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The political economy of carbon farming: Analyzing agribusiness' accumulation strategy and the imaginary of soil carbon markets

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ABSTRACT

The global food regime plays a significant role in accelerating the climate crisis. Carbon Farming (CF) has emerged as a new strategy aimed at reducing emissions and removing carbon from the atmosphere. Major agribusiness corporations, such as BASF, Bayer, Cargill, Corteva, Syngenta, and Yara International, are driving the development and promotion of CF schemes as part of climate-smart agriculture. In this paper, we analyze their motivations, approaches, and the material and discursive practices behind this from a Cultural Political Economy perspective. Using a qualitative analysis of documents, websites and interviews we identify *infrastructuring, assetization* and *incorporation* as foundational components of the accumulation strategy, while *robust carbon measurement, soil carbon markets*, and *co-benefits* are key components of the imaginary related to CF. We conclude that although the concept of CF remains somewhat vague, it resonates with problematic patterns seen in other sectors, particularly regarding incumbency and the risk of mitigation deterrence.

1. Introduction

The global food regime significantly contributes to global greenhouse gas (GHG) emissions, biodiversity loss and soil degradation (Newell and Taylor, 2018; IPCC, 2019). Sustainable agri-food systems are key to the objectives of the European Green Deal (EGD), which aims to address this nexus via the Farm to Fork Strategy, and among other things, by promoting carbon sequestering practices (also called regenerative agriculture).[1] In its latest report, the Intergovernmental Panel on Climate Change (IPCC) has mentioned agricultural soil carbon sequestration as an important mitigation option (IPCC, 2022). Against this background, the European Commission (EC) is advancing soil carbon sequestration standardization and certification initiatives under the term Carbon Farming (CF). CF is propagated in the European Union (EU) and beyond as a new strategy of responding to the agricultural sectors' responsibility for climate mitigation. It is an umbrella term that covers a spectrum of approaches, from a set of management practices to a business model. Companies and international institutions such as the EC promote carbon-sequestering practices and the generation of tradable credits through various initiatives, labeling it a "green business model" that rewards land managers and promotes biodiversity (EC, 2020: 8). Drivers of soil carbon markets include large corporations, start-ups, governments, and a range of political institutions. Governments and private companies invest in this facet of climate-smart agriculture (CSA), which neatly aligns with technological paradigms such as precision farming and digital agriculture (Newell and Taylor, 2018; Hackfort 2023). While voluntary soil carbon markets are already established in the United States, (Scherger, 2022), the EC aims to establish standards with the recent Carbon Removal and Carbon Farming Directive (CRCF), a regulation that certifies carbon removal and facilitates carbon credits as financial incentives (EC, 2024). Globally, large agribusiness companies and numerous start-ups are developing CF programs, creating methodologies, and implementing monitoring, reporting, and verification (MRV) technologies. These efforts include platforms for data

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[1] Regenerative agriculture (RA) refers to a set of agricultural practices, such as no-till farming, the use of cover crops, and reducing external inputs, that enhances soil health and biodiversity and reduces GHG emissions (Bless, 2023). RA has somewhat superseded "climate-smart agriculture" (CSA), another concept used by corporations and international organizations like the FAO to denote efforts aiming to increase agricultural productivity and mitigate and enhance resilience to climate change (Newell and Taylor, 2018). Many actors seem to have moved away from CSA; instead, they are now promoting RA as a new sustainable approach. As a result, scholars have highlighted the risks of corporate cooptation in regenerative agriculture, arguing that, unlike agroecology, it offers limited transformative potential for agricultural production due to its failure to address issues of power and equity (Beste, 2021; Bless, 2023).

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collection, with the aim of reshaping agriculture into what is now referred to as an "agri-carbon landscape." (Ag Funder News, 2022).

CF involves practices to enhance sequestering and storing of carbon and/or reducing GHG emissions at farm level through, for instance, agroforestry, soil protection measures like cover crops, conservation tillage, and hedgerows; and improving fertilizer use efficiency to cut nitrous oxide emissions (McDonald et al., 2021; EC, 2024). In order to do so, so called results-based payments (as opposed to action-based payments) for the new agricultural practices become inextricably linked to digital technology for measurement, computational modeling and monitoring soil carbon (Raina et al., 2024). The idea of using these technologies to provide real-time data on crop growth, soil health, and greenhouse gas emissions neatly fits into what the EGD refers to as the green and digital "twin transition" with digital technology as "a critical enabler for attaining the sustainability goals of the Green Deal" (Muench et al., 2022).

With agribusinesses developing and promoting CF schemes as a solution for sustainable and climate-smart agriculture, their motivations, approaches, and practices merit analysis. To this end, we ask: how and why do incumbent agribusiness companies engage with Carbon Farming, and what are the implications of their activities? To answer this question, we analyze the material practices and imaginaries of powerful corporate actors in the agri-food system. With the term "imaginaries," we refer to the semiotic dimension, that is the social production of meaning by large agribusiness corporations via discursive practices. "Material practices," meanwhile, refers to these corporations' actions and strategies that extend the semiotic, for instance, the infrastructure and technology they create and operate.

