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The emerging global agricultural soil carbon market: the case for reconciling farmers' expectations with the demands of the market

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ABSTRACT

In the absence of a global environmental policy framework to standardise the monitoring, reporting and verification of soil carbon stock changes and/or reductions in soil-derived greenhouse gas emissions, private sector and civil society organisations have played a key role in governing the production and trade, and/or direct sale of carbon credits. This paper takes the United Kingdom as a case study region where carbon codes, rather than environmental policies, have served to shape the agricultural soil carbon market. It explores innovative farmers' willingness to adopt soil health practices; interest in participating in soil carbon sequestration schemes; and expectations regarding their scope to derive benefits from the market. Data was collected through online questionnaires administered to 100 farmers and six private sector and civil society organisations. Results indicate farmers' adoption of practices does not necessarily translate into a willingness to adopt additional practices and/or an ability to engage with the carbon market. Moreover, there is, currently, a gap between farmers' expectations and market demands, as articulated by carbon standards. The paper adds to global literature on the agricultural soil carbon market by illustrating how descriptive case study research can enhance understanding of the opportunities and challenges associated with incentivising farmers' market participation. Furthermore, it generates insights of relevance for policymakers and practitioners globally by outlining how a temporary relaxation of carbon code rules could facilitate early and subsequent entrants' engagement with the market; thereby kick-starting and supporting the growth and development of the market, and enhancing its transparency, robustness and integrity.

1. Introduction

Globally, there are calls for concerted action to bring soils to the forefront of the carbon agenda for climate change mitigation and adaptation (Amelung et al., 2020; Minasny et al., 2017), and for scaling up of improved management of agricultural soils through carbon schemes that reward farmers for their adoption of soil health practices which promote soil carbon sequestration (SCS) (Vermeulen et al., 2019). Policymakers and practitioners alike are increasingly recognising that there is an imperative to transform agricultural SCS from an aspirational to a widely implemented, mainstream climate mitigation strategy (Amelung et al., 2020). SCS schemes –are regarded as key to securing the provision and regulation of ecosystem services associated with the carbon cycle (e.g., greenhouse gas (GHG) and climate regulation) (Mills et al., 2020; Lal et al., 2021). Moreover, these schemes provide a framework for driving the global economy towards net zero (Costa et al., 2022) and for taking climate action in line with the UNFCCC Paris Agreement and the global '4 per 1000 Initiative: Soils for Food Security and Climate', as well as 'the international community's best expression of a collective vision for a desirable future', namely, the UN Sustainable Development Goals (SDGs) (Honegger et al., 2021, p.679). Launched in 2015, the '4 per 1000 initiative' aims to increase soil organic carbon (SOC) by 0.4% annually and contribute to efforts to keep global warming below 1.5° above a pre-industrial baseline (Rumpel et al., 2020; Soussana et al., 2019; Minasny et al., 2017).

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A proliferation of farm-focused GHG emissions calculators has reduced the transaction costs associated with direct measurement or empirical and process-based modelling of changes in soil carbon stocks (Smith et al., 2020; Paustian et al., 2019). Synthesising scientific knowledge on carbon storage mechanisms and translating this knowledge into actionable information, however, remains a challenge for policymakers and practitioners looking to guide farmers in determining the interaction and impact of soil health practices on carbon stocks (Derrien et al., 2023). Carbon accounting issues - stemming from the difficulties associated with ensuring the additionality and permanence of carbon sequestered, and avoiding leakage (associated with a change in farm strategies), and reversals of carbon stored in soils - risk undermining farmers' willingness to participate in SCS schemes and, by extension, the emerging global agricultural soil carbon market (Keenor et al., 2021; Kreibich and Hermwille, 2021; Vermeulen et al., 2019). The pervasiveness of carbon accounting issues underscores the fact that an innovative and responsive science-based approach has, to date, not been taken in developing institutional agreements, processes, and arrangements governing the production, trade, and/or direct sale of soil carbon credits (Dynarski et al., 2020; Rodríguez de Francisco and Boelens, 2015).

Addressing farmers' perceptions of the risks associated with participation in SCS schemes and the carbon market (Buck and Palumbo-Compton, 2022), hinges on policymakers and practitioners acknowledging that farmers' confidence in the robustness, transparency, and integrity of the market is eroded by the issuance of non-equivalent credits (B.E.E. Oldfield et al., 2022). Recognising that there is an imperative to develop an environmental policy framework for the management of SCS (Hannam, 2021), policymakers in France and Australia, for example, have developed monitoring, reporting and verification methods and a policy framework to generate carbon credit units (i.e., 'Label Bas Carbone' and the 'Carbon Farming Initiative', respectively). However, there is still a paucity of context-specific, rigorous, and transparent protocol standards for measuring, reporting, and verifying SCS and/or reductions in soil-derived GHG emissions at a national and global level (Beka et al., 2022; Jackson Hammond et al., 2021; Alexander et al., 2015). In the absence of an environmental policy framework, the integrity of soil carbon credits in countries in the global North and global South has been guaranteed solely by rules and regulations articulated by private sector and civil society organisations - such as Verra, Gold Standard, Soil Heroes, Nori, Gentle Farming and Soil Capital - that have developed and operationalised 'carbon codes' (Black et al., 2022).

