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Policy Coherence of the EU Carbon Removal Certification Framework: Integration of Carbon Farming in Climate and Agricultural Policy

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***Abstract* — Adoption of the "Regulation (EU) 2024/3012 of the European Parliament and of the Council establishing a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products" represents a significant policy shift, introducing a voluntary, harmonised EU certification framework. This study assesses the policy coherence of the CRCF Regulation and related EU regulatory and policy documents, examining how the certification framework for carbon removals, including carbon farming, is integrated into the EU' broader climate and agricultural policy landscape. A qualitative content analysis was conducted on 31 EU documents, which were selected using snowballing sampling approach and nine search terms related to carbon removals, soil emissions and carbon farming. The identified text fragments were coded and grouped into nine thematic groups and qualitatively analysed to assess whether they reflect horizontal and vertical policy coherence or, indicate gaps and ambiguities. The results highlight a high degree of horizontal coherence with key EU documents, including the EU's Land Use, Land Use Change and Forestry Regulation and the Common Agricultural Policy. However, several gaps and ambiguities remain, particularly regarding baseline methodologies, potential overlaps in funding mechanisms, and practical implementation pathways. These findings underscore the need for stronger vertical integration and methodological clarity to ensure that certified activities effectively support EU climate goals.**

Keywords **– Carbon farming; certification framework; CRCF regulation; EU climate policy; SDG 13.**

1. INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) adopted in 1992 and the subsequent Kyoto Protocol in 1997 marked the first international steps to combat climate change [1]–[3]. The Paris Agreement which entered into force in November 2016 and was replaced the Kyoto Protocol sets the goal of keeping the global temperature increase well below 2 °C, aiming for 1.5 °C above pre-industrial levels [4], [5]. These international commitments are complemented by the 17 Sustainable Development Goals (SDGs), adopted through the United Nations "2030 Agenda for Sustainable Development" in 2015 [6]. Among these, SDG 13 calls for urgent action to combat climate change and is closely linked to other

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goals such as life on land (SDG 15), zero hunger (SDG 2), and responsible consumption and production (SDG 12) [6].

Under the Paris Agreement the EU has committed to reduce greenhouse gas (GHG) emissions by 55 % by 2030 compared to 1990 levels [7], [8]. These reductions also apply to the Land Use, Land Use Change and Forestry (LULUCF) sector [1]. The EU's internal commitments on climate neutrality by 2050 are set out in the European Green Deal and made legally binding by the European Climate Law. These objectives are operationalised through the legislative package "Fit for 55 %" [8]–[10]. While it was initially expected that the EU's climate targets could be met through incremental mitigation measures, it is now clear that this will not be sufficient, and large-scale carbon removal will be necessary [9]. One potential pathway is the wider application of carbon farming practices. The importance of the LULUCF sector for carbon sequestration in natural ecosystems has long been recognised: as early as 2004, Lal [11] demonstrated that the conversion of natural ecosystems to agroecosystems can lead to a decline in soil organic carbon (SOC) stocks by up to 60–75 %, while also identifying a range of land management practices with high carbon sequestration potential [11]. Two decades later, carbon sequestration in ecosystems is no longer solely a scientific concern – it is increasingly framed as a strategic policy tool [12].

Despite the well-documented potential of carbon farming [13]–[15], the EU lacked a harmonised framework to quantify and reward the uptake of such practices. This gap is now being addressed by "Regulation (EU) 2024/3012 of the European Parliament and of the Council of 27 November 2024 establishing a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products" (CRCF Regulation) [16]. This development builds on a broader shift in EU climate un agricultural policy, shaped by several strategic initiatives – most notably the European Commission Communication "Sustainable Carbon Cycles" (COM (2021) 800 final) [17]. Earlier policy frameworks, such as the Circular Economy Action Plan (COM (2020) 98 final) [18] and the Farm to Fork Strategy (COM (2020) 381 final) [19], had already emphasised the need to align food supply chains, land use and product design with climate and environmental goals, laying important groundwork for the CRCF Regulation and its integration with the greening of the Common Agricultural Policy (CAP) [9].

The CRCF Regulation is positioned not only as a new green business model for farmers and land managers, but also as a mechanism to support EU Member States (MS) in meeting their emission reduction targets under the revised LULUCF Regulation EU 2018/841 [20]. It requires that carbon removals be quantified using methodologies consistent with the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (IPCC guidelines), which also underpin national GHG inventory reports [21]–[23]. Since certified activities and associated removals will follow the same methodological basis, they may be integrated into MS reporting obligations under the UNFCCC, the Paris Agreement, and Regulation (EU) 2018/1999 on the Governance of the Energy Union [23], [24].

While this study focuses on the application of carbon farming practices under the CRCF Regulation, it is important to note that the CRCF Regulation also encompasses permanent carbon removals and carbon storage in long-lasting products [16], [25]. Technological solutions such as Direct Air Carbon Capture and Storage (DACCS) and Bio-Energy Carbon Capture and Storage (BECCS) are considered vital for the EU's long-term decarbonisation strategy [17], [25]. In parallel, the CRCF Regulation promotes the use of bio-based construction materials, effectively transforming buildings into long-term carbon storage units [25].

The reminder of this paper is structured as follows: Section 2 provides a theoretical overview of carbon farming, focusing on definitional variations and implementation challenges. Section 3 outlines the research methodology, including document selection, search term identification, and application of the qualitative content analysis (QCA). Section 4 presents both quantitative and qualitative findings derived from the QCA, including document characteristics, search term frequency, and a synthesis of findings structured into eight thematic groups. Finally, Section 5 summarises the main insights, discusses regulatory and policy implications in the context of EU climate and agricultural policy, and reflects on implementation challenges at the MS level.

The aim of this study is to evaluate the policy coherence of the newly adopted CRCF Regulation and the certification framework it introduces for carbon removals, including carbon farming. The analysis focuses on both horizontal coherence – the alignment of the CRCF Regulation with other EU climate and agricultural policy instruments, and vertical coherence, referring to the consistency between EU level objectives and potential implementation at the national level. The following research questions were formulated to guide the analysis: (1) How is the CRCF Regulation horizontally integrated with other EU climate and agricultural policy documents, particularly in relation to carbon farming? and (2) What are the main challenges and opportunities for achieving vertical policy coherence when implementing the CRCF Regulation at the national level?

2. THEORETICAL BACKGROUND: CARBON FARMING

In order to understand how carbon farming is operationalised within the CRCF Regulation and related EU regulatory and policy documents, it is essential to examine how the term is defined and conceptualised in different sources. Carbon farming practices are defined in various ways in EU documents, research reports and scientific articles. These definitions range from descriptions of farm-level activities aimed at managing carbon pools, flows, and GHG fluxes, to more conceptual framings that emphasise climate change mitigation and new green business models [26], [27]. Therefore, to understand the activities addressed by the CRCF Regulation, a comparative analysis of carbon farming definitions was conducted (see Table 1). Definitions were drawn from core EU documents published in 2021, including the Communication "Sustainable Carbon Cycles" and the European Parliament ENVI Committee study "Carbon farming – Making agriculture fit for 2030", as well as from the proposal and final version of the CRCF Regulation. These policy-based definitions were complemented by three peer-reviewed scientific publications selected for their conceptual relevance and academic visibility.

When comparing the definitions based on the GHGs they cover, it becomes evident that most regulatory and policy documents, as well as the Carbon Cycle Institute [30], focus primarily on CO_2 emissions, referring to their removal, reduction or storage. Only one definition, provided by McDonald *et al*. [29] (a), explicitly includes all three major GHGs (CO_2, CH_4, N_2O). Panchasara *et al*. [32] refer more generally to GHG emissions without specifying individual gases, suggesting a broader but less clearly defined scope. In terms of content, the definitions vary in scope, ranging from general to specific, and differ in the mechanisms they emphasise. Some definitions include a combination of carbon removal, emission reductions and carbon storage, while others refer only to one or two of these. As shown in Table 1, several definitions (e.g., McDonald *et al*. [29] (b), Cavallin [21]) do not specify which part of the carbon cycle they target. Instead, they frame carbon farming as a business model rather than a set of quantifiable climate actions. It is also notable that the definitions differ in terms of their focus.