We focus on six agricultural corporations: BASF, Bayer, Cargill, Corteva, Syngenta and Yara International. These major firms promote soil carbon sequestration practices to farmers, while other agribusiness and agritech players such as Nestlé or Microsoft embrace this trend claiming to reduce their supply chain's climate impact by paying for credits issued for adopted CF practices (Scherger, 2022). We argue that CF is employed by agribusinesses to secure their established business model and to avoid a structural transformation of agricultural production. This reshaping of the existing agricultural system is very likely to deprioritize efforts to reduce emissions. By interrogating the strategies of large transnational corporations in their engagement with CF, this article sheds light on a highly dynamic but under-researched development at the intersection of climate and agricultural politics.

After intensive engagement with the politics behind carbon sinks and the unfulfilled promises of carbon offset mechanisms such as REDD+ , political economy/ecology scholars have begun to engage critically with existing debates about carbon removal. Debates which have gained a new momentum after numerous net-zero pledges by countries and companies (Buck et al., 2023; Carton et al., 2023; Lund Christiansen et al., 2023). While much literature critically interrogates net-zero and carbon removal policies in industry (Brad et al., 2024), the emerging schemes in agriculture and the implications of CF are understudied. Among the few exceptions for instance are studies on farmers perceptions and attitudes toward CF (cf. Buck and Palumbo-Compton, 2022) and the analysis of corporate attempts to coopt movements toward regenerative agriculture (Bless, 2023). Yet, soil carbon markets have so far received limited research attention, especially when compared to forest-related carbon markets (e.g., Seymour, 2020; Greenfield, 2023). This article aims to fill this gap in analyzing material and discursive dimensions of the political economy behind CF; it contributes to critical agrarian studies, to the literature focusing at corporate net-zero claims, incumbency, and mitigation deterrence in the agricultural sector.

In the following, we develop our analytical perspective, which is based on approaches from cultural political economy (CPE). We primarily work with the concepts of imaginary and accumulation strategy. In the third section, we describe our methodological approach and data. We conduct a qualitative analysis of documents and websites from six agribusiness corporations and triangulate these with six expert interviews. In the fourth section, we present the results of our analysis, detailing key components of the imaginary and the accumulation strategy related to CF employed by the corporations. In the fifth section, we discuss the findings, including the relationship between the imaginary and the accumulation strategy, as well as uncertainties and tensions. In the sixth section, we summarize the article's insights and outline further research needs.

2. Conceptual framework: cultural political economy

We employ a CPE framework to analyze how large agribusiness companies relate their business models to CF. An analytical perspective based on CPE aims to understand the mediation between economic structures (structuration) and the social production of meaning (semiosis). Within the CPE framework there are different nuances on the relationship between politics, economics, and culture (for an overview see Sum and Jessop, 2013: 20–22). The common core of the CPE approach is that, following a post-positivist eclectic understanding of science, it does not conceptualize politics, economics, and culture as separate spheres but as co-constitutive. In contrast to structuralist approaches, CPE points to the importance of the social production of meaning. And in contrast to constructivist approaches, CPE emphasizes that social structures significantly influence the construction of meaning (ibid.). With this starting point in mind, we analyze how CF is used by agribusiness corporations to further develop business models, what visions of the future they associate with it and how the business models and the discursive future-making relate to each other.

As the foundations of the CPE research agenda are developed on a rather high level of abstraction (Sau, 2021; Haas, 2024), we employ two concepts from the CPE toolbox that are helpful for analyzing corporate strategies on carbon farming: 'accumulation strategy' and 'imaginary'. The concept of accumulation strategy is based on Marx's theory of capitalism. He showed that capital is principally geared toward limitless accumulation. For this purpose, each company is condemned to maximize its profits (Marx, 1990). According to Jessop, an accumulation strategy unites different capital fractions and points beyond the economic context: "An 'accumulation strategy' defines a specific economic 'growth model' complete with its various extra-economic preconditions and also outlines a general strategy appropriate to its realization." (Jessop, 1990: 198) The concept is helpful in understanding how the established agribusiness corporations are trying to reshape and renew their business models against the background of accelerating climate change and the increasing integration of the agricultural sector into climate policies. In contrast to Jessop, we employ the concept of an accumulation strategy not related to the nation-state or a post national-regime but rather in working out the corporate activities and determining the extent to which an overarching accumulation strategy of the agribusiness is emerging around the concept of CF. We aim to identify key components in incorporating net-zero claims into their own business models.

One of the central "extra-economic conditions" mentioned above is how an accumulation strategy is linked to certain interpretations of society and visions of the future. Sum and Jessop (2013): 165) here delineate the term "imaginary" as "a semiotic ensemble (or meaning system) […] that frames individual subjects lived experience of an inordinately complex world and/or guides collective calculation about that world." Collective actors use imaginaries to "relate to their environments, make decisions, or engage in strategic action. (…) Imaginaries are not pre-given mental categories but creative products of semiotic and material practices with more or less performative power"

(Sum and Jessop, 2013: 165). Accordingly, imaginaries serve as a mediating concept between social structures (structuration) and the social production of meaning (semiosis).[2] There are points of connection here to economic sociology studies on imaginaries with a focus on companies (Beckert, 2021; Frisch, 2023). Frisch, for example, identifies an overpromising by companies with regard to their role in combating climate change. He distinguishes three forms: overpromising as contradiction refers to the neglect of contradictions, such as between economic growth and emission reduction. Overpromising as exaggeration refers to the fact that the possibilities for emission reduction are often exaggerated. Overpromising as commitment refers to companies committing to ambitious climate protection goals in the face of public pressure.