Several recent studies have explored farmers' willingness and motivation to engage with the global agricultural soil carbon market and, based on an analysis of barriers faced, explored whether participation in the market constitutes an opportunity or a challenge for new entrants (Buck and Palumbo-Compton, 2022; Davidson, 2022; Fleming et al., 2019). In Australia, for example, engagement in market-based programmes generating soil carbon credits is low as farmers currently do not feel that their long-term management of soil carbon is recognised by SCS schemes (Amin et al., 2023). Farmers' willingness to participate in SCS schemes hinges on rules and administrative processes being 'easy to follow'; the Carbon Farming Initiative in Australia has, to date, however, not addressed farmers' concerns about the permanence obligations and additionality requirements associated with carbon sequestered (Rochecouste et al., 2017). As Amin et al. (2023a) note, 'the dominant neoliberal paradigm has distanced government policy from farmers on the assumption that market forces will be sufficient to lead to change and adoption of SCM'. There has been a failure to recognise that farmers may be inherently 'reticen [t] to participate in carbon trading' (Amin et al., 2023, p. 15). SCS has also primarily been explored with a view to identifying soil carbon accumulation processes and ecological triggers or settings for soil carbon improvement. There has been 'little consideration of farmers' perspectives or identification of the influential socio-ecological system components in soil carbon management' (Amin et al., 2023a, p. 295). This is a major shortcoming given that, in the absence of farmers' enthusiasm for and willingness to "buy into" carbon schemes, 'the market for soil carbon offsets may be expected to remain thin or not function at all' (Gramig and Widmar, 2018, p. 518).

Although a limited number of studies have looked at the lived experience of those farmers who have maintained soil carbon over a sustained period (Amin et al., 2023, 2023a), studies have, to date, not considered the factors that might attract less experienced farmers to manage soil carbon and, by extension, engage with the emerging global agricultural soil carbon market. We are not aware of any study that has explicitly explored how farmers who have already adopted soil health practices that promote SCS – and may be excluded from carbon schemes based on additionality criteria - might be incentivised to adopt additional practices and participate in the carbon market. Innovative, early adopters of practices, however, may play a key role - as early market entrants - in encouraging farmers who have not yet extensively adopted SCS-promoting practices to engage with the carbon market as subsequent entrants. Innovative farmers transmit information and reduce the level of uncertainty surrounding agricultural technologies and practices, and may be expected to promote individual and social learning related to practices (Chavas and Nauges, 2020) and, by extension, the carbon market. A lack of forerunner, innovative farmers has long been perceived as constituting a bottleneck in scaling up 'carbon farming' (Mattila et al., 2022). However, an increasing number of farmers are implementing SCS practices to improve soil health and peer-to-peer learning involving these farmers could, therefore, be key to reaching and motivating participation in carbon schemes by broader farming populations (Amin et al., 2023a; Jaworski et al., 2023; Mattila et al., 2022).

This paper takes the United Kingdom (UK) as a case study to explore the opportunities and challenges associated with incentivising farmers' participation in the emerging global agricultural soil carbon market. Specifically, it explores farmers' willingness to adopt soil health practices; interest in participating in SCS schemes; and expectations regarding their scope to derive benefits from the market. There are several reasons for choosing the UK as a case study region. Firstly, the UK is increasingly embracing carbon sequestration in agricultural soils as a strategy for capturing and ensuring long-term storage of atmospheric GHG emissions. UK policymakers have recognised that greenhouse gas removal (GGR) will be key to balancing residual emissions in hard-to-abate sectors in 2050, such as aviation and heavy industries (BEIS, 2021b). Secondly, as evidenced by the establishment of the UK Voluntary Carbon Markets Forum in April 2021, there is growing momentum with regard to creating a high-integrity ecosystem market capable of assessing and verifying the effectiveness of this nature-based solution (Wentworth and Tresise, 2022; Stafford et al., 2021; Seddon et al., 2020). Thirdly, the emergence of a UK agricultural soil carbon market has led to calls for its regulation and the development of minimum standards.

Recommended standards have recently been developed as part of the 'UK Farm Soil Carbon Code' (UKFSCC) project funded by the Environmental Agency Natural Environment Investment Readiness Fund (NEIRF) and Yorkshire Integrated Catchment Solutions Programme (iCASP) (Sustainable Soils Alliance, 2022). Although only 10% of total GHG emissions in the UK are estimated to stem from agriculture (DEFRA, 2021), it is envisaged that the development of an environmental policy framework by DEFRA for this carbon market could catalyse the broader land use change required to realise targets outlined in the UK's landmark net zero strategy published in 2021 (BEIS, 2021a).

This paper recognises the important contribution that descriptive case study research can make to the global literature on the agricultural soil carbon market. As Amin et al. (2023) argue, there is a need to ensure that policymaking related to SCS is more targeted and nuanced in its conceptualisation of farmers' long-term approaches to SCM. Drawing on the UK as a case study region, this paper elicits farmers' perceptions of the emerging agricultural soil carbon market and compares their expectations with the demands of the market as articulated by the carbon codes driving its growth and development. Specifically, the research questions for this study were.

1. What are farmers' perceptions of the emerging agricultural soil carbon market?
2. Does farmers' adoption of soil health practices translate into a willingness to adopt additional practices and "buy into" carbon schemes?
3. How do farmers' perceptions of the market compare to the demands of the emerging agricultural soil carbon market, as articulated by the carbon codes driving its growth and development?
4. How do potential early entrants' expectations regarding their scope to derive benefits from participation in the carbon market align with the reality and demands of the market?
5. Is incentivising potential early entrants to adopt additional practices and facilitating their participation in the market, alongside subsequent entrants, contingent on reconciling farmers' expectations with the demands of the market?

2. Methodology

2.1. Sampling strategy and study area

Data was collected from UK farmers through a self-administered online questionnaire between March and June 2022. This facilitated data collection within a relatively short period from a geographically distributed target population and rendered the process more cost-effective than traditional methods (e.g. face-to-face, postal, or telephone surveys) (Wright, 2017; Regmi et al., 2016; Lefever et al., 2007). An online questionnaire enables respondents to answer questions at a convenient time and take as much time as they need to respond (Regmi et al., 2016). It also benefits researchers who can engage in preliminary analysis of data already collected, while waiting for a desired number of responses to accumulate (Wright, 2017). As data collection and compilation into a database is automated, data entry costs are eliminated and data management is straightforward (Wright, 2017; Regmi et al., 2016).

