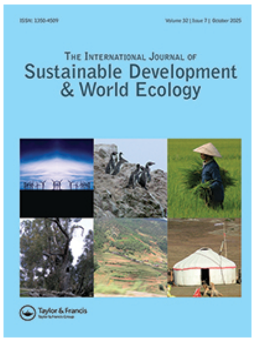

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The race for carbon in farmland: global mapping of the emerging voluntary market for soil carbon credits

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ABSTRACT
Carbon farming is increasingly promoted as a strategy to achieve net-zero climate targets. This paper examines voluntary carbon market programmes through a global inventory and discourse analysis to identify key actors and how they frame and implement carbon farming. Findings show that agri-chemical firms, agri-tech companies, and new carbon farming startups mainly target large-scale farmers in the Global North. These programmes promote a 'triple win' narrative – climate mitigation, sustainable agriculture, and farmer profit – under a regenerative agriculture branding. However, practical commitment to transformation is limited, often serving corporate interests. The study also highlights challenges in credit integrity and reflects on how soils are revalued as carbon sinks, contributing to debates on the prospects of carbon farming as a dual tool for climate action and agricultural sustainability.

KEY POLICY HIGHLIGHTS
- We explored key actors, interests, practices, and narratives that shape carbon farming as a strategy for climate action and agricultural sustainability.
- Most carbon farming programmes primarily target large-scale farmers in the Global North.
- Programs led by agrochemical and agri-tech companies tend to promote practices aligned with their own commercial interests.
- Some programmes, particularly those developed by newcomers, take a more inclusive, bottom-up approach to tailor their carbon farming practices.
- When carbon is treated as a tradable commodity, there is a risk that broader environmental and social goals will become sidelined.
- Therefore, carbon farming programmes should be supported by governance mechanisms beyond voluntary markets.

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KEYWORDS
Carbon credits; voluntary carbon market; farming; regenerative; agriculture; climate

1. Introduction

'Carbon farming' – agricultural soil-carbon sequestration – has gained traction in science and policy as a promising strategy for achieving net-zero greenhouse-gas targets, while offering socio-environmental co-benefits such as improved soil health (Amundson et al. 2022; Moinet et al. 2023). Concurrently, programmes that generate verified agricultural carbon credits through carbon farming practices are rapidly being rolled out and integrated into the voluntary market, where companies and individuals purchase credits to compensate for their emissions (Oldfield et al. 2022; Paul et al. 2023; Raina et al. 2024). Although agriculture-based credits remain a relatively small segment of the voluntary carbon market, they are among the fastest-growing project categories (Ecosystem Marketplace 2024).

Revaluing soils for their carbon sequestration potential creates new socio-environmental dynamics with implications not only for climate action but also for the agricultural sector. In particular, persistent challenges and uncertainties surrounding the prediction, measurement and verification of soil carbon sequestration undermine the reliability of carbon farming as a climate-mitigation activity (Berta and Roux 2024; Don et al. 2024).

Extensive research on forest-based carbon projects has raised critical questions about the social distribution of benefits and risks (e.g. Fischer K, Giertta F, et al. 2019; Carton 2020). These concerns are equally relevant as agriculture emerges as a key site for carbon projects. Like other land-use interventions for climate-change mitigation, carbon farming may privilege certain landscapes and actor interests while marginalising others. At present, the voluntary market for agricultural carbon credits operates in a largely unregulated space. Programmes follow a patchwork of monitoring, reporting and verification protocols that vary in transparency and robustness (Black et al. 2022). This variability complicates market accountability (Oldfield et al. 2022; Paul et al. 2023) and makes it difficult for farmers to

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assess potential opportunities and risks (Phelan et al. 2024).

Because of the concerns listed above, and the growing momentum behind agricultural soil-carbon credits in the voluntary market, critical scrutiny of the actors, interests, procedures, practices and discourses that shape how carbon farming unfolds is warranted. An expanding body of scholarship is beginning to examine (i) the extent to which existing accounting and verification standards safeguard the integrity of soil-carbon credits and how these frameworks might be improved (e.g. Black et al. 2022; Oldfield et al. 2022); (ii) how programmes can be designed to attract farmers (Sharma et al. 2021; Raina et al. 2024); and (iii) the lived experiences of participating farmers. Nevertheless, comprehensive reviews and inventories of the evolving global voluntary market for agricultural soil-carbon credits remain limited (Paul et al. 2023), and analyses of what agricultural pathways that are being stimulated by carbon farming (Hackfort and Haas 2025).

We seek to address this gap by presenting a global inventory of carbon farming programmes that operate within the voluntary market. Our research questions are as follows: Who are the actors behind carbon farming programmes, and when and where have these programmes been implemented? How is carbon farming framed by programmes and who is it targeting? What are the terms and conditions for farmer participation? By answering these questions, we aim to contribute to ongoing debates on the potential and limitations of carbon farming as a dual tool for climate action and agricultural sustainability.

The structure of the article is as follows: We first provide a background of the development and key controversies of carbon faming, followed by a methods section where we describe our data collection strategy, thematic mapping of all programmes, and discourse analysis of selected programmes. Thereafter, we present and discuss our results in line with our research questions. Lastly, we conclude by reflecting on what development trajectories carbon farming programmes currently promote within the agricultural sector, and needs for governance mechanisms beyond voluntary markets.

2. Background

2.1. The acceleration of agricultural soil carbon sequestration as a climate measure

The potential of agricultural soils to serve as a carbon sink has been studied since the 1990s (Amundson et al. 2022). Nevertheless, employing agricultural soil carbon sequestration as a climate measure – particularly for offsetting – has for long been met with scepticism due to significant uncertainties (Oldfield et al. 2022; Berta and Roux 2024). With few exceptions, most notably Australia (Verschuuren 2017), countries have generally taken a cautious approach to including agricultural carbon credits in their compliance market emission trading systems (Black et al. 2022).

Since the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement, however, there has been a general shift in climate discourse towards the need for large-scale carbon dioxide removals, also known as 'negative emissions technologies', to achieve net-zero global emissions (Carton 2020; Jaschke and Biermann 2022). Subsequently, increasing attention has been paid to the use of natural systems and processes to sequester atmospheric CO_2 (Silva et al. 2022). While soils are the largest pool of terrestrial organic carbon (Friedlingstein et al. 2022), soil carbon has drastically declined globally due to agricultural intensification (Beillouin et al. 2023). The agricultural sector is currently a major source of greenhouse gas emissions and is highly vulnerable to climate change, yet progress in reducing its climate impact has been limited (Roe et al. 2019; Shukla et al. 2019). Against this backdrop, carbon farming has gained traction as a strategy for rebuilding soil carbon stocks and reducing emissions (Lal 2013; Dignac et al. 2017; Roe et al. 2019; Beillouin et al. 2023). The Intergovernmental Panel on Climate Change (IPCC) first recognised agricultural carbon sequestration as a mitigation option in its Third Assessment Report (2001). Its more recent Special Report on Climate Change and Land (IPCC 2022) identifies soil carbon sequestration in croplands and grasslands as among the most effective agricultural climate mitigation options (136).

