URBAN AND RURAL REPORTS 2024:5

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Editors
Andrew Butler, Associate Professor and Senior Lecturer in Landscape Architecture
Klara Fischer, Associate Professor in Rural Development, Senior Lecturer in Environmental Communication

Legally responisible publisher: Stina Powell
eISBN: 978-91-85735-67-9

Author's ORCID ID:
Alejandra Figueredo, Research Assistant SLU, 0009-0003-3598-3203

Swedish University of Agricultural Sciences • Department of Urban and Rural Development

Postal address: P.O. Box 7012, SE-750 07 Uppsala SWEDEN
Visiting address: Ulls väg 27
Delivery address: Ulls gränd 1
Phone: +46 18 67 10 00
Web address: www.slu.se/sol

Summary

There is a growing emphasis on carbon farming, a set of land management and farming practices aimed at sequestering soil organic carbon and abating greenhouse gas emissions from agricultural production, as a potential climate mitigation strategy, with numerous farms participating in voluntary carbon offset schemes, often supported by national initiatives in various countries. This report reviews the academic literature on what this new climate-mitigating strategy may entail for farmers and how they perceive the potential possibility of adopting carbon farming practices, including their views on policy or market schemes for carbon farming. While there is general positivity towards the farming practices associated with carbon farming, due to their co-benefits, such as improved soil health and productivity, adoption is hindered by several factors. Different studies report that farmers express scepticism about the feasibility of carbon farming, particularly concerning the high initial costs of adopting new practices, bureaucratic hurdles, lack of information, inadequate training, and the long-term commitment required. Additionally, the heterogeneity of farms and local conditions means that the benefits of carbon farming are not uniformly experienced, with smaller farms and those with less fertile soils being less likely to benefit.

Research also explores farmers' beliefs and environmental values as influencing their attitudes towards carbon farming, with inconclusive findings regarding the relations between perceptions and awareness of issues like climate change and the uptake of practices. A couple of studies highlight how socio-psychological factors like cultural traditions and the influence of peers, personal values, and structural constraints all play significant roles in shaping farmers' responses to farming strategies. Variations in perceptions of climate change and the effectiveness of carbon farming practices add further complexity to understanding adoption.

Several studies exploring farmers' perceptions of carbon farming schemes identify economic incentives as a key driver for farmer involvement, with the potential for additional income being a significant motivator. Nonetheless, research also shows that financial compensation is often seen as inadequate, and concerns are raised about the fairness and transparency of market-based mechanisms. This review also notes that the focus on economic drivers and the commercialization of carbon farming may undermine intrinsic motivations for sustainable practices and lead to resistance among farmers.

Looking forward, a number of themes can be identified for further research. These include studies looking beyond individual farmer attitudes and individual farms to wider cultural and political factors; attention to the impact of non-economic factors for carbon farming adoption; longitudinal studies; studies focusing on resource constrained smallholders and those farming in marginal and less productivce environments; and inter- or transdisciplinary approaches that jointly evaluate the different factors that influence adoption or non-adoption of carbon farming measures.

Keywords: farmers, carbon farming, soil carbon sequestration, agriculture, perceptions, attitudes, motivations.

Author

Alejandra Figueredo, Research Assistant in the Division of Environmental Communication, Department of Urban and Rural Development, at the Swedish University of Agricultural Sciences, SLU.

Content

1 Introduction

Agriculture is a major contributor to climate change, as the sector is accountable for more than a quarter of global greenhouse gas emissions[1] (Smith, 2018). Simultaneously, agriculture is highly sensitive to climate change, given its reliance on local environmental and climatic conditions, notably impacted by increasing and accelerating extreme weather events[2] (Rochecouste, Dargusch and King, 2017; US EPA, 2022). Although global attention to climate change mitigation has largely centred on the forestry and transport sectors (Lynch *et al.*, 2021; Abbass *et al.*, 2022), the potential of the agricultural sector to contribute to climate change mitigation and adaptation through 'carbon farming' is a topic that is receiving increasing scientific and policy attention (e.g. European Commission, 2022).

Carbon farming broadly refers to agricultural and land management practices that aim to sequester carbon in natural sinks, such as biomass in the form of soil organic carbon (SOC), and to abate greenhouse gas emissions from agricultural production (Paul *et al.*, 2023). The goal is to convert atmospheric carbon dioxide into soil carbon and store it as organic matter, thereby mitigating soil carbon loss (Hermann, Sauthoff and Mußhoff, 2017). Given the potential of SOC as the "major terrestrial carbon pool" (Wiese *et al.*, 2021, p. 1006), programmes and policy measures around the globe are turning to carbon farming to achieve global targets to reduce emissions, fostering transformation of agricultural practices in exchange of financial incentives for farmers. At the same time, those practices promoted for increasing SOC levels are also acknowledged for contributing co-benefits like improved soil health, higher or more stable harvests, and increased biodiversity (Sharma *et al.*, 2021).

It should be noted here that there is still an ongoing and intense scientific debate surrounding the mitigation potential of carbon sequestration. It has been highlighted that carbon farming might have unintended consequences on soil health and agricultural productivity (Amundson, Buck and Lajtha, 2022); that

1 According to the evidence review report "A sustainable food system for the European Union" this estimate could be higher, with up to 37% of global GHG emissions linked to food systems, "including crop and livestock production, transportation, changing land use (including deforestation) and food loss and waste" (SAPEA, 2020, p. 39).

2 Some of this impacts may focus on biological factors like soil erosion, modified precipitation patterns and water scarcity, loss of quality and quantity in food production, and affections in livestock which is highly dependant on agriculture itself (Yohannes, 2015).

the possibility for carbon sequestration is highly varied depending on differences in factors such as soil type, climate, topography (Rosinger *et al.*, 2023) and in socioeconomic factors (Demenois *et al.*, 2020); and that the potential for negative emissions through carbon farming is often overestimated (Günther *et al.*, 2024). While noting that this is a vivid ongoing debate, the focus of the present report is on farmers' perspectives of carbon farming. Indeed, carbon farming practices and schemes have been met with diverse reactions from the farmers and farm managers implementing them, something that needs further exploration in research (Günther *et al.*, 2024).

The present report reviews the academic literature on what this new climate-mitigating strategy may entail for farmers, and how farmers perceive the potential possibility of adopting carbon farming practices, including how they are impacted by associated policies and market schemes. We draw on studies that explore experiences and perceptions of farmers in different parts of the world, to outline possible venues for future research and exploration in this regard.

1.1 What does carbon farming entail?

Practices like cover cropping, managing crop residues, introducing no-tillage and conservation tillage (Mills *et al.*, 2020), mulching and using hedges, reducing the use of fertilisers and applying biochar as soil amendment (Mahmoud *et al.*, 2021; Davidson, 2022), and fallowing and crop rotation are among the most common strategies promoted by carbon farming initiatives to increase SOC stocks and abate greenhouse gas emissions from agricultural production (Ovchinnikova *et al.*, 2006; Ingram *et al.*, 2014; Paul *et al.*, 2023). These practices are predicted to increase carbon sequestration, while also decreasing carbon losses from soils by reducing soil disturbance, and promoting the accumulation of additional organic biomass, thus, contributing to carbon balance and enrichment of soils (Barbato and Strong, 2023). Such farming practices are also expected to generate a number of co-benefits for farmers and agricultural production, like improved soil health and quality, reduced erosion, increased biodiversity and enhanced productivity (Ingram *et al.*, 2014; Johansson, Brogaard and Brodin, 2022).

It should be noted that carbon farming, like other climate mitigation practices, is based on premises of additionality and permanence. *Additionality* refers to that the SOC sequestered as part of a carbon farming initiative should be additional to what would have been sequestered during a "business as usual" scenario, i.e. without implementing any carbon farming practices. *Permanence* refers to that changes need to lead to some form of permanent carbon storage, avoiding both the reversal to practices that release carbon, as well as *leakage*, meaning that adoption of carbon farming practices in one place displaces emitting activities to elsewhere. Permanence can be affected by externalities like increasing temperatures that can reduce the carbon storage properties in the soil (Rochecouste *et al.,* 2017; Gramig and Widmar, 2018; Paul *et al.,* 2023). It might also be challenged by the fact that land use practices change over time due to, e.g. economic changes on the farm or changes in land ownership, in ways that cannot be known or controlled in the present. In addition, the issue of permanence has become a source of concern in existing voluntary schemes as their permanence clauses and contracts may deter farmers from joining their programs, or prioritising some practices over others (Rochecouste *et al.*, 2017; Gramig and Widmar, 2018; Paul *et al.,* 2023).

The functioning of a market for carbon farming also requires that the activities and change in soil carbon stocks are measured and monitored (Barbato and Strong, 2023; Paul *et al.*, 2023). However, research has shown that both measuring soil carbon and ensuring additionality and permanence of storage remain major challenges. It is yet fairly unknown to what extent different land use practices affect the storage and release of carbon in different soils (Rosinger *et al.*, 2023), and the effectiveness of carbon stock indicators to assess land-based climate change mitigation programmes and policies is also debated (Günther *et al.*, 2024).

1.2 How is carbon farming currently governed?

The importance of storing soil carbon has long been encouraged internationally through different instruments. In recent years however, the focus on soil carbon has increased as carbon farming has emerged on global and national policy agendas, and in an increasing number of public and private sector initiatives (Barbato and Strong, 2023; Günther *et al.*, 2024). Thus, different mechanisms to promote carbon farming uptake and to measure carbon sinks in soils have been created in different contexts from voluntary markets, compliance markets (at regional and national levels) and private initiatives by companies implementing carbon farming in their production and supply chains.

One stimulating factor on the global level has been the Paris agreement initiative “4 per 1000: Soils for Food Security and Climate”, which is an outcome of the Lima-Paris Plan of Action. This multi-stakeholder platform fosters SOC sequestration in agricultural land as a means to mitigation, which has encouraged different projects on national levels to foster soil health (Phelan, Chapman and Ziv, 2024). Similarly, the European Union (EU) and national policies relating to sustainable transitions and food systems have included carbon farming, and related carbon storage practices, as a way to reduce greenhouse emissions and foster soil health and biodiversity. Policy frameworks at the EU level, like the EU soil initiative (2021) recent revisions in the Common Agriculture Policy[3] (CAP) include measures and objectives to foster soil health and restoration, as well as soil monitoring mechanisms (BirdLife Europe and EEB, 2022). Other initiatives like the "LIFE Carbon Farming" (2021) and "INTERREG Carbon Farming" (2018) programs, and the "Farm to Fork Strategy" (2020), have encouraged the promotion and upscaling of carbon farming in agricultural businesses (European Network for Rural Development, 2022).

Governments around the world are currently developing and adopting initiatives and incentives to promote carbon farming and land management practices that enhance SOC stocks and reduce GHG emissions, for example, in the case of Australia, with its national carbon credit unit scheme (Kragt, Dumbrell and Blackmore, 2017). Soil carbon certificate schemes in voluntary carbon markets are equally on the rise. Market-based instruments[4] (MBIs) as well as incentive-based programs, have become popular, and provide financial support for farmers to adopt restorative agriculture practices (Paul *et al.,* 2023). As carbon farming became a centerpiece for climate change mitigation investments, it has also raised the interest among leading carbon standars such as Gold Standard and Verra, which provide certification for carbon offseting projects (PIRSA, 2021), and are responsible for monitoring and verifying compliance, aggregating and then trading the credits (Nogues *et al.*, 2021). At the same time, the private sector has become more engaged through investments in carbon markets, driven either by voluntary goals (e.g. sustainability or environmental impact goals, social responsibility strategies, etc.), legal obligations in the contexts where they run their operations, and are perceived as an opportunity for an additional income stream, and a source of "benefits" to farmers who invest in other products from the company (e.g. herbicides and different digital solutions for precision farming).

At this early stage of developing a market for carbon farming, the market is still largely unregulated, and there is a large variety among schemes regarding terms and conditions. Offset schemes linked to carbon farming, often build on a relationship between farmers and investors or funders, linked either through a private platform or a public agency, which serves as a broker between the farms and the credit purchasers (or clients). This report does not entangle the full complexity of these schemes here but rather aims at providing an overarching understanding of them for the sake of being able to discuss farmers' experiences based on literature exploring mostly their links with voluntary markets, and compliance markets and government payment schemes.

3 CAP 20 supported afforestation measures in the Rural Development Programs (RDPs) funded by Pillar 1, while CAP 2024–2027 has included targeted measures on soil health and preventing soil erosion related to carbon farming. Pillar 2 of the CAP also provides a variety of measures that can contribute to the development of carbon farming, by fostering the exchange of know-how, advisory services and collaboration between farmers (European Environmental Bureau, 2023).

4 Other MBIs have been explored in research, like the adoption of a "carbon-tax" to punish emissions that damage the climate and unsustainable land-use practices (Hermann, Sauthoff and Mußhoff, 2017), although it does not necessarily incentivise carbon sequestration, and may affect the livelihoods of lower-income farmers in developing countries (Djanibekov and Villamor, 2017).