TABLE 1. COMPARATIVE OVERVIEW OF CARBON FARMING DEFINITIONS IN POLICY AND SCIENTIFIC SOURCES

Source	**Definitions of carbon farming**	**GHGs covered**	**Emission reduction**	**Carbon removal**	**Carbon storage**	**Business model**	**Environment***
Communication *"Sustainable Carbon Cycles"* [17]	"a green business model that rewards land managers for taking up improved land management practices, resulting in the increase of carbon sequestration in living biomass, dead organic matter and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere, in respect of ecological principles favourable to biodiversity and the natural capital overall"	CO_2	X	X	–	X	T
Proposal for CRCF regulation [28]	"… a carbon removal activity related to land management that results in the increase of carbon storage in living biomass, dead organic matter and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere"	CO_2	X	X	X	–	T
CRCF Regulation [16]	"… any practice or process carried out over an activity period of at least five years, related to the management of a terrestrial or coastal environment and resulting in the capture and temporary storage of atmospheric or biogenic carbon in biogenic carbon pools, or in the reduction of soil emissions"	CO_2	X	X	X	–	T C
McDonald *et al*. [29]	"(a) … farm management practices that aim to deliver climate mitigation in agriculture. This involves the management of both land and livestock, all pools of carbon in soils, materials, and vegetation, plus fluxes of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). It includes carbon removal (sequestration and permanent storage of carbon in soils and biomass), avoided emissions (preventing the loss of already stored carbon), and emissions reductions (i.e., reductions of GHGs below current levels of farm emissions)"	CO_2 CH_4 N_2O	X	X	X	–	A
McDonald *et al*. [29]	"(b) … also refers to the business model that aims to upscale climate mitigation by paying farmers to implement climate-friendly farm management practices"	–	–	–	–	X	A
Carbon Cycle Institute [30], Harman un Uphoff [31]	"Implementation of agricultural practices that are known to improve the rate at which CO_2 is removed from the atmosphere and converted into plant material and/or soil organic matter, such as agroforestry and conservation agriculture"	CO_2	–	X	–	–	A
Panchasara *et al.* [32]	"a way to reduce GHG emissions by capturing and holding the carbon in vegetation or soils. Carbon farming seeks to reduce the emissions in its production stage while still managing to increase the yield production, sequestering carbon within the landscape"	GHG	X	X	X	–	T
Cavallin [21]	"… in the context of agricultural soils is meant to leverage the carbon cycle in relation to soils to make the farmland more fertile and more resilient and take advantage of its potential for climate change mitigation, with the added benefit of generating opportunities for the agro-food chain" [33]	–	–	–	–	X	A

Where the term "carbon" is used without further specification, it is assumed to refer to carbon dioxide (CO_2), consistent with common usage in EU policy documents.

*Abbreviations used: T – terrestrial (land-based); A – agriculture/ agricultural soils; C – coastal

Some refer explicitly on agriculture, agricultural land, and agricultural soils and biomass, while others extend the scope to include other land managers and landscapes. The definition in the CRCF Regulation [16] is the only one that specifies activities in coastal environments. It also stands out as the only definition to introduce a time constraint, requiring that measurable carbon removal or emission reduction be achieved within a five-year period. However, this definition narrows the emission reduction objective to a specific category – soil emissions, rather than addressing the full set of emissions from agricultural or land management activities, such as those related energy and fuel use.

This definitional diversity reflects the fragmented nature of carbon farming as a policy and scientific construct. While the CRCF Regulation provides a specific and legally binding definition focused on measurable removals and soil emission reductions, scientific literature reveals a much broader and diverse set of related concepts, such as: climate-smart agriculture; soil-based carbon farming; regenerative agriculture; agroecological agriculture; green agriculture; organic regenerative agriculture; sustainable agriculture [26], [34]–[36]. These overlapping and sometimes ambiguous terms vary in scope, underlying principles, and implementation contexts. As a result, the alignment between the CRCF Regulation's definition and the science-based practices described in the literature may be limited. This misalignment could pose challenges for the practical implementation of carbon farming measures, especially in terms of translating evidence-based approaches into certifiable actions under the CRCF framework.

To better understand the nature of carbon farming, it is essential to consider not only how it is defined but also the practical methods it encompasses. These methods are grounded in effective land management practices that enhance carbon sequestration while generating co-benefits for ecosystems and biodiversity [17]. "Technical Guidance Handbook - setting up and implementing result-based carbon farming mechanisms in the EU" [27], along with the "Sustainable Carbon Cycles" Communication [17], identify several priority methods appropriate for the EU context. These include: (a) conversion of arable land to grassland to sequester SOC; (b) new agroforestry; (c) wetland/peatland conservation/restoration; (d) woodland planting; (e) management of existing woodland, hedgerows, woody buffer strips and farmland trees; (f) reduced and minimum tillage; (g) leaving crop residues on the soil surface; (h) optimised feeding strategies for livestock; (i) improved on-farm energy efficiency, etc.

Transitioning from conventional farming to carbon farming practices often entails significant upfront costs and risks. Therefore, the development of effective support mechanisms is critical. For this reason, three models of support payments for carbon farming practices can be distinguished: action-based, where payments are made for following a particular practice and are already supported by the CAP; results-based, where payments are made for the amount of carbon sequestered; and hybrid schemes, which combine both approaches [21], [27].

Despite growing interest in carbon farming, its practical implementation faces several challenges. One of the most significant is the accurate measurement, monitoring and verification of carbon sequestration [21], [34], which is often hampered by technical constraints, high costs related to measurements, and the temporal variability of SOC changes over time [13], [21], [34]. In addition to these technical barriers, the broader uptake of carbon farming practices is constrained by low carbon credit prices, high transaction costs, lack of information and awareness among land managers, and uncertainty about long-term policy and market conditions [21], [26]. A key conceptual and methodological challenge is the demonstration of additionality, that is, proving that the observed carbon removal or emission reduction would not have occurred without the implementation of specific carbon farming

practices. Ensuring the long-term permanence of stored carbon in soils or biomass is another major concern [13], [26]. Baumber *et al*. [26] highlight that insufficient awareness, knowledge and understanding are among the main reasons why many farmers remain disengaged from carbon farming schemes. Strengthening stakeholder collaboration [26], particularly through bottom-up initiatives [37], is therefore seen as essential. Bento *et al*. [38] emphasise the importance of establishing robust, credible baselines that accurately reflect business-as-usual emission levels. More credible baselines can reduce the need for conservative methodological assumptions, thus improving the financial attractiveness of carbon farming projects [38]. To further support uptake, a variety of modelling tools, including DayCent, COMET-Farm, Cool Farm and WaCSE, have been developed to estimate SOC sequestration potential over a period of time [34]. These models differ in terms of input data requirements, level of detail and whether they are tailored to the farm level or regional level [34]. However, existing models cannot capture the high level of process complexity, meaning they cannot be used as the sole quantification tool without additional on-the-ground measurements [22].

2.1. International Context and Critiques of the CRCF Regulation

Before drawing conclusions on the CRCF Regulation's policy coherence, it is important to position it within a broader international context and reflect on critical viewpoints concerning its conceptual and practical implementation. Several comparative insights and critiques help to contextualise the CRCF framework's scope, limitations, and the challenges of operationalisation.

The design of carbon farming schemes varies across jurisdictions. For example, Australia, for example, has been a global frontrunner, first through its Carbon Farming Initiative (2011), later replaced by the Emission Reduction Fund in 2015, under which carbon credits are purchased via auctioning [26], [39]. Although similar credit-based mechanisms have been introduced in other countries such as Canada (Alberta), India and China [26], they differ in terms of scale, governance structures, credit calculation methodologies, and eligibility criteria.

Although the CRCF Regulation is expected to promote carbon farming in the EU, several studies have raised concerns about the CRCF Regulations approach. Brad and Schneider [9] claim that the EU missed the chance to adopt robust carbon removal measures in the early stages, instead choosing offsetting mechanisms. They also highlight the lack of clear separation between emission reduction and removals in the European Climate Law, which may enable large emitters to offset rather than actually reduce their emissions [9], as also noted by Landers *et al*. [36]. Cavallin [21] highlights methodological robustness and accountability gaps in the CRCF Regulation, and challenges the assumption that increased soil carbon content necessarily indicates sustainable soil health. There are ongoing concerns about the reversibility of sequestered CO_2 and the limited clarity on surrounding the functioning of carbon credits under the CRCF framework [21]. Similarly, Paul *et al*. [13] are sceptical, warning that the framework may not lead to effective mitigation and suggesting that funding should focus directly on emission reductions instead.

These international experiences and critical assessments provide an important basis for evaluating the coherence of the CRCF Regulation. The next section outlines the methodology employed to analyse EU policy and regulatory documents within the CRCF framework.