Carbon farming typically encompasses strategies to increase carbon sequestration in soil and vegetation, and to reduce greenhouse gas emissions from farming activities. Practices include no- or reduced-tillage, cover cropping, agroforestry, crop residue management, crop diversification, and improved livestock and fertiliser management (Smith et al. 2008; Toensmeier 2016; Dignac et al. 2017). In addition to climate change mitigation, it is often emphasised that such practices provide multiple co-benefits like increased soil health and fertility, improved water retention capacity, reduced soil erosion and increased biodiversity, which are crucial for climate change adaptation and the overall sustainability of agriculture (Toensmeier 2016; Paustian et al. 2019; Sykes et al. 2020). Compared to other negative emission options, soil carbon sequestration is often favoured in policy circles, with emphasis on co-benefits and little mention of risks (Jaschke and Biermann 2022).

The past decade has seen the emergence of several initiatives promoting carbon farming. Notably, the '4 per 1000 initiative' (4p1000.org), launched by the French government at COP21 in 2015, has had a significant international impact by linking soil carbon restoration with food security and climate mitigation (Dignac et al. 2017). Another high-level initiative is the RECSOIL programme, launched by the Food and Agriculture Organization of the United Nations in 2019 to support the re-carbonisation of soils through carbon farming (FAO 2019). Carbon farming has gained further political legitimacy since the IPCC Sixth Assessment Report (2023) emphasised the critical role of agriculture and land use in climate action (108). This growing acceptance is evident in evolving policy frameworks. The European Union's Soil Strategy for 2030 (European Commission 2021) and its Farm to Fork Strategy (European Commission 2020) – both integral to the European Green Deal – explicitly identify soil carbon sequestration as a key mitigation measure. In the United States, building soil carbon has become a stated objective in various agricultural and climate policies (Gelardi et al. 2023), but this is now challenged under the Trump administration.[1] Australia, with its extensive experience in integrating agricultural carbon credits into its carbon market (Van Oosterzee et al. 2014; Evans 2018), is often cited as a forerunner in developing governance systems for carbon farming (Verschuuren 2022).

2.2. Key controversies around carbon farming as a climate measure

The ability of carbon farming to act as an effective and valid climate measure is subject to intense debate within the scientific community (e.g. Leifeld 2023; Paul et al. 2023; Günther et al. 2024) and beyond (Carbon Gap 2023; Friends of the Earth 2023). While a comprehensive review of such debates is beyond the scope of this paper, it is useful to highlight some of the key controversies to provide a broader context for our analysis. To ensure the validity of carbon credits, offsetting projects should follow several general principles, including permanence, additionality and prevention of leakage effects (Thamo and Pannell 2016; Paul et al. 2023). A growing body of research point to numerous challenges that carbon farming projects face in meeting these requirements.

A general definition of permanence is that carbon should remain sequestered for a minimum of 100 years – the estimated lifetime of one tonne of CO_2 in the atmosphere (Lin et al. 2013). However, long-term soil carbon sequestration in agricultural land is notoriously difficult to guarantee since soil carbon is inherently dynamic and volatile. While soils store organic carbon, they also constantly release carbon back into the atmosphere, thus these dynamics cannot easily be translated into the simple logic of offsetting (Berta and Roux 2024). Unlike geological carbon sequestration that stores carbon for millennia, soil carbon can quickly be reversed by changes in management, climate conditions or extreme events such as wildfires (Sommer and Bossio 2014; Schlesinger and Amundson 2019; Paul et al. 2023; Poeplau and Dechow 2023). Current carbon farming programmes typically 'solve' this challenge by redefining the permanence requirements to much shorter timescales and creating a 'credit buffer' to account for possible re-emissions (Smith et al. 2020; Oldfield et al. 2022). Although temporary carbon sinks may also provide measurable climate benefits (Leifeld 2023), this is deeply problematic as agricultural carbon credits are traded to offset greenhouse gas emissions.

Additionality implies that carbon sequestration or emission reduction must be additional in comparison with a baseline-scenario, meaning that the changes would not have happened without the carbon farming programme (Paul et al. 2023). However, predicting what farmers would have done without programme incentives is difficult as decisions regarding land management are complex and influenced by multiple factors (Phelan et al. 2024). If a farmer adopts a practice primarily to improve soil health or yields, or if overlapping adoption incentives exist (e.g. agricultural subsidies), it becomes hard to argue that the carbon credits are additional (Searchinger et al. 2018; Paul et al. 2023). The additionality principle has also given rise to equity concerns as it prevents early adopters from enrolling in credit programmes and could create perverse incentives to reverse practices (Barbato and Strong 2023; Ogle et al. 2023).

Carbon credit projects also need to demonstrate that there are no leakage effects, i.e. total farm-level greenhouse gas emissions should not rise due to management changes, and such changes should not lead to reductions in soil carbon sequestration and/or increased emissions elsewhere. For example, the cultivation of cover crops may lead to additional fertilisation, which may cause increased emissions (Ogle et al. 2023; Paul et al. 2023). Prevention and monitoring of leakage effects is a significant challenge for carbon farming programmes, especially as agricultural supply chains often span multiple countries or regions (Günther et al. 2024).

Another challenge for carbon farming programmes is the general lack of reliable and affordable scientific methods to quantify and monitor changes in soil carbon stocks (IPCC 2023, 789). Existing protocols for measuring, monitoring, reporting and verifying soil organic carbon (i.e. MRV protocols) have been criticised for not being robust enough to generate high-integrity carbon credits (Zelikova et al. 2021; Van Hoof 2023). Protocols differ widely in how stringently the principles of permanence, additionality and prevention of leakage effects are interpreted and applied, and in how changes in soil carbon stocks and net greenhouse gas emissions are estimated (Oldfield et al. 2022; Dupla et al. 2024). The large temporal and spatial variability of soil carbon stocks due to factors like soil type, moisture levels and biological activity imply major uncertainties regarding estimations and models (Paul et al. 2023). While protocols rely heavily on simulation models to ensure the authenticity of carbon credits, a comprehensive review of existing models shows that these are poorly validated and contain numerous flaws, making them inadequate for ensuring reliable carbon crediting (Garsia et al. 2023).

3. Methods

We employed two main methods: a broad global inventory and thematic mapping of carbon farming programmes and a discourse analysis of selected initiatives.

3.1. Identification and selection of carbon farming programmes for analysis

For the inventory, we included a diverse set of carbon farming programmes that aim to generate carbon credits for the voluntary market. Our selection criteria required that programmes: i) focus on crop or livestock farming practices (not only afforestation and reforestation); ii) target farmers in their marketing; iii) have a website with operational details; iv) were operational during the data collection period (March 2023-February 2024).