1.2.1 A look into the carbon farming schemes

Under carbon farming schemes, farmers can register their fields with private certificate providers, who then measure and certify the soil organic carbon stocks and sell those certificates as carbon emissions offsets. In exchange for the verified offsets, farmers receive payments which can take different forms depending on the verification mechanism. Farmers' payments can be action-based, related to the uptake of particular farming practices or technologies, and these are the easiest to monitor; result-based payments are centred around "actual mitigation outcome[s]", and can provide more certainty of the effects of carbon farming; and hybrid payments that include one initial payment for practice adoption, and additional payments based on the mitigation results, which might reduce the financial burden on farmers (McDonald *et al.*, 2021, p. 27). Existing carbon farming schemes can involve both public authorities and private actors from national to international scales, providing funding or payments for changing practices, and for the monitoring and verification that is required for the offsets. Thus, carbon farming schemes can adopt different models depending on the actors and funding involved, and the types of incentives and payments to farmers. Governmental agencies or private companies might, for example, fund mitigation strategies implemented by farmers, and then also engage in monitoring and verifying, as well as the trading of the carbon credits with private buyers, usually implementing either result-based or hybrid payments (McDonald *et al.*, 2021; Nogues *et al.*, 2021). Under this model, farmers usually receive a carbon credit, which then is sold to third parties to compensate for the carbon emissions of these third parties. The intermediaries often also provide training and other forms of technical support to the farmers. There are also platforms that offer a marketplace for farmers to trade offset credits directly, after implementing the approved or certified methods for mitigation, meaning that it is result-based (McDonald *et al.*, 2021).

Carbon schemes are also part of corporate supply chains in agribusinesses, where companies in different ways incentivise farmers to adapt carbon farming practices in exchange for the credits being used to compensate for the company's own emissions in other parts of the supply chain (sometimes referred to as insetting) (Nogues *et al.*, 2021, p. 12). The company, in this case, has both the role of buyer and verifier of the carbon capture and might even sell the credits to third party actors. Companies like the cooperative *Arla Foods* in Northern Europe[5] have developed their own Climate Check tool to estimate the baseline for their emissions annually (Arla Foods, no date), which is then validated by an external auditor, while farmers get paid a bonus in their milk price to complete the survey (McDonald *et al.*, 2021; Arla Foods, 2022).

5 Cooperative farmer owners present in seven countries: Denmark, Sweden, Germany, United Kingdom and Belgium, the Netherlands and Luxembourg.

The following sections of this report will describe the search methodology (section 2) and findings (section 3) of the review of academic literature on farmers' perspectives on carbon farming. The report will engage specifically with key findings on the types of studies performed to understand farmers' perspectives on carbon farming (3.1), farmers' experiences and attitudes towards carbon sequestering practices (3.2) and perceptions and concerns about carbon farming schemes (3.3). The final section will (4) summarize key findings from the review in order to outline future research priorities and opportunities on this subject.

2 Review methodology

This report draws on a performed systematic search of publications in English using the search enginges Scopus and Web of Science performed in December 2023, and then repeated on Januray 2024. The search focused on research on farmers' perspectives, attitudes and motivations towards carbon farming and was designed as: “(("carbon sequestration" OR "soil carbon" OR "carbon storage") AND (farmer OR farmers) AND (perspectiv* OR perception* OR attitud* OR motivat*))”. The search captured 178 publications in Scopus and 215 in Web of Science[6], out of which 103 overlapped, resulting in a total of 290 original publications. In addition, snowballing based on reference lists of initially captured literature, was used to find additional papers of interest for the focus of the report.

Based on reading headings of all papers 117 papers were removed from further analysis, as an initial scanning of paper titles revealed that the publications did not relate to farmers' perspectives on carbon farming, or where published in a language other than English. Thereafter, the abstracts (or introduction in cases where the paper did not have an abstract) of the remaining publications that were deemed relevant for our review were read. The continued analysis focused on publications reporting on perceptions, attitudes and motivations of farmers to adopt carbon farming – both related to soil management measures, as well as financial schemes. In this step, another 41 publications were removed from the analysis. Finally, 60 publications were read in full and are included in this review (see Fig. 1). The following section (3.1) describes the types of studies performed on this topic.

6 The search generated 216 publications, but one was duplicated and was removed, leaving 215 hits.

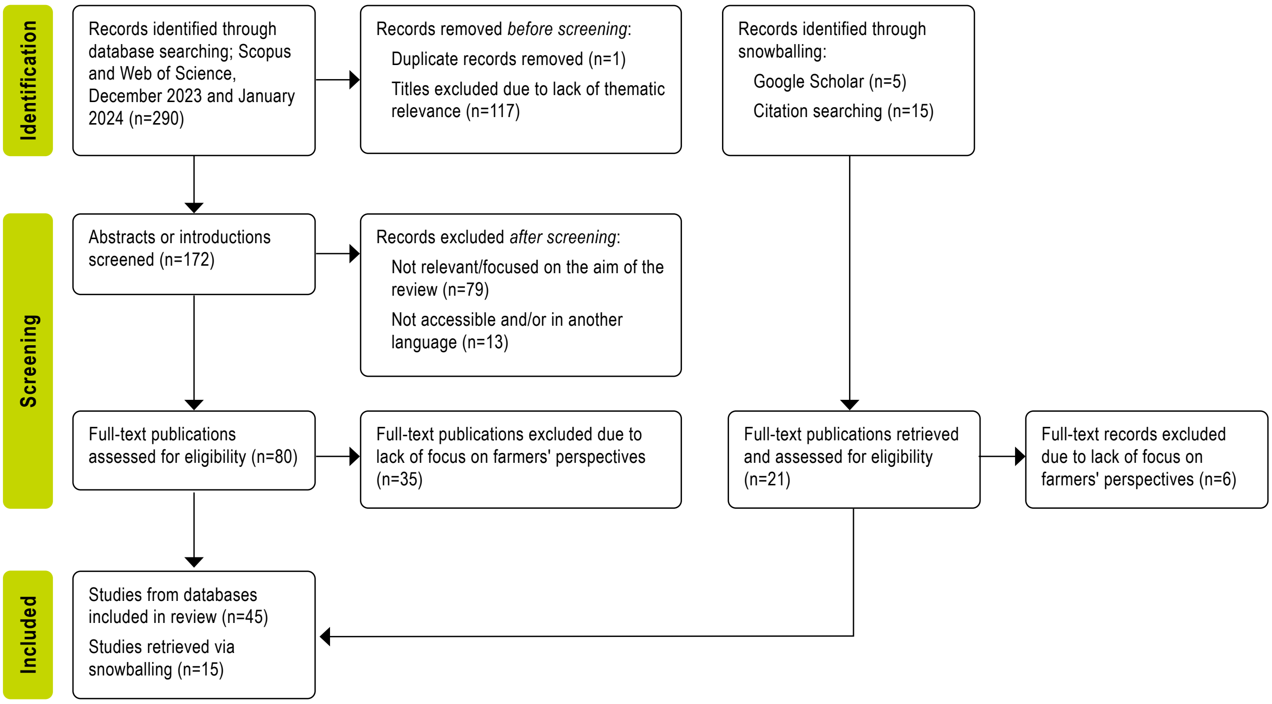

Figure 1. Summary of literature search process based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page *et al.*, 2021).

3 What do we know about farmers' perceptions on carbon farming and the factors that impact their willingness to adopt it?

3.1 What types of studies are performed to explore farmers' perceptions of carbon farming?

An overview of the retrieved publications shows the predominance of studies mainly related to the fields of environment, sustainability and technology, as well as agriculture, agronomy and forestry. In line with this, the majority of studies in the review focused on environmental conditions (e.g. biological processes and environmental co-benefits) that enable carbon farming (Stevens, 2018; Schnitkey, Sellars and Gentry, 2023) and their potential for climate mitigation (Kokkora, Vrahnakis and Kleftoyanni, 2022). The analysis of the literature shows that carbon farming is associated with terms such as “climate mitigation” and “adaptation”, “soil health”, and “emission offsets”. Some studies focus on related land use management strategies like agroforestry, conservation agriculture and regenerative agriculture, the two latter are often used to refer to farming practices that could equally be termed carbon farming. Out of the 60 publications analysed, 23 focus on farmers' perspectives and mainly rely on case studies and a qualitative research design with semi-structured interviews, focus groups and workshops with farmers, experts and other stakeholders. These studies explore actors' beliefs, attitudes, experiences and perspectives on carbon farming practices, as well as other climate mitigation measures in agriculture (Ingram *et al.*, 2014; Rochecouste, Dargusch and King, 2017; Scheba, 2017; Kawa, 2021); and existing carbon farming markets, and their interest in either joining or continuing in these programs (Carmichael *et al.*, 2023; Vinco *et al.*, 2023). Some studies collected data through surveys with farmers with different levels of adoption of carbon farming practices in various cultural and geographical contexts (Amin *et al.*, 2023; De Pinto, Robertson and Obiri, 2013; Kragt, Dumbrell and Blackmore, 2017; Hijbeek *et al.*, 2018; Ng'ang'a, Jalang'o and Girvetz, 2020). For example, Dumbrell *et al.* (2016) performed a "Best-Worst Scaling Survey" with farmers in Western Australia to identify the SOC sequestration practices that farmers are more interested to adopting and not, as well as the conditions that affect that decision, pointing out soil health and soil quality as a major factor. It was more common to rely on quantitative or semi-quantitaitve data than qualitative; 33 publications focus on potential opportunities and viability of carbon farming through modelling and quantitative analysis, aiming to understand the factors that influence farmers' adoption of soil carbon management practices (Wade and Claassen, 2017) and their willingness to join market schemes (Jiang and Koo, 2014), different incentive models and compensation estimates (Yu, Yao and Zhang, 2014; Gramig and Widmar, 2018; Chang *et al.*, 2022), the impact of risk perceptions over their decision-making (De Pinto, Robertson and Obiri, 2013; Ng'ang'a, Jalang'o and Girvetz, 2020), as well as measuring farmers' interest and commitment to those programs (Wang *et al.*, 2021). Two studies are based on long-term experiments that measure the impact of carbon farming in different geographical areas within the same country, in Greece (Cavalaris, Gemtos and Karamoutis, 2023) and in India (Pathak *et al.*, 2011), while Gramig and Widmar (2018) performed a choice experiment with farmers in the state of Indiana in the U.S., focusing on the willingness to accept (WTA) changes in tillage practices to comply with carbon offset schemes to mitigate climate change.

Finally, the search also captured a few literature reviews that focus either on the general patterns and processes associated with carbon farming (Amin *et al.*, 2020; McDonald *et al.*, 2021; Paul *et al.*, 2023), or analysis of the complexity of soil health economics (i.e., inputs required to maintain soil quality, while guaranteeing productivity) and the challenges that this might pose for policymaking and designing incentives for farmers to adopt carbon farming (Stevens, 2018). The systematic literature review by Barbato and Strong (2023) focuses on studies that engage with farmers' adoption of SOC sequestration practices and their participation in offset schemes, stressing the lack of social science literature on the subject and the need to fill a research gap in attaining a deeper understanding of farmers' motivations towards carbon farming. A review performed by Department of Primary Industries and Regions, South Australia – PIRSA (2021) explored the reasons why carbon offset schemes fail to gain more support among farmers in South Australia. The studies by Barbato and Strong (2023) and PIRSA (2021) both stress that farmers' motivations to adopt carbon farming are not only driven by factors related to financial incentives for SOC storage, which is something that will be discussed further in this review.

It is relevant to differentiate between farmers' perspectives on carbon sequestering practices *per se*, and farmers' perspectives on carbon farming schemes. While it is not possible to draw a hard line between studies that focus on the practices and schemes, section 3.2 focuses on perceptions, beliefs and attitudes about carbon farming practices – carbon sequestration and mitigation measures – and section 3.3 focuses more on the schemes.

On the one hand, studies report that farmers are generally positive towards carbon sequestration measures associated with carbon farming initiatives, given the co-benefits that they provide for soil health and productivity (Buck and Palumbo-Compton, 2022; Barbato and Strong, 2023), such as increased soil quality and reduced erosion (Dumbrell, Kragt and Gibson, 2016; Kragt, Dumbrell and Blackmore, 2017), which in turn are said to influence farmers' engagement. Well established concepts like conservation agriculture (Govaerts *et al.*, 2009) and regenerative agriculture[7] (Burns, 2021; EASAC, 2022; Cavalaris, Gemtos and Karamoutis, 2023), are increasingly being used to describe practices linked to carbon farming as well, with their increased and overlapping focus on soil health, biodiversity conservation and carbon sequestration in the agricultural sector. On the other hand, the review indicates that farmers may remain reluctant to adopt said practices due to the perceived risks and costs of transitioning to new land management practices, doubts about the available support for transitioning, scepticism on some specific measures and the impacts they may have on their land, etc. The sections below provide some details of what the literature indicates on these matters.