A purposive and convenience sampling strategy was used to select individuals from the target population of innovative farmers who could potentially participate as early entrants in the carbon market. Although the objective was to draw a diverse population sample from across the UK, self-selection bias led to the majority of respondents (Fig. 1) being from England (90% of the sample), with the counties of Gloucestershire, Devon, Yorkshire, Cambridgeshire, Cornwall, Norfolk, Cumbria, Lincolnshire, North Yorkshire, and Worcestershire accounting for two-thirds of the sample. Respondents located in Scotland accounted for 6% of the sample, while respondents in Wales and Northern Ireland equated to 2%, respectively. The sampling approach yielded a sample that was similar in composition (i.e., age and gender) to that of Jaworski et al. (2023) who explored the sustainable soil management and regenerative agriculture practices adopted by farmers in the UK.

2.2. Contents and structure of online questionnaire administered to farmers

The objective of the online questionnaire, created using Qualtrics (Qualtrics XM, 2022), was to gain insight into farmers' willingness and capacity to (a) adapt their farming strategies as appropriate to include soil health practices that could increase the carbon stored in the soil; and (b) participate in the emerging agricultural soil carbon market.

The questionnaire comprised 18 close-ended questions related to farm type; land ownership; source(s) of income; motivation for and perceived impact of soil health practices adopted on farm productivity and profitability; and willingness to accept terms and conditions associated with implementing a carbon project, participating in a SCS scheme, and the emerging agricultural soil carbon market. Farmers were required to provide an answer to each of the questions displayed unless built-in skip patterns were activated. As farmers were unable to refrain from responding to questions, several questions included answer options such as "I don't have a preference", "I don't know" and "I don't agree with any of these statements". The majority of questions were multi-choice questions, with farmers ticking a box to indicate selection of a pre-determined response option from a given list. For several questions, respondents were asked to select up to three options or permitted to select a maximum of three options only. This facilitated identification and ranking of the most selected options. The questionnaire comprised two questions that required respondents to provide answers in free text boxes. These questions reduced the risk of implausible responses to the questionnaire being recorded and facilitated identification and removal of such responses from the database during the data cleaning process. To contextualise data collected, the questionnaire comprised four close-ended questions relating to respondents' demographic characteristics (e.g. age, gender, level of education, and years of farming experience).

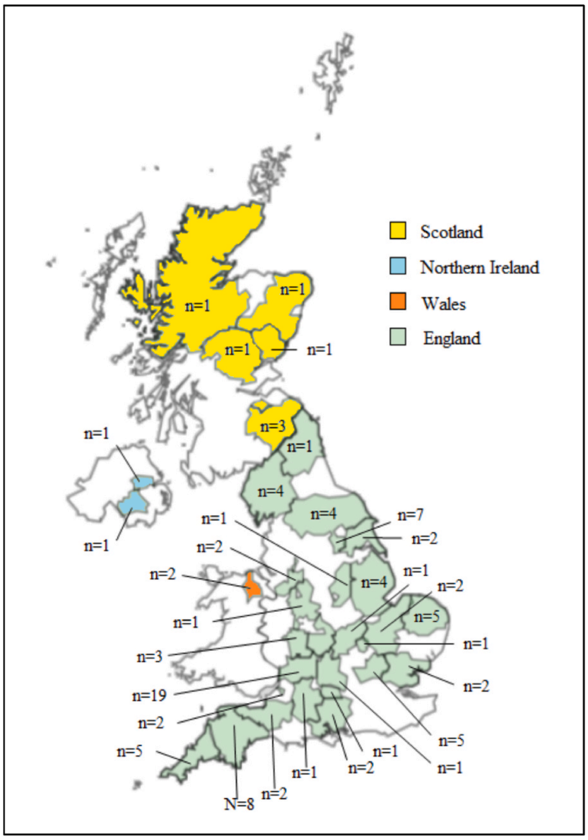

Fig. 1. Map of the study area indicating the number of respondents by county and country.

2.3. Process by which the online questionnaire was administered to farmers

The questionnaire was pilot-tested by six innovative farmers recruited through social media to ensure it would facilitate the collection of reliable and valid data. These farmers were asked whether the instructions provided regarding the research objectives were clearly worded and easily understood. Moreover, they were asked whether the questionnaire layout was user-friendly, and questions were appropriate, comprehensive, and ordered in a logical sequence. On average, it took the pilot farmers 10 min to complete the questionnaire.

The online questionnaire (Annex 1) was revised based on the feedback received during the piloting stage and disseminated via a link shared on social media platforms (e.g. Twitter and LinkedIn); emailed to self-registered stakeholders of the UKFSCC project; and shared in the online newsletters of NGOs and private sector actors providing extension services across the UK.

In total, 170 farmers interacted with the link and started filling out the questionnaire; however, only 100 farmers provided full responses to Q1-Q24 and were included in the final dataset. A total of 57 respondents who indicated, by their answers to Q1, that they were not farmers but rather agronomists, academics, business sector stakeholders, policymakers and/or civil sector actors were automatically excluded from the study.

2.4. Additional data collection through an online questionnaire completed by UK carbon codes

To facilitate comparison of farmers' expectations of the carbon market with the demands of carbon codes driving its growth and development, data were also collected through a self-administered online questionnaire (Annex 2) distributed via email to ten private sector and civil society organisations responsible for operationalising carbon codes in the UK. Four private sector organisations and two civil society organisations responded to the call for participation in the research, with data provided anonymised to protect their commercial interests. The online questionnaire completed by private sector and civil society organisations comprised 23 close-ended questions related to the scope of their carbon codes; their approaches to determining soil carbon stocks; their position on farmers' eligibility to participate in carbon projects; and the approach to carbon project administration and implementing the rules associated with farmers' participation in SCS schemes and the emerging agricultural soil carbon market.

