/verzamelaanvraag-randvoorwaarden/verzamelaanvraag
Databank Ondergrond Vlaanderen	https://www.dov.vlaanderen.be/
Koolstofsimulator	https://www.vlaanderen.be/publicaties/koolstofsimulator-adviessysteem-voor-het-koolstofbeheer-in-akkergronden
Demetertool	https://www.vlm.be/nl/projecten/Europeseprojecten/Demeter/Demetertool
Carbon Action	https://carbonaction.org/en/front-page/
Baltic Sea Action Group	https://www.bsag.fi/en/
Biodiversity strategy for 2030	https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en
Soil strategy for 2030	https://environment.ec.europa.eu/publications/eu-soil-strategy-2030_en
Paris Agreement	https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
Article 6	https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf
long-term strategy to be climate-neutral by 2050	https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy_en
European Green Deal	https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
Farm to Fork strategy	https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en
Statbel	https://statbel.fgov.be/en/themes/agriculture-fishery/organic-farming
EU Strategy on Adaptation to Climate Change	https://ec.europa.eu/clima/eu-action/adaptation-climate-change/eu-adaptation-strategy_en
European Climate Law	https://ec.europa.eu/clima/eu-action/european-green-deal/european-climate-law_en
Fit for 55	https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
Sustainable Carbon Cycles	https://ec.europa.eu/clima/eu-action/forests-and-agriculture/sustainable-carbon-cycles_en
Flemish Climate Strategy 2050	https://www.vlaanderen.be/publicaties/vlaamse-klimaatstrategie-2050
Flemish Energy and Climate Plan	https://energiesparen.be/vlaams-energie-en-klimaatplan-2021-2030
survey	https://ilvo.vlaanderen.be/uploads/documents/Mededelingen/271_EJPSOIL_WP2.pdf
VCS Program Advisory Group	https://verra.org/vcs-program-advisory-group/
VCS Program Guide	https://verra.org/wp-content/uploads/2022/06/VCS-Program-Guide-v4.2.pdf

VCS Standard	https://verra.org/wp-content/uploads/2022/06/VCS-Standard_v4.3.pdf
VCS Methodology Approval Process	https://verra.org/wp-content/uploads/2022/06/VCS-Methodology-Approval-Process-v4.1.pdf
VCS Registration and Issuance Process	https://verra.org/wp-content/uploads/2022/07/VCS-Registration-and-Issuance-Process-v4.2.pdf
CDM tool	https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v7.0.0.pdf
Soil Organic Carbon Framework	https://globalgoals.goldstandard.org/402-luf-agr-fm-soil-organic-carbon-framework-methodolgy/
Statistiek Vlaanderen	https://www.vlaanderen.be/statistiek-vlaanderen/landbouw-en-visserij/land-en-tuinbouwbedrijven
StatLine	https://opendata.cbs.nl/” \l ”/CBS/nl/dataset/81302ned/table?dl=6B19E
Agreste	https://agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/Pri2105/Primeur%202021-5_Recensement-Agricole-2020.pdf
(SNK	https://nationaleco2markt.nl/sample-page/tarieven-stichting-nationale-koolstofmarkt/
WCC	https://www.woodlandcarboncode.org.uk/images/PDFs/WCC_CarbonUnitRegistry_Fees_July2016.pdf
CITEPA	https://fr.wikipedia.org/wiki/Appellation_d%27origine_protégée
Label Rouge	https://www.labelinfo.be/nl/label/label-rouge
Protected	https://agriculture.ec.europa.eu/farming/geographical-indications-and-quality-schemes/geographical-indications-and-quality-schemes-explained_en
High Environmental Value label (HVE)	https://vignobles-occitanie.fr/en/haute-valeur-environnementale-hve/
CCP	https://europa.eu/youreurope/business/product-requirements/compliance/conformity-assessment/index_en.htm
COFRAC	https://www.cofrac.fr/en/
ISO 14064-2	https://www.iso.org/standard/66454.html
ISO 14064-3	https://www.iso.org/standard/66455.html
Organic Farmers & Growers'	https://ofgorganic.org/about
Soil Association	https://www.soilassociation.org/
ICROA	https://www.icroa.org/
Farmmaps.be	https://www.farmmaps.net/en/
Cool Farm Tool	https://coolfarmtool.org/coolfarmtool/
Farm Carbon Toolkit	https://farmcarbontoolkit.org.uk/
Databank Ondergrond Vlaanderen	https://www.dov.vlaanderen.be/
DJustConnect	https://djustconnect.be/nl
Dacom	https://www.dacom.nl/nl/
CarboSeq	https://ejpsoil.eu/soil-research/carboseq/