Our CPE-based approach focusing on accumulation strategy and imaginary centered around large corporations relates in various ways with climate social science research on incumbency and mitigation deterrence. The term "incumbency" denotes the existence of large, well-established, and influential economic actors in a sector and suggests their unclear role in (sustainability) transformations (Fairbairn and Reisman, 2024; Kungl, 2024). The research focus of this field in recent years has increasingly shifted to the question of why climate mitigation policy progress significantly lags behind what is deemed necessary from a climate science perspective (Stoddard et al., 2021). Within the sustainability transitions community, the role of incumbent firms has attracted attention due to their enormous power resources (Ford and Newell, 2021; Kungl, 2024). Ford and Newell (2021) show how incumbent energy companies and their associations have used their material, discursive, and institutional power to prevent a rapid transition to a renewable energy regime. Newell and Taylor (2018) have worked how material and discursive power operates at the interface of the climate and agri-food system in the neoliberal food regime largely shaped by transnational capital. Lund et al. (2023) illustrate the dynamics behind corporate net-zero claims and how they might serve to legitimize a continuation of corporate climate approaches.

As part of research on Carbon Dioxide Removal, Markusson et al. (2018) developed the concept of mitigation deterrence to explain the delay in emission reductions. They define mitigation deterrence as "the prospect of reduced or delayed mitigation resulting from the introduction or consideration of another climate intervention" (Markusson et al., 2018: 1). The authors argue that mitigation deterrence should neither take existing social relations and technologies as given (realist perspective), nor should social reality be seen as exclusively socially constructed (cultural perspective). Accordingly, they develop the concept of mitigation deterrence based on a CPE approach. From such a perspective, reasons for the delay in emission reductions can be located in very different political, economic, or cultural mechanisms (Palm et al., 2024, page 2). Brad and Schneider (2023), for example, examine to what extent mitigation deterrence effects can be detected in EU policies. Palm et al. (2024) focus on the role of imaginaries, i.e., future visions developed by the petrochemical industry to continue operating its existing business model while simultaneously portraying itself as part of the solution to the climate problem. Central to this, as the authors show, is the "circular carbon imaginary" (ibid.: 1), which allows the industry to imagine its existing business model as compatible with the net-zero ambition, as the industry's discourse suggests that only the closure of the carbon cycle is needed to reach net-zero.

Our analytical perspective based on CPE is thus located at the interface of research on the role of large corporations in sustainability transitions and the question of mitigation deterrence in the food regime, i.e., whether and, if so, how incumbent companies try to prevent or delay agri-climate policy approaches and more fundamental transformations, such as a different agricultural model. We focus our analysis on the accumulation strategy and imaginary of six of the largest agricultural corporations.

[2] In contrast to the concept of the "socio-technical imaginary" from science and technology studies (Jasanoff and Kim 2013), a CPE-based approach to defining an imaginary refers more to social structures (and accumulation strategies) and puts less emphasis on the role of science.

3. Material and methods

We selected BASF, Bayer, Cargill, Corteva, Syngenta, and Yara International as objects of investigation due to their significant market shares in highly concentrated agricultural markets, particularly seeds, synthetic fertilizers and pesticides. Syngenta, Bayer, Corteva, and BASF alone collectively represent approximately 65 % of the global market concentration in agrochemicals; Yara is one of the world's biggest producers of synthetic fertilizers and Cargill among the largest multinational traders of agricultural commodities (Howard, 2020; Clapp, 2022). All of these companies are engaged with CF to varying degrees: they offer CF programs, provide one or sometimes multiple digital platforms and tools such as calculators and schemes through which farmers can participate in voluntary carbon markets, and some have published statements or answered questionnaires on EU CRCF. The scope and outreach of these companies' CF-initiatives are primarily in the US, South America, and Europe.

Our analysis is based on a qualitative analysis of publicly available materials, including websites, videos, and gray literature of their CF activities (Silverman 2020). First, specifically, for all of these firms, we conducted an in-depth analysis of their material practices, which include their main carbon programs and platforms. Through an investigation of the firms' websites, we identified the platforms they provide and the models and measurement methodologies they use. We collected the data in an excel spreadsheet and distilled all relevant information about the underlying business models, programs, platforms and technologies, as well as the measurement and certification models they use including collaborations with third parties. Table 1 shows the carbon programs and platforms that result from these material practices.

Secondly, in addition to these data, we evaluated the statements of the companies on the EC's Call for Evidence in preparation for the EU CRCF from 2022 (Bayer, Syngenta, and Yara commented). While Bayer, Corteva and Syngenta responded to the questionnaire provided by the EC, only Bayer and Syngenta contributed with more detailed statements on the Call for Evidence.

Thirdly, we conducted six interviews in 2023 and 2024 to triangulate our findings: two with representatives of agribusiness firms (Bayer, BASF), three with academic experts working in the field, and one with a representative from a think tank closely following the topic (see list with interviews in Annex). The interviews provided various insider perspectives from firms, research, and civil society. We used a structured interview guide to conduct the interviews and AI software (NoScribe) for automatic transcription. For the analysis and coding of the interviews

Table 1
Carbon programs and platforms.