Through academic and non-academic literature, Google searches, and lists we obtained from webpages and personal communication, we identified 78 programmes that we reviewed manually, finally selecting 30 programmes based on our criteria. Our inventory is unlikely to be complete as there is currently no comprehensive global database of carbon farming programmes and new initiatives emerge continuously. Some of the programmes included in this study can also be found in the Voluntary Registry Offsets Database developed by Berkeley Carbon Trading Project (Barbara et al. 2025). However, many programmes identified in this study were not included in that database since they follow other (or no) protocols. To identify as many programmes as possible, a multi-step process was conducted, beginning with Google searches using terms like 'carbon farming', 'carbon offset agriculture' and 'voluntary carbon market agriculture'. There was no active search for programmes in other languages than English, thus our sample is biased towards the English-speaking world. The final Google search to identify new programmes was conducted on 2023. Additional programmes were identified through snowball sampling via references in initial searches, from academic and non-academic literature and lists shared by carbon farming actors and networks, e.g. Svensk Kolinlagring (personal communication) and the Soil Carbon Farming network (SCARF 2025). Websites for the programmes included in our study were frequently revisited during the empirical analysis, which concluded in February 2024.

In the initial analysis, we systematically compiled key thematic features for each of the 30 programmes, including: geographical location of programme and enrolled farmers; year of implementation; definitions of carbon farming, and crops and practices incentivised; enrolment requirements, costs and payments; contract length (indicating permanence), and; look-back period (indicating additionality).

We then inductively grouped the programmes into three categories based on the type of implementing actor: Agri-food and agrochemical corporations; agri-tech companies; and newcomers – organisations or companies created specifically to run carbon farming programmes. This categorisation assumes that motivations to engage with carbon farming differ between these groups, influencing the project designs and farming practices promoted. Agri-food and agrochemical corporations tend to have a long-term presence in the market for agricultural inputs, while agri-tech companies consist of a mix of old and new actors who offer different types of technological (more recently digital) solutions to farmers. In contrast, newcomers are typically start-ups with no prior presence on the market but established particularly for promoting carbon farming and carbon credit marketplaces (Figure 1). While there is considerable diversity within each of these broad groups, this categorisation serves as a heuristic that assists the analysis of potential commonalities and differences. Some, such as IndigoAg, straddle multiple categories, but were classified based on their primary role in carbon farming.

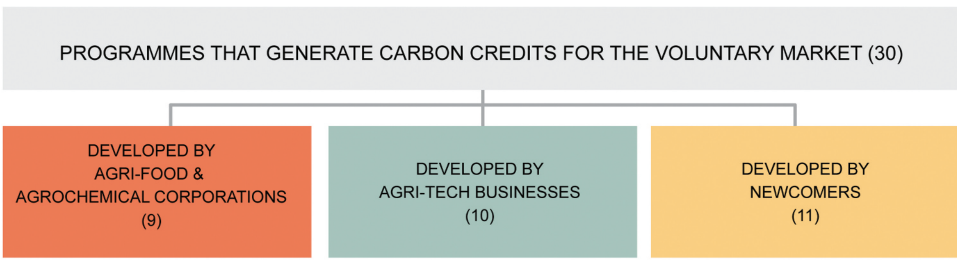

Figure 1. Carbon farming programmes selected for analysis and the categorisation of actor types.

Table 1. Selected carbon farming programmes from each of the three actor categories in the discourse analysis.

Actor group	Platform	Justification for inclusion
Agrifood and agrochemical corporations	Bayer	Agro-input giant with new but well-developed carbon farming platform
	Corteva	Agro-input giant with new but well-developed carbon farming platform, with very short contracts
	Truterra (Land O'Lakes)	Giant farmers' cooperative in the US
Agri-tech businesses	Indigo Ag	Well-known agri-tech company and one of the primary carbon farming actors in the US; also acts as a marketplace for other initiatives to sell, buy or generate carbon credits
	Agreena	Claims to be the largest soil carbon platform, leading in remote sensing, and owns the technology Hummingbird for monitoring, reporting and verification of carbon sequestration
	Boomitra	Claims to be the leading marketplace for soil carbon, relies on high-resolution satellite imagery and is the only initiative that has no geographical restrictions on where farmers generating carbon credits can be located
Newcomers	Svensk Kolinlagring	Non-profit bottom-up initiative that frames carbon faming as a vehicle for agricultural transformation, from a farmer's perspective
	Climate Farmers	For-profit bottom-up initiative that frames carbon faming as a vehicle for agricultural transformation and corporate climate action, from a farmer's perspective
	Nori[1]	Well-established platform for selling and buying carbon credits, with a specific programme for agricultural-based carbon credits
	Soil Capital	Focus on carbon farming as an offsetting opportunity for corporations. Links to some agribusiness giants (Cargill). Easy to join with no commitments, dynamic pricing and no prescribed practices (conventional or organic)

1.Nori shut down in September 2024 due challenges of a stagnant Voluntary Carbon Market (VCM) and a constrained funding environment. https://carbonherald.com/carbon-marketplace-nori-shuts-down/

3.2. Discourse analysis

Of the 30 programmes, we purposively selected 10 for discourse analysis from the three actor categories (Table 1). We aimed to include a diversity of programmes – both well-established (e.g. IndigoAg) and newer ones (e.g. Boomitra), both presenting carbon farming as an opportunity for sustainability transformations of agriculture and those primarily approaching it as a novel avenue for corporate carbon offsetting.

The discourse analysis focused on how actors promote their programmes and therefore builds on readily available information (including text and images) from each programme's main webpage. When necessary, additional program information was accessed through onward links. Drawing on Adger et al. (2001), the analysis focused on messages, narrative structures and policy prescriptions. Specifically, we examined how problems were framed to align with certain solutions Bacchi (2009) and how key actors were portrayed (Adger et al. 2001). This helped reveal broader causal narratives. Our initial analysis was guided by four key questions: How is carbon farming framed (e.g. descriptions, synonyms)? What problem(s) is carbon farming presented to solve? Who are the main target groups of their marketing? How do programmes position themselves in relation to carbon farming? From this, we inductively identified additional themes to capture recurring issues in the emerging discourse, including: Digitalisation; trust and legitimacy; flexibility in participation; benefits without risk; and co-benefits. Quotations from the discourse analysis are incorporated in the results and discussion section to support our findings.