2.5. Data management and analysis process

Data generated by the online questionnaire administered to farmers were downloaded as a database for data cleaning and descriptive analysis was conducted using R statistical software. In line with the research questions underpinning this study, the data was used to explore farmers' perceptions of the emerging agricultural soil carbon market and examined whether adoption of soil health practices translated into a willingness to adopt additional practices and "buy into" carbon schemes. Data collected through the online questionnaire completed by the six private sector and civil society organisations responsible for implementing carbon codes in the UK were compiled into a single Excel file for data analysis purposes. The data were used to explore how farmers' perceptions of the market compared to the demands of the market, as articulated by the carbon codes. Both datasets were used to explore whether potential early entrants' expectations regarding their scope to derive benefits from participation in the carbon market aligned with the reality and demands of the market. Moreover, both datasets were used to explore how farmers' expectations might be reconciled with the demands of the market to incentivise and facilitate potential early market entrants' adoption of additional practices and participation in the market, alongside subsequent entrants.

3. Results

3.1. Demographic characteristics of farmers sampled

Table 1 presents the demographic characteristics of farmers sampled. Respondents were predominantly male, aged between 35 and 64 years, and had extensive farming experience. One-quarter of respondents had not completed any agriculture-related formal education. The majority of respondents (85%) owned land, but more than one-third of farmers additionally rented land under short-term or long-term farm business tenancy agreements. Landholdings of <500 ha were most common, however, several respondents had large

Table 1
Demographic characteristics of farmers sampled (n = 100).

			n
Gender	Male		78
	Female		19
	Prefer not to say		3
Age	18–24 years		1
	25–34 years		9
	35–44 years		20
	45–54 years		26
	55–64 years		26
	65 years and over		15
	Prefer not to say		3
Education	I have not completed any formal training		24
	Engaged in ongoing technical/vocational training (e.g. BASIS)		25
	Bachelor's degree		32
	Master's degree		13
	Doctorate degree		6
Farming experience	Less than 5 years		9
	6–10 years		8
	11–20 years		22
	21–30 years		18
	More than 30 years		43
Source of income	Earning income from farming, but also off-farm activities		45
	Earning sole source of income from farming		38
	Earning income by managing a farm on behalf of a company		12
	Not earning an income from farming		3
	Earning income from farm diversification/value-adding activities		2
Land tenancy situation	Own land		85
	Land rented under short-term agreement		29
	Land rented under long-term agreement		9
	Share farm (arable) land		2
Farm size (ha)	0–50		28
	51–100		14
	101–200		18
	201–500		19
	501–1000		10
	More than 1000		8
Type of farm	Mixed crop-livestock production		34
	Livestock production	Lowland grazing livestock production	16
		LFA grazing livestock production	14
		Dairy production	2
		Specialist pig production	1
	Crop production	Arable production	28
		Horticulture and arable production	3
		Horticulture production	2

farms (i.e., 500–1000 ha) or managed estates of >1000 ha on behalf of a land owner or agribusiness company. Half of the respondents derived income solely from mixed crop-livestock production; livestock production (e.g., beef and/or sheep production in lowland or less-favoured areas); or crop production (e.g., potatoes, beet, peas, beans, cereal, and oilseed crops). Two-fifths of the respondents also derived income from off-farm activities.

3.2. Soil health practices implemented and drivers of adoption at farm level

Table 2 presents an overview of farmers' implementation of soil health practices; factors which motivated adoption of these practices, perceptions of benefits derived (other than SCS); and willingness to adopt additional practices.

The majority of respondents (63%) regarded reducing tillage as the single most important soil health practice. Respondents primarily adopted in-field practices such as incorporating legumes and herbs into grasslands; managing livestock stocking rates; introducing cover crops (e.g. mixed winter forage crops) and leys in rotations; incorporating straw into the soil; and applying biologically-complete composts. However, farmers also indicated they sought to manage field margins by establishing hedges and taking margins out of cropping, allowing margins to re-vegetate naturally or sowing wildflower species and/or cover crops. One-fifth of respondents maintained part of their farm or the estate managed as an agroforestry system; for example, grazing cattle or sheep in an area of land shaded by trees.

Only a minority of respondents (6%) had not yet implemented any of the soil health practices on their farms; 94% of farmers had adopted multiple practices to improve soil health, address soil fertility decline, and reduce production costs (Fig. 2).

Respondents implemented soil health practices for a variety of reasons. Recognising that soil fertility was declining, they reported high input costs had led them to explore soil fertility improvement strategies beyond application of synthetic fertilisers. Although farmers were cognisant of the impact of extreme weather events on agricultural production, only a minority (12%) perceived a responsibility to contribute to climate change mitigation, recognising the importance of and the potential for soil health practices to contribute to SCS and to building carbon stocks. Farmers who chose to provide an optional 'other' response (to Q8), in addition to selecting one or more of the given options referenced 'tradition' as the main reason for their adoption of soil health practices, asserting they 'ha [d] always farmed this way'; 8% of farmers who selected 'other', however, indicated they had not necessarily been motivated by any particular reason to adopt practices.

Table 2
Practices implemented, factors influencing adoption, and willingness to adopt additional practices (n = 100).