Studies that focus on farmers' perceptions of carbon farming initiatives – i.e. involving measures to incentivise uptake of carbon sequestration and related practices – might be seen to fall on a continuum in terms of how they see carbon farming and how they draw conclusions about farmers' perspectives on carbon farming. On one end of the continuum, there are studies that frame carbon farming as a taken-for-granted good, and to a limited extent unpack the practices. These kinds of studies commonly focus on how farmers might be nudged to be willing to adopt carbon farming practices, stressing the potential of carbon farming for improving environmental conditions while also being critical of the productivist and financial focus of some measures (e.g. Kragt, Dumbrell and Blackmore, 2017; Dumbrell, Kragt and Gibson, 2016; Ingram *et al.*, 2016; Fleming *et al.*, 2019; Chitakira and Ngcobo, 2021). In other words, these studies make use of farmers' voices about carbon farming mainly to give recommendations about how to promote the adoption of carbon farming or how to provide information and support to farmers who already implement what is framed as carbon farming

7 Both conservation agriculture and regenerative agriculture are concepts used to imply sustainable agricultural practices and often also implying more climate friendly agricultural practices. Different uses of the terms include and emphasise different sets of aspects but often centre on reduced soil disturbance, reduced use of synthetic inputs, improved soil health and enhancement of biodiversity (EASAC, 2022; Govaerts *et al.*, 2009).

practices. At the other end of this continuum, there are studies that emphasize farmers' scepticism to various parts of carbon farming measures as reasons to question, criticise or change existing carbon farming schemes, and call for more critical research on the subject (e.g. Rochecouste, Dargusch and King, 2017; Creemers *et al.*, 2019; Buck and Palumbo-Compton, 2022; Cavalaris, Gemtos and Karamoutis, 2023).

Another way of describing the different studies is to say that some studies focus on individual attitudes and social aspects of farmers' attitudes to carbon farming, e.g. to what extent farmers are influenced by their peers when they make choices about carbon farming (e.g., Kragt, Dumbrell and Blackmore, 2017; Jassim, Witt and Evans, 2022) or about cultural dimensions of attitudes to carbon farming (e.g., Carmichael *et al.*, 2023; Beacham *et al.*, 2023); whereas other studies (or parts of studies) focus on how farmers' material conditions (such as farm economy, topographic conditions, land tenure, relative power in the value chain etc.) influence their views on carbon farming (e.g., Ingram *et al.*, 2014; Creemers *et al.*, 2019; Cavalaris, Gemtos and Karamoutis, 2023; Payen *et al.*, 2023). Lastly, there is a group of studies that focus on the relationship between farmers' views on climate change and sustainability and how these relate to farmers' views of carbon farming (e.g., Jørgensen and Termansen, 2016; Chingombe and Musarandega, 2021; Carmichael *et al.*, 2023). Below we provide some more detail on what these different types of studies conclude.

The majority of the studies that focus on farmers' perceptions of and willingness to adopt carbon farming focus on geographical contexts that have established incentives for SOC sequestration and/or carbon farming schemes, such as Australia (Rochecouste, Dargusch and King, 2017; Fleming *et al.*, 2019), the US (Cook and Ma, 2014; Barbato and Strong, 2023), Canada (Carmichael *et al.*, 2023; Vinco *et al.*, 2023) and across Europe (Ingram *et al.*, 2014). We decided to also highlight some studies that are centred in the Global South, which represent a minority in our review (approximately 20% of all the publications retrieved in the dataset), but may provide important insights into the adoption of carbon farming under different socio-economic and environmental conditions in relation to those that currently dominate the literature, and likewise introduce another perspective on the attitudes and motivations of smallholder farmers (Ng'ang'a, Jalang'o and Girvetz, 2020).

3.2 Farmers' views, beliefs and attitudes towards views on land management practices for carbon farming

As aforementioned, carbon farming is associated to a vast array of land management practices aimed to sequester carbon in vegetation and soils, and to abate GHG emissions in agricultural activities. The reviewed literature explores the experiences of farmers implementing mitigation and carbon sequestering practices such as cover cropping (Ullah, Oladosu and Crooks, 2023); increasing crop diversity and crop rotation (Rosinger *et al.*, 2023); reforestation or avoided deforestation (Baumber *et al.*, 2022; Wang *et al.*, 2021) and planting trees on marginal agricultural land (Yu, Yao and Zhang, 2014); grassland conversion and grazing management – for example through rotational grazing (Amin *et al.*, 2023); conservation tillage and reduced soil disturbance (Amin *et al.*, 2023); nutrient planning and the use of organic fertilisers (manure) (Ingram *et al.*, 2014), as well as the use of bio-energy production to reduce emissions (Ingram *et al.*, 2014). As aforementioned, conservation agriculture and regenerative agriculture are also used to describe practices centred on soil health, biodiversity conservation and carbon sequestration.

Perceptions, beliefs and attitudes towards these sets of agri-environmental practices are varied, and could be clustered in two sets: ideas and views on the ecological, economic and structural factors associated to these agri-environmental measures – including both co-benefits and "disbenefits"; and farmers' values and environmental beliefs, coupled with their awareness about climate change and its effects.

3.2.1 Farmers' views on the benefits and "disbenefits" from the practices, and perspectives on drivers and barriers for adoption

In general, studies report that farmers are positive towards carbon sequestration measures associated with carbon farming initiatives, given the co-benefits that they provide for soil health and productivity (Buck and Palumbo-Compton, 2022; Barbato and Strong, 2023), such as increased soil quality and reduced erosion (Dumbrell, Kragt and Gibson, 2016; Payen *et al.*, 2023). Mentions of the potential for higher yields and economic benefits (Kragt, Dumbrell and Blackmore, 2017) – including alternative or additional sources of income (Saha *et al.,* 2011) – are also present among the reviewed publications as co-benefits and incentives for practice adoption. The overall recognition and emphasis on these co-benefits, can be seen as building on the same assumption as previous studies that argue that farmers' decision-making is "predominantly based on rational, economic cost-benefit considerations" (Brown *et al.*, 2021, p. 18), which in this case go beyond (but also include) economic stimuli.

In addition to discussions about co-benefits, some studies analyse the influence of demographic (e.g. age, gender), socioeconomic (e.g. off-farm income, educational background), farm typology (e.g. size, market orientation, sales), biophysical factors – mostly linked to soil co-benefits and ecological outcomes – and enabling environments on the adoption of carbon sequestering practices and other mitigation measures (Ingram *et al.*, 2014). Wade and Claassen's (2017) estimate that farm size, soil type and climate may influence corn and soy bean producers' adoption of no-till over time in the US; market orientation (i.e. engaging in commercial farming) and off-farm income were relevant factors contributing to the adoption of soil carbon enhancing practices in East Africa (Ng'ang'a, Jalang'o and Girvetz, 2020). Factors like age influence practice adoption both positively and negatively in different contexts, with older farmers in North Dakota, for example, being more resistant to adopting conservation tillage, supporting the assumption that younger farmers might be more concerned with climate change (Jiang and Koo, 2014); while older arable farmers in the Netherlands show more positive attitude towards increasing soil organic matter than younger and medium age farmers (Hijbeek *et al.*, 2018). Biophysical outcomes are prevalent in driving soil carbon sequestration practices among French winegrowers (namely an improvement in soil and grape quality), followed by economic motivations in second place according to Payen *et al.* (2023). Interestingly, the latter study also finds that biophysical factors are also some of the main barriers for adoption – i.e. water and nutrient competition, the incompatibility of certain practices with the soil and types of plantations – followed by other technical concerns – i.e. lack of adequate equipment and time, lack of proper training and information, financial constraints and concerns over yields (Payen *et al.*, 2023).

The influence of factors enabling farmers adoption of carbon farming practices is a common subject, often emphasising economic, political and social factors (Demenois *et al.*, 2020). Hijbeek *et al.* (2018) surveyed 435 arable farmers in the Netherlands to identify the factors motivating them to adopt practices that enhance soil organic matter (SOM) through the inclusion of organic material inputs, i.e. compost, green manures, straw and slurry. The study concludes that despite 90% of the surveyed farmers being interested in increasing their soil organic matter and indicating great awareness of the possible outcomes of this practice (especially the improved productivity and workability), costs of organic inputs, the existing regulation on manure and fertilisers, and the "(economic) needs to cultivate specialized crops [namely potatoes and sugar beat]" (Hijbeek *et al.*, 2018, p. 98), were significant in limiting the increase of SOM content.

With a similar focus on enabling factors, a multi-stakeholder study by Demenois *et al.* (2020) explores barriers and drivers of the adoption of SOC sequestration practices in different farming systems[8] (called "innovations" in the study) for the 4 per 1,000 initiative in France and Senegal. The results indicate that rather than a prevalence of technical barriers or a lack of willingness amongst farmers to change, limits to implementing carbon sequestration relate more to social, economic and political barriers, with issues related, but not limited to "legal compliance, governance, lack of training and capacity building, [and] lack of economic incentives" (Demenois *et al.*, 2020, p. 9). Another multi-stakeholder study finds that farmers in North East Scotland are already implementing climate mitigation practices including some related to soil conservation management leading to SOC sequestration (Feliciano *et al.*, 2014). However, financial constraints, physical-environmental limitations and a lack of information and education prevent farmers from implementing new practices, even if they would lower their operational costs. Practices like reduced or no-tillage, peatland restoration and managing permanent grasslands followed this trend, while practices like woodland planting or agroforestry, although perceived by experts as a cost-effective mitigation practice and conducive to carbon sequestration, was perceived negatively by farmers (Feliciano *et al.*, 2014).

Studies have targeted both adopters and non-adopters of SOC sequestration and conservation practices and their perceptions of drivers and limitations for adoption. Dunn *et al.* (2016) explore the factors associated with an expansion of cover crop adoption, drawing data from a US national survey on cover crops targeting farmers already using this practice in their land. The study finds that most farmers had self-funded their adoption of cover crops (63% of respondents), although it also revealed a link between discontinuance and self-funding. Moreover, Dunn *et al.* (2016) argue that although cover crops provide several co-benefits for their adopters, "these benefits may only be realized if the intricacies of the practice (seed selection, timing, and means of planting and termination) complement the farm operation" (p. 38). For many farmers, planning how to best implement this form of land management may require several years as the practice is still perceived as costly. While the authors do not contradict the findings of other studies on how funding and financial incentives might contribute to the adoption of conservation practices, they argue in their findings that farmers may weigh in their decision-making other elements like "social pressures, intrinsic motivation and environmental attitudes" (Dunn *et al.*, 2016, p. 39), for example, the results indicate that willingness to self-learn and experiment with cover-cropping is associated to long-term adoption.

Myers and Wilson (2023) study the concerns and perceptions of non-adopters of cover cropping based on the results from a series of surveys about cover

8 In France, the selected case studies included "(i) Polyculture-breeding in Meuse, (ii) Cattle breeding in Creuse, (iii) Field crops in Cher, and (iv) Vineyards in Beaujolais" (Demenois *et al.*, 2020, p. 2), while the selected systems for discussion in Senegal included "(i) Peri-urban agriculture in the Niayes, (ii) Irrigated agriculture in the Senegal River valley, (iii) Agroforestry in Faidherbia albida parklands, and (iv) Rain-fed agriculture and extensive livestock integration" (Demenois *et al.*, 2020, p. 3)

crops conducted with farmers in the US between 2013 and 2020. Like adopters, non-adopters recognise the benefits of cover cropping in terms of erosion, soil compaction, and yields and show openness to implementing it on their farms. However, they also share concerns in challenges like risks for reduced profitability, lack of adequate equipment and the increase labour demand for sowing cover crops and dealing with more weeds resulting from cover-cropping (Myers and Wilson, 2023, p. 6).

Furthermore, taking up new practices might be costly for farmers, especially under uncertainty and increasing climate impacts, which might limit their capacity and/or interest in making such changes in farm management for SOC sequestration (Ullah, Oladosu and Crooks, 2023). Clare *et al.* (2014) question the socioeconomic suitability and poverty alleviation framing of biochar production and application among smallholders and subsistence farmers in China. While commercially produced biochar is too costly for smallholders as an independent farming input, on-farm produced biochar would need households to double their yields to compensate for high labour costs and limited technological capacity, which is extremely unlikely given the marginal environments and limited investment possibilities of these smallholders (Clare *et al.*, 2014).

Hijbeek *et al.* (2018) also argue that adoption of practices that contribute to carbon sequestration can conflict with other farming objectives prioritised by farmers such as "profit maximization, labour use efficiency or minimization of gross margin variation" (p. 85), which become more salient when short-term financial gains may exceed long-term sustainability objectives (Ingram *et al.*, 2014; Hijbeek *et al.*, 2018). Finnish farmers linked to the co-op Valio Ltd.'s carbon-neutral milk chain program, for example, stress their perceived challenges about profitability and high production costs when adopting carbon sequestration practices (Puupponen *et al.*, 2022). Similarly, crop farmers may be hesitant to switch to practices involving, for example, no-tillage due to concerns about the initial costs of new equipment, chemical costs, and labour input (Ng'ang'a, Jalang'o and Girvetz, 2020). Thus, balancing practice uptake and environmental outcomes with profit-related objectives can become a significant challenge.

In contrast to the co-benefits, generally praised in the literature, Baumber *et al.* (2022) and Jassim, Witt and Evans (2022) warn about the existence of negative outcomes or "disbenefits" from these land management practices due to unaccounted effects on ecosystems as well as possible shifting effects from carbon farming. For example, the revegetation initiatives in Australia have taken place mostly in rangelands, where some communities of farmers claim that carbon farming has also led to a dense expansion of invasive native scrub or mulga, natural to the area, which "created a 'mulga desert' with a lack of biodiversity, increased pest management issues and inability to sustain grazing activity with mulga as fodder" (Jassim, Witt and Evans, 2022, p. 82).