3. MATERIALS AND METHODS

QCA was chosen as a suitable method for analysing EU regulatory and policy documents, as it enables systematic identification of themes, meanings and underlying patterns across a diverse set of texts [40], [41]. This method was considered appropriate because it supports the structured analysis of regulatory and policy documents, and is particularly useful for exploring policy formation and coherence in the context of policy development and implementation [40], [41]. As defined by Mayring [42], QCA is a systematic, rule-guided method for interpreting textual material. It allows for an empirical, theoretically grounded analysis without premature quantification. QCA is reliable and transparent [43] and is particularly suitable for examining the normative and interpretative aspects of grey literature, such as policy documents [43], [44]. The method enables analytical categories to be developed based on the research question and these can be adjusted as new insights emerge [44]. Coding units are not predefined but are created during the coding process [43]. The research question guided the development of the coding structure and subsequent thematic analysis, ensuring alignment between the analytical process and the study's objectives [43]. This study used a hybrid categorisation approach, combining deductive and inductive strategies [43]. The deductive approach is based on an existing theoretical framework and is used to develop the initial categories [43] derived from EU regulatory and policy context of the CRCF Regulation and its expected operational elements. By contrast, an inductive (data-driven) approach was employed to identify additional themes or concepts that emerged during the analysis process [43].

The research began with the definition of the research question (see Section 1), followed by the selection of five initial search terms via a deductive approach. These were searched for in the CRCF Regulation to identify relevant text passages. The snowballing approach [45], [46], was used, whereby references to other policy or regulatory documents found within the text passages were included in analysis. Thus, a further 14 documents were selected for the next stage of analysis, along with two additional search terms. In the third iteration, a further 16 EU regulatory or policy documents were identified, bringing the total to 31 EU regulatory and policy documents. Nine search terms were applied across these documents in total. Figure 1 summarises the process and methodological steps of the QCA. The top part of the figure shows the search term and document selection steps. Text fragments were initially grouped into 17 codes, which were then reviewed and structured into nine broader thematic groups (categories) based on recurring topics. The corresponding analysis steps are indicated at the bottom.

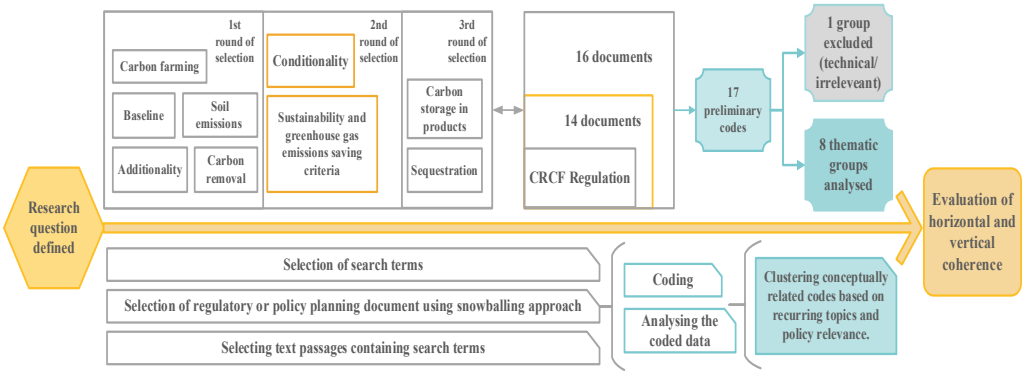

Fig. 1. Research process methodology (above the arrow: search terms and their selection stages, document selection phases, and the nine identified thematic groups; below the arrow: corresponding methodological steps).

The search terms are intentionally formulated as compounds phrases, with extensions applied in only selected cases. The search terms for which no extensions were applied were – carbon farming, baseline, conditionality, sequestration. The search term "additionality" was used with and extension to capture related references to additional actions, even where the full term itself was not explicitly mentioned. For the search terms "carbon removals" and "soil emissions", an extension was applied to include singular uses ("carbon removal", "removal", "soil emission"). During the analysis it was also found that the search term "sustainability and greenhouse gas emissions saving criteria" sometimes appeared with the additional article "the" (sustainability and the greenhouse gas emissions saving criteria), so this variation was included in the search extension. For the search term "carbon storage in products", the extension "carbon storage" was used to include a wider range of text on carbon storage options in products and, where possible, other wording related to carbon storage options that may have been omitted previously.

Relevant text fragments were manually selected and entered into an Excel database. They were then grouped according to search terms and initially coded thematically. Text fragments that were clearly unrelated to the research question or contained technical information were excluded. The remaining fragments were compiled into a single spreadsheet and duplicates were deleted. In the next step, each text fragment was manually assigned a short descriptive title summarizing its main theme (e.g., rules for defining baseline; reversal of previous removals; definition and explanation of carbon farming practices; blue carbon, etc.). This inductive process resulted in 17 preliminary codes. These were then reviewed and merged into broader themes, to reduce overlap and provide a clearer analytical structure for the study. The final coding framework consisted of nine thematic groups, created by clustering conceptually related codes based on recurring topics, contextual links, and policy relevance observed across the data set. Eight of these groups are described in detail in the results section, including the number of text fragments per group. The ninth group, consisting of text fragments not directly related to the research question, is not discussed further. The full coding structure, including the initial 17 codes, the final nine thematic groups and all analysed text fragments, is available in the accompanying open-access Excel file on Zenodo https://zenodo.org/records/15012191.

The results section presents and overview of the analysed documents, the frequency and distribution of search terms, and the thematic synthesis derived from the coded text fragments.

4. RESULTS

4.1. Overview of Selected Documents

In this study, QCA was used to analyse 31 regulatory and policy documents, including one international treaty (the Paris Agreement) and one Proposal for a Regulation. Documents closely related to the CRCF Regulation included three directives and nine regulations, while the largest number of documents (17) were European Commission Communications. The structure of the documents analysed by type of document is shown in Fig. 2.

In terms of timeframe, the oldest document is from 2003, "Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community" [39], and the latest is from 2024. Comparing the number of documents by year, only five documents were included from 2003 to 2017, while 26 documents were adopted from 2018 to 2024, which shows the rapid development of regulatory and policy documents in the context of the research question.

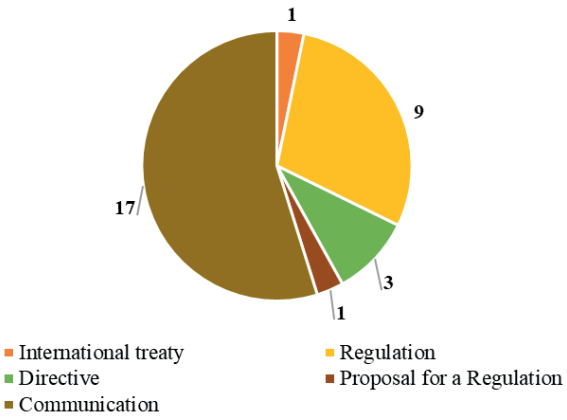

Fig. 2. Documents analysed by type of document.

4.2. Analysis of Search Term Frequency and Distribution

Research question is not only reflected in the number of documents analysed, but also in the frequency of the search terms used in them. Comparing the two periods of adoption of the documents 2003–2017 and 2018–2024, there is a significant increase in the number of mentions. In the first period (2003–2017), the documents analysed contain a total of only 26 mentions of search terms, whereas between 2018 and 2024, the number of mentions increases to 1473. It should be stressed that these data reflect the unfiltered frequency of search terms across all 31 documents, before the exclusion of technical and irrelevant passages during content analysis. The sharp increase in search term mentions from 2018 onwards coincides with the change in EU climate policy following the Paris Agreement at the end of 2015. The transition period following the adoption of the Paris Agreement reflects a typical cycle of regulatory revision and policy adaptation, in which the EU started to flesh out new policies and policy instruments to mitigate climate change and promote carbon removal and sequestration.

Summarising the frequency of mentions of search terms (Table 2) across the documents analysed (before data filtering), search terms are mentioned a total of 1499 times. The most frequently used search terms are “carbon removals” (535 times), “additionality” (388 times) and “carbon farming” (194 times). It should be noted that the extended search term “additional” was used to search for “additionality”, which increased the frequency of mentions unrelated to the research question. Other search terms were “baseline” (93 times), “soil emissions” (77), “sequestration” (67) and “carbon storage in products” (60). The least frequently mentioned search terms were “conditionality” (53 times) and “sustainability and greenhouse gas saving criteria” (32 times), which were added at a later stage of the analysis to further explore the relationship of the CRCF Regulation with the CAP and other regulations. A detailed breakdown of mentions is shown in Fig. 3.