		N
Adopted practices	No/low/minimal/conservation tillage	63
	Incorporation of a mix of legumes and herbs into grasslands	61
	Low intensity/rotational/mob grazing	60
	Management of field margins	56
	Incorporation of organic amendments into soils	54
	Cover crops	52
	Introducing leys in crop rotations	34
	Agroforestry	19
	Application of biochar	4
	Not implementing any practices	5
Motivation to adopt practices	Desire to reduce reliance on agrochemicals and/or synthetic fertilisers	50
	Declining soil fertility	31
	Desire to express my pro-environmental identity	26
	Exposure to extreme weather events	23
	High production costs	22
	Government subsidies/payments	21
	Pressure to contribute to climate change mitigation	12
	Pressure to align practices with certification standards	4
	Pressure from customers/consumers to change farming strategy	2
	Desire to gain respect in the community	1
Benefits derived	Improved soil health	66
	Increased biodiversity on the farm	49
	Improved soil fertility	34
	Reduced production costs	31
	Reduced soil erosion	20
	Increased resilience to extreme weather events	17
	Access to new markets for my produce	6
	Increased crop yields	5
	Improved standing in the community	3
Willingness to adopt additional practices and interest in receiving carbon payment	Willing to adopt additional practices if paid to do so	61
	Not willing to adopt additional practices, but would like to receive a 'carbon payment' for already adopted practices	19
	Willing to adopt additional practices, but no interest in carbon payment	11
	Not interested in adopting additional practices and/or a carbon payment	3
	Not sure	6

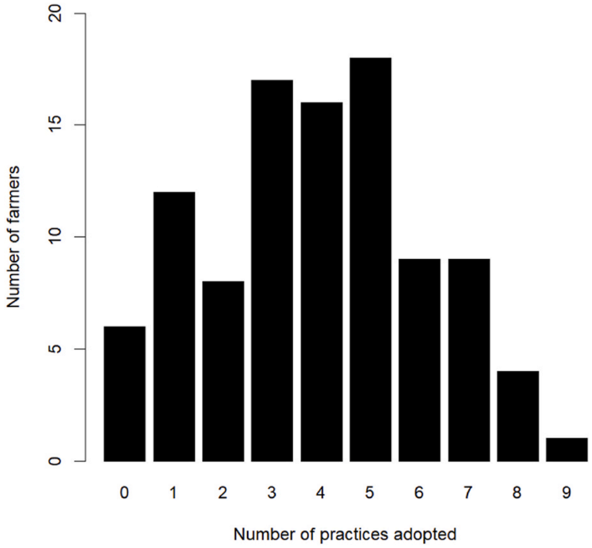

Fig. 2. Number of practices adopted by farmers (n = 100); on average, farmers adopted 3.9 practices.

Beyond improved soil health, respondents indicated they had derived multiple benefits from practices adopted, including reduced production costs, improved soil fertility, reduced soil erosion, and increased resilience to extreme weather events. Additionally, they reported deriving co-benefits such as increased biodiversity on their farms. Although farmers thought that the condition of their soils had improved, they did not regard their adoption of practices as having led to increased crop yields. Few respondents perceived practices as having led to direct economic benefits (e.g., higher prices for produce), or as having enabled them to gain access to new markets for their produce (e.g., certification) and receive compensation from an entity within their supply chain (e.g., payment for providing soil-related ecosystem services). Providing an 'other' response (to Q9), 10% of farmers indicated it was 'too early to say at this stage' what the impact of practices had been on farm profitability and productivity. Moreover, they were unsure of the impact as 'tools to measure soil improvements are not reliable or easily available'. Farmers who chose to provide an optional 'other' response - in addition to one or more of the given options - cited benefits including 'personal satisfaction', 'improved personal understanding of the ecology of soil health' and an 'ability to farm in harmony with nature'.

The majority of respondents (72%) were willing to adopt practices additional to those that they were already implementing to improve soil health. Most respondents (61%) stated their adoption of additional practices would be contingent on being paid to do so. However, several farmers (11%) indicated they were willing to adopt practices in the absence of monetary compensation (e.g., a carbon payment). Approximately one-fifth of respondents (19%) indicated they did not want to adopt additional practices; however, they wanted to be paid for practices already adopted and for maintaining existing soil carbon stocks. Only a minority of farmers (3%) indicated they were neither interested in adopting additional practices nor receiving a carbon payment. The extent to which farmers had already adopted practices did not significantly influence their willingness to adopt additional practices (Figs. 3–7 in supplementary material).

3.3. Preferences and opinions regarding carbon schemes and the carbon market

As indicated by Table 2, a subset of farmers (i.e., 80 farmers) was willing to participate in carbon schemes; these farmers were interested in either receiving a carbon payment for adopting additional practices (61% of respondents) or as compensation for already adopted practices (19% of respondents). Table 3 presents an overview of farmers' preferred source of carbon payment; preferred partner in planning and implementing a carbon project; willingness to enter into a contract for a fixed number of years and the length of time deemed acceptable; and willingness to maintain soil carbon stocks beyond the initial contract period.

Few respondents had the confidence to plan and implement a carbon project in conjunction with a government department or entity from their supply chain; instead, they expressed a preference to work with a project developer or not-for-profit NGO as this would allow them to assert a greater degree of control over the project design and implementation process. One-fifth of farmers indicated their preference was to receive a carbon payment from a public funding source. Although one-fifth of respondents did not want to sign up for contracts lasting more than five years, one-third of respondents were willing to accept a 5–10 years contract. The majority of respondents (80%) were unwilling to commit to maintaining soil carbon stocks, post-contract, beyond a period of 10 years.

Table 4 presents farmers' perceptions of the agricultural soil carbon market as indicated by their agreement with pre-formulated statements and their preferences regarding carbon project contract conditions (e.g., actions capable of generating carbon credits and carbon payments; timing of carbon payments; acceptable share of carbon credits to contribute to a buffer).