Some studies also highlight farmers' concerns about particular carbon farming practices. A long-term experiment conducted in central Greece exploring the effects of five different methods of tillage (Cavalaris, Gemtos and Karamoutis, 2023), indicates that farmers remain sceptical towards no-tillage, as they associated this with soil compaction and more challenging weed management, despite the contrary effects suggesting an improvement in the farming system. Instead of adopting no-till practices, some farmers enrolled in a rotational tillage scheme decided to go for occasional heavy tillage instead of the prescribed rotation, which compromised their participation in carbon schemes (Cavalaris, Gemtos and Karamoutis, 2023).

Farmers in Spain and Italy participating in a project to explore and test SOC sequestration practices in multiple European countries, also express concern about the effectiveness of proposed measures and to what extent claimed effectiveness can be generalised given the diverse agroecological contexts and farm-land ownership structures across the continent (Ingram *et al.*, 2014). Similarly, focusing on how these practices are framed and communicated, some of the respondents in a study on carbon farming conducted with conventional farmers[9] in Canada voice their scepticism and frustration with organic farming practices being presented as "better" than conventional farming (Carmichael *et al.,* 2023).

Experiences with the implementation of practices can also be heterogeneous, and some of the reviewed studies are cautious about the efficacy and compatibility of certain conservation practices with the agro-ecological conditions in which their uptake is promoted (Dougill *et al.*, 2017). A study conducted in a mixed crop-livestock system with smallholder farmers in Murewha, Zimbabwe, quantified the possible trade-offs between crop and livestock production caused by competing uses of maize crop residues, concluding that it made sense for farmers to "prioritise the sustenance of cattle with crop residues over soil fertility management" (Rusinamhodzi *et al.*, 2015, p. 39). Results from an ethnographic study conducted with farmers in Indiana, US, suggest that the "win-win" narrative associated with practices like no-tillage may elide trade-offs, despite the environmental and economic advantages in no-till perceived by no-till adopters (Kawa, 2021). First, there is a risk for negative views of no-till emerging for aesthetic reasons as the crop residue layer that remains on the fields with no-till makes the field look messy and farmers generally take pride in maintaining "clean and open" fields (Kawa, 2021, p. 30). Secondly, and one of the most contested trade-offs of no-till in this study, is the fact that some farmers use more herbicides to manage weeds, questioning the extent to which this practice actually contributes to soil conservation.

A group of articles also point out that an obstacle faced by farmers to adopt carbon farming practices is a lack of information, and not receiving adequate and targeted advice and training regarding which practices are recommended, along with a lack of financial resources to support the adoption of new practices (Ingram *et al.*, 2014; Ng'ang'a, Jalang'o and Girvetz, 2020). Considering that a change in land management practices is needed, the literature indicates that

9 To be included in the study, farmers needed to produce "food through farming on land, own or rent the land on which they farm, and reside in Canada" (Carmichael *et al.*, 2023, p. 4).

measures like training, technical support, and access to advisory services can help farmers build their confidence and capacity to adopt these methods (Ingram *et al.*, 2016; Ng'ang'a, Jalang'o and Girvetz, 2020). Scheba's (2017) work explores the performance of REDD+-financed conservation agriculture farmer field schools in two villages of Tanzania, and their impact on farmers perceptions. The study finds that farmer field schools effect on participants' perspectives on conservation agriculture is heterogeneous and the implementation of conservation agriculture principles – like minimal soil disturbance, crop rotation, and mulching – is heavily constrained by socio-economic factors (Scheba, 2017). Farmers often find the labor demands of conservation agriculture higher than expected, contrary to the promised advantages of reduced labor; and structural challenges, such as lack of credit facilities and markets, can further complicate the adoption process.

It has also been pointed out that programs that promote carbon farming should be tailored to the specific needs of farmers, to empower them to make informed decisions about their soil carbon management in favour of climate mitigation (Paul *et al.*, 2023). However, when assessing farmer engagement in carbon schemes, research should also be cautious against uncritical support to conservation practices, and pay attention to the impacts and performance they have on farmers, and the way in which practices and schemes are promoted and implemented in different communities and farming systems (Hendrickson and Corbera, 2015). As Scheba (2017) notes in Tanzania, for example, conservation agriculture was promoted as a "promotional package including training on [non-CA-related] fertilizers, pesticides and improved planting techniques" (p. 216), which farmers directly associated with higher costs and some even abstained from joining; and, in retrospect these inputs may even defeat the purpose of soil conservation.

3.2.2 Farmers' values and environmental beliefs around the practices

Some studies find that environmental concerns, the values farmers perceive as relevant and how they attach them to the land can influence their interest in adopting carbon sequestering practices. A study performed by Beacham *et al.* (2023) with regenerative farming clusters in East and South-West England, highlights that farmers associated emotional connections and values underpin the adoption of regenerative agriculture to strengthen environmental protection. Through in-depth interviews with 21 farmers and farm managers, they stress the "redemptive value, enhancing care for the environment and helping them 'to sleep at night'", as well as "the connection they felt with 'the soil, the environment [and the] community'", as main motivation for practice adoption (Beacham *et al.*, 2023, pp. 4–5).

A study conducted with farmers from the prairies in Canada, reported that farmers express their view of farming beyond as a mere occupation, and rather as "an identity with environmental overtones" (Carmichael *et al.*, 2023, p. 10). In this study, farmers articulate their feelings of pride as caretakers and stewards of the land, feeling compelled "to do the right thing" (Carmichael *et al.*, 2023, p. 10), adopting land management practices to improve soil quality and adaptation, compatible with carbon farming in most cases. Correspondingly, a metaeconomic analysis exploring motivations for adopting conservation tillage among farmers in Nebraska, found that willingness to embrace this practice is significantly influenced by "empathy toward others' perspectives and a farmer's feelings about shared conservation ethics" (Sautter *et al.*, 2011, p. 143), beyond more conventional notions of profit-maximization and pecuniary incentives for practice adoption. Thus, the study suggests that the adoption of conservation tillage is linked to a stronger commitment to "environmental stewardship" (Sautter *et al.*, 2011, p. 142).

Conservation ethics is also prevalent in a focus group study conducted with farmers in Iowa exploring how they navigate field-level (agronomic) and structural (economic and market drivers) challenges in managing cover crops. The farmers emphisize the importance of "cultivating a soil conservation ethic despite high costs of production and low profit margins" (Roesch-McNally *et al.*, 2018, p. 329), to promote long-term sustainability of land deeply affected by erosion. Similarly, the participants in the study recognise how held beliefs and regional cultural norms about production practices and output maximisation of their crops can both positively and negatively influence farmers' willingness to implement cover cropping.

A group of studies focused on the relation between farmers' perceptions about sustainability, climate change and carbon farming (e.g., Gramig, Barnard and Prokopy, 2013; Cook and Ma, 2014; Jørgensen and Termansen, 2016; Rochecouste, Dargusch and King, 2017; Chingombe and Musarandega, 2021; Beacham *et al.*, 2023; Carmichael *et al.*, 2023). Carmichael *et al.* (2023) for example suggest that we must understand farmers' perceptions of environmental sustainability as these are likely to influence their views on carbon farming, because "their livelihood [and that of future generations] depends on their stewardship of the land" (p. 10). This finding also hints towards particular understandings of temporality and expectations about the future of the farmland that might influence farmers' decisions over conservation practices, both in relation to the attachment and values associated with the land in connection to farmers' identity and history associated with the land (Carmichael *et al.*, 2023), and in relation to the sense of control and decision-making capacity over how the farmland is used (Rochecouste, Dargusch and King, 2017).

Lees *et al.* (2023) delve into the perceptions of different land managers (game keepers, farmers, estate managers and land-owning organisations) around sustainable peatland management in the Yorkshire Dales, an area with high potential for carbon sequestration, and found that while land managers agreed on desired conservation outcomes, they disagreed in the the preferred methods to reach these conservation outcomes. Particularly, Lees *et al.* (2023) find that all the land managers shared relational values linked to a sense of ownership of the land, aesthetics of the landscape, and stewardship, which manifested diversely with either a defense of traditional land management or the need for change in peatland conservation, and stressed the relevance of including this perspective when designing interventions to minimize resentment among communities.

A survey with rangeland farmers in Utah inspects the relationship between farmers' beliefs, values and attitudes towards climate change, and their awareness about carbon farming (Cook and Ma, 2014), reporting a correlation between higher environmental values and belief in climate change with a positive attitude towards carbon sequestration. The results even report that respondents "valued the potential ecological benefits of carbon sequestration more than the potential financial or climate change benefits" (Cook and Ma, 2014, p. 90). However, the study also revealed that "perceived changes in local weather patterns did not always match up with general climate change beliefs" (Cook and Ma, 2014, p. 94), with some respondents indicating their awareness of climate change impacts at the same time they perceive no changes when asked more specifically about precipitation levels and temperature.

Similarly, a survey study conducted across six farming regions in Australia compares farmers who have adopted practices to improve soil health and carbon storage with conventional farmers who have not been engaged in programs to promote such practices. The study concludes that knowledge about anthropogenic climate change could be a driver for the adoption of soil-improving practices (Alexanderson, Luke and Lloyd, 2023, p. 7). In contrast, a national-scale survey conducted in Denmark indicates that farmers who engage with practices to improve storage of soil organic carbon do not connect these practices with climate change mitigation nor with their own experiences of the effects of climate change, which they assume as "normal weather variability" (Jørgensen and Termansen, 2016, p. 283).

Another study with farmers in peri-urban areas in South Africa shows that despite the farmers' lack of awareness about the official framing of climate-smart agricultural practices and technologies that support adaptation (as promoted by public authorities and private actors), they were still engaging in several practices that contributed to carbon farming, such as planting a diverse range of crops, the use of compost, cover crops, and crop rotation, as these practices were a core part of their traditional way of farming (Chitakira and Ngcobo, 2021). Likewise, in their research, Dunn *et al.* (2016) agree that "associations between environmental attitudes and participation in the use of agricultural conservation practices cannot always be presumed" (p. 30). Thus, these different studies suggest that beliefs and awareness around climate change might not in themselves be a driver for adopting mitigation practices, though this does not exclude the increasing experiences of its effects in farming land. Overall the studied literature indicates no conclusive direction regarding the relationship between perceptions of environmental issues like climate change and the uptake of practices.

While some farmers are marginally interested in climate change adaptation as a motivation for adopting carbon farming, this review also finds that cultural beliefs and the influence of such beliefs over farmers' practices and their own definitions of soils and how to care for them are also important drivers for practice uptake. An interview study on farmers' perspectives on agroforestry across eight European countries also identifies that the main drivers for adoption relate to the preservation of traditions in the family and region where the farms are located, the capacity to learn from others (through meetings, exchanges and sharing experiences with colleagues and other farmers), and the benefits of diversifying farm products (Rois-Díaz *et al.*, 2018). Although the study also recognises that awareness about agroforestry was limited among farmers, even if they had integrated it into their crop and livestock production, some farmers didn't relate the practices to agroforestry or know its definition.

Tracing back the experiences and beliefs of the Buryat people close to Lake Baikal, the Dogon people in Mali and groups of farmers in France around soil organic matter, Feller *et al.* (2015) find a connection between these beliefs and adoption of minimal and no-tillage. Feller *et al.* (2015) invite research to further explore how farmers "understand and characterize their soils" (p. 174). By using farmers' own wording about soils, they argue that research can elucidate farmers' ideas and concerns over soil organic matter and their attitudes towards the adoption of carbon sequestration and conservation practices.

Similarly, Saha *et al.* (2011) argue that the adoption and maintenance of carbon-sequestering practices are closely linked to socio-psychological factors involving cultural traditions passed on by ancestors, the imitation of peers (family, friends and/or neighbours) and the level of education, which can result in different outcomes based on normative and behavioural beliefs. Studying the case of home gardens[10] in Kerala, India, they find that while farming traditions and the influence of peers are linked to the use of more tillage in the home gardens, which hinders carbon sequestration, the same factors are also linked to the application of plant residues over the crops, which promotes carbon sequestration. The authors also show that while higher levels of education are related to more tree planting and less deforestation, they are also linked to the use of more fertilisers, showing again a double effect from the same trait (Saha *et al.*, 2011).

On another direction, a group of studies highlight that farmers sometimes perceive tradeoffs between adapting to climate change and adopting carbon farming practices, due to available resources and ecological and structural conditions. A study with Australian grain farmers that explores their interest in providing vegetation services by tree planting projects in non-cropped land[11], stressed their concern about available irrigation under extreme weather conditions due to rising temperatures (Rochecouste, Dargusch and King, 2017). The concern over irrigation, in this example, became more tangible for farmers when considering the challenge associated with having to sustain both their productive fields and their non-cropped areas to comply with carbon farming schemes, especially under

10 Home gardens are defines as traditional, small-scale, multi-species farming systems commonly found in the tropics, integrating trees, crops, and sometimes livestock around the home (Saha *et al.*, 2011).

11 Part of the listed activities under the Carbon Farming Initiative in Australia.

dry seasons. A similar concern was lifted by Canadian farmers reflecting on the high costs and lack of immediate returns of the conversion of farmland into non-cropped areas for carbon farming, which might hinder the adoption of carbon farming practices, despite farmers acknolweding the long term sustainability of adopting such practices (Carmichael *et al.*, 2023).