The dispersion of search terms across documents was highly uneven, with the number of mentions per document ranging from 1 to 387. The five documents with the highest mention frequency: the CRCF Regulation [16] (387 times), “Sustainable Carbon Cycles” [17] (199 times), and key legislative documents such as Regulations (EU) 2021/2115 [47] (107 times), Regulation (EU) 2018/1999 [48] (98 times) and Regulation (EU) 2018/841 [49] (94 times). This is understandable given that the CRCF Regulation [16] was the starting point of the analysis and the basis for the research question, while “Sustainable Carbon Cycles” [17] provided the conceptual basis for the development of the CRCF Regulation. Almost half of

the documents analysed (15 out of 31 documents) contain less than 20 mentions of search terms, indicating their limited relevance to the research topic.

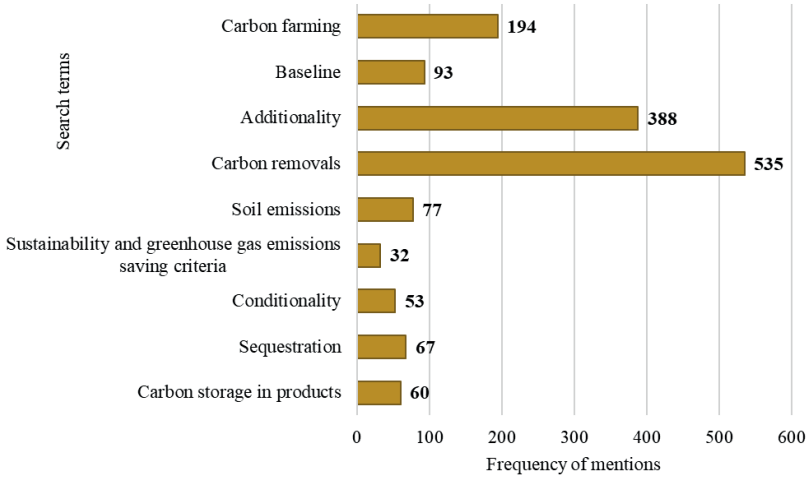

Fig. 3. Frequency of search term mentions in the set of documents analysed.

The lowest number of mentions (1) is found in the Communication "Innovating for Sustainable Growth: A Bioeconomy for Europe" (COM/2012/060 final) [50], where the search term "sequestration" is mentioned. This is followed by Directive 2003/87/EC [51]; Directive 2009/31/EC [52] and Communication "New European Bauhaus" (COM/2021/573 final) [53], where search terms are mentioned five times in each document. Most of these documents were adopted before 2018, which coincides with the observed increase in thematic relevance in recent years. Looking at individual search terms in more detail, the words "carbon farming" and the search extension "carbon storage" appear in documents for the first time in 2018 in the Communication "A sustainable Bioeconomy for Europe" (COM (2018) 673 final) [54]. The search term "removal" on the other hand, is already mentioned in the 2009 Directive 2009/31/EC [52]. Search term "soil emissions" is only found in two documents: the 2018 Communication "A Clean Planet for all" (COM/2018/773 final) [55] and the CRCF Regulation [16] (76 times). Detailed number of mentions per document and search terms are available in the attached Zenodo open access repository https://zenodo.org/records/15012191.

4.3. Thematic Groups of Extracted Text Fragments

Thematic analysis of the coded text fragments resulted in their classification into nine thematic groups (Table 2). These groups reflect the main areas of interaction and coherence between the CRCF Regulation and other EU regulatory and policy documents, particularly in relation to climate and agricultural policy. The thematic groups were formed based on their relevance to the research question and help illustrate how the CRCF framework is structured and horizontally integrated across EU policy instruments, as well as its links to practical implementation. Eight of the nine themes are described in detail below, while the ninth includes fragments that were excluded due to their technical character or lack of direct relevance the research question.

TABLE 2. THEMATIC GROUPS OF TEXT FRAGMENTS IDENTIFIED IN THE DOCUMENTS

No.	Thematic group	Number of text fragments	Documents from which text fragments were extracted*
1.	General information on EU GHG emission reduction targets	117	[10], [16], [17], [19], [47], [48], [49], [50], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68]
2.	The CRCF Regulations certification framework as an instrument for implementing EU climate objectives	42	[16], [17], [18], [19], [54], [58], [61], [63], [64]
3.	Certification framework, monitoring, support tools	84	[16], [17], [19], [54], [62], [64]
4.	Quantification, baseline, reversal of previous removal	53	[16], [17], [49], [58], [65]
5.	Links and interactions between CRCF and CAP	42	[17], [19], [47], [60], [61], [62], [63], [67], [69], [70], [71]
6.	Carbon farming as a business model	34	[17], [19], [54], [58], [60], [61], [62], [64], [65], [67]
7.	Carbon farming and carbon storage in ecosystems and products	29	[16], [17], [18], [49], [53], [54], [55], [60], [61], [63], [69]
8.	Sustainability, additionality and activities with co-benefits	14	[10], [16], [57]
9.	Text fragments excluded from further analysis**	485	–

* The references refer to the documents that are listed in the bibliography.

** A detailed description of thematic group 9 is not provided because it contains text fragments that were excluded from further analysis due to limited relevance of the research question or highly technical content.

It should be noted that although thematic group eight "Sustainability, additionality and activities with co-benefits" was initially identified as conceptually distinct, further analysis revealed that its content did not form a self-contained theme directly addressing the research question. Instead, insights from group eight were found to reinforce and overlap with themes already covered in other groups, especially in relation to certification principles and quantification (thematic group two and three), and carbon storage in ecosystems and products (thematic group seven). Therefore, thematic group eight is not discussed as a standalone section, and its relevant content has been integrated where appropriate in the respective thematic discussions.

4.3.1. Thematic group 1: General information on EU GHG emission reduction targets

Thematic group one included the largest number of text fragments (117), summarising the overarching climate policy goals that shape the context in which the CRCF Regulation is implemented. It illustrates how the CRCF Regulation fits into the broader EU regulatory and policy framework for reducing GHG emissions, enhancing carbon sequestration and ensuring long-term storage, particularly within the bioeconomy, LULUCF, renewable energy and related sectors. This thematic group assists in assessing the degree of horizontal policy coherence between the CRCF Regulation and other key EU climate and energy policies on a broader, strategic level. More specific dimensions of policy coherence are examined in the subsequent thematic groups.

The European Green Deal sets a target of climate neutrality by 2050, made legally binding for MS by Regulation (EU) 2021/1119 [10], [65], along with an interim target of a 55% reduction in GHG emissions by 2030 compared to 1990 levels [65]. Under the UNFCCC, the EU and its MS are required to prepare, regularly update, publish and report national GHG inventory reports, quantifying anthropogenic emissions and carbon sinks [48], [49], [67]. A common methodology developed by the IPCC ensures the comparability and consistency of reporting in line with the requirements of the UNFCCC and the Kyoto Protocol [48], [49]. In addition, Regulation (EU) 2018/1999 obliges the MS to develop and regularly update integrated national energy and climate plans outlining their contributions to the EU's Energy Union objectives [48].

The bioeconomy contributes to climate targets by reducing fossil fuel emissions through replacing GHG-intensive materials with bio-based and sustainable products in the energy, transport, chemical and construction sectors [17]. Bioresource extraction sectors, such as agriculture and forest sectors currently sequester around 300 Mt CO_2e per year [55], but national GHG inventories also indicate decline in net removals over the past decade, mainly due to degradation of forest ecosystems [17]. MS are therefore encouraged to promote the sustainable use of resources, increase mobilisation and develop new forestry and agricultural production systems [60] that meet sustainability and GHG reduction criteria, thereby ensuring positive environmental and climate impacts [57].

The CRCF Regulation complements other instruments that support forest-based carbon sequestration. These include the new EU Forest Strategy [61], which promotes sustainable forest management, afforestation, agroforestry practices, and biodiversity conservation [59], [61]. It also aligns with the Renewable Energy Directive 2018/2001 [57], introducing additional safeguards for the use of wood and other bio-based fuels. It implements enhanced sustainability and GHG emission saving criteria for biofuels, bioliquids and biomass fuels, and establishes voluntary certification schemes to ensure the traceability of biomass extraction [57]. These measures are directly relevant to the CRCF Regulation, as certifiable operations must also comply with the sustainability criteria [16], [57]. Although severely affected by climate change, the LULUCF sector is essential for the long-term storage of carbon stocks with minimal risk of leakage [49]. Improving the productivity and regeneration capacity of the LULUCF sector through sustainable land management practices would reduce its carbon and environmental footprint [49], making it possible to achieve the LULUCF Regulation's target of 310 Mt CO_2e net carbon sequestration by 2030 [17], [60], [61]. Additional carbon sequestration is also anticipated through ecosystem restoration initiatives outlined in the EU Biodiversity Strategy 2030 [67].