Table 3
Preferences regarding design and implementation of carbon projects (n = 80).

		n (%)
Preferred source of 'carbon payment'	From several different sources (e.g. public funding sources and private investors)	46 (58)
	From a public funding source	20 (25)
	From private investors (e.g. agribusinesses and/or the food industry, banks, pension funds, aviation industry)	6 (8)
	No preference	5 (6)
	Not sure	3 (4)
Preferred partner in planning a carbon project contract	A carbon project developer	26 (33)
	A not-for-profit NGO	24 (30)
	A government department	13 (16)
	An entity within the supply chain (e.g. processor)	2 (3)
	No preference	1 (1)
	Not sure	8 (10)
	Not interested in being involved in the design of a contract	6 (8)
Length of time willing to enter into a contract	Less than 5 years	27 (34)
	5–10 years	41 (51)
	11–20 years	7 (9)
	21–50 years	1 (1)
	More than 50 years	2 (3)
	Not sure	2 (3)
Willingness to maintain carbon stocks after a contract has ended	Less than 5 years, unless another contract is initiated	35 (44)
	5–10 years	29 (36)
	11–20 years	5 (6)
	21–50 years	6 (8)
	More than 50 years	1 (1)
	Not sure	4 (5)

Table 4
Agreement with statements about agricultural soil carbon market and preferred carbon project contract terms and conditions (n = 100).

		n
Agreement with statements about the emerging soil carbon market	Farmers should be paid based on in-situ measured increases in soil carbon stocks before and after a contract	48
	There should be two rates of payment - one rate for farmers who have historically managed soils 'well' and another rate for farmers who have not historically managed soils 'well'	33
	Farmers should be paid based on modelled (estimated) changes in soil carbon stocks	24
	Farmers should only be paid if adopt new, additional farming practices	19
	Farmers should not be paid for existing soil carbon stocks, even if farms are managed 'well' and soil is not degraded	8
	I do not agree with any of these statements	8
Actions cable of generating carbon credits and 'carbon payments'	Increasing the amount of carbon stored in the soil	83
	Avoided emissions from fertiliser manufacturing, linked to reduced use of synthetic fertilisers	46
	Reduction in emissions of all GHG from soils	44
	Reduction in GHG emissions linked to reduced on-farm use of fossil fuels	36
	Reduction in soil erosion	35
	Avoided emissions linked to increased use of renewable energy	25
	I don't know	3
Timing of 'carbon payments'	In several instalments during the contract, based on in-situ measurements and/or modelled increases in soil carbon stocks and reductions in GHG emissions	85
	Upfront, based on predicted (modelled) carbon uptake as a result of implementing certain practices	12
	Retrospectively, after 5–10 years, based on measured and/or estimated (modelled) increases in soil carbon stocks and/or GHG emissions avoided during the contract	8
	I don't know	3
Perception of acceptable share of carbon credits to contribute to a buffer	Less than 5%	28
	5–10%	43
	11–20%	18
	More than 20%	2
	I don't know	9

Regardless of their interest in implementing a carbon project, respondents opined the emerging soil carbon market had the potential to generate economic and non-economic benefits if well-governed. One-third of respondents thought there should be two rates of payment to acknowledge farmers' historic approaches to managing their land had resulted in differences in SOC stocks between farms, also reflected in SOC baselines. A minority of respondents (8%) thought farmers should not be paid for existing soil carbon stocks. One-fifth of respondents asserted farmers should be paid only if they adopted new, additional practices.

Half of the respondents believed carbon payments should be based on in-situ measured increases in soil carbon stocks before and at the end of a contract period, while one-fifth of respondents thought payments should be based on modelled or estimated changes in soil carbon stocks. Beyond receiving payments for SCS, many respondents took the view that carbon payments should be provided on-farm use of synthetic fertiliser was reduced (46% of farmers) or use of renewable energy was increased (25% of farmers), resulting in avoidance of emissions. One-third of respondents thought carbon payments should be given to farmers who reduced their use of fossil fuels, while one-third of respondents thought those who reduced soil erosion should also receive carbon payments. Half of the respondents thought the carbon market should compensate farmers for reducing all GHG emissions (i.e. carbon dioxide, nitrous oxide, and methane).

The majority of respondents (85%) believed carbon payments should be received in instalments throughout a carbon project contract (rather than upfront) or retrospectively, based on an increase in soil carbon stocks and/or GHG emissions avoided during a contract. Respondents were divided as to their willingness to contribute a share of carbon credits to a buffer to compensate for unavoidable consequences resulting in reversals of carbon sequestered and/or leakage; the option most preferred by farmers was a share of 5–10% credits. Only a minority of farmers (2%) were willing to contribute a share of carbon credits of more than 20% to a buffer.

3.4. Terms and conditions of carbon codes sampled in the UK

Table 5 (supplementary material) provides an overview of the carbon codes operationalised by the six private sector and civil society organisations that participated in the study. Distinct in their design and scope, the codes differed in the criteria imposed on farmers as regards carbon project ownership and monitoring, reporting and verification of SCS and/or GHG emissions reductions.

All of the codes stipulated that carbon projects could only be initiated by farmers with land tenure security. Although not specifying that those implementing carbon projects should be land-owning farmers, the conditions relating to carbon project development and registration favour those pursuing agricultural production on their own land. Tenant farmers' capacity for initiating a project hinges on their relationship with the landowner and the conditions of their tenancy agreement. The majority of the codes permitted farmers and/or carbon project developers to register carbon projects, however, one of the codes only accepted projects being registered by carbon project developers which could increase the costs associated. Although most codes required monitoring of changes in soil carbon stocks through modelling or in-situ measurement, two of the codes permitted farmers to use GHG emissions factors in calculating and reporting GHG emissions reductions.

Table 6 (supplementary material) presents an overview of the land use types and management practices considered by carbon codes to be eligible for inclusion in carbon projects. All of the codes regarded cropland and grassland as eligible land use types. Two of the codes excluded permanent pasture, one code excluded permanent crop production, and one code excluded land used for root vegetable production from being used to generate carbon credits. Most codes had predefined lists of practices that farmers could implement to sequester carbon in the soil and/or reduce soil-derived GHG emissions. One code did not specify which practices farmers should adopt; however, it nevertheless mandated that practices should be 'additional' and outlined several criteria that should be met for practices to be eligible for a carbon project.