4. Results and discussion

4.1. Who are the actors behind carbon farming programmes, and when and where have they been implemented?

Of the 30 programmes that met our selection criteria, nine are led by agrifood and agrochemical corporations, 10 by agri-tech businesses, and 11 by newcomers. The agrochemical companies include multinationals with annual revenues ranging from US $4 million to $115 billion. Some, such as Cargill, Corteva and Nutrien not only run their own carbon farming programmes, but are also involved in other programmes as investors, founders or credit buyers. For example, they are linked to programmes such as the Ecosystem Services Market Consortium (ESMC), the Soil and Water Outcomes Fund (SWOF) and Soil Capital (see Figure 3). Other ESMC founding members include General Mills, Land O'Lakes, McDonald's, Nestlé, Nutrien and Syngenta. SWOF, a subsidiary of the Iowa Soybean Association, is funded by Cargill and the Walton Family Foundation. These examples of actors playing multiple roles across carbon programmes illustrate the intricate linkages between major agri-food corporations in the global food system, reflecting a broader trend of corporate concentration and control over multiple aspects of the food system (Clapp 2021). The growing interest and investment in carbon farming by these corporations may reinforce these corporate ties. For example, the agri-tech Boomitra is heavily funded by the multinational fertiliser company Yara. Boomitra describes the collaboration as a way for Yara to provide solutions (i.e. inputs and mechanisation) to smallholder farmers in East Africa. This case also exemplifies the growing interest in digital tools among key players in the global food system (Clapp 2021), and how agrochemical corporations gain increased influence to target specific products to farmers enrolled in carbon farming programmes. Agri-tech businesses not only run their own carbon farming programmes but also develop and provide various data-driven agricultural tools, such as precision-farming software and digital tools for MRV. Indigo Ag, one of the most established companies in this category, owns and offers a range of digital products for MRV. Similarly, AgreenaCarbon uses its own technology, Hummingbird, for MRV of carbon credits generated in their programme. The actors who provide tech solutions for carbon farming generally emphasise the potential of technologies such as artificial intelligence (AI), blockchains and machine learning to quantify soil carbon. Carbon farming programmes run by newcomers primarily aim to provide platforms that connect farmers with companies or investors interested in purchasing soil carbon credits.

Most programmes (24 out of 30) were established after 2019, with all the agrochemical corporations entering the market after 2020 (Figure 2). This surge in soil carbon restoration efforts might be linked to the rising trend of net-zero pledges and other corporate climate commitments, with companies – particularly in the agri-food sector – seeking new strategies to meet these goals through carbon offsetting and insetting (i.e. carbon compensation within a company's own supply chain) (Tilsted et al. 2023).

In terms of geographic location, the programmes included in this study are concentrated in North America and Europe, and participating farmers are often based in the same country as the programme (Figure 3). However, it is not always clear where farms are located, e.g. the Danish agri-tech Agreena states that its carbon farming programme includes farmers in 14 European countries but does not specify where. In the way the programmers promote themselves, the discourse analysis shows a strong bias towards large-scale industrial farming. A minority of the programmes show an interest in low- and middle-income countries and regions, e.g. Nori claims to have programmes in Africa and South-East Asia and eAgronom is developing programmes in South Africa, Tanzania, Kenya and Rwanda. Boomitra has no geographical restrictions on where farmers can be located and claims to be 'inclusive for farmers and ranchers of all landholding sizes'.

4.2. How is carbon farming framed?

4.2.1. Carbon farming broadly framed as regenerative agriculture

Most programmes explicitly connect carbon farming to sustainability-related terms such as regenerative agriculture, conservation farming and agroecology. This positions carbon farming as an alternative to conventional practices, establishing a positive association between carbon farming and agricultural sustainability. The most frequent term is regenerative agriculture (19 out of 30 programmes; Table 2), often used interchangeably with carbon farming. For example, Soil Capital states: 'Regenerative agriculture has the potential to capture more carbon than it emits, while promoting biodiversity, water retention, and ecosystem health. It fixes the planet!'. This reflects the recent buzz around regenerative agriculture, largely driven by corporate actors who are investing in soil carbon sequestration to meet their climate commitments (Bless 2024; Wilson et al. 2024). The discourse analysis reveals varying degrees of specificity regarding what the programmes include under regenerative agriculture. As a reference point, it is worth noting that there is no agreement within academia on a precise definition of the term, but it generally involves practices aimed at reducing external inputs, building soil health, promoting agrobiodiversity and minimising nutrient leakage (Giller et al. 2021).

Three of the 30 programmes (SWOF, Agoro Carbon Alliance, Radicle) connect carbon farming with conservation agriculture, strongly connected with minimum or no-till practices (Giller et al. 2015). Bayer uses the term 'carbon-smart agriculture' and points to the

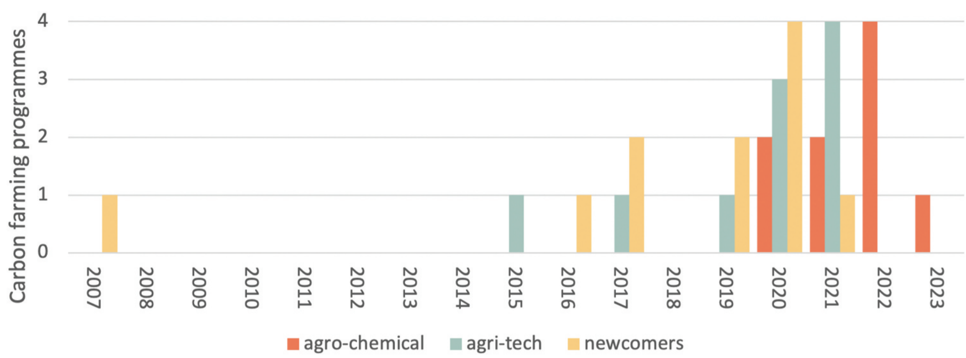

Figure 2. Timeline of the establishment of carbon farming programmes in the voluntary carbon market, categorised by actor type.