Company	Description
Bayer	Program: Bayer Carbon Program Platforms: Climate FieldView™; ForGround
BASF	Program: The Global Carbon Farming Program (collaborating with Regrow, based on e.g., Verra, Climate Action Reserve) Platforms: xarvio Field Manager, AgBalance
Cargill	Program: Partner on Data Collection for Carbon Payment Program (collaborating with Regrow, based on e.g., Verra, Climate Action Reserve) Platform: RegenConnect® Online Platform
Corteva	Program: Corteva's Carbon Initiative (collaborating with Indigo Ag, based on e.g., Verra, Climate Action Reserve) Platform: Granular Insights
Syngenta	Program: Carbon Pilot with Nutrien Ag
Yara International	Program: Agoro Carbon Alliance (based on Verra certification) Platform: my.agorocarbon.com

we used MAXQDA software (Kuckartz and Rädiker, 2023). Based on our research questions and the conceptual approach, we coded key components of the agribusiness' imaginary and accumulation strategy. We triangulated all gathered data with the interviews which were helpful to contextualize the public communication of the corporations and to verify and consolidate our findings.

With this methodological approach, we can examine the material and discursive practices of companies with respect to CF. However, there are limitations. It became evident that some information about CF could not be made available such as how many farmers are participating in CF programs and the current scale of CF activities for the companies. Additionally, despite several requests, we were unfortunately only able to speak with two company representatives. Nevertheless, the collected and analyzed material provides a solid data foundation for defining the companies' CPE of CF.

4. Results: the cultural political economy of carbon farming

Based on our conceptual and methodological approach, we have identified different foundational components of the accumulation strategy and the imaginary related to CF as essential elements of the agribusiness' political economy (see Tables 2 and 3).

4.1. Accumulation strategy

The companies' accumulation strategy embraces three key elements: Infrastructuring (1) denotes the expansion of digital Monitoring, Reporting, and Verification (MRV) technology; assetization (2) refers to expected future revenues; and incorporation (3) describes the alignment of old and new business models.

4.1.1. Infrastructuring

Establishing and expanding technological infrastructure, a process that we call infrastructuring, is a key element of the multiple firms' accumulation strategy. Digital infrastructure plays a key role in facilitating CF and soil carbon markets. Carbon markets heavily rely on agricultural data collection and digital MRV technologies, including soil sampling, laboratory analysis and computational modeling of carbon levels. Consequently, companies leverage existing digital platforms and tools while further expanding their technological infrastructure in conjunction with their CF activities. All companies are actively developing digital MRV technology and offer carbon credit programs (see Table 1 for an overview of collaborations among agribusinesses and start-ups).

BASF offers more than one tool for their Global CF Program, the company's sustainability assessment tool, AgBalance®, to assess the data and derive informed decisions to improve sustainability, and their digital farming solution, the BASF xarvio Field Manager. Bayer utilizes its Climate FieldView (CFV) platform, a major digital farm management platform, as a key tool for its CF Program. In April 2024, Bayer introduced ForGround, another brand-new platform that includes a carbon calculator for farmers to participate in the Bayer Carbon Program specifically addressing the US carbon market (Bayer 2024; interview A2).

Table 2
Accumulation Strategy.

Accumulation strategy components	Key elements
Infrastructuring	– expansion of digital MRV technology
Assetization	– expectations for future revenues from soil carbon credits
Incorporation	– alignment of old and new business models – excluding transformative agricultural practices – insetting

Source: Own elaboration.

Table 3
Imaginary.

Imaginary components	Key elements
Robust carbon measurement	– scientific accuracy – - quantification of carbon
Soil Carbon Markets	– trading soil carbon credits – economic efficiency
Co-benefits	– increasing farmer's income – improving soil health – enhancing agricultural sustainability

Source: Own elaboration.

As part of their infrastructuring, companies collaborate with start-ups that offer advanced digital MRV and modeling skills that they do not have in-house, as in the collaboration between BASF and Regrow (e.g., Regrow, 2024; interview A1). For issuing soil carbon credits, BASF collaborates with the startup firm Regrow, using their model and technical infrastructure by integrating Regrow's proprietary MRV software into the xarvio Field Manager crop optimization platform (BASF, 2023). Corteva issues carbon credits using its own digital platform tool, Granular Insights, and in collaborating with IndigoAg by using their model DayCent-CR for quantifying emissions and soil carbon fluxes (Corteva, 2024).

To participate in Cargills initiative RegenConnect, farmers log their practices in the firms' Granular Insights tool, while quantification, certification and issuance of carbon credits is done via a collaboration with IndigoAg and with Climate Action Reserve, an initiative that validates and approves models for quantifying emissions and soil carbon fluxes (Cargill, n.d.; Regrow, 2024). Syngenta's activities regarding CF is notably sparse although they claim to be part of the EU Carbon+ Farming Coalition and developed a program named Carbon Pilot for which they collaborate with Nutrien Ag Solutions in a program, aiming to assist growers in adopting sustainable agricultural practices and generating carbon credits (EMSC, 2024; Syngenta, 2024). Yara international offers its standalone CF program Agoro Carbon Alliance and the platform my.agorocarbon to upload the data while they are using the Verra Verified Carbon Standard (VCS) Methodology for the creation of credits (Agoro Carbon Alliance n.d.)