Hyperledger Fabric'	https://www.ibm.com/topics/hyperledger
Energy Blockchain Labs	https://www.ibm.com/case-studies/energy-blockchain-labs-inc
Interwork Alliance	https://interwork.org/resources/mrv-framework/
Hyperledger Carbon Accounting and Neutrality Working Group	https://wiki.hyperledger.org/display/CASIG/Carbon+Accounting+and+Certification+WG
VLIF-support	https://clustercollaboration.eu/content/vlif-financial-support-flemish-agricultural-investment-fund
Landbouwers Koolstofbouwers	https://www.bdb.be/nl/onderzoek-en-studies/projecten/landbouwers-koolstofbouwers
Koolstofboeren	https://www.boerennatuur.be/koolstofboeren/
carbon farming in Beernem	https://www.visitbeernem.be/item/carbon-farming-wandelroute
https://www.claire-co2.com/	https://www.claire-co2.com/
https://soilcapital.com/	https://soilcapital.com/
SDG impact tool	https://ec.europa.eu/clima/eu-action/forests-and-agriculture/sustainable-carbon-cycles_en
Climate, Community and Biodiversity Standard (CCB)	https://www.climate-standards.org/ccb-standards/
W+ Standard	https://www.wplus.org/
letter	https://www.foodandwaterwatch.org/wp-content/uploads/2021/04/Oppose-GCSA-2021_Final-2.pdf
CCA_CFIStudyPublicReportChapter4.pdf (climatechangeauthority.gov.au)	https://www.climatechangeauthority.gov.au/sites/default/files/2020-06/CCARRP/CCA_CFIStudyPublicReportChapter4.pdf
FAQ: Deciphering Article 6 of the Paris Agreement - Carbon Market Watch	https://carbonmarketwatch.org/2021/12/10/faq-deciphering-article-6-of-the-paris-agreement/" \l "article-6-intro
Carbon Offset Brokers - Carbonfund.org	https://carbonfund.org/carbon-offset-brokers/
vcmprimer.org	https://vcmprimer.org/
Why does ClimateTrade use blockchain technology? - ClimateTrade.	https://climatetrade.com/why-does-climatetrade-use-blockchain-technology-to-offset-carbon-emissions/
Pre-ecoregelingen | Departement Landbouw & Visserij (vlaanderen.be)	https://lv.vlaanderen.be/nl/subsidies/perceelsgebonden/pre-ecoregelingen
Article 6 and its Glasgow Rulebook: the Basics - Ecosystem Marketplace	https://www.ecosystemmarketplace.com/articles/article-6-and-its-glasgow-rulebook-the-basics/
Voluntary Carbon Markets Top $1 Billion in 2021 with Newly Reported Trades,a Special Ecosystem Marketplace COP26 Bulletin - Ecosystem Marketplace	https://www.ecosystemmarketplace.com/articles/voluntary-carbon-markets-top-1-billion-in-2021-with-newly-reported-trades-special-ecosystem-marketplace-cop26-bulletin/
https://publicaties.vlaanderen.be/view-file/35658	https://publicaties.vlaanderen.be/view-file/35658
CARBON PRICING: What is a carbon credit worth? | The Gold Standard	https://www.goldstandard.org/blog-item/carbon-pricing-what-carbon-credit-worth
Post-COP26 – Reflections on Article 6 Outcomes | The Gold Standard.	https://www.goldstandard.org/blog-item/post-cop26-%E2%80%93-reflections-article-6-outcomes

Output library, Interreg VB North Sea Region Programme.	https://northsearegion.eu/right/output-library/
After COP26: The interplay between Article 6 of the Paris Agreement and the Voluntary Carbon Market Building a better working world (ey.com)	https://www.ey.com/en_pl/law/after-cop26-the-interplay-between-paris-agreement-and-the-voluntary-carbon-market
What does Article 6 mean for the voluntary carbon market? (puro.earth).	https://puro.earth/articles/what-does-article-6-mean-for-the-voluntary-carbon-market-int-730
Race-to-Zero-Lexicon.pdf (unfccc.int)	https://racetozero.unfccc.int/wp-content/uploads/2021/04/Race-to-Zero-Lexicon.pdf
Lack of consensus on premium of popular REDD+ carbon projects grow | S&P Global Commodity Insights (spglobal.com)	https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/051122-lack-of-consensus-on-premium-of-popular-redd-carbon-projects-grow
210701-Methodedocument-blijvend-grasland_vastgesteld.pdf (nationaleco2markt.nl)	https://nationaleco2markt.nl/wp-content/uploads/2021/07/210701-Methodedocument-blijvend-grasland_vastgesteld.pdf
Beleidsadditionaliteit-versie-April-2021.pdf (nationaleco2markt.nl)	https://nationaleco2markt.nl/wp-content/uploads/2021/12/Beleidsadditionaliteit-versie-April-2021.pdf

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