Table 7 (supplementary material) presents an overview of the carbon codes' expected carbon project contract length; permanence of soil carbon stocks; and approaches to establishing soil carbon stock baselines and the reporting of modelled and/or in-situ measured changes in soil carbon stocks and/or reductions in soil-derived GHG emissions. Codes differed in their conceptualisation of permanence and expectations of the length of time that soil carbon stocks should be maintained after a carbon project contract had ended, with permanence timeframes stipulated ranging from 5 to 25 years. Two of the codes did not provide information regarding the length of time that carbon stocks should be maintained. Most codes stipulated a baseline should be established at the start of a carbon project, to enable retrospective carbon crediting as well as to facilitate measurement of changes over the contract period. Two of the codes took a fixed average approach to establishing a baseline (i.e., the baseline is constant and approximated based on historical baseline values captured within a fixed reference timeframe), while the other codes regarded baselines as dynamic (i.e., the baseline changes and is calculated based on a 'moving' reference timeframe, e.g., 5 years). The amount of historic field management data required to establish a baseline varied by code. Although all of the codes required modelling on an ongoing yearly basis, the frequency of measuring soil carbon stocks and/or reductions in soil-derived GHG emissions varied by code.

Table 8 (supplementary material) presents an overview of the conditions associated with carbon payments. The majority of codes permitted retrospective carbon crediting (i.e., issuance of credits for soil carbon evidenced as accumulating during a limited period of time, before the start of a carbon project, e.g., 3–5 years), and half of the codes allowed for stacking of payments, facilitating blended finance (i.e., public and private funding of practices resulting in SCS). All codes required farmers to contribute a share of carbon credits to a buffer fund. Most carbon codes did not offer a guaranteed carbon floor price (i.e., a binding minimum price for future carbon sequestered and/or GHG emission reductions to counter carbon price volatility and the level of risk faced by carbon credit producers and buyers); however, three of the codes had put in place discounting arrangements in anticipation of contingencies and developments in the carbon market (e.g., ensuring the carbon price is equivalent to ~70% of agreed sale price for one tonne carbon dioxide equivalent).

4. Discussion

4.1. Farmers' adoption of soil health practices

Farmers in the UK are proactively adopting soil health practices (Table 2). These practices are widely regarded as having the potential to enhance soil carbon stocks by promoting the recycling of carbon-containing biomass (Tiefenbacher et al., 2021). Moreover, these practices are viewed as reducing the rate of decomposition of organic matter by the soil microbial community, the physical disturbance of soil which increases the stability of soil aggregates, and the rate of carbon loss to the atmosphere via respiration (Lal, 2021; Tiefenbacher et al., 2021; Thamo et al., 2004; Alexander et al., 2015). SCS and/or a reduction in soil-derived GHG emissions may be realised, for example, through reduced tillage or no-tillage to improve rotations (i.e. establishment of cover and catch crops, reduction of bare fallow, a shift from annual to perennial crops; incorporation of ley crops into rotations; set-aside of arable land) (Henderson et al., 2022; Alexander et al., 2015). Equally, soil carbon stocks may be enhanced and/or GHG emissions reduced through organic resource management (i.e. application of organic amendments such as livestock manure, crop residue retention, and application of biochar) (Tiefenbacher et al., 2021; Alexander et al., 2015); optimised nutrient management to enhance net primary productivity (Henderson et al., 2022); management of soil pH levels (i.e. liming acidic soils) (Tiefenbacher et al., 2021); management of soil water content (i.e. irrigation) (Tiefenbacher et al., 2021; Alexander et al., 2015); and soil erosion control (Tiefenbacher et al., 2021; Dumbrell et al., 2016; Aertsens et al., 2013). Carbon stocks may also be enhanced and GHG emissions reduced through grazing land management (i.e., optimised stocking density, pastureland restoration, sward management, incorporation of leguminous and non-leguminous species); integration of livestock and trees into crop systems; and improved fire management (Henderson et al., 2022; Lal, 2021).

It is important to note, however, that Table 2 must be interpreted with caution. There may be perspective-specific and context-specific variations in farmers' conceptualisation and implementation of practices and non-uniform understanding of their impact on soil carbon stocks and/or GHG emissions. In the case of tillage-related practices, for example, the concentration of SOC along a soil profile, rather than overall SOC content, may reflect soil disturbance (Sun et al., 2018; Baker et al., 2007), yet the 'true' impact of tillage systems on crop production and environmental outcomes may be confounded by the depth of sampling (Derpsch et al., 2014). The use of a variety of terms to describe grazing-related practices – reflecting different philosophical and physical approaches to grassland management – has similarly led to confusion regarding the impact of practices on soil carbon stocks (Fielding, 2022; Garnett et al., 2017). The inconsistent and interchangeable use of terms by farmers, as well as practitioners and scientists, makes it difficult to compare and discuss the environmental outcomes of grazing management-related practices on soil carbon stocks and/or GHG emissions and verify benefits claimed by advocates of continuous and intermittent grazing, respectively (Zaralis, 2015).

4.2. Factors driving farmers' adoption of practices

The impact of land use change, land management and land degradation on soil carbon stocks globally has been extensively documented, including by Henderson et al. (2022), Subedi et al. (2022); Lal (2021), Tiefenbacher et al. (2021), Smith et al. (2016), and Frank et al. (2015). Farmers' adoption of practices could be indicative of a growing realisation among farmers that enhancing carbon inputs to the soil from vegetative biomass has the potential to halt and reverse soil degradation and can positively impact resilience to climate change, as well as soil health, biodiversity, structure, moisture retention and nutrient storing capacity, as documented by Saco et al. (2021) and Dumbrell et al. (2016).