By building and expanding digital MRV infrastructure, companies achieve or maintain technological leadership and secure the means to collect farm data at a large scale. Many carbon programs and platforms contain technical lock-ins, through which technology providers secure both their market position and access to the valuable agricultural data essential to their accumulation strategy. Through these mechanisms, infrastructuring lays the foundation for assetization.

4.1.2. Assetization

Assetization of soil carbon is another key element of the companies' accumulation strategy; denoting a process where accumulation is based on revenues likely to be generated in the future rather than on yet existing commodities. Assetization generally refers to the generation of speculative future value from intangible goods such as patents and data (cf. Birch and Muniesa, 2020; Hackfort et al., 2024).

Our data suggest that CF activities have been relatively marginal to date, and that soil carbon credits have not yet become a significant source of revenue or income—either for the numerous start-ups in the field, for incumbent agribusinesses, or for farmers. This means the monetization of soil carbon credits is based on their expected prospective value with expanding markets and increasing prices. As one expert put it, currently firms are "betting on a takeoff in demand for these carbon credits […] to secure a seat at the table of the carbon market when this grows" (interview E2). Insights from the firms' representatives illustrate this speculation on the future: "(…) we're now building business models. But in the future, we believe that this could be profitable for farmers, and by that also profitable for us. (…) (interview A2). They clearly see assetization avenues in the context of the numerous net-

zero pledges by governments all around the world, and expect higher prices for carbon in the future, as the following quote illustrates:

> "(…) in our pilot stage we're producing and certifying a ton of carbon for between 80 and 120 euros per hectare—which if you compare the current market price today it's between 20 and 30 euros— is laughable. (…) But we do believe that the market for carbon credits will develop and the carbon price will go up and we do believe that once we enroll more hectares we can achieve economies of scale and we can drive those carbon credit production costs down" (interview A1).

Assets are controlled, traded, and capitalized for prospective revenue, often involving the valuation of future earnings from property rights or data (Birch and Muniesa, 2020) or in this case from carbon as a new potential revenue stream that is incorporated into the existing business models as explained in the next paragraph.

4.1.3. Incorporation

Incorporation is another component of the firms' accumulation strategy. The term refers to the alignment of new soil carbon market schemes with established business models to reconcile established practices with changing conditions and the need for transformation. Our data show three aspects of this incorporation:

First, firms are further entangling farmers in their specific business models and platforms. Their carbon programs allow them to strengthen relations with clients; they are used as an opportunity to fortify existing bonds and dependencies:

> "We are not a pure carbon market player. (.) It is an opportunity for us to work with our customers to enable them to do something different which they may otherwise not have the opportunity to do. But equally it maintains for us a very close relationship with those farmers or those value chain players (…)" (interview A1).

This happens, for instance, through rebate mechanisms, by which firms incorporate and further bind farmers even more to their companies and products. For example, Cargill's platform RegenConnect requires farmers to be Cargill customers to enroll in the CF program (Cargill, 2024). Bayer offers one year of free access to Bayer's CFV if farmers also use the new ForGround platform; and linking both accounts allows for a "$100 discount off FieldView™ Plus or Premium" - the next level of the offered software packages Bayer (2024). Such mechanisms can lock farmers into specific corporate techno-economic systems.

Second is the incorporation of new business models with old ones when firms align their new carbon programs with established product portfolios, as the sale of petrochemicals tailored for agro-industrial production, e.g.,

> "Doesn't matter whether it's a digital solution or (…) better fertilizer management through the use of nitrification inhibitors, or whatever we have in portfolio. (…) Just because you are carbon farming, pests and diseases are still going to be out there in the field–so you are still going to need herbicides, you are still going to need fungicides to protect and maintain yields, because if you get a dip in your yield you may not get a carbon credit. (…)" (interview A1).

This is evidenced by the fact that the corporations remain rather vague in their definitions of CF and mainly incentivize activities that fit the agro-industrial production model: reduced tillage and the use of cover crops are compatible with large fields and monocrops. Meanwhile, practices such as agroforestry and intercropping, which require restructuring towards a greater diversity of crops and are less compatible with large-scale monocrop production, tend to be excluded (e.g., Agoro Carbon Alliance, n.d.; Bayer, 2024; Cargill, 2024; Corteva, 2024).

Lastly, through insetting, companies compensate for their emissions through projects within their own supply chain rather than relying on external carbon offsets. Through insetting, firms work towards incorporating soil carbon market schemes further into their own value chains. The interview partner from BASF explains:

> "There's another side of the carbon market, which is called an 'inset', which is basically where the value chain comes together (…) to reduce and measure and monitor that reduction in carbon intensity or the CO2 emitted along that value chain." (interview A1). With insetting the firms aim at the decarbonization of their supply chains by trading carbon credits among value chain players, for instance between a farmer and a food processing and trading company (Bayer, 2024).

Insetting is a corporate practice, particularly common among agribusinesses, that complements existing offsetting efforts in voluntary carbon markets. It is criticized as a form of greenwashing that distracts from real emissions reduction because it lacks clear standards and independent verification, making impact claims uncertain (Scherger, 2022).

In this section we describe how agribusinesses, as a powerful capital fraction, develop the tools and structures to ensure future capital accumulation. We identify three elements of this accumulation strategy, which arise from the simultaneity of conserving established agricultural practices and the need to respond to new socio-ecological challenges. Through a CPE lens, a firm's incorporation of net zero claims into their business models and the renewal of their practices and profits through assetization is a form of future-making.