Both in the Australian and Canadian studies, farmers saw that the negative impacts of climate change on farming create additional obstacles to adopting carbon farming practices due to initial costs and lack of immediate returns when transitioning to carbon farming (Rochecouste, Dargusch and King, 2017; Carmichael *et al.*, 2023). Pointing in the same direction, another study conducted with farmers in different agroecological zones in Zimbabwe explored the barriers to climate adaptation when implementing conservation agriculture. The farmers highlight extreme weather conditions, especially prolonged droughts, infrastructural challenges, constrained water resources, inefficient bureaucracy and gender inequality as intricately connected barriers (Chingombe and Musarandega, 2021).

Creemers *et al.* (2019) find a different kind of farmer opposition to carbon farming. While some farmers in their study (mainly beetroot farmers) are reluctant to change the scale of their production and practices as they already consider themselves to be practicing sustainable farming (Creemers *et al.*, 2019), others (in particular dairy farmers) acknowledge the negative carbon impacts of their farming but emphasised that the responsibility and burden for reducing climate impact must be distributed amongst the actors in the value chain, as they perceived their ability to effect broader change as limited. Likewise, Puupponen *et al.* (2022) argue that a fair transition to new land management practices requires distributing the burden also to other actors in the agricultural value chain and that other actors understand and show appreciation for the work done by farmers towards such transition.

3.3 Farmers' views on carbon farming schemes

Many carbon farming schemes are inter- or multinational in character, and involve both private and public funding, monitoring and certification, with farmers across the world largely targeted by similar types of schemes. However, their experiences of these schemes might differ depending on context-specific factors like farm size, style of operation, access to financial capital and information, as well as social and environmental factors such as soil typology and existing social networks that can influence engagement to the schemes.

Economic incentives are considered as a relevant driver for the adoption of carbon farming, as well as persistence in the commitment to carbon farming initiatives. Myers and Wilson (2023) argue that non-adopters of cover crops expressed their interest in adoption with cost-sharing and incentive payments – including soil carbon payments – as well as other financial measures like tax credits and crop insurance discounts, supporting the argument for monetary incentives to induce practice uptake. In the case of farmers already involved in carbon projects, they may perceive the schemes as additional farming income and remain in projects largely due to "their belief [it] may increase their incomes in the future" (Wang *et al.*, 2021, p. 5). According to Aslam, Termansen and Fleskens (2017), even if farmers are reluctant to make significant changes to their land use and management systems, appropriate financial compensation coupled with limited (non-restrictive and progressive) measures can encourage the adoption of carbon farming.

Similarly, Jassim, Witt and Evans (2022) identify financial incentives as being the main drivers for the adoption of carbon farming schemes for individual farmers in the Mulga Lands bioregion in Australia, as the added income contributes to the diversification of income sources to their debilitated agricultural enterprises, "despite sharing concerns with the broader community over potential environmental and social impacts" (p. 82). Nandakishor *et al.* (2022) conducted a survey study with farmers in Kerala, India, to assess the acceptance of a tree banking incentive program based on coffee agroforestry as a mitigation strategy, showing that a majority of farmers are willing to plant trees on their land despite the potential impact on crop yields, with financial incentives increasing their willingness to participate, although they remained selective of the selection of tree species for their farms.

Despite the strength of financial schemes in promoting practice uptake, farmers can be critical and resistant towards carbon schemes. Gramig and Widman (2018) assess farmers' willingness to adopt reduced or no-tillage in the corn belt in the US through a choice experiment based on different payment policies or market designs to farmers in exchange for carbon sequestration. While the study establishes a higher cap in payments for conservation tillage, farmers actually prefer an increase in their yield and profit derived from practice adoption without any payment, and they showed less aversion to government payments than to carbon market payments. Part of the aversion to carbon payments is explained through farmers' "dislike of multi-year contracts" (Gramig and Widmar, 2018, p. 512), with permanence being the main barrier for adopting new tillage practices. Something worth mentioning is the fact that the study also finds that farmers that already switched to reduced- or no-tillage did so in the absence of any payment, although it does not explore their motivations. This supports the relevance of researching other than pecuniary drivers for adoption.

Research about carbon farming has also targeted more "biophysical effects of land management on soil carbon and market mechanisms for promoting carbon sequestration" (Cook and Ma, 2014, p. 92). As stressed in the previous sections, co-benefits like soil and crop quality, as well as economic sustainability are relevant drivers for taking up carbon farming (Barbato and Strong, 2023), and some literature even invites policy to focus on them to ensure farmers' engagement (Amin *et al.*, 2023). Still, farmers emphasize that their interest in long-term sustainability and the co-benefits of SOC practices are a motivation to participate in carbon farming, as long as they match production objectives (Dumbrell, Kragt and Gibson, 2016).

However, most studies indicate concerns from farmers related to market-based mechanisms for soil carbon sequestration, pointing out financial compensation as too low or allocated "too uniformly" without accounting for variations in soil structures and stock capacity (Yu, Yao and Zhang, 2014), substantial paperwork burdens, a lack of predictability and transparency in credit calculations, and that the markets are being skewed to benefit large-scale agriculture (Schapel *et al.*, 2018; Buck and Palumbo-Compton, 2022; Paul *et al.*, 2023; Barbato and Strong, 2023). Current variability and low carbon prices in the market make carbon sequestration projects unattractive for farmers unless there are subsidies or eco-compensations that support farmers' participation in the said projects (Chang *et al.*, 2022), as shown in a study exploring potential financial benefits for farmers in a forest carbon sink project in Northwest China.

Regarding the latter point, the reviewed literature suggests that carbon schemes are based on the fundamental assumption that farmers would fully respond to the price signal provided by a carbon market that pays for GHG emissions mitigation. However, Jiang and Koo (2014) note that farmers have different preferences for carbon farming, which implies that they also perceive different benefits and costs from participating in the schemes. Even if farmers are likely to respond to market incentives for carbon farming, low carbon prices, the perceived private costs in changing farming practices and possible risks steaming from a binding contract might limit that response (Jiang and Koo, 2014). Similarly, De Pinto *et al.* (2013) argue that more attention should be paid to farmers' preferences and their heterogeneity, and criticise studies that ignore, for example, how farmers' attitudes towards risk and other context-related traits affect their choice of adoption of carbon farming beyond possible compensation.

Farmers also express concern about how changing political environments and regulations might impact the benefits and risks of adopting carbon farming (Dumbrell, Kragt and Gibson, 2016; Kragt, Dumbrell and Blackmore, 2017; Beacham *et al.*, 2023). Uncertainty about future governance arrangements is identified by farmers in New South Wales as relevant impediment for joining conservation programs, considering their awareness of how contentious the inclusion of agriculture in climate policy remains, and the prevalence of other financial and information access constraints (Page and Bellotti, 2015).

A survey with farmers in Norway, Belgium, Germany and the Netherlands linked to the Carbon Farming (2018-2022) Interreg North Sea project, also highlighted insufficient knowledge (about both practices and compensation schemes), restrictive policies and financial reasons as the most relevant barriers to adopting carbon farming (Demeyer *et al.*, 2021). Likewise, a multistate survey[12]

12 The farmers participating in the survey are engaged with row-crop production in 27 states in the US.

conducted with farmers in the US to assess their willingness to participate in carbon markets shows that even if a majority of farmers know about carbon credits and are interested in them – i.e. are willing to adopt new farming practices in exchange for payments – they are concerned with the uncertainty of the carbon prices, the market, associated policies and possible costs (Han and Niles, 2023).

The reviewed literature points out the need for more research on the total cost of carbon sequestration for farmers who adopt a carbon farming scheme (Govaerts *et al.*, 2009), with few studies accounting for the co-benefits in their analysis of mitigation costs and the integrated impact of carbon farming and other land management strategies (Tang *et al.*, 2016). For example, Rochecouste, Dargusch and King (2017) inquire about Australian dryland farmers' perception of their non-cropped land and the barriers to engaging in vegetation services as part of the Australian Carbon Farming Initiative. The farmers interviewed in their study, argue that the lack of funds to assess business proposals and their possible return, together with the challenges posed by current project approval processes, and the lack of profitability in producing offsets from dryland grain cropping operations, make them continue with farming practices they already know and implement (Rochecouste, Dargusch and King, 2017).

Farmers in different contexts also perceive the adoption of carbon sequestration practices as costly, as it may require extra labour, outweighting the potential benefits from adoption (Latawiec *et al.*, 2019). Access and connectivity might also affect the scope and reach of carbon farming schemes, which might leave smallholders or lower-income farms excluded from gaining awareness of the existence of different carbon farming schemes. There has also been limited attention in the literature to the costs of adopting carbon farming for smallholders (Ng'ang'a, Jalang'o and Girvetz, 2020) and the intricate array of trade-offs related to the adoption of carbon farming (Tang *et al.*, 2016). Moreover, the retrieved literature does not offer clarity about who gets to bear which costs in carbon farming, something that should be relevant in any policy and scheme design, which also leaves the farmers in a disadvantage position when invited to join different schemes.

Some studies emphasise that the economic feasibility of implementing carbon farming should be considered when designing incentive systems and policy support for farmers (Pathak *et al.*, 2011). At the same time, this calls for an innovation in schemes beyond the measurement of SOC stock additionality, which might loose sight of the other co-benefits generated from carbon sequestration and mitigation practices and ways to fund them. Alternative forms of compensation have been explored, for example, among dairy producers in Finland pressured to reduce their carbon footprint and engage with carbon-neutral farming, like payments for guaranteeing animal welfare (Puupponen *et al.*, 2022).

It has also been emphasised that transforming farming practices to comply with carbon farming might entail risks that need to be considered when incentivising farmers to join the schemes (Aubert, Foucherot and Svensson, 2022). Different farmlands and farming practices are also more and less suited to create benefits from carbon farming, which impacts farmers' interests in carbon farming alternatives. For example, dryland cropping in sandy soils with "low nutrient and water holding capacity" (Schapel *et al.*, 2018, p. 3) has a harder time capturing soil carbon, which limits the interest of farmers in adopting carbon farming and/or joining carbon schemes, unless implemented in marginal land with no cropping value otherwise (Rochecouste, Dargusch and King, 2017).

Monitoring and verifying carbon sinks is also a complex and costly endeavour. Once in place, carbon schemes based on measuring SOC stocks over time, may reward farmers implementing similar practices differently, posing a "fairness and equal treatment challenge" (Rosinger *et al.*, 2023, p. 2) and increasing the level of uncertainty for the participating farmers about the financial outcomes of participating in a carbon farming scheme (Barbato and Strong, 2023). The scholarship urges policy and private initiatives to account for this uncertainty in carbon uptake in the design of their programs, and to develop monitoring methods and potential assessment for carbon farming that harnesses farmers' local knowledge and experience to adapt practices to their landscapes and social conditions (McDonald *et al.*, 2021).

Brown *et al.* (2021) criticise the focus on economic drivers and the apparent "productivist ethos" (p. 19) fostered in policy instruments as well as private schemes to engage farmers in carbon farming, arguing that they alter the views and attitudes towards certain practices and systems. The bias towards focusing on economic factors has also resulted in simplified understandings of factors influencing farmers' adoption of carbon farming, without considering other-than-financial motivations that affect farmers' choices. De Pinto, Robertson and Obiri (2013, p. 47) argue that "uncertainty and risk-aversion are notably absent in the modelling of farmers' adoption of climate change mitigation practices in developing countries", while modelling farmers as risk-neutral agents may lead to over-estimated perceptions of the success, implications and reach of carbon compensating projects. As such, they criticise that incentive schemes assume farmers as benefit-maximisers, which should imply their interest in carbon farming and their duration in the programs. However, farmers are not a monolithic group (Barbato and Strong, 2023), and their heterogeneity in local conditions and different risk attitudes can influence the amount of compensation required to address potential costs from climate mitigation interventions, which is why it is relevant to consider this heterogeneity in the analysis (De Pinto, Robertson and Obiri, 2013).

Some studies also show that framing carbon farming from a profit perspective, and promoting it through certification schemes, has generated adverse reactions amongst some farmers, like cynism and resistance (Brown *et al.*, 2021). Fleming (2019) argues that framing carbon farming as a financial opportunity may not be the most effective approach, which relates to the limited return and unpredictability of the certificate values (PIRSA, 2021). Some research even suggests that "modest financial payments [are] 'crowding out' intrinsic motivations for contributions to public goods such as soil conservation" (Andrews *et al.*, 2013, p. 501). Other concerns relate to the perception of "greenwashing" from the companies that buy and use the carbon credits and that market-based approaches might, in fact, enable some companies to continue with 'business as usual' by compensating for their emissions (Barbato and Strong, 2023). Yet another concern is that of leakage, i.e. that the adoption of carbon farming schemes could lead to "increased GHG emissions and biodiversity degradation in other regions due to land-use change" (Günther *et al.*, 2024, p. 19), if conventional agriculture just expands to other areas. Jassim, Witt and Evans, (2022) highlight unaccounted impacts on social structures in their study with farmers in the Mulga Lands in Australia, where the scale of the pace of changes in the landscape practices due to carbon farming, has contributed to the emergence of tensions and divisions among communities between adopters and non-adopters, given the stress in individual landholders rather than communities and a landscape perceptive.