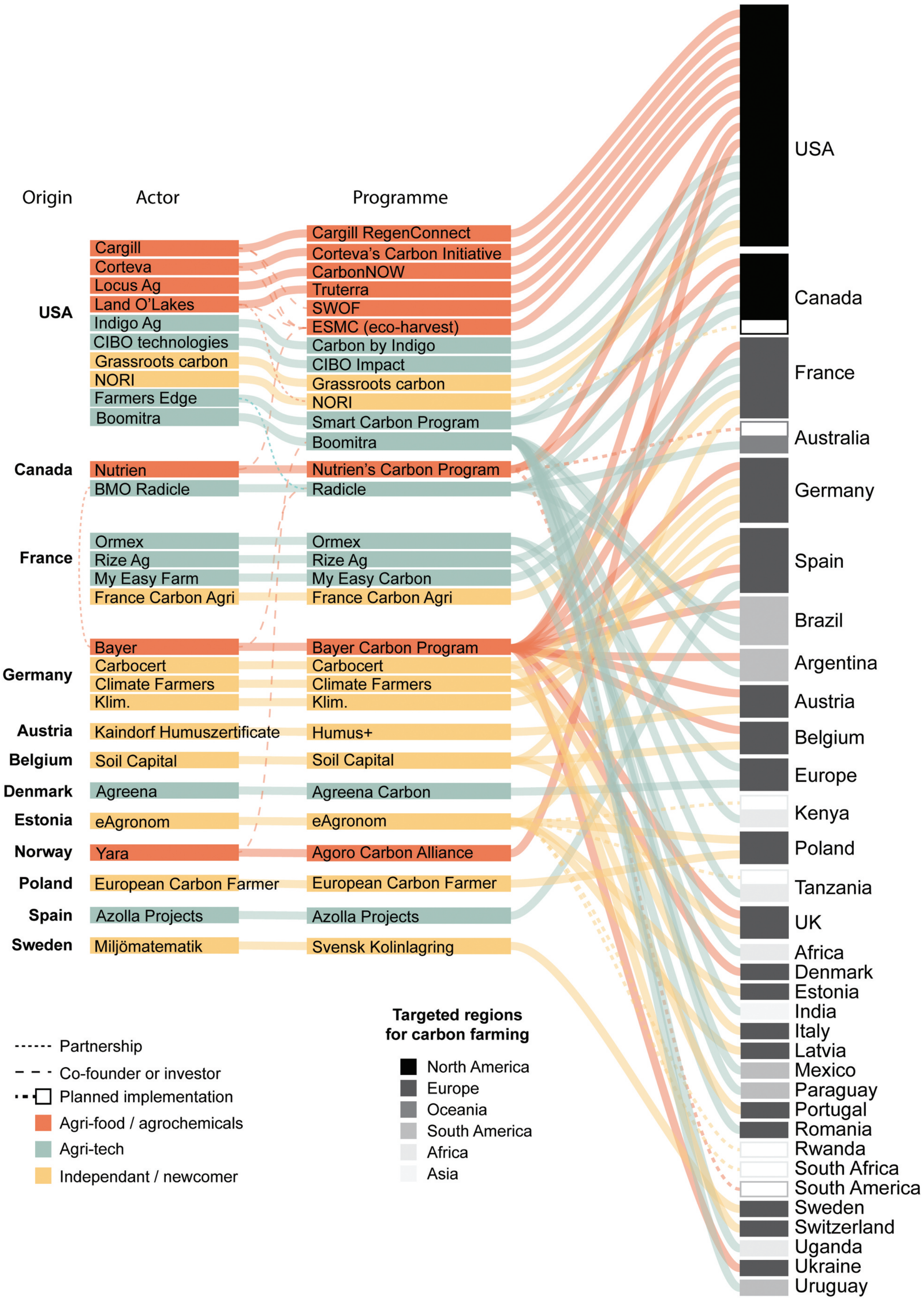

Figure 3. Origin and type of actor behind the carbon farming programmes analysed and the location of participating farmers*. Note: * The figure is based on information provided on the programmes own webpages. Dashed lines and hollow rectangles indicate planned expansions. Dashed lines between actor and programme indicates an actor's role as an investor, partner or buyer of carbon credits.

Table 2. Framing of carbon farming by all 30 programmes included in the study.

Carbon farming programme	Regenerative agriculture	Conservation farming	Climate/ Carbon Smart Agriculture	Precision farming	Agroecology	Sustainable agriculture	No term
Bayer Carbon Program	■		■				
Agoro carbon alliance		■					
RegenConnect (Cargill)	■						
Corteva's Carbon Initiative							■
Nutrien's Carbon Program			■				
CarbonNOW (LocusAg)							■
Truterra	■						
SWOF		■					
ESMC	■						
Carbon by Indigo							■
AgreenaCarbon	■						
Farmers edge				■			
CIBO	■						
ORMEX	■						
Rize ag					■	■	
My Easy Carbon	■			■			
Azolla	■						
Radicle		■					
Boomitra	■						
Nori	■						
Svensk Kolinlagring	■						
Soil Capital	■						
Carbocert	■						
Humus+							■
France Carbon Agri							■
European Carbon Farmer	■						
Climate Farmers	■						
Grassroots Carbon	■						
eAgronom	■						
Klim.	■						
Total	**19**	**3**	**2**	**2**	**1**	**1**	**5**

*Highlighted cells indicate terms used on the programmes' webpages, and colours indicate the type of actor running it.

unique position of farmers and the agricultural sector in contributing to climate benefits, stating that:

> Farmers around the world, and the billions of acres of cropland they manage, are in a great position to reverse the present climate trend. They can do this through *carbon-smart* agricultural practices. Methods like cover crops and conservation tillage keep the soil covered and undisturbed so that carbon can't escape

. We interpret Bayer's choice of term as a strategic shift away from the term 'climate smart agriculture', possibly to distance themselves from the negative publicity surrounding the latter (Newell and Taylor 2018), while still invoking its positive associations and general recognition.

4.2.2. Crops and farming practices promoted

The term carbon farming has for long been associated with carbon sequestration in vegetation and soils, along with social and environmental co-benefits (Evans 2018). However, we find that it is currently being increasingly linked to specific farming practices and crop choices. Even though programmes incorporate a range of agricultural practices under carbon farming, it is often unclear how these practices are translated into carbon credits. While many programmes use language that emphasises diversity – such as 'making farmland more diverse' (Climate Farmers), and 'promoting biodiversity' (Soil Capital), the actual incentives for enhancing biodiversity are often limited, especially in programmes run by agrochemical and agri-tech actors. All agrochemical actors focus on specific commodity crops such as corn, soybeans and wheat, aligning with their business models, while also promoting leguminous cover crops. For instance, Corteva's approach to 'increasing biodiversity' means adding legumes to cover crop blends or introducing a new cash crop in the crop rotation (e.g. wheat in a corn-soy rotation). Most agri-tech businesses similarly promote a narrow set of crops but recommend slightly more diverse practices, such as annual-perennial crop mixes (ORMEX) or integrated livestock-crop systems (Radicle). In contrast, newcomers generally emphasise more diverse farming systems without prescribing specific crops. For example, Svensk Kolinlagring bases its carbon credit criteria on broader system attributes, such as maintaining 70% soil coverage with living vegetation and cultivating at

Table 3. Overview of farming practices promoted by the different carbon farming programmes, sorted by the most frequently mentioned measures from left to right.

Carbon farming programme	Reduced till	Cover crops	Nutrient management	Crop rotation	Grazing management	Agroforestry and hedges	Incorporation of compost and plant residues	Reduced fuel use
Bayer Carbon Program	■	■						
Agoro carbon alliance	■	■	■	■	■			
RegenConnect (Cargill)	■	■						
Corteva's Carbon Initiative	■	■	■	■				
Nutrien's Carbon Program	■	■						
CarbonNOW (LocusAg)	■	■			■			
Truterra	■	■						
SWOF	■	■						
ESMC	■	■						
Carbon by Indigo	■	■	■	■				
AgreenaCarbon	■	■	■	■			■	■
Farmers edge	■							
CIBO	■	■	■	■				
ORMEX	■	■	■	■				
Rize ag		■	■	■				■
My Easy Carbon	■	■	■				■	
Azolla	■		■	■	■	■	■	
Radicle								
Boomitra	■	■	■	■	■			
Nori	■	■	■	■				
Svensk Kolinlagring	■	■	■	■	■	■		
Soil Capital	■	■	■	■				■
Carbocert						■		
Humus+	■	■				■	■	
France Carbon Agri					■	■		
European Carbon Farmer	■	■	■	■				
Climate Farmers	■	■			■	■		
Grassroots Carbon					■			
eAgronom	■	■	■	■		■	■	■
Klim.	■	■	■	■	■			■
Total	**25**	**24**	**16**	**15**	**9**	**7**	**5**	**5**

*Highlighted cells indicate what was mentioned on the programmes' webpages, and colours visually emphasise the actor group to whom the programme belongs.

least four crop species per year. Although the effects of biodiversity on soil carbon are uncertain, there is growing evidence that plant diversity generates more soil organic carbon than monocultures (Chen et al. 2020).