4.2. Imaginaries

Based on the data analyzed, we identify three central components of an imaginary that agribusinesses promote. First, the promise of robust carbon measurement, which forms the basis for carbon certification. Second, the promise that carbon credits can be generated and traded, which enables a soil carbon market. Third, the promise that CF is linked to various co-benefits, especially for farmers.

4.2.1. Robust carbon measurement

The promise of being able to accurately measure carbon is a fundamental claim of CF programs. Yara's Agoro Carbon Alliance strongly emphasizes this commitment:

> "One of the most important elements of a successful carbon program is accurately measuring soil organic carbon (SOC), or the amount of carbon stored in the soil. Through scientifically proven modeling, soil sampling design, and lab analysis, Agoro Carbon built a robust SOC measurement process that empowers the company to accurately measure carbon stored in the soil before, during, and after farmers and ranchers deploy new practice changes like rotational grazing or cover crops. Together with farmers and ranchers, Agoro Carbon estimates they will sequester more than 5 million tons of carbon over the next 10 years." (Agoro Carbon Alliance, 2023)

Cargill promises on its website: "Cargill is partnering with carbon measurement firm Regrow to make it easy for farmers to measure, report and verify (MRV) carbon outcomes using in-field data, remote sensing, and crop and soil health modeling." (Schilling, 2021) Regrow asserts that it is built according to scientific standards and fully complies with common certification standards: "Regrow's science meets or exceeds global accounting standards like Greenhouse Gas Protocol and carbon crediting standards like Verra, Climate Action Reserve, and SustainCert." (Regrow, (2024))

With the same focus, Bayer expresses its commitment more cautiously and as a promise for the future, aiming to establish a comprehensive MRV system:

> „Our program is only as good as its results. So, to ensure we are staying on the cutting edge of all things, we've created a virtual space where we can work with farmers and food value chain experts to test, iterate, and evolve our best practices. The final product? An accurate

and reliable digital Monitoring, Reporting and Verification (MRV) solution […].” Bayer (2024)

The common thread in these statements is that the companies claim to conduct robust carbon measurements, based on scientific principles, which serve as the foundation for carbon certification. By means of these discursive practices, the incumbent agrobusiness corporations constitute a key component of the imaginary of CF.

4.2.2. Soil carbon markets

Building on this, farmers participating in CF programs are promised the ability to generate carbon credits, thereby creating an additional source of income. For example, BASF announces on the homepage of its Global Carbon Farming Program: “BASF will build the global framework to allow farmers to generate carbon credits from recognized certifiers that will lead to second revenue streams from their carbon reduction efforts” (BASF, 2021). Corteva also promises farmers additional income through carbon credits, stating that they will “help farmers generate carbon credits from implementing soil health practices that sequester carbon dioxide from the atmosphere and into their soil.” (Corteva, 2022).

While all the companies promise high scientific standards for their credits and offer farmers soil-based carbon credits as an additional revenue stream, they also appear to agree that the standards for these credits should remain as flexible as possible. This is particularly evident in their responses to the EU CRCF. Bayer, Syngenta, and Yara/Agoro Carbon Alliance all addressed this issue. When asked about the role of baselines and additionality in certification, all three companies advocated for maximum flexibility: “The EU certification framework should allow for a variety of baselines and additionality criteria to cater for different types of removals” (Bayer, 2022; Syngenta, 2022; Agoro Carbon Alliance, 2022). This indicates that, despite the claim to scientific accuracy (which actually would imply an exact quantification of the impacts related to CF), agribusiness corporations demand maximum flexibility for their CF programs.

It is clear that carbon markets are a key component of the promises made about CF. At the same time, agribusiness corporations aim to ensure the greatest possible flexibility in generating credits and place significant importance on voluntary carbon markets. Accordingly, Syngenta explicitly urges the EU not to interfere in voluntary carbon markets in their statement: “There is no need for the EU to intervene in voluntary carbon markets.” (Syngenta, 2022). These companies envision a future in which an increasing number of soil carbon credits are generated and traded on the basis of a coexistence of voluntary and compliance carbon markets.

4.2.3. Co-benefits

This picture is rounded off by the promise of various social and ecological co-benefits associated with CF. These benefits are primarily targeted at farmers, likely because the companies are currently trying to attract and retain farmers for their CF programs. A prime example of this is Bayer’s communication:

> “ForGround by Bayer can help farmers get a jump on adopting cover crops, strip-till and no-till practices and earn income through the Bayer Carbon Program. With exclusive agronomic resources and discount programs, ForGround helps implement these new techniques and rewards farmers with reliable income streams for adopting them. Farmers may also share in the upside if carbon credit prices increase. The benefits for farmers – improved soil health and resiliency, new income streams and overall stronger farms – will benefit everyone else around the world, too.” (Bayer, (2024))

Similarly, the president of BASF Agricultural Solutions proclaims in a company press release the following:

> “The launch of our Global Carbon Farming Program is a testament to our strong commitment to sustainable agriculture. It will enable farmers worldwide to increase the health of their soils, reduce emissions, sequester carbon and – at the same time – be rewarded for their sustainability efforts to combat climate change.” (BASF, 2021)

In a similar vein, Corteva proclaims that “[a]gricultural carbon programs are one of the most beneficial and cost-effective ways to reduce greenhouse gas emissions.“ (Corteva, 2024) They also promise farmers various co-benefits alongside additional income from carbon credits, such as healthier soils. Corteva claims to “help farmers generate carbon credits from implementing soil health practices that sequester carbon dioxide from the atmosphere and into their soil.” (Corteva, 2022) In a study commissioned by Cargill, the Soil Health Institute found that 85 % of corn growers and 88 % of soybean farmers were able to increase their income through “soil health management systems.” (Schilling, 2021) Carbon farming is envisioned by the involved corporations as a business model that not only helps mitigate climate change but also offers numerous co-benefits, such as higher income for farmers and overall improved soil quality.