Alongside nature-based approaches, the EU is also exploring industrial carbon removal technologies, such as DACCS or BECCS [58]. However, deployment remains limited due to the associated costs, energy intensity and volatile prices of the CO_2 removal [58]. Nevertheless, the European Commission has set a target to ensure that at least 20 % of the carbon used in the chemical industry is sustainable by 2030, as well as achieving at least 5 Mt CO_2e capture and storage [58].

4.3.2. Thematic group 2: The CRCF Regulations certification framework as an instrument for implementing EU climate objectives

Thematic group two focuses on the strategic role of the CRCF Regulation's certification framework within the EU policy architecture, moving beyond its technical functions to examine how it contributes to long-term climate governance and policy coherence. While the thematic group one outlined the general alignment of the CRCF Regulation with high-level EU climate goals, this group explores its functions as a structural instrument underpinning

multiple regulatory and policy pathways, particularly its relevance for the European Climate Law, LULUCF Regulation, Renewable Energy Directive, and international commitments under the Paris Agreement. This group highlights both horizontal policy coherence with parallel EU strategies (e.g., biodiversity, bioeconomy, forest and agricultural policies) and vertical alignment with international climate compliance systems. It builds upon the earlier policy vision laid out in the "Sustainable Carbon Cycles" Communication, but shifts the focus form methodological development to the broader governance function of the CRCF certification framework.

The activities certified under the CRCF Regulation must demonstrate a clear and measurable climate benefit, while also avoiding the risk of greenwashing [16]. Priority is given to solutions that remove CO_2 from the atmosphere and ensure its long-term storage in ecosystems or products, provided they preserve biodiversity and ecosystem integrity, and respect the precautionary and the "do no significant harm" principles [16], [17]. This aligns the CRCF Regulation with broader EU climate policy framework, including 2050 climate neutrality target set by the European Climate Law (Regulation (EU) 2021/1119) [16], [65]. The certification framework should initially focus on solutions implemented within the EU that provide sufficient guarantees on storage duration, accuracy of measurements and management [17]. Certified carbon removal under the CRCF Regulation could potentially support the EU's Nationally Determined Contributions under the Paris Agreement, depending on how they are integrated into the EU's official GHG accounting and reporting framework, particularly under the Regulation (EU) 2018/1999 [16], [48].

The CRCF Regulation is an essential tool for the implementation of other EU policies, particularly those addressing land use, sustainable bioeconomy, climate change mitigation and rural development [50], [54], [59]–[63], [67], [69]. It is closely aligned with the LULUCF Regulation (EU) 2018/841 [49], which already provides a binding governance framework for monitoring and incentivising land-based carbon sinks at the MS level. In the industrial sector, the 2023 revision of the EU Emission Trading System Directive recognises that carbon stored in certain products can be considered permanent [58]. The CRCF Regulations certification framework extends this recognition by allowing the certification of industrial activities that store atmospheric or biogenic CO_2 in products in a way that prevents re-emission to the atmosphere [58].

4.3.3. Thematic group 3: Certification framework, monitoring, support tools

The third thematic group focuses on the operational principles of the CRCF Regulation's certification framework, its monitoring procedures, and support instruments for practitioners. With 84 text fragments, primarily from the CRCF Regulation and the "Sustainable Carbon Cycles" Communication, this group reflects how the political commitments made at the strategic level have been operationalised into regulatory practice. Thematic group three provides insight into how definitions, prioritisation criteria for eligible activities, monitoring tools, and advisory measures are structured to ensure the functionality of the certification framework. It illustrates a key aspect of horizontal policy coherence: the alignment of the CRCF Regulation with other EU strategies relating to agriculture, forest sector, and digitalisation. In particular, it reflects to continuation and concretisation of goals set out in earlier policy documents, such as the "Sustainable Carbon Cycles" Communication. Moreover, the inclusion of digital innovation, traceability, and support services connects the CRCF regulation to broader EU policy frameworks, demonstrating a coordinated approach to carbon farming implementation.

The CRCF Regulation provides definitions of permanent carbon removals, carbon farming and carbon storage in products, their criteria and certification requirements, additionality and

concepts related to accounting methodologies are defined [16]. The above and other related definitions define the requirements for activities to be certifiable and for methodological consistency with IPCC guidelines, LULUCF Regulation requirements and other binding regulatory documents [16]. The CRCF Regulation should encourage land managers to undertake activities that go beyond standard practices and legal requirements, i.e. activities that are not already mandated by existing legislation [16]. Certification methodologies should be developed first for activities that are at the highest stage of maturity, can deliver the highest co-benefits, contribute to biodiversity conservation and meet sustainability and GHG emissions saving criteria [16], [57]. In addition, certified activities must not cause significant environmental damage and must deliver at least one of the sustainability objectives listed in the CRCF Regulation Article 7 [16]. With regard to carbon storage in products, the development of certification methodologies for wood and bio-based building materials is a priority [16]. To ensure transparency and avoid fraud and double counting, the CRCF Regulation foresees the establishment of an EU registry within four years of its entry into force [16]. Certified units will be issued only upon verified net benefit of CO_2 removal or soil emission reduction [16]. In parallel, additional requirements may be needed to align the CRCF Regulations framework with the Paris Agreement and best practices from voluntary carbon markets, particularly regarding methodology, monitoring, baselines, additionality and emissions leakage [16].

The successful implementation of the CRCF Regulation will depend heavily on the use of advanced technological solutions to minimise the cost of on-site measurements. Digital technologies, geographic information systems, remote sensing and innovative on-site quantification systems for CO_2, as well as artificial intelligence and machine learning solutions, will play a pivotal role in monitoring and verifying GHG emissions and removals. These technologies enhance the accuracy, efficiency and comparability of CO_2 accounting by combining on-site measurements with remote sensing and modelling [16], [17], [62], [64]. The promotion of such digital tools is consistent with broader EU policy directions. For example, the EU Strategy to Reduce Methane Emissions envisages a digital carbon navigator template to support farm-level carbon balance calculations [62]. Proposal for a Regulation on a Monitoring Framework for Resilient European Forests highlights the need to standardise remote sensing data products to support climate and biodiversity indicators, including carbon removals and certification [64]. Similarly, “The Future of Food and Farming” Communication emphasises the importance of digital technologies, big data and precision agriculture to enhance the sustainability and climate resilience of farming systems [70]. Taken together, these initiatives reinforce the horizontal policy coherence of the CRCF Regulation, aligning digitalisation objectives across climate, forest and agricultural strategies.

To support broader uptake carbon farming, the CRCF Regulation emphasises the need for tailored advisory services, improved data management, and reduced administrative burdens for farmers and foresters [16], [17]. Particular attention should be paid to small-scale land managers who often lack the experience and resources to implement carbon farming practices and meet certification requirements [16], [17]. They require tailored support through guidance, digital tools, and monitoring systems to assess the performance and ensure compliance with quality criteria [16], [17]. Targeted education and training in sustainable practices can enhance understanding and engagement [16], [17]. These support measures also reflect horizontal alignment with other EU policies, such as the CAP and the new EU Forest Strategy, which highlight the role of capacity building and digital innovation in sustainable lang management [47], [61]. The Horizon Europe mission “A Soil Deal for Europe” identifies carbon farming as a hotspot for research and innovation [17], while the European Climate

Pact encourages knowledge exchange among land managers through initiatives such as the European Climate Pact Ambassadors [17].

4.3.4. Thematic group 4: Quantification, baseline, reversal of previous removal

This thematic group summarises the CRCF Regulation's methodological framework for quantifying net carbon removals and soil emission reductions. It comprises 53 text fragments and outlines the use of standardised and activity-specific baselines, the requirements for consistency with IPCC guidelines, and the risk of reversal of previously certified removals. These elements are critical for ensuring the credibility of certified carbon removals and for aligning the CRCF Regulation with broader EU's climate governance framework. The thematic group focuses on vertical coherence between the CRCF Regulation certification framework and the application of international and EU-level reporting obligations at the MS level. These obligations are as set out in the Paris Agreement, the LULUCF Regulation EU 2018/841 and the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action. At the same time, it demonstrates methodological consistency with internationally acknowledged standards, such as the IPCC guidelines, which are recognised by the UNFCCC and form the basis for GHG accounting under Paris Agreement transparency framework.