We identify five key practices central to carbon farming programmes: reduced or no-till, cover cropping, nutrient management, crop rotation and grazing management (Table 3). These practices are also highlighted as core components of carbon farming by other studies (McDonald et al. 2021; Raina et al. 2024). While no-till is traditionally promoted as a method to reduce soil erosion, its effectiveness for carbon sequestration remains contested, as its potential varies significantly by site (Powlson et al. 2014; White et al. 2018; Blanco-Canqui 2021).

We observe that agrochemical corporations typically promote less transformative changes in farming practices, often centring their programmes around no-till and cover cropping, likely motivated by their interests in selling agro-inputs (Bless 2024). No-till farming is known to increase weed pressure (Maheswari 2021; Colbach and Cordeau 2022), which in turn drives demand for herbicides and herbicide-tolerant seeds – products from which companies like Corteva and Bayer derive significant revenue. Although their programme websites for carbon farming do not explicitly tie no-till practices to the marketing of such products, these are heavily promoted on other company channels targeting farmers.

In most programmes, improved nutrient management means reducing synthetic fertiliser use through precision farming technologies or increasing organic fertilisation. Climate Farmers support integrated crop-livestock systems for enhanced nutrient cycling, while Corteva emphasise improved fertiliser efficiency – specifically through 'improved nitrogen timing', a practice likely linked to their nitrogen-stabilising product (Corteva 2024). This example illustrates how carbon farming measures are often designed to align with the company's own products and services.

Programmes that incentivise grazing management focus on rotational grazing and crop-livestock integration. For instance, Agoro Carbon Alliance offers carbon credits based on grazing management changes (e.g.

stocking rates, grazing days), biodiversity (e.g. adding species) and fertilisation to improve forage. Other programmes mention livestock but are less specific about how grazing management is rewarded. Klim, for instance, identifies livestock integration as a core principle of regenerative agriculture, yet it is unclear how this is reflected in their payment structure.

Less commonly incentivised practices include incorporating crop residues into fields, optimising fuel and irrigation use, and establishing agroforestry systems. Only a few newcomers (like Svensk Kolinlagring, Carbocert and European Carbon Farmers) emphasise that farm management should be site-specific and determined by the farmer. This contrast in engagement models across programmes – from top-down to bottom-up – highlights not only differing degrees of farmer autonomy in designing carbon farming strategies but also important trade-offs between flexibility and the complexity of translating diverse practices into carbon credits while ensuring consistent and robust MRV procedures.

4.2.3. Co-benefits and win-win framings of carbon farming

In promoting carbon farming, programmes frequently adopt positive yet vague language, using phrases like 'help repair our planet' (Bayer) and 'driving economic and environmental sustainability' (Agreena). Across all three actor groups, carbon farming is typically framed as a multifaceted solution – benefiting climate, agriculture, and business alike. It is presented as a promising opportunity for farmers to advance agricultural sustainability, while offering other companies a new avenue for climate action through investment in soil carbon credits.

For example, Climate Farmers assert that '[m]ore and more companies are looking to support farmers' transition to regenerative agriculture through the voluntary carbon market. This delivers a win–win solution for society, the environment, and you as a farmer'. Similarly, IndigoAg present soil carbon credits as an opportunity to simultaneously build 'resilient soil and a more profitable operation'. Notably, Corteva emphasises financial incentives over other benefits, promising to 'get you the most money for your soil health practices' and assuring farmers, 'we'll help you get paid for your soil health'. Programmes also commonly highlight a range of co-benefits associated with carbon farming, including improved crop productivity, enhanced biodiversity, better soil health and water retention, and reduced erosion. However, as Lin et al. (2013) point out, trade-offs can emerge between measures that maximise carbon sequestration and those that prioritise other agronomic benefits. When financial rewards are tied solely to calculated climate benefits, with other positive outcomes treated merely as co-benefits, land managers may opt for methods that maximise carbon credit output with the lowest effort or cost.

4.3. Who is carbon farming targeting?

Carbon farming programme webpages primarily target two audiences: farmers, who are encouraged to enrol, and investors, who are offered opportunities to purchase carbon credits. By enrolling, farmers become part of broader networks that may serve interests beyond their own operations (Fairbairn and Kish 2022). Most carbon farming programmes are designed, either directly or indirectly, for large-scale farms, with minimum size requirements often exceeding 500 acres (Agoro Carbon Alliance, CarbonNow). Enrolment typically requires registering farm operation data and adhering to detailed reporting protocols. This bias toward larger operations has been noted by others (Barbato and Strong 2023) and is evident when analysing the images on the programme websites. Images frequently feature white farmers, expansive fields, tractors and digital tools. The focus on commercial farmers with access to capital and technology stands in sharp contrast to carbon offset projects in the forestry sector, which often centre on smallholder farmers in the Global South (Carton and Andersson 2017; Fischer and Hajdu 2018).

One notable exception is the agri-tech company Boomitra, which allows farms as small as 0.5 acres to participate and explicitly promotes inclusion of smallholders in agricultural carbon markets. However, Boomitra also heavily focuses on digitalisation and advanced technologies in its marketing – claiming to use satellite and AI technology for MRV of carbon credits globally. As Green (2023) discusses, there are high hopes that agri-tech innovations could transform agriculture through smart, efficient and sustainable practices related to precision farming and data-driven decision-making. In carbon farming, such technologies may also reduce the high costs of soil sampling (Kyriakarakos et al. 2024). However, this reliance on detached, automated systems also risks marginalising farmers' agency in shaping carbon farming practices while raising concerns about data privacy, security, and the ownership of sensitive farm data (Bakker and Ritts 2022; Fairbairn and Kish 2022).

4.4. What are the terms and conditions for farmer participation?

4.4.1. Contract length and lookback periods as proxies for permanence and additionality

Many carbon farming programmes highlight their flexibility, emphasising that participation does not require farmers to compromise their preferred agricultural methods. For example, Agreena state: 'We encourage implementing your transition to climate-friendly farming at your own pace', while Truterra reassures farmers that their land, practices and investments are tailored to their specific needs. Similarly, Corteva affirms that farmers can 'change field plans as needed' without worrying about financial penalties. This flexible, farmer-centric approach portrays carbon farming as low-risk and appealing for participants.

Contract durations across the examined programmes vary considerably, but are remarkably short, ranging from no commitment to 20 years (see Table 4). There is no clear pattern between contract length and the type of actor offering the programme. Commitments of 5 years (7 of 30 programmes) or 10 years (6 of 30) are most common. Notably, many (12 of 30) do not clearly specify contract length, while others explicitly promote opt-out flexibility to attract participation. For instance, Rize ag advertise 'no long-term commitment' and Soil Capital promote 'no binding commitment – no lock in. You are free to leave the programme at any time'.