In this section, we describe how agribusinesses construct an imaginary through discursive practices that assign a specific meaning to CF and frame it as indispensable for sustainable food systems. We identify three key elements of this imaginary, which envisions the future as a continuation of the existing agricultural model: the promise of robust carbon measurement, the establishment of soil carbon markets, and the creation of co-benefits (see Table 3).

5. Discussion – congruences, uncertainties, and tensions in Carbon Farming

CF is a promise related to a future flourishing climate-smart agriculture. Our analysis using a CPE perspective shows that agribusinesses incorporate CF as part of their accumulation strategy dovetailing with visions of a climate-smart agriculture. However, how should the strategic focus on CF be understood in the context of the role of incumbent firms and the risk of mitigation deterrence, i.e., the delay and weakening of emission reductions in the agricultural sector? We distill six key findings which relate to different tensions and uncertainties regarding CF.

First, there is a considerable congruence between the elements of the accumulation strategy and the imaginary. The promise of robust carbon measurement (imaginary: robust carbon measurement) corresponds with the development of digital measurement and computational modeling methods (accumulation strategy: infrastructuring). Digital infrastructure—e.g., for collecting farm data via agricultural platforms for modeling and sensors for the measuring process—serves (future) monetization of soil carbon sequestration. Put differently: carbon only exists in the financial world of markets through digital means—without digital technology, we cannot visualize, account for, or trade carbon (Moreno, 2024). As necessary precondition for establishing soil carbon markets, (digital) infrastructuring enables financial benefits and accumulation for agribusinesses and it allows them to consolidate their power (Bronson and Sengers, 2022; Hackfort et al., 2024). This forms the foundation for establishing soil carbon markets (imaginary: soil carbon markets), which the corporations frame as a central component of CF. The key role of carbon markets is expressed in the imaginaries of soil carbon markets and co-benefits, which in turn correspond with the accumulation strategy components of assetization and incorporation. Put all these aspects together there is an imagination of a future prosperous market for soil carbon credits as a core component of climate-smart agriculture. This vision serves as “a vehicle for reconciling global neo-liberal models of agricultural production and consumption and the imperative to identify new sites of accumulation” in the corporate food regime (Newell and Taylor, 2018: 119).

Second, despite the development of infrastructures for CF, it remains less a current practice than a promising future one. Therefore, the different elements of CF’s imaginary allow the incumbent agribusiness

corporations to present themselves as part of the climate-smart agriculture solution (and disguise their role in the problem of an unsustainable agricultural system). At the same time, CF's imaginary opens up new possibilities when it comes to renewing the existing accumulation strategy. All companies studied have set up CF programs. However, these are still in an early phase. Concrete figures regarding the revenues and profits generated from CF are not available. Companies are not yet making notable profits from CF (interviews A1, A2). Nevertheless, the programs and the link between CF and the established accumulation strategy suggest that CF is indeed a serious development in an agricultural sector driven by agri-climate policies and advanced by various actors—in addition to large agribusiness corporations, this also includes various start-ups and large tech corporations (Ag Funder News, 2022)—that strive to turn it into more than just a future promise.

Third, the term CF itself remains very vaguely defined, allowing for different practices and interpretations to be associated with it (interview T1). For instance, most of the companies examined during research do not provide a clear-cut definition of what they understand by CF on their respective websites. If they do so, it is a very general one, such as "[an agricultural practice] that involves managing land in a new way that sequesters carbon from the atmosphere and stores it in the soil and vegetation" (BASF, 2021). Despite this conceptual vagueness, it is notable that the corporations mainly issue credits for CF practices that do not harm their growth model, which is based on large-scale, input intensive industrial agriculture. Cover crops and reduced tillage, which are frequently mentioned, align with this model; in fact, the latter is even criticized for its heavy reliance on glyphosate (Agroganic, 2024; Beacham et al., 2023). Through this incorporation they avoid transformation and structural change, e.g., toward more crop diversity and less petrochemical inputs.

Forth, the issue of measuring carbon sequestration is very controversial. While all companies promise to make scientifically sound, accurate, and robust measurements of carbon (imaginary: robust carbon measurement), research suggests that the sequestration of carbon in soils is subject to significant fluctuations; depending on when and where organics soil carbon is measured, it can vary greatly (e.g., Don et al., 2023; Oldfield et al., 2024). Furthermore, Moinet et al. (2023) argue that the potential for carbon sequestration in soils is limited and strongly determined by local contexts and that an ideal "win-win" constellation (soil carbon sequestration and co-benefits such as food security) cannot necessarily be realized. Meanwhile, incumbent agribusinesses largely obscure any uncertainty about this approach by using the term "measurements" where "estimations" would be more appropriate and promising co-benefits that may impossible to realize.