Carbon farming requires a long-term planning perspective, as it takes years for SOC increase to be detected, which requires a commitment from farmers to the transformation of their land management schemes. For some landholders, joining carbon farming schemes is perceived as leading to a loss of flexibility in their decision-making capacity over land-use practices (Baumber *et al.*, 2022). Some Australian farmers have raised concerns, for example, that signing up for government-led carbon farming schemes meant losing control over how they could use their land in the future (Rochecouste, Dargusch and King, 2017). In particular, current permanence clauses have made farmers concerned in this regard, as the Australian Carbon Credit Unit (ACCU) scheme has a crediting period of 25 years for a sequestration offset project, and seven years for an emission avoidance project, with a permanence of carbon farming projects of 25 or 100 years, while emission avoidance projects do not have a permanence clause (CFI Act, 2011).

A couple of reviewed studies also highlight that farmers who already engage in carbon sequestering practices, before signing up for a carbon scheme, may be excluded from these schemes due to "additionality" requirements (Barbato and Strong, 2023; Vinco *et al.*, 2023). This creates a risk that farmers might revert soil carbon storage efforts done before signing up for a carbon market scheme, to make sure to qualify, which would lead to negative climate impacts. With this in mind, it has been suggested current additionality requirements need to be revised and that carbon farming schemes should be designed in ways that make them available also for those farmers who already engage in practices that are counted as carbon farming (Barbato and Strong, 2023).

On another note, it is commonly brought up in studies how land tenure arrangements and sense of control of the future of one's land may influence the interest and ability of farmers to engage in carbon farming practices. Land tenure arrangements are pointed out to affect the flexibility and long-term planning management in farms as well as land availability (Demenois *et al.*, 2020), especially for small-scale farming (Ng'ang'a, Jalang'o and Girvetz, 2020) and rented farmland (Potthoff and Dramstad, 2023), making it difficult for these farmers to implement any practices and commit to the requirements of many carbon farming schemes. Even if farmers entertain the idea of joining a carbon scheme, while land owners might be motivated to engage in models that involve "major land use change", tenants would most likely participate in schemes that do not require drastic changes in land use (Jiang and Koo, 2014, p. 236). Land ownership could stimulate participation in those programs that involve major land use change. Nonetheless, land tenure and ownership, as well as other structural factors like farm size are multidimensional, with studies reporting them as having "positive, negative or neutral associations with environmental management" (Brown *et al.,* 2021, p. 8). Myers and Wilson's (2023) survey study finds little difference in farm size between cover crop adopters and non-adopters in the US; while Brown *et al.* (2021) argue that while previous research had pointed out the effects of land ownership on soil conservation in the farmland, their study with dutch farmers did not find a significant relation in that sense. Conversely, Hendrickson and Corbera (2015) find that one of the motivations for participants to join a carbon forestry project in Chiapas, Mexico, is their perception of a potential to overcome inequalities associated with a lack of land tenure and access to resources, while gaining a "sense of inclusion with the others" and collaborative work (p. 68). These findings support the conclusion that there is a complex relationship between farmers' uptake of conservation practices and these structural factors (Ranjan *et al.*, 2022). The studies also indicate a great variation in farmer decision-making and that it is as of yet difficult to identify reliable and cut-through motivational factors that explain farmer uptake of carbon farming. Something definitely worth of further exploration in research.

Altogether, these studies seem to agree that a focus on co-benefits and broader economic incentives could enhance the adoption of carbon farming. Some studies suggest focusing on the co-benefits and the yields from biodiversity and soil health that carbon farming generates in research, policies and financial schemes (Buck and Palumbo-Compton, 2022). Research also points to further research on the specific co-benefits that resonate with different farmers (Ingram *et al.*, 2016; Fleming *et al.*, 2019). One study suggests that incentive schemes for carbon farming could benefit from the inclusion of other-than-financial motivations of farmers in the design and that this could be achieved through closer cooperation and knowledge co-production between researchers and farmers (Demeyer *et al.*, 2021). Although benefits and costs are major considerations for farmers' decision-making, they are not always the most relevant factors driving the use of conservation methods (Roesch-McNally *et al.*, 2018). Here, research calls for more efforts in exploring socio-attitudinal factors among farmer motivations for implementing changes in their land management systems, such as their values and perceptions of their role in agriculture and society, their beliefs about justice and the environment, their traditions and culture, and their societal connectedness and the influence of social networks surrounding individual farmers on their choices and the promotion of change (Brown *et al.*, 2021).

4 What can we learn about the factors that impact farmers' willingness to adopt carbon farming? Possible research pathways

Studies on farmers' perceptions on carbon farming have increased during the past decade. Overall, these studies introduced a broad picture of multiple factors influencing farmers' choices and abilities to implement certain farming practices. Taken together, the reviewed research highlights a complex interaction between perceived benefits and risks (related to the new practices as well as the schemes), economic considerations, views of and experiences with climate change, environmental values, etc., in shaping farmers' attitudes towards carbon farming. Several different farm attributes such as farm size, farmer age and education, access to labour and skills, and household economy, among others, were connected with different perspectives on carbon farming in the literature, without being conclusive about the importance of different impacts. While the findings from the reviewed publications indicate that economic factors are indeed the most frequent in focus, they also suggest that farmers beliefs, perceptions and values towards carbon farming go well beyond economic concerns.

The review indicates a general interest and positive outlook from farmers towards land management practices related to carbon farming, stressing the opportunities from the co-benefits generated from such model, which align with broader sustainability goals. However, despite many farmers being positive towards carbon sequestering practices and other mitigation measures per se, the review indicates that farmers can still be reluctant to adopt such practices and sign up for different schemes for other reasons, such as concerns with costs and risks of transitioning to new land management systems, availability of support for transitioning (both financial and technical support, e.g. training), the need for new machinery and extra labour, as well as the sense of schemes creating future inflexibility in farming. Similarly, the reviewed studies suggest that more research is needed on the risks, negative outcomes and total costs of carbon farming. In this regard, some of the reviewed studies stress the need for more attention in research to the variation and experiences amongst farmers, and the particular vulnerability to risks of farmers who might be facing food insecurity, for whom investing time and labour on initiatives with uncertain benefits can be extremely difficult (Scheba, 2017).

Because of the complexity of carbon farming, some of the literature advocates inter- and transdisciplinary research that engages with both the technical aspects and questions of justice, fairness, livelihood and social capital with regard to carbon farming. Furthermore, although other social science research on farming has established that farmers' social networks, peer pressure and wider discourses have key influence on farmer decision-making (Burton *et al.*, 2020), this has not been explored in relation to carbon farming where most studies so far focus on farmers as individuals. Thus, attention to community effects as well as wider cultural influences on individual farmers' attitudes to carbon farming might be relevant. One particular dimension of this is already attended to in the literature and that is how farmers' environmental values, wider cultural and traditional beliefs connected with the land impact carbon farming.

Another, as of yet less explored topic worthy of further research is time-aspects in relation to carbon farming. As carbon farming is a long term commitment, longitudinal studies are warranted, as well as more attention to farmers' perceptions about time and about the future.

Altogether, the findings from this review highlight a complex picture of the factors shaping farmers' views and attitudes towards carbon farming and suggests that more research is needed in terms of studies that:

- look beyond individual attitudes
- look beyond economic incentives
- take a longitudinal approach
- address heterogeneous farmer populations and specifically focus more on resource constrained smallholders and those farming in marginal and less productive environments
- take an inter- or transdisciplinary approach, jointly evaluating the different factors that influence adoption or non-adoption of carbon farming measures.

References

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H. and Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 29(28), pp. 42539–42559. https://doi.org/10.1007/s11356-022-19718-6

Alexanderson, M. S., Luke, H. and Lloyd, D. J. (2023). Regenerative farming as climate action. *Journal of Environmental Management*, 347: 119063. https://doi.org/10.1016/j.jenvman.2023.119063

Amin, M. N., Hossain, M. S., Lobry de Bruyn, L. and Wilson, B. (2020). A systematic review of soil carbon management in Australia and the need for a social-ecological systems framework. *Science of The Total Environment*, 719: 135182. https://doi.org/10.1016/j.scitotenv.2019.135182

Amin, M. N., Lobry de Bruyn, L., Hossain, M. S., Lawson, A. and Wilson, B. (2023). The Social-Ecological System of Farmers' Current Soil Carbon Management in Australian Grazing Lands. *Environmental Management*, 72(2), pp. 294–308. https://doi.org/10.1007/s00267-023-01801-4

Amundson, R., Buck, H. and Lajtha, K. (2022). Soil science in the time of climate mitigation. *Biogeochemistry*, 161(1), pp. 47–58. https://doi.org/10.1007/s10533-022-00952-6

Andrews, A. C., Clawson, R. A., Gramig, B. M. and Raymond, L. (2013). Why do farmers adopt conservation tillage? An experimental investigation of framing effects. *Journal of Soil and Water Conservation*, 68(6), pp. 501–511. https://doi.org/10.2489/jswc.68.6.501

Arla Foods. (n.d.). *How We Measure Dairy Farming's Carbon Footprint*. Retrieved 7 February 2024, from https://www.arla.com/sustainability/the-farms/how-we-measure-dairy-farmings-carbon-footprint/

Arla Foods. (2022). *Arla Foods Climate Check Report 2022. Data driven daire. How climate checks are driving action to reduce emissions on Arla farms*. https://www.arla.com/49162b/globalassets/arla-global/sustainability/dairys-climate-footprint/climate-check-report-2022.pdf

Aslam, U., Termansen, M. and Fleskens, L. (2017). Investigating farmers' preferences for alternative PES schemes for carbon sequestration in UK agroecosystems. *Ecosystem Services*, 27, pp. 103–112. https://doi.org/10.1016/j.ecoser.2017.08.004

Aubert, P.-M., Foucherot, C. and Svensson, J. (2022). *Design principles of a Carbon Farming Scheme in support of the Farm2Fork and FitFor55 objectives*. IDDRI. https://www.iddri.org/en/publications-and-events/policy-brief/design-principles-carbon-farming-scheme-support-farm2fork

Barbato, C. T. and Strong, A. L. (2023). Farmer perspectives on carbon markets incentivizing agricultural soil carbon sequestration. *Npj Climate Action*, 2(1), Article 1. https://doi.org/10.1038/s44168-023-00055-4

Bartkowski, B. and Bartke, S. (2018). Leverage Points for Governing Agricultural Soils: A Review of Empirical Studies of European Farmers' Decision-Making. *Sustainability*, 10(9): 3179. https://doi.org/10.3390/su10093179

Baumber, A., Cross, R., Waters, C., Metternicht, G. and Kam, H. (2022). Understanding the Social Licence of Carbon Farming in the Australian Rangelands. *Sustainability*, 14(1), Article 1. https://doi.org/10.3390/su14010174

Beacham, J. D., Jackson, P., Jaworski, C. C., Krzywoszynska, A. and Dicks, L. V. (2023). Contextualising farmer perspectives on regenerative agriculture: A post-productivist future? *Journal of Rural Studies*, 102: 103100. https://doi.org/10.1016/j.jrurstud.2023.103100

BirdLife Europe, and EEB (2022). *Soil and carbon farming in the new CAP: alarming lack of action and ambition*. https://eeb.org/wp-content/uploads/2022/06/Briefing-Soil-Health-No-Branding-V2.pdf

Brown, C., Kovács, E., Herzon, I., Villamayor-Tomas, S., Albizua, A., Galanaki, A., Grammatikopoulou, I., McCracken, D., Olsson, J. A. and Zinngrebe, Y. (2021). Simplistic understandings of farmer motivations could undermine the environmental potential of the common agricultural policy. *Land Use Policy*, 101: 105136. https://doi.org/10.1016/j.landusepol.2020.105136

Buck, H. J. and Palumbo-Compton, A. (2022). Soil carbon sequestration as a climate strategy: What do farmers think? *Biogeochemistry*, 161(1), pp. 59–70. https://doi.org/10.1007/s10533-022-00948-2

Burns, E. A. (2021). Placing regenerative farming on environmental educators' horizons. *Australian Journal of Environmental Education*, 37(1), pp. 29–39. https://doi.org/10.1017/aee.2020.21

Burton, R.J., Forney, J., Stock, P. and Sutherland, L.A., (2020). *The good farmer: Culture and identity in food and agriculture*. Routledge.