For the calculation of CO_2 removals and GHG emission reductions from carbon farming practices, the Tier 3 methodology should be applied in accordance with the IPCC guidelines. This ensures consistency with national GHG inventories and compliance with both Regulation (EU) 2018/841 and Annex V, Part 3 of Regulation (EU) 2018/1999 [16]. The requirements of Regulation (EU) 2018/841 apply to GHG emissions and removals from the following land inventory categories: afforested land; deforested land; cultivated arable land; cultivated grassland; cultivated forest land; cultivated wetland [49]. These land areas are vulnerable to natural disturbances such as forest fires, insect and disease outbreaks, extreme weather events and geological disturbances, which may lead to increased GHG emissions or the reversal of previous removals [49]. Reversals may also result from management decisions, such as tree felling or planting. To avoid double counting, it is important to ensure that emissions and removals are not recorded in more than one land accounting category [49].

The CRCF Regulation sets out calculation formulae to quantify the permanent or temporary CO_2 removal or storage resulting from an activity [16]. An activity is considered a net CO_2 removal benefit if the CO_2 removal above the baseline is greater than the increase in GHG emissions associated with its implementation, including machinery use, indirect land use change emissions and carbon leakage [16]. Additional GHG emission reductions (excluding agricultural soil emissions) should be considered as co-benefits for the sustainability objective of climate change mitigation and can increase the value of the certified carbon sink [16]. Calculation formulas defined in the CRCF Regulation for carbon removal and soil emission reduction activities are summarised in Table 3.

The calculations will be performed on the basis of a pre-defined baseline. The reference values (CR_{baseline}, LSE_{baseline}, ASE_{baseline}) should reflect the standard performance levels of comparable activities and processes under similar social, economic, environmental, technological and regulatory conditions [16]. Such baselines must account for applicable legislation and market conditions, include geographical and local pedoclimatic factors [16]. If an activity is mandatory and does not require incentives, it should be considered part of the standardised baseline, with the corresponding baselines defined by the European Commission in the relevant certification methodologies [16]. Once an activity becomes common practice, it can no longer be certified [16]. Standardised baselines will facilitate the demonstration of additionality and reduce the administrative burden, which is particularly important for small land managers [16]. Where justified (e.g., due to lack of data or comparable activities), an

activity-specific baseline may be used and updated regularly [16]. The baseline emissions from agricultural soils ($ASE_{baseline}$) and the total emissions from agricultural soils (ASE_{total}) should be consistent with the IPCC agricultural source category, subcategory 3.D Agricultural soils [16]. Additionally, emission reductions from agricultural soils under subcategory 3.D should be included in the quantification of carbon farming activities, in accordance with the IPCC guidelines [16].

TABLE 3. QUANTIFICATION FORMULAS FOR CARBON REMOVAL AND SOIL EMISSIONS UNDER THE CRCF REGULATION [16]

Activity type	**Quantification formula**
Permanent net carbon removal benefit	$CR_{baseline} - CR_{total} - GHG_{associated} > 0$
A carbon farming activity: (a) temporary net carbon removal benefit	
Carbon storage in product activity: temporary net carbon removal benefit	
where: $CR_{baseline}$ – the amount of carbon removals under the baseline; CR_{total} – the total amount of carbon removals of the activity; $GHG_{associated}$ – the increase in direct and indirect GHG emissions over the entire lifecycle of the activity which are attributable to its implementation, including indirect land use change, calculated, where applicable, in accordance with the protocols set forth in the IPCC guidelines and any further refinements.	
A carbon farming activity: (b) net soil emission reduction benefit:	$LSE_{baseline} - LSE_{total} + ASE_{baseline} - ASE_{total} - GHG_{associated} > 0$
where: $LSE_{baseline}$ – the amount of LULUCF soil emissions under the baseline; LSE_{total} – the total amount of LULUCF soil emissions of the activity; $ASE_{baseline}$ – the amount of agricultural soil emissions under the baseline; ASE_{total} – the total amount of agricultural soil emissions of the activity; $GHG_{associated}$ – the increase in direct and indirect GHG emissions over the entire lifecycle of the activity which are attributable to its implementation, including indirect land use change, calculated, where applicable, in accordance with the protocols set forth in the IPCC guidelines and any further refinements.	

Quantifications are given a negative sign (–) for GHG removals and a positive sign (+) for GHG emissions, and are expressed in tonnes of CO_2e [16]. Quantification must be appropriate, conservative, accurate, complete, consistent, transparent and comparable, in accordance with the best available science [16]. While carbon farming generally improves soil quality, it can sometimes reduce food production and lead to indirect land use changes and carbon leakage, therefore, the associated indirect emissions must be considered [16]. Monitoring should be based on an appropriate combination of on-site measurements and remote sensing or modelling, in accordance with the applicable methodology's provisions [16].

Carbon removals from atmospheric or biogenic sources may be reversed due to natural or anthropogenic causes; therefore, preventive measures and continuous monitoring are required throughout the designated monitoring period [16]. To account for potential reversals, both carbon sequestration unit and the unit for carbon storage in products are subject to expiry dates, with a minimum of 35 years [16]. By 2028, all land managers should have access to verified emissions and removals data to facilitate the widespread adoption of carbon farming and achieve and additional 42 Mt CO_2e in net removal [17].

4.3.5. Thematic group 5: Links and interactions between CRCF Regulation and CAP

Thematic group five explores the linkages between the CRCF Regulation and the new CAP (2023–2027), focusing on their overlapping objectives and implementation mechanisms

related to carbon farming. While the CAP remains predominantly action-based support scheme, the CRCF Regulation introduces a result-based approach. This creates both opportunities and challenges for coordination, particularly where practices may be eligible under both instruments. The 42 text fragments in this group reflect an emerging horizontal policy coherence between the two frameworks, especially in how they incentivise sustainable land management, enhance climate and environmental performance, and promote the uptake of carbon farming through national CAP Strategic Plans.

The new CAP (2023–2027) sets higher environmental and climate targets, including reducing GHG emissions, promoting CO_2 sequestration and sustainable energy, halting biodiversity decline, and improving ecosystem services [47], [67]. The measures set out in Regulation (EU) 2021/2115 are closely linked with carbon farming practices, which will be promoted through CAP Strategic Plans of MS [47]. Voluntary eco-schemes are expected to support environmental and climate performance beyond minimum requirements, and cover at least two key sustainability areas, including: "(a) climate change mitigation, including reduction of GHG emissions from agricultural practices, as well as maintenance of existing carbon stores and enhancement of carbon sequestration; (b) climate change adaptation; (c) protection or improvement of water quality and reduction of pressure on water resources; (d) prevention of soil degradation, soil restoration, improvement of soil fertility and of nutrient management and soil biota; (e) protection of biodiversity, conservation or restoration of habitats or species, including maintenance and creation of landscape features or non-productive areas; (f) actions for a sustainable and reduced use of pesticides; (g) actions to enhance animal welfare or combat antimicrobial resistance" [47]. These areas substantially overlap with the sustainability criteria set out in Article 7 of the CRCF Regulation, which highlight similar domains including climate change mitigation and adaptation, water and marine protection, biodiversity and ecosystem restoration, soil health and land degradation prevention [16]. This alignment demonstrates horizontal policy coherence and potential synergies in the implementation of carbon farming practices across both frameworks.

The new conditionality system for CAP support includes statutory management requirements (SMRs) and good agricultural and environmental conditions (GAEC) [47]. The SMRs cover a range of legislation on the environment, animal welfare, plant health, food safety and land requirements [47]. The GAEC in turn aims to contribute to climate change mitigation and adaptation, water management, soil protection and quality, and biodiversity protection and quality [47]. Several CAP impact and performance indicators directly relate to carbon farming activities covered by the CRCF Regulation. These include impact indicators: I.10 Contribution to climate change mitigation: GHG from agriculture; I.11 Enhancing carbon sequestration: SOC in agricultural land [47]. As well as performance indicators R.14PR Carbon storage in soil and biomass, emission reduction or carbon stock increase, and R.17 Afforested land – afforestation, agroforestry and restoration [47]. These shared monitoring objectives illustrate the potential for coordinated implementation and coherent reporting between the CAP and the CRCF Regulation. This is further supported by tools un the reformed CAP such as the Farm Sustainability Tool (FaST) for nutrient and integrated GHG accounting at farm level [17].

Although the CAP and CRCF Regulation are based on different support concepts – action-based and results-based – there is currently no clear delineation between the two financing approaches. MS may include action-based CAP payments in their CAP Strategic Plans to support carbon farming practices, while the CRCF certification framework is designed to operate on a results-based mechanism, where certified carbon removals may serve as the basis for issuing tradable units. Those units could potentially be sold to private buyers or counted

towards climate targets, depending on future policy arrangements. Therefore, a clear distinction between the financing approaches is essential to avoid double funding [19].