Fifth, CF and soil carbon markets risk to reproduce problems with yet established carbon markets. This relates to the problem of permanence of removals and potential leakages (Paul et al., 2023). For example, Bayer acknowledges in its answer to the Questionnaire on the EU CRCF: "Natural carbon removals are less permanent than technical solutions." (Bayer, 2022) However, what "less permanent" means in concrete terms remains unclear. Establishing carbon markets based on non-permanent forms of carbon storage indicates that soil-based carbon markets will likely face problems similar to those occurring with forest-based markets (e.g., REDD and REDD+): problems regarding the measurability and permanence of removals, as well as additionality and the question of what constitutes an adequate baseline scenario (Paul et al., 2023). These issues have been illustrated by the failures of Verra, a key carbon credit registry. A global team of academic researchers evaluated 29 projects that purported to have saved 89 million carbon credits, and discovered that over 90 percent of the credits were founded on dubious claims of avoided emission (The Guardian, 2023). It is important to note here that Verra is involved in many agricultural soil carbon credit projects (see Table 1). Agribusiness reacts to this crisis of legitimacy by trying to build trust in these markets, for instance, by suggesting robustness of carbon measurements and by framing flexible soil carbon markets as the most effective solution, ignoring the failures of carbon markets in the past.

Sixth, given the above findings, we assume that overpromising, as identified by Frisch (2023) for corporations from various sectors, is also evident among the incumbent agribusiness corporations. CF is a very vague concept associated with the promise of reducing emissions in the agricultural sector and sequestering carbon in soils. However, it is neither sufficiently defined nor is there clarity on how the promises associated with CF will be fulfilled. Nevertheless, the debate around CF suggests that the major agribusiness corporations, similar to the petrochemical industry (Palm et al., 2024), position themselves as part of the solution to the climate problem in the agricultural realm. Yet, their deployed accumulation strategy and the imaginary related to CF aligns well with established agribusiness models and detracts attention from alternatives. It is thus very likely that CF will prove to be a form of mitigation deterrence (Markusson et al., 2018), as it promises further development of the existing agro-industrial model in such a way that it becomes compatible with net-zero targets.

6. Conclusion

In this paper, we analyze the cultural political economy of CF by large agribusiness corporations as part of the digital and green transition advocated in the EU and beyond. The agribusiness corporations' accumulation strategy is primarily based on the components of infrastructuring, assetization, and incorporation. The related imaginary consists of robust carbon measurement, soil carbon markets, and co-benefits. The accumulation strategy and the associated imaginary converge in the vision of climate-smart agriculture (Newell and Taylor, 2018). However, the concept of CF remains vague, and the realization of the promises associated with it is highly questionable.

With our analysis, we contribute to critical studies on the political economy of the agri-food system and to the research field of incumbency and mitigation deterrence. Our study of major agribusiness corporations confirms numerous findings that have been observed in other sectors, such as the petrochemical industry (Palm et al., 2024) or the energy industry (Ford and Newell, 2021). Incumbent corporations attempt to position themselves as part of the solution to the climate problem and develop corresponding imaginaries which, at the same time, aim to enable them to continue their existing business models.

In contrast to the petrochemical industry, which has developed the circular carbon imaginary (Palm et al., 2024), CF remains largely vague. It is not possible to clearly determine what significance CF already has today, nor what the associated ideas for the future look like in detail.

Accordingly, we outline four areas of further research: First, comparative analyses of incumbent companies from different sectors would be beneficial in order to better identify commonalities and differences across the sectors. Second, it would be valuable to analyze individual companies that operate in different business fields. BASF's agribusiness division, for example, falls within the scope of this research, but the company is also part of the petrochemical industry (Palm et al., 2024). How are the different business areas coordinated within the company, and what tensions and possible contradictions arise from this? Third, it would be beneficial to analyze lobbying activities, i.e., the influence of companies on policy processes. The evaluation of position papers and statements does not provide any conclusions about the extent to which corporations are able to influence policy processes in their favor, for example, with regard to the legislative acts concerning the EU CRCF (see, for example, the analysis by Brad and Schneider 2023 on the risk of mitigation deterrence in EU climate policy). Fourth, there is a need for further research on the extent to which CF will actually materialize as an agricultural practice. Despite all the vagueness, uncertainties, tensions, and the high probability of overpromising (Frisch, 2023), it is very likely that CF and the establishment of soil carbon markets will make further progress.

Against this backdrop, we argue that many of the practices promoted under the banner of CF are essential for maintaining the socio-ecological reproductivity and sustainability of food systems. However, these

practices should become standard agricultural practices, independent of private companies and their profit-oriented platforms and programs and offsetting and insetting mechanisms, which run the risk of being mere greenwashing (Beste, 2021, IPES-Food, 2022). We would like to emphasize that CF, as a key component of CSA in its current form, is deeply intertwined with an agricultural policy path that reinforces existing power relations. Its compatibility with the accumulation strategy of incumbent firms limits alternative approaches, such as food systems that prioritize territorial markets, promote agroecology, and advance food sovereignty (IPES-Food, 2022; 2024).

CF, based on current patterns, may further entrench the flaws of the global industrialized food system, and it is unlikely to achieve the necessary GHG emission reductions in the agri-food sector to bring net-zero targets within reach anytime soon.

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Data Availability

Data will be made available on request.

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