Carmichael, J., Cran, A., Hrvatin, F. and Matthews, J. (2023). "We are stewards and caretakers of the land, not exploiters of resources": A qualitative study exploring Canadian farmers' perceptions of environmental sustainability in agriculture. *PLOS ONE*, 18(8): e0290114. https://doi.org/10.1371/journal.pone.0290114

Cavalaris, C., Gemtos, T. and Karamoutis, C. (2023). Rotational Tillage Practices to Deal with Soil Compaction in Carbon Farming. *Soil Systems*, 7(4). Scopus. https://doi.org/10.3390/soilsystems7040090

Chang, W.-Y., Li, Z., Lu, K. and Chang, S. J. (2022). Optimal Eco-Compensation for Forest-Based Carbon Sequestration Programs: A Case Study of Larch Carbon Sink Plantations in Gansu, Northwest China. *Forests*, 13(2): 268. https://doi.org/10.3390/f13020268

Chingombe, W. and Musarandega, H. (2021). Understanding the Logic of Climate Change Adaptation: Unpacking Barriers to Climate Change Adaptation by Smallholder Farmers in Chimanimani District, Zimbabwe. *Sustainability*, 13(7), Article 7. https://doi.org/10.3390/su13073773

Chitakira, M. and Ngcobo, N. Z. P. (2021). Uptake of Climate Smart Agriculture in Peri-Urban Areas of South Africa's Economic Hub Requires Up-Scaling. *Frontiers in Sustainable Food Systems*, 5. https://www.frontiersin.org/articles/10.3389/fsufs.2021.706738

Clare, A., Barnes, A., McDonagh, J. and Shackley, S. (2014). From rhetoric to reality: Farmer perspectives on the economic potential of biochar in China. *International Journal of Agricultural Sustainability*, 12(4), pp. 440–458. https://doi.org/10.1080/14735903.2014.927711

Cook, S. L. and Ma, Z. (2014). The interconnectedness between landowner knowledge, value, belief, attitude, and willingness to act: Policy implications for carbon sequestration on private rangelands. *Journal of Environmental Management*, 134, pp. 90–99. https://doi.org/10.1016/j.jenvman.2013.12.033

Davidson, E. A. (2022). Is the transactional carbon credit tail wagging the virtuous soil organic matter dog? *Biogeochemistry*, 161(1), pp. 1–8. https://doi.org/10.1007/s10533-022-00969-x

De Pinto, A., Robertson, R. D. and Obiri, B. D. (2013). Adoption of climate change mitigation practices by risk-averse farmers in the Ashanti Region, Ghana. *Ecological Economics*, 86, pp. 47–54. https://doi.org/10.1016/j.ecolecon.2012.11.002

Demenois, J., Torquebiau, E., Arnoult, M. H., Eglin, T., Masse, D., Assouma, M. H., Blanfort, V., Chenu, C., Chapuis-Lardy, L., Medoc, J.-M. and Sall, S. N. (2020). Barriers and Strategies to Boost Soil Carbon Sequestration in Agriculture. *Frontiers in Sustainable Food Systems*, 4. https://doi.org/10.3389/fsufs.2020.00037

Demeyer, A., Roels, J., Krol, M., Marten Paulsen, H., Klinkert, H., Lambrecht, E., Jumshudzade, Z., Coopman, F., Kürsten, E., Sundet, H. and Hørluck Berg, E. (2021). *Incentivising carbon farming; policy recommendations from the Carbon Farming project* (White Paper). https://northsearegion.eu/media/18284/whitepaper-carbon-farming-digital.pdf

Department of Climate Change, Energy, the Environment and Water (2011). *Carbon Credits (Carbon Farming Initiative) Act 2011* (Latest version with amendments, 20 October 2023). Australian Government. https://www.legislation.gov.au/C2011A00101/latest

Djanibekov, U. and Villamor, G. B. (2017). Market-based instruments for risk-averse farmers: Rubber agroforest conservation in Jambi Province, Indonesia. *Environment and Development Economics*, 22(2), pp. 133–155. https://doi.org/10.1017/S1355770X16000310

Dougill, A. J., Whitfield, S., Stringer, L. C., Vincent, K., Wood, B. T., Chinseu, E. L., Steward, P. and Mkwambisi, D. D. (2017). Mainstreaming conservation agriculture in Malawi: Knowledge gaps and institutional barriers. *Journal of Environmental Management*, 195, pp. 25–34. https://doi.org/10.1016/j.jenvman.2016.09.076

Dumbrell, N. P., Kragt, M. E. and Gibson, F. L. (2016). What carbon farming activities are farmers likely to adopt? A best–worst scaling survey. *Land Use Policy*, 54, pp. 29–37. https://doi.org/10.1016/j.landusepol.2016.02.002

Dunn, M., Ulrich-Schad, J., Prokopy, L., Myers, R., Watts, C. and Scanlon, K. (2016). Perceptions and Use of Cover Crops Among Early adopters: Findings From a National Survey. *Journal of Soil and Water Conservation*, 71(1), pp. 29–40. https://doi.org/10.2489/jswc.71.1.29

EASAC (2022). Regenerative agriculture in Europe. A critical analysis of contributions to European Union Farm to Fork and Biodiversity Strategies (*EASAC Policy Report 44*). https://easac.eu/publications/details/regenerative-agriculture-in-europe/

European Environmental Bureau (2023). *Promoting carbon farming through the CAP*. AgriCaptureCO2 (Horizon 2020 Project). https://eeb.org/wp-content/uploads/2023/09/Policy-Brief_Role-of-the-CAP-in-promoting-carbon-farming.pdf

European Network for Rural Development (2022). *Upscaling carbon farming in the EU*. ENRD Thematic Group on Carbon farming. European Commission. https://ec.europa.eu/enrd/sites/default/files/upscalingcarbonfarming-report_1209.pdf

European Union (2022). *Proposal for a Regulation of the European Parliament and of the Council Establishing a Union Certification Framework for Carbon Removals* COM/672/Final, 2022/0394(COD). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022PC0672

Feliciano, D., Hunter, C., Slee, B. and Smith, P. (2014). Climate change mitigation options in the rural land use sector: Stakeholders' perspectives on barriers, enablers and the role of policy in North East Scotland. *Environmental Science and Policy*, 44, pp. 26–38. https://doi.org/10.1016/j.envsci.2014.07.010

Feller, C., Compagnone, C., Goulet, F. and Sigwalt, A. (2015). Historical and sociocultural aspects of soil organic matter and soil organic carbon benefits. In: S. A. Banwart, E. Noellemeyer, and E. Milne (Eds), *Soil carbon: Science, management and policy for multiple benefits* (1st ed., pp. 169–178). CABI. https://doi.org/10.1079/9781780645322.0169

Fleming, A., Stitzlein, C., Jakku, E. and Fielke, S. (2019). Missed opportunity? Framing actions around co-benefits for carbon mitigation in Australian agriculture. *Land Use Policy,* 85, pp. 230–238. https://doi.org/10.1016/j.landusepol.2019.03.050

Govaerts, B., Verhulst, N., Castellanos-Navarrete, A., Sayre, K. D., Dixon, J. and Dendooven, L. (2009). Conservation Agriculture and Soil Carbon Sequestration: Between Myth and Farmer Reality. *Critical Reviews in Plant Sciences*, 28(3), pp. 97–122. https://doi.org/10.1080/07352680902776358

Gramig, B. M., Barnard, J. M. and Prokopy, L. S. (2013). Farmer beliefs about climate change and carbon sequestration incentives. *Climate Research*, 56(2), pp. 157–167.

Gramig, B. M. and Widmar, N. J. O. (2018). Farmer Preferences for Agricultural Soil Carbon Sequestration Schemes. *Applied Economic Perspectives and Policy*, 40(3), pp. 502–521. https://doi.org/10.1093/aepp/ppx041

Günther, P., Garske, B., Heyl, K. and Ekardt, F. (2024). Carbon farming, overestimated negative emissions and the limits to emissions trading in land-use governance: The EU carbon removal certification proposal. *Environmental Sciences Europe*, 36(1): 72. https://doi.org/10.1186/s12302-024-00892-y

Gutierrez, S., Grados, D., Møller, A. B., de Carvalho Gomes, L., Beucher, A. M., Giannini-Kurina, F., de Jonge, L. W. and Greve, M. H. (2023). Unleashing the sequestration potential of soil organic carbon under climate and land use change scenarios in Danish agroecosystems. *Science of The Total Environment*, 905: 166921. https://doi.org/10.1016/j.scitotenv.2023.166921

Han, G. and Niles, M. T. (2023). Interested but Uncertain: Carbon Markets and Data Sharing among U.S. Crop Farmers. *Land*, 12(8), Article 8. https://doi.org/10.3390/land12081526

Hendrickson, C. Y. and Corbera, E. (2015). Participation dynamics and institutional change in the Scolel Té carbon forestry project, Chiapas, Mexico. *Geoforum*, 59, pp. 63–72. https://doi.org/10.1016/j.geoforum.2014.11.022

Hermann, D., Sauthoff, S. and Mußhoff, O. (2017). Ex-ante evaluation of policy measures to enhance carbon sequestration in agricultural soils. *Ecological Economics*, 140, pp. 241–250. https://doi.org/10.1016/j.ecolecon.2017.05.018

Hijbeek, R., Pronk, A. A., van Ittersum, M. K., ten Berge, H. f. m., Bijttebier, J. and Verhagen, A. (2018). What drives farmers to increase soil organic matter? Insights from the Netherlands. *Soil Use and Management*, 34(1), pp 85–100. https://doi.org/10.1111/sum.12401

Ingram, J., Mills, J., Dibari, C., Ferrise, R., Ghaley, B. B., Hansen, J. G., Iglesias, A., Karaczun, Z., McVittie, A., Merante, P., Molnar, A. and Sánchez, B. (2016). Communicating soil carbon science to farmers: Incorporating credibility, salience and legitimacy. *Journal of Rural Studies*, 48, pp. 115–128. https://doi.org/10.1016/j.jrurstud.2016.10.005

Ingram, J., Mills, J., Frelih-Larsen, A., Davis, M., Merante, P., Ringrose, S., Molnar, A., Sanchez, B., Ghaley, B. B. and Karaczun, Z. (2014). Managing Soil Organic Carbon: A Farm Perspective. *Eurochoices*, 13(2), pp. 12–19. https://doi.org/10.1111/1746-692X.12057

Jassim, D., Witt, B. and Evans, M. C. (2022). Community perceptions of carbon farming: A case study of the semi-arid Mulga Lands in Queensland, Australia. *Journal of Rural Studies*, 96, pp. 78–88. https://doi.org/10.1016/j.jrurstud.2022.10.010

Jiang, Y. and Koo, W. W. (2014). Producer preference for land-based biological carbon sequestration in agriculture: Some implications from a sample of North Dakota farmers. *Journal of Soil and Water Conservation*, 69(3), pp. 231–242. https://doi.org/10.2489/jswc.69.3.231

Johansson, E. L., Brogaard, S. and Brodin, L. (2022). Envisioning sustainable carbon sequestration in Swedish farmland. *Environmental Science and Policy*, 135, pp. 16–25. https://doi.org/10.1016/j.envsci.2022.04.005

Jørgensen, S. L. and Termansen, M. (2016). Linking climate change perceptions to adaptation and mitigation action. *Climatic Change*, 138(1–2), pp. 283–296. Scopus. https://doi.org/10.1007/s10584-016-1718-x

Kawa, N. C. (2021). A "Win-Win" for Soil Conservation? How Indiana Row-Crop Farmers Perceive the Benefits (and Trade-offs) of No-Till Agriculture. *Culture, Agriculture, Food and Environment*, 43(1), pp. 25–35. https://doi.org/10.1111/cuag.12264

Kokkora, M. I., Vrahnakis, M. and Kleftoyanni, V. (2022). Soil quality characteristics of traditional agroforestry systems in Mouzaki area, central Greece. *Agroforestry Systems*, 96(5), pp. 857–871. https://doi.org/10.1007/s10457-022-00746-7

Kragt, M. E., Dumbrell, N. P. and Blackmore, L. (2017). Motivations and barriers for Western Australian broad-acre farmers to adopt carbon farming. *Environmental Science and Policy*, 73, pp. 115–123. Scopus. https://doi.org/10.1016/j.envsci.2017.04.009

Latawiec, A. E., Strassburg, B. B. N., Junqueira, A. B., Araujo, E., D. de Moraes, L. F., Pinto, H. A. N., Castro, A., Rangel, M., Malaguti, G. A., Rodrigues, A. F., Barioni, L. G., Novotny, E. H., Cornelissen, G., Mendes, M., Batista, N., Guerra, J. G., Zonta, E., Jakovac, C. and Hale, S. E. (2019). Biochar amendment improves degraded pasturelands in Brazil: Environmental and cost-benefit analysis. *Scientific Reports*, 9(1): 11993. https://doi.org/10.1038/s41598-019-47647-x

Lees, K. J., Carmenta, R., Condliffe, I., Gray, A., Marquis, L. and Lenton, T. M. (2023). Protecting peatlands requires understanding stakeholder perceptions and relational values: A case study of peatlands in the Yorkshire Dales. *Ambio*, 52(7), pp. 1282–1296. https://doi.org/10.1007/s13280-023-01850-3

Lynch, J., Cain, M., Frame, D. and Pierrehumbert, R. (2021). Agriculture's Contribution to Climate Change and Role in Mitigation Is Distinct From Predominantly Fossil CO2-Emitting Sectors. *Frontiers in Sustainable Food Systems*, 4. https://www.frontiersin.org/articles/10.3389/fsufs.2020.518039

Mahmoud, Y., Njenga, M., Sundberg, C. and Roing de Nowina, K. (2021). Soils, sinks, and smallholder farmers: Examining the benefits of biochar energy transitions in Kenya. *Energy Research and Social Science*, 75: 102033. https://doi.org/10.1016/j.erss.2021.102033