The growth of the bioeconomy through sustainable entrepreneurship should be a priority in the CAP Strategic Plans, supporting the development of the circular economy and new business models [70]. By promoting clean energy production and the use of sustainable biomass, the CAP can contribute not only to rural development and increased farm income, but also to broader EU objectives such as the Energy Union and industrial policy [70]. In this context, several other EU strategies reinforce the integration of carbon farming within agricultural policy. The "EU Strategy to Reduce Methane Emissions" encourages MS to incorporate carbon farming practices into their CAP Strategic Plans [62], while the "EU Soil Strategy" sets out actions to support climate-neutral soil management and adaptation to climate change [60]. Rural areas are further acknowledged for their role in biodiversity restoration and climate mitigation, with legally binding targets under discussion to limit the drainage of wetlands and organic soils, restore peatlands and conserve carbon stocks [55], [60].

4.3.6. Thematic group 6: Carbon farming as a business model

Thematic group six explores carbon farming as a potential business model for farmers and foresters, highlights how the CRCF Regulation could monetise environmental services and incentivise CO_2 removals beyond traditional products. This thematic group contributes to answering the research question by evaluating the extent to which the CRCF certification framework is aligned with existing EU climate and market policies. It reflects horizontal policy coherence with EU strategies on industrial carbon management, forest resilience, environmentally friendly food systems, and the bioeconomy. It also addresses gaps, particularly the current absence of carbon removals from compliance markets like the EU Emission Trading System (EU ETS). In this context, the CRCFR Regulation serves as a bridging mechanism between climate action, agricultural entrepreneurship and voluntary carbon market development.

Switching to carbon farming practices offers the potential for an environmentally sustainable business model that rewards land managers for increasing carbon storage in living biomass, dead organic matter, and soil, while respecting biodiversity and ecosystem protection principles [17], [19], [60]. Certified carbon credits could serve as an additional "product" for land managers alongside food and biomass, while buyers may include bioeconomy actors, such as food processing companies aiming to decarbonise their supply chains [17].

The "Proposal for a Regulation on a Monitoring Framework for Resilient European Forests" is expected to create new opportunities for small and medium enterprises in terms of access to digital services for forest monitoring, and innovation in monitoring technologies [64], [65]. In addition, forest stakeholders will benefit from the additional income generated by the certification framework established by the CRCF Regulation [16], [64]. While the EU ETS does not currently recognise negative emissions, biogenic and atmospheric carbon capture and storage have not yet been incentivised through a carbon market price for compliance [58]. The voluntary EU certification framework under the CRCF Regulation can help to address this gap by mobilising funding while ensuring environmental integrity [58]. In parallel, the banking and financial sectors are increasingly investing in sustainable agriculture, creating market-based incentives for carbon sequestration [60].

Unlocking the potential of carbon farming requires overcoming several barriers identified prior to the adoption of the CRCF Regulation, especially the fragmentation of existing private carbon schemes, which apply widely differing methodologies and criteria, undermining trust

in credit quality [17], [62]. The EU certification framework is therefore expected to provide a harmonised and transparent standard, ensuring environmental integrity and methodological consistency. This would support the emergence of credible carbon market by enabling land managers to estimate potential revenues, allowing policymakers to align activities with regulatory frameworks, and increasing buyer confidence [17]. As a business model, carbon farming could offer farmers and foresters an additional source of income, while simultaneously incentivising emission "insetting" - allowing companies in the agri-food and bioeconomy sectors to reduce their carbon footprint through carbon removal within their own operations. Unlike the EU ETS, which targets emission reductions, the CRCF Regulation introduces financial incentives for the removal and long-term storage of already emitted CO_2.

4.3.7. Thematic group 7: Carbon farming and carbon storage in ecosystems and products

This thematic group focuses on the types of carbon farming activities that could be eligible for certification under the CRCF Regulation, emphasising their environmental potential as well as their policy alignment across EU frameworks. It demonstrates horizontal coherence between the CRCF Regulation and other EU strategies on biodiversity, sustainable land use and product circularity. The group illustrates how land and product-based sequestration options, ranging from soil management to wood use in long-lived products, are gradually being integrated into broader EU environmental, climate and product policies. However, some gaps were identified, especially with regard to blue carbon, suggesting a need for more balanced integration across domains.

The CRCF Regulation covers a wide range of land-based carbon farming practices also identified in the "Sustainable Carbon Cycles" Communication, including afforestation, reforestation, and sustainable land management; as well as agroforestry; intercropping, cover crops, conservation tillage and increasing landscape elements. It also covers the conversion of arable land to fallow land or permanent grassland; and the restoration of peatlands and wetlands [16], [17], [55], [69]. Actions with the highest potential for positive co-benefits should be prioritised for certification [16], [17], [55]. Maintaining and enhancing carbon stocks in mineral soils is crucial for supporting soil biodiversity, health, and fertility [60]. Unsustainable land use leads to annual losses of approximately 7.4 Mt CO_2e across the EU, yet a wider uptake of climate-smart management practices could enable mineral soils to sequester between 11 and 38 Mt CO_2e annually [60].

In addition to terrestrial practices, the CRCF Regulation also extends to carbon farming activities in marine and coastal ecosystems, where "blue carbon" is sequestered by algae, seagrasses, mangroves and salt marshes [16], [17]. While the CRCF Regulation recognises the potential of these ecosystems, other EU regulatory and policy documents rarely emphasise blue carbon, suggesting a potential mismatch in policy attention. Nature-based solutions such as regenerative aquaculture and marine permaculture could enhance sequestration, biodiversity and coastal resilience [17], [63]. Further development would require targeted investments in habitat restoration and improved data collection for robust quantification of blue carbon stock.

Although carbon storage in products is not a primary focus of this study, it represents a relevant aspect of the CRCF Regulation's broader scope and its alignment with other EU policy initiatives. Certification methodologies should contribute to food security, biodiversity and ecosystem protection [16], [55], [69], but they are also expected to align with the Corporate Sustainability Reporting Directive (EU) 2022/2464, which promotes transparency in corporate reporting and encourages carbon sequestration in durable products [17]. This enables recognition in product-specific regulations such as the Construction Products Regulation and the Sustainable Products Initiative [17]. CO_2 accounting should also be

reflected in the EU's Product and Organisation Environmental Footprint methodologies [17]. The new European Bauhaus initiative supports the conversion of woody biomass into durable wood products and buildings as a means of extending carbon storage [53], [61]. Furthermore, the LULUCF Regulation requires MS to report changes in carbon stocks for harvested wood product categories (paper, wood panels, sawn timber) [49], [61], while the EU is developing a comprehensive strategy for a sustainable built environment, promoting life-cycle assessment, circularity, and sustainable financing [18].

5. DISCUSSION AND CONCLUSIONS

This study addressed two research questions: (1) How is the CRCF Regulation horizontally integrated with other EU climate and agricultural policy documents, particularly in relation to carbon farming? and (2) What are the main challenges and opportunities for achieving vertical policy coherence when implementing the CRCF Regulation at the national level? These questions were explored through a QCA of 31 policy and regulatory documents. The terms "carbon farming" and "carbon storage" were first introduced in the 2018 "A sustainable Bioeconomy for Europe" Communication [54] where they were identified as innovative approaches with high potential for climate change mitigation. This marked their entry into EU policy landscape, where they were framed as economically viable, result-based public goods provision models for farmers and foresters, and linked with broader policy domains such as the bioeconomy, circular economy and climate neutrality [54]. Similarly, the term "soil emissions" first appeared in the 2018 "A Clean Planet for all" Communication [55], but was further elaborated in the CRCF Regulation, where it is included as a separate carbon sink category [16]. In earlier EU policy documents terms such as "carbon sequestration" were used broadly to describe the process of storing carbon in soil or biomass, often in connection with land management practices [17], [18], [55]. In the CRCF Regulation, however, a conceptual shift is evident: "carbon removal" and "soil emission reductions" are introduced as distinct, process-based certification categories, while "sequestration" refers to a quantifiable outcome (sequestration unit), which represents a verified result of these practices [16]. This evolution in terminology illustrates the move towards greater precision, methodological differentiation, and market applicability in EU carbon management frameworks.