Yet, maintaining soil carbon stocks requires ongoing, consistent practice (Paul et al. 2023). Short contract durations and flexible exit options therefore undermine the permanence of carbon sequestration. While few clearly address this issue, Nori openly depart from the conventional 100-year permanence standard, instead guaranteeing permanence for just 10 years. Nori defend this position by arguing that long-term guarantees are unrealistic for soil-based solutions. They also argue that a 10-year commitment is reasonable because 'maintaining a fair and equitable marketplace is important' and assert that 'farmers are primarily interested in restoring their soil, making subsequent reversals in soil health unlikely'. However, research on agricultural decision-making and technology adoption suggests that this assumption is overly simplistic (Burton et al. 2008; Fischer K, Sjöström K, et al. 2019). Farmers frequently face uncertainties related to market conditions, climate variability, and evolving land-use demands, all of which may hinder long-term engagement with carbon farming. While temporary carbon sinks can still provide climate benefits (Leifeld 2023), issuing carbon credits without durable guarantees remains problematic due to the risk that carbon gains may not be sustained.

As regards additionality, transparency about how it is defined and ensured varies across programmes. Some – such as Bayer, CarbonNOW and Truterra – permit 5-year 'lookback periods', allowing participation of early adopters of practices. While this may avoid penalising proactive farmers, it challenges the core principle of additionality. In contrast, programmes like Soil Capital and Svensk Kolinlagring permit early adopters by defining additionality against regional or national business-as-usual baselines. As illustrated in Table 4, most initiatives do not clearly state if lookback periods are allowed. One exception is Corteva, which explicitly note: 'We do not offer carbon credits for historical practices at this time'.

4.4.2. Costs and payments for farmers

Farmers' ability to participate in carbon farming schemes – and the scalability of these programmes – depends significantly on enrolment costs, expenses, and earnings from carbon credits (Dumbrell et al. 2016; Raina et al. 2024). Although most programmes reviewed do not specify a minimum land requirement (see Table 4), associated costs suggest that farmers must enrol relatively large land areas to achieve meaningful returns.

For example, AgreenaCarbon charge a monthly fee of €100 for platform access, while offering approximately €25 per carbon credit (1 tonne CO_2e). They also impose an additional transaction fees of 15–30% when farmers sell carbon credits, whether through their platform or externally. Soil Capital advise farmers to enrol at least 100 hectares to ensure profitability, offering a minimum payment of £23 per tonne of CO_2e. Participation in their five-year programme requires an upfront investment by farmers of £5,880 (excluding VAT) for baseline assessment and annual diagnosis. In most programmes, 15–25% of the generated carbon credits are withheld to cover administrative, monitoring and verification costs, and/or to serve as a buffer against quantification uncertainties and non-permanence.

While a few programmes (Svensk Kolinlagring, Corteva, and Boomitra) offer free enrolment, most charge annual fees for access to data and consultancy via proprietary software platforms. For instance, Bayer's Fieldview costs US$99/year, while eAgronom's Farm Management Software charges €0.5/ha (with a €250 minimum).

Software and service fees also represent new corporate revenue streams as companies monetise data – either through direct sales or by leveraging it to promote their own agricultural products and services (Shelton et al. 2022). Furthermore, many programmes retain ownership of the generated carbon credits, paying farmers only a portion of their market value. At the same time, they may impose long-term carbon sequestration obligations and claim exclusive rights to farm data (Hackfort et al. 2024).

Payments to farmers vary widely across programmes. Some offer fixed credit prices, while others link payments to fluctuating carbon market rates (see Table 4). Some programmes, such as ESMC and Rize ag, guarantee minimum payments of US$15 and €25 per tonne of CO_2e, respectively, allowing farmers to benefit from rising prices. Humus+ is the only programme that explicitly offers results-based payments, compensating farmers based on verified increases in soil carbon stocks. Most programmes, however, rely on action-based payments, which are easier to implement

Table 4. Terms and conditions of participation, along with costs and payments, and standards for carbon credits/certificates.

Carbon farming programme	Contract length (years)	Minimum field size	Payment	Cost	Lookback period
Bayer Carbon Program	10	4 ha or 10 acres	$3-9/ha/yr	US$99/yr for software; US$550 starting fee	5 years
Agoro carbon alliance	10	500 acres	market competitive prices		
RegenConnect (Cargill)	3	No minimum/maximum acre requirement	$25/tonne CO2e		
Corteva's Carbon Initiative	5		$20/tonne CO2e	No fees	No
Nutrien's Carbon Program		Pilot phase	Not stated		
CarbonNOW (LocusAg)		500 acres	$9-12/acre/yr (performance bonus if Locus Ag biologicals are shown to increase SOC)	No fees, the only expense you will have is to purchase our biological products	5 years
Truterra	1		$5/acre/yr (strip or no-till and/or cover crops) $10/acre/yr (nitrogen management)		5 years
SWOF	1		$35/acre/yr		
ESMC	5 (20 year maximum)	No minimum	$15/tonne CO2e minimum	Per-unit cost recovery fee from ecosystem service outcomes transactions	
Carbon by Indigo	5	150 acres	$15-30/tonne CO2e	25% to Carbon by Indigo	
AgreenaCarbon	10	No minimum	€25/tonne CO2e	€100/month to access the platform; 15% to Agreena for verification and issuance costs; 15% fee if Agreena sells certificates	
Farmers edge	"No long-term commitment"				
CIBO					
ORMEX					
Rize ag	1		€25/tonne CO2e minimum	€199/year to access data about farm; €299/yr to enter carbon programme and access potential earnings	
My Easy Carbon					
Azolla Projects					
Radicle					
Boomitra		Any size (0.5 acre to >100 000 acres)	Agreed-upon revenue from share of carbon credit	No fees, but agreed-upon share of credit	

(*Continued*)

Table 4. (Continued).

Nori	10	Any size	$10-22/tonne CO2e	Verification cost $3,000-5,000 for a 10 yr contract	
Svensk Kolinlagring	5	4 ha	1000 SEK/ha/yr	1/3 to Svensk kolinlagring for support, measurement and verification	Farmers' performance compared to a standardised baseline for Sweden
Soil Capital	No commitment	Recommends minimum 100 ha to ensure financial benefits	€27.5/tonne CO2e	£5,880 excluding VAT	Farmers' performance compared to a fixed regional reference
Carbocert	3		€ 30/tonne CO2e	Costs for soil samples are deducted from the sold credits	
Humus+	10-12		Not stated, but 2/3 goes to farmer		
France Carbon Agri	5		€30-35/tonne CO2e	A share of the certificate to FCAA	
European Carbon Farmers				€3 to FCAA; €5 to programme developer	
Climate Farmers	10	>50 ha		35% commission to cover the project development, verification, monitoring, issuance, and sales of credits	
Grassroots Carbon	5	1000 acres	Determined on a year-to-year basis	US$200-750/yr for software; 20% of credit	
eAgronom	20	No minimum, but at least 200 ha as a rule of thumb	€30/CO_2e minimum	€0.5/ha (€250 minimum) for eAgronom Farm Management Software	
Klim.	5		€2-273/yr	It varies	

Colours represent the actor group to whom the programme belongs. Blank cells mean that the information is not contained on the programme's webpage.

but require lower standards for monitoring, reporting and verification (MRV) than result-based systems (Raina et al. 2024).