McDonald, H., Frelih-Larsen, A., Lorant, A., Duin, L., Andersen, S. P., Costa, G. and Bradley, H. (2021). *Carbon farming | Making agriculture fit for 2030* (Study Requested by the ENVI Committee). European Union. https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695482/IPOL_STU(2021)695482_EN.pdf

Mills, J., Ingram, J., Dibari, C., Merante, P., Karaczun, Z., Molnar, A., Sánchez, B., Iglesias, A. and Ghaley, B. B. (2020). Barriers to and opportunities for the uptake of soil carbon management practices in European sustainable agricultural production. *Agroecology and Sustainable Food Systems*, 44(9), pp. 1185–1211. https://doi.org/10.1080/21683565.2019.1680476

Myers, R. L. and Wilson, K. R. (2023). Farmer perspectives about cover crops by non-adopters. *Frontiers in Sustainable Food Systems*, 7: 1011201. https://doi.org/10.3389/fsufs.2023.1011201

Nandakishor, T. M., Gopi, G., Champatan, V., Sukesh, A. and Aravind, P. V. (2022). Agroforestry in Shade Coffee Plantations as an Emission Reduction Strategy for Tropical Regions: Public Acceptance and the Role of Tree Banking. *Frontiers in Energy Research*, 10. https://doi.org/10.3389/fenrg.2022.758372

Ng'ang'a, S. K., Jalang'o, D. A. and Girvetz, E. H. (2020). Adoption of technologies that enhance soil carbon sequestration in East Africa. What influence farmers' decision? *International Soil and Water Conservation Research*, 8(1), pp. 90–101. https://doi.org/10.1016/j.iswcr.2019.11.001

Nogues, M., Husson, M., Paul, G., Reynders, S. and Soussana, J.-F. (2021). *Framework of possible business models for the implementation of a carbon demonstrator* [Report, INRAE ; LISIS ; NATAÏS]. https://doi.org/10.15454/fc2z-7d70-EN

Ovchinnikova, N., Lynne, G. D., Sautter, J. and Kruse, C. (2006). *What motivates farmers to sequester carbon: An empirical investigation*. 2006 Annual Meeting, July 23–26, Long Beach, CA, Article 21288. https://ideas.repec.org//p/ags/aaea06/21288.html

Page, G. and Bellotti, B. (2015). Farmers value on-farm ecosystem services as important, but what are the impediments to participation in PES schemes? *Science of The Total Environment*, 515–516, pp. 12–19. https://doi.org/10.1016/j.scitotenv.2015.02.029

Pathak, H., Byjesh, K., Chakrabarti, B. and Aggarwal, P. K. (2011). Potential and cost of carbon sequestration in Indian agriculture: Estimates from long-term field experiments. *Field Crops Research*, 120(1), pp. 102–111. https://doi.org/10.1016/j.fcr.2010.09.006

Paul, C., Bartkowski, B., Dönmez, C., Don, A., Mayer, S., Steffens, M., Weigl, S., Wiesmeier, M., Wolf, A. and Helming, K. (2023). Carbon farming: Are soil carbon certificates a suitable tool for climate change mitigation? *Journal of Environmental Management*, 330: 117142. https://doi.org/10.1016/j.jenvman.2022.117142

Payen, F. T., Moran, D., Cahurel, J.-Y., Aitkenhead, M., Alexander, P. and MacLeod, M. (2023). Why do French winegrowers adopt soil organic carbon sequestration practices? Understanding motivations and barriers. *Frontiers in Sustainable Food Systems*, 6. https://doi.org/10.3389/fsufs.2022.994364

Phelan, L., Chapman, P. J. and Ziv, G. (2024). The emerging global agricultural soil carbon market: The case for reconciling farmers' expectations with the demands of the market. *Environmental Development*, 49: 100941. https://doi.org/10.1016/j.envdev.2023.100941

PIRSA (2021). *Carbon Opportunities in the South Australian Mallee. Literature Review.* Government of South Australia. https://cdn.environment.sa.gov.au/landscape/docs/mr/220217-AgForum-carbon-opportunities-in-the-SA-Mallee-literature-review-PDF-1MB.pdf

Potthoff, K. and Dramstad, W. E. (2023). Management of rented farmland in Norway: Factors impacting on tenants' decisions to make investments. *Land Use Policy*, 135. Scopus. https://doi.org/10.1016/j.landusepol.2023.106941

Puupponen, A., Lonkila, A., Savikurki, A., Karttunen, K., Huttunen, S. and Ott, A. (2022). Finnish dairy farmers' perceptions of justice in the transition to carbon-neutral farming. *Journal of Rural Studies*, 90, pp. 104–112. https://doi.org/10.1016/j.jrurstud.2022.01.014

Ranjan, P., Arbuckle, J. G., Church, S. P., Eanes, F. R., Floress, K., Gao, Y., Gramig, B. M., Singh, A. S. and Prokopy, L. S. (2022). Understanding the relationship between land tenure and conservation behavior: Recommendations for social science research. *Land Use Policy*, 120: 106161. https://doi.org/10.1016/j.landusepol.2022.106161

Rochecouste, J.-F., Dargusch, P. and King, C. (2017). Farmer perceptions of the opportunities and constraints to producing carbon offsets from Australian dryland grain cropping farms. *Australasian Journal of Environmental Management*, 24(4), pp. 441–452. Scopus. https://doi.org/10.1080/14486563.2017.1379037

Roesch-McNally, G. E., Basche, A. D., Arbuckle, J. G., Tyndall, J. C., Miguez, F. E., Bowman, T. and Clay, R. (2018). The trouble with cover crops: Farmers' experiences with overcoming barriers to adoption. *Renewable Agriculture and Food Systems*, 33(4), pp. 322–333. https://doi.org/10.1017/S1742170517000096

Rois-Díaz, M., Lovric, N., Lovric, M., Ferreiro-Domínguez, N., Mosquera-Losada, M. R., Den Herder, M., Graves, A., Palma, J. H. N., Paulo, J. A., Pisanelli, A., Smith, J., Moreno, G., García, S., Varga, A., Pantera, A., Mirck, J. and Burgess, P. (2018). Farmers' reasoning behind the uptake of agroforestry practices: Evidence from multiple case-studies across Europe. *Agroforestry Systems*, 92(4), pp. 811–828. https://doi.org/10.1007/s10457-017-0139-9

Rosinger, C., Keiblinger, K., Bieber, M., Bernardini, L. G., Huber, S., Mentler, A., Sae-Tun, O., Scharf, B. and Bodner, G. (2023). On-farm soil organic carbon sequestration potentials are dominated by site effects, not by management practices. *Geoderma*, 433, 116466. https://doi.org/10.1016/j.geoderma.2023.116466

Rusinamhodzi, L., Wijk, M. T. van, Corbeels, M., Rufino, M. C. and Giller, K. E. (2015). Maize crop residue uses and trade-offs on smallholder crop-livestock farms in Zimbabwe: Economic implications of intensification. Agriculture, *Ecosystems and Environment*, 214, pp. 31–45. https://doi.org/10.1016/j.agee.2015.08.012

Saha, S. K., Stein, T. V., Nair, P. K. R. and Andreu, M. G. (2011). The Socioeconomic Context of Carbon Sequestration in Agroforestry: A Case Study from Homegardens of Kerala, India. In: B. M. Kumar and P. K. R. Nair (Eds), *Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges* (pp. 281–298). Springer Netherlands. https://doi.org/10.1007/978-94-007-1630-8_16

SAPEA (2020). A sustainable food system for the European Union: Evidence review report (1.2). https://scientificadvice.eu/advice/a-sustainable-food-system-for-the-european-union/

Sautter, J. A., Czap, N. V., Kruse, C. and Lynne, G. D. (2011). Farmers' Decisions Regarding Carbon Sequestration: A Metaeconomic View. *Society and Natural Resources*, 24(2), pp. 133–147. https://doi.org/10.1080/08941920903012502

Schapel, A., Reseigh, J., Wurst, M. and Herrmann, T. (2018). Offsetting greenhouse gas emissions through increasing soil organic carbon in SA clay-modified soils: Knowledge gap analysis. *Goyder Institute for Water Research Technical Report Series No. 18/05*. https://goyderinstitute.org/wp-content/uploads/2023/06/goyder_trs_18-5_offsetting_ghgs_knowledge_gap_analysis.pdf

Scheba, A. (2017). Conservation agriculture and sustainable development in Africa: Insights from Tanzania. *Natural Resources Forum*, 41(4), pp. 209–219. https://doi.org/10.1111/1477-8947.12123

Schnitkey, G. D., Sellars, S. C. and Gentry, L. F. (2023). Cover crops, farm economics, and policy. *Applied Economic Perspectives and Policy*, n/a(n/a). https://doi.org/10.1002/aepp.13404

Sharma, M., Kaushal, R., Kaushik, P. and Ramakrishna, S. (2021). Carbon Farming: Prospects and Challenges. *Sustainability*, 13(19), Article 19. https://doi.org/10.3390/su131911122

Smith, P. (2018). Managing the global land resource. *Proceedings of the Royal Society B: Biological Sciences*, 285(1874): 20172798. https://doi.org/10.1098/rspb.2017.2798

Stevens, A. W. (2018). Review: The economics of soil health. *Food Policy*, 80, pp. 1–9. https://doi.org/10.1016/j.foodpol.2018.08.005

Tang, K., Kragt, M. E., Hailu, A. and Ma, C. (2016). Carbon farming economics: What have we learned? *Journal of Environmental Management*, 172, pp. 49–57. https://doi.org/10.1016/j.jenvman.2016.02.008

Ullah, K. M., Oladosu, G. A. and Crooks, A. (2023). Evaluating the incentive for soil organic carbon sequestration from carinata production in the Southeast United States. *Journal of Environmental Management*, 348: 119418. https://doi.org/10.1016/j.jenvman.2023.119418

US EPA (2022, October 19). *Climate Change Impacts on Agriculture and Food Supply* [Overviews and Factsheets]. https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply

Vinco, E., Morrison, N., Bourassa, J. and Lhermie, G. (2023). Climate policy and Canadian crop production: A qualitative study of farmers' attitudes and perceptions towards nitrous oxide reductions. *Journal of Cleaner Production*, 418: 138108. https://doi.org/10.1016/j.jclepro.2023.138108

Wade, T. and Claassen, R. (2017). Modeling No-Till Adoption by Corn and Soybean Producers: Insights into Sustained Adoption. *Journal of Agricultural and Applied Economics*, 49(2), pp. 186–210. https://doi.org/10.1017/aae.2016.48

Wang, W., Wang, L., Gu, L., and Zhou, G. (2021). Understanding farmers' commitments to carbon projects. Science of The Total Environment, 784: 147112. https://doi.org/10.1016/j.scitotenv.2021.147112

Wiese, L., Wollenberg, E., Alcántara-Shivapatham, V., Richards, M., Shelton, S., Hönle, S. E., Heidecke, C., Madari, B. E. and Chenu, C. (2021). Countries' commitments to soil organic carbon in Nationally Determined Contributions. *Climate Policy*, 21(8), pp. 1005–1019. https://doi.org/10.1080/14693062.2021.1969883

Yohannes, H. (2015). A Review on Relationship between Climate Change and Agriculture. *Journal of Earth Science and Climatic Change*, 07(02). https://doi.org/10.4172/2157-7617.1000335

Yu, J., Yao, S. and Zhang, B. (2014). Designing afforestation subsidies that account for the benefits of carbon sequestration: A case study using data from China's Loess Plateau. *Journal of Forest Economics*, 20(1), pp. 65–76. https://doi.org/10.1016/j.jfe.2013.09.001

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ISSN: 1654-0565, ISBN: 978-91-85735-00-6

Carbon farming is a set of land management and farming practices aimed at sequestering soil organic carbon and abating greenhouse gas emissions from agricultural production. Different schemes for carbon farming are currently emerging where farmers are incentivised to adopt carbon farming practices. This report reviews the academic literature on what carbon farming may entail for farmers and how farmers perceive related practices, policies and market schemes. While there is general positivity towards the practices associated with carbon farming, different studies report that farmers are sceptical to enrol in carbon farming schemes. Issues raised include high initial costs of adopting new practices, bureaucratic hurdles, lack of information, inadequate training, and the long-term commitment required. Additionally, the heterogeneity of farms and local conditions means that the benefits and risks of carbon farming are not uniformly experienced, with smaller farms and those with less fertile soils being less likely to benefit.

There is currently a dominance of studies focusing on economic dimensions of acceptance or scepticism to carbon farming, and on farmers as individuals. However, some studies indicate that other than economic aspects, such as wider environmental values might be of significant importance in shaping farmers' decisions about carbon farming. Looking at the wider farming literature it is also clear that the wider social and cultural environment is important for shaping farmer decision making suggesting a need for studies that look beyond the individual farmer. The review concludes that there is a need for future studies that look beyond individual attitudes and economic incentives, that take a longitudinal approach and that address the heterogeneity of farmer populations.

About this research

This report is produced in the project “Carbon farming as a climate measure: a farmer perspective” (Dnr. 2022-00222), which aims to develop an interdisciplinary assessment of the potential of carbon farming in Sweden as a climate measure, focusing on the farmers' perspectives. The project is financed by FORMAS.