An assessment of horizontal policy coherence based on the first four thematic groups (Table 2) provides an understanding of the role of the CRCF Regulation in the broader context of EU climate, agriculture, LULUCF, and energy policy. These groups highlight the link between the CRCF Regulation and strategic objectives, including increasing carbon removal, developing the bioeconomy, and achieving climate neutrality. The methodological approach of the CRCF Regulation is illustrated, including the certification framework, monitoring, the need for innovation and digitalization, which are part of the overall vision for the development of EU policy and regulatory documents. Strengthening the knowledge and capacity of land managers, their involvement and trust building. The CRCF Regulation builds on the political vision set out above, in particular in the Communication on "Sustainable Carbon Cycles", and complements existing tools by providing a coordinated approach to the implementation of carbon farming practices.

The fifth and sixth thematic groups focus on the interconnection between the CRCF Regulation and the CAP, and the development potential of carbon farming as a green business model. Horizontal policy coherence between the CAP and the CRCF Regulation was identified in relation to sustainable land management, climate objectives and improved environmental performance. The CRCF Regulation is positioned as a voluntary and complementary mechanism to be implemented on a results-based approach, while the CAP

continues to operate within an activity-based support system. The sixth thematic group demonstrates coherence with other EU strategies, including industrial carbon management, promoting forest resilience, decarbonising food chains and bioeconomy development. At the same time, it reveals shortcomings of the existing system: the EU ETS was designed to focus on incentivising emission reductions by large emitters, where the mitigation outcomes are relatively easy to quantify and verify. However, the EU ETS does not currently recognise negative emissions, such as CO_2 removal from the atmosphere, as eligible units for compliance purposes. Consequently, no market-based mechanism was in place to signal or financially reward investments in land-based or technological carbon removal. In this context, the CRCF Regulation introduces a complementary framework that expands the EU's climate policy instruments beyond emission reduction, by establishing a voluntary, scientifically grounded and transparent certification system. This enables the development of a voluntary carbon market and stimulates investments not only in emission reductions but also in CO_2 removals and long-term storage in ecosystems and biomass, opening up opportunities for new business models and long-term climate solutions.

The seventh thematic group demonstrates horizontal coherence with EU policies on biodiversity conservation, sustainable land management and carbon sequestration in products. It illustrates the gradual integration of various carbon removal and sequestration solutions, ranging from land management to the use of wood in durable products, into the EU's environmental, climate, and product policies. However, a gap has been identified in the integration of marine and coastal carbon sequestration, or "blue carbon", into the broader policy framework. Policy documents assign an uneven level of importance to it, indicating an imbalance between sectors. This could be linked to a lack of scientifically based knowledge regarding the sequestration potential of marine and coastal ecosystems, monitoring methods and practical implementation options, which could hinder their inclusion in climate policy action plans.

The second research question focused on the assessment of vertical coherence, aiming to identify the main challenges and opportunities for implementing the CRCF Regulation at the national level. This dimension was especially reflected in thematic groups two, four, five and six, as seen in Table 2. The second and fourth thematic group explores vertical coherence between the CRCF Regulation's certification framework and the application of international and EU-level reporting obligations at MS level. These obligations arise from the Paris Agreement, the LULUCF Regulation EU 2018/841 and the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action. The CRCF Regulation aligns with these frameworks by applying IPCC guidelines, which underpin GHG accounting methodologies used both in EU and international climate reporting under the Paris Agreement. However, the CRCF Regulation also introduces a degree of methodological uncertainty. It requires the use of a predefined baseline (CR_{baseline}) for calculating carbon removal benefit, in accordance with the provisions of Regulation (EU) 2018/841. Although this regulation establishes overall carbon removal targets for the LULUCF sector at the EU and MS levels, it does not define specific baselines by land use type or removal activity [49]. Consequently, it remains unclear whether the indicators used to set the LULUCF targets will also be used to establish baselines under the CRCF Regulation. At the same time, the CRCF Regulation stipulates carbon removal and soil emission reduction benefit must be calculated in line with IPCC guidelines and the LULUCF framework, suggesting that the CR_{baseline} and LSE_{baseline} baselines are expected to align with existing data structures. This situation highlights the uncertainty around how methodological consistency will be achieved between the certification framework and MS reporting mechanisms.

Thematic group five illustrates both horizontal and vertical policy coherence between CAP and the CRCF framework. However, it also identifies information and policy gaps, raising the question: How will potential overlaps in funding be managed between the CAP and the CRCF framework? Will land managers be expected to choose between guaranteed, action-based CAP payments, the more unpredictable, results-based CRCF certification framework, which requires the demonstration of a net carbon removal benefit over a five-year period and the ensured permanence of stored carbon? Or is the current CAP (2023–2027) simply a transitional mechanism designed to facilitate the uptake of carbon farming practices? These uncertainties are further exacerbated by market-related factors, particularly the question of whether carbon credit prices will be high enough to offset the risks faced by land managers. While the study could not provide definitive answers to these questions, the certification methodologies, which were still under development at the time of the study, are likely to contain the necessary details to resolve these ambiguities.

Thematic group six presents carbon farming as a green business model, which could provide land managers with an additional source of income, while signalling a shift away from traditional carbon offsetting towards carbon insetting [72], where carbon credits are purchased by companies within the same value chain. This approach encourages the adoption of climate-smart agriculture and forestry practices and reflects a growing corporate responsibility for Scope 3 emissions further down the supply chain [72]. This model exemplifies vertical policy coherence, as it links EU-level regulatory efforts under the CRCF Regulation with national-level implementation through private sector engagement and value chain-based emission reduction strategies. Fig. 4 summarises the thematic groups identified during the coherence assessment, along with the types of policy and regulatory documents analysed, and search terms used to structure the QCA.

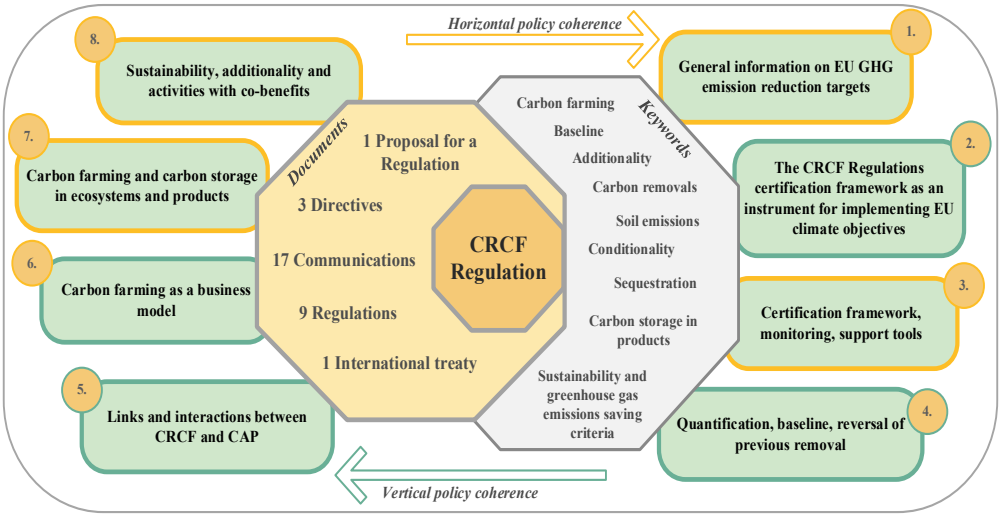

Fig. 4. Overview of analysed documents, search terms and thematic groups (thematic groups indicating horizontal coherence are marked with a yellow frame; those also showing vertical coherence are framed in green).

The certification framework established by the CRCF Regulation is not applied as a penalty or a mandatory obligation. Instead, it upholds the voluntary principle, functioning as an incentive mechanism to encourage farmers and other land managers to engage in carbon farming activities, while simultaneously delivering co-benefits such as biodiversity conservation and enhanced ecosystem services. While this approach positions the CRCF

Regulation as a constructive and flexible policy tool, it also raises a critical question regarding its sufficiency: would embedding such mechanisms into the mandatory structure of the CAP be more effective in achieving the EU's long-term climate objectives? The CRCF Regulation nevertheless represents a pivotal step toward positioning the EU as a global leader in the certification of carbon removals, spanning both land-based and industrial domains.

As a new instrument within the EU climate policy architecture, the CRCF Regulation holds substantial potential. However, its effectiveness will ultimately depend on how it is implemented across MS. Key challenges include clarifying certifiable carbon farming activities, defining robust and consistent baselines, ensuring environmental integrity of certification methodologies, and establishing transparent conditions for the use of carbon credits. Equally important will be the CRCF Regulations integration with existing mandatory policy instruments, such as the CAP, LULUCF Regulation EU 2018/841 and the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, to ensure alignment and avoid duplication. National policymakers will play a decisive role in shaping how consistently and purposefully carbon farming practices are supported and embedded within national support systems, advisory services and market mechanisms.

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STATEMENT

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