This approach facilitates rapid implementation of carbon farming but introduces uncertainly about actual carbon sequestration outcomes. In this context, trust-building becomes central to programme legitimacy – especially given ongoing public scepticism about the unreliability of soil carbon markets. Concerns about legitimacy stem from contested debates on carbon farming as a valid climate measure, inconsistent accounting and certification standards, and the widely varying terms for participation (Barbato and Strong 2023). In response, programmes frequently use trust-building rhetoric to portray carbon farming as credible and low-risk. Corteva, for instance, claims, 'There's a lot of noise in carbon, but one voice you trust'.

Programmes also seek to build credibility by highlighting third-party evaluations, staff expertise, and the use of certified, standardised and precise tools to measure soil carbon changes and ensure the authenticity of carbon credits. Soil Capital, for example, state that they have had 'agronomists working alongside farmers for more than 10 years' and that 'our roots are firmly planted in agriculture'. Another common strategy for trust-building involves showcasing programme partners, supporters, or collaborators on their webpages to strengthen perceived legitimacy by association with established actors.

At this early stage in the development of agricultural carbon markets, there is a clear race among programmes to attract both farmers and investors. This appears to be driven, in part, by fears of a future 'supply squeeze' of available carbon farmers and farmland (Erb et al. 2024; IPES-Food 2024). The discourse analysis reveals a competitive landscape, with many programmes promoting carbon farming as a new, low-risk revenue stream for farmers. Corteva promise 'premium prices', while Agreena reassures farmers that they will be paid even before certificates are issued, offering 'pricing certainty' and transforming 'no-till efforts into no-hassle economics'.

5. Conclusions

This paper has examined the rapidly evolving voluntary market for agricultural soil carbon credits through an inventory and thematic mapping of carbon farming programmes, supplemented by discourse analysis of selected initiatives. Our analysis explored the key actors, interests, practices, and narratives shaping carbon farming as a climate strategy. Such scrutiny is essential, as carbon farming gains increasing attention and political legitimacy – trends with significant implications for both climate action and agricultural development. Most carbon farming programmes have emerged within the past five years, largely in response to corporate climate commitments that drive demand for new carbon offsetting and insetting opportunities. These programmes primarily target large-scale farmers in the Global North and frequently present carbon farming as a triple-win solution – delivering global climate benefits, ecological sustainability and financial benefits for farmers. Terms like regenerative agriculture are often invoked to convey this synergy, yet most programmes provide limited details on what regenerative agriculture entails or its potential to transform agricultural systems. This suggests that such a terminology functions more as a strategic branding than as a commitment to systematic change.

In terms of eligible practices, carbon credits are most commonly linked to reduced/no-till, cover cropping, crop rotation, and nutrient and grazing management. The emphasis on reduced/no-till and cover cropping is especially pronounced in programmes led by agro-chemical corporations, revealing a narrow and selective interpretation of regenerative agriculture. While these practices may contribute marginally to diversification in farming systems – for example, by adding a crop to a basic two-crop rotation – they largely remain within the bounds of industrial annual cropping and offer limited potential to address the broader unsustainability of the agricultural sector.

Our analysis highlights how many carbon farming programmes are designed to align with the commercial interests of agrochemical and agro-tech firms. This is evident in the promotion of practices like no-till farming, which support herbicide use and herbicide-tolerant crops, and in the integration of proprietary digital tools and platforms. Major corporate agri-food actors often have multiple roles across carbon farming programmes – funders, implementers, and data service providers – raising concerns about deepening corporate control in food systems. This suggests that leaving corporate interest to define carbon farming as a climate strategy may entrench existing power dynamics. Particularly problematic is the reliance on company-owned digital infrastructure, which reflects broader critiques of agricultural digitalisation that emphasise growing corporate influence over data, technology and advisory services – ultimately limiting farmer autonomy.

Nonetheless, our analysis demonstrates that there are alternatives to the way dominant actors frame carbon farming to preserve status quo– some programmes, particularly those developed by newcomers, take a more inclusive, bottom-up approach and tailor their strategies to specific local contexts. They tend to present carbon farming as a vehicle for transforming agricultural systems, and empathise co-benefits beyond carbon sequestration, such as soil health, biodiversity and climate adaptation. However, we still see the risk that when carbon is treated as a tradable commodity, these broader environmental and social goals may become sidelined.

While flexible, farmer-centric strategies can foster locally relevant solutions and generate important co-benefits, they also complicate the standardisation needed for robust MRV systems. The technical precision required for carbon crediting may constrain the potential of transformative models, particularly when these models rely on diverse and complex agroecosystems. In addition, the digital technologies enabling such quantification may favour simplified and uniform farming systems, running counter to diversity and ecological complexity as typical principles of agricultural sustainability.

Drawing on critical debates about agricultural carbon credits, we find that carbon farming programmes face persistent challenges in demonstrating core carbon market criteria: accurate measurement of sequestration, permanence, additionality, and avoidance of leakage. This arguably casts serious doubt on the reliability of soil carbon as an offset mechanism. Still, agriculture remains central to climate action – both due to its substantial emissions and its vulnerability to climate change. The growing focus on soil carbon is therefore encouraging, but framing matters.

Echoing Moinet et al. (2023), we argue for a conceptual shift: from focusing on 'soils for carbon' to embracing 'carbon for soils' (2384). This reframing places soil carbon sequestration within a broader agenda for agricultural sustainability, emphasising soil health, biodiversity, and climate resilience – rather than as a strategy for offsetting emissions. For genuine progress, we believe in soil carbon initiatives that support farmers in adopting practices that aim to build soil health, biodiversity, and climate resilience, supported through a wider set of governance mechanisms beyond voluntary markets. Ultimately, focusing on carbon for soils rather than soils for carbon requires political will to prioritise long-term ecological and social benefits over carbon commodification.

A major limitation of this study is that the global inventory of carbon faming programmes is incomplete, partly due to their rapid emergence and closure. For example, during the course of this study, one established programme (NORI) shut down, and Climate Farmers began stepping away from carbon markets.[2] While programme webpages are useful for analysing the outward marketing of carbon farming – our focus here – they offer limited detail on actual operations. Interviews and reviews of e.g. strategic documents and financial reports could provide deeper insights into how companies operationalise carbon farming. Further research is also needed to examine farmers' perspectives on carbon farming, their participation in such programmes, and the ways these initiatives influence farmer decision-making and agricultural development pathways.

Notes

1. " Trump administration cancels $3 billion climate-friendly farming program". https://www.reuters.com/world/us/trump-administration-cancels-3-billion-climate-friendly-farming-program-2025-04-14/
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