Beyond improving soil fertility and reducing soil erosion, farmers may be aware that the adoption of soil health practices delivers tangible, co-benefits such as improved food and nutritional quality, improved water quality and availability, and increased biodiversity. However, the results of this study suggest that an awareness of non-tangible co-benefits of SCS and climate change mitigation does not currently underpin farmers' adoption of practices. This finding is in contrast to other studies, including Dumbrell et al. (2016), which suggest farmers who are well-informed about the carbon market may be incentivised to adopt practices that promote SCS by information regarding these co-benefits rather than financial compensation mechanisms offered by the market.

4.3. Farmers' willingness to adopt additional practices and participate in carbon schemes

Studies have shown economic incentives can crowd out intrinsic motivations for providing social goods such as SCS (Buck and Palumbo-Compton, 2022). It is encouraging, therefore, that the results of this study suggest that, alongside a desire to reduce production costs and their reliance on agrochemicals and synthetic fertilisers, farmers' inherent pro-environmental identities and values may play a role in driving their adoption of soil health practices.

To understand innovative farmers' reluctance to engage with the market, despite their adoption of practices (Table 2), it is necessary to differentiate between barriers to the adoption of practices and barriers to participation in the carbon market (Kragt, Dumbrell and Blackmore, 2017). Farmers – particularly those who own their land or have an additional, off-farm source of income – may not face barriers in adopting practices. However, their willingness and capacity to engage with the carbon market may be undermined by conflicting information regarding practices and SCS schemes; carbon price uncertainty; ease of use of carbon calculators and methodologies to verify changes in carbon stocks; the intergenerational implications of lengthy carbon project contracts; and expectations that carbon stocks are 'permanently' maintained (Kragt, Dumbrell and Blackmore, 2017; Rochecouste et al., 2017). Moreover, farmers' willingness and capacity may be undermined by perceptions that policies and regulations may change and that they may, in the future, be expected to be carbon neutral before trading and/or selling carbon credits (Fleming et al., 2019). Education and training may play a key role in determining farmers' willingness to adopt practices and participate in carbon schemes. Those who have the skills and knowledge required to adapt to changing circumstances may find themselves in a better position to survive in an ever-evolving and demanding agricultural sector (Augère-Granier, 2017).

4.4. Farmers' expectations of the carbon market compared to the demands of 'carbon codes'

Farmers adopt practices based on an assessment of their cost-effectiveness and likely impact on farm productivity and profitability (Henderson et al., 2022; Lal, 2021; Mills et al., 2020). In the present study, farmers' adoption of practices reflects a degree of autonomy and independence which is at odds with the demands of private and/or public sector actors. Carbon codes aim to uphold the crucial carbon market principle of additionality by stipulating that farmers adopt practices that are not commonly adopted; new to a farm; not adopted in response to government subsidies; and/or not adopted using funding from other sources (Table 6, supplementary material). As indicated by Table 2, the majority of farmers have already adopted practices and would, therefore, not be eligible for carbon schemes such as those included in Table 6. The extent to which additionality may constitute a barrier to participation in the market has also been reported by Blum (2020). In Australia, Rochecouste, Dargusch and King (2017) have observed that farmers' ability to participate in the market hinges on passing a 'common practice test', whereby a carbon code determines whether a given farmer is eligible for a carbon scheme based on practices adopted relative to peers in a similar geographic area. This test is designed to ensure that soil carbon stocks are enhanced and/or soil-derived GHG emissions reduced through the implementation of practices that would not be adopted in a 'business as usual scenario' (i.e. in the absence of a carbon payment).

Many UK carbon codes require that farmers select practices from pre-defined lists (Table 6). This condition, and the related condition that practices adopted are 'additional', has implications as regards curtailing farmers' freedom of choice in determining their farming strategy. The adverse impact that top-down, climate change policy can have on farmers' behaviour and decision-making related to land management has also been documented by Renwick and Wreford (2011).

There is currently a disconnect between farmers' expectations regarding the opportunities to derive compensation from participation in the agricultural soil carbon market and the actual compensation offered by the market. Albeit offering a value proposition similar to international carbon codes (Black et al., 2022), the results of this study suggest, in compensating farmers for their soil stewardship, there is currently a failure among carbon codes in the UK to recognise and appreciate that potential early entrants to the carbon market will start from a disadvantaged position as regards their scope to benefit from participation in the market relative to subsequent entrants. This disadvantage stems from potential early entrants' historic management of soils and resultant soil carbon stocks; baselines against which SOC changes will be measured; and the potential to sequester additional SOC. There is a failure to fully acknowledge that this disadvantage may, perversely, serve to incentivise farmers to lower soil carbon stock baselines before initiating and registering a carbon project. For example, farmers may be incentivised to refrain from implementing certain practices and/or revert from practices (e.g., minimal tillage or direct drilling back to conventional tillage) to reverse the historic, positive impact of soil health practices. The imperative to address the risk of such perverse incentives being created, and thereby avoid the release of carbon from soils resulting from actions taken by farmers to lower their baselines before entering into SCS schemes, has also been argued by E. E. Oldfield et al. (2022).

Farmers' preference to receive a carbon payment from several different sources rather than a single source (Table 3) is in agreement with UK carbon codes' willingness, in principle, to permit stacking of payments (Table 8). However, in reality, stacking is complex and constitutes a challenge. Although stacking recognises the interconnectedness of ecosystem services on a landscape level (Deal, Cochrane and LaRocca, 2012), it introduces a risk of double counting of carbon credits. This undermines policymakers' and carbon buyers' confidence in the market, while farmers may face higher transaction costs in participating in the market (Duguma et al., 2018).

The results of this study suggest that farmers prefer public to private funding or blended finance, for example, through the soil standards of the Sustainable Farming Incentive (SFI) component of the new Environmental Land Management Scheme (ELMS) in England. However, there is growing pressure to move away from a 'dominant market-based, ecosystem services 'public goods' approach [that] does not provide any meaningfully transformative avenues to foster sustainable and equitable food systems' (Coulson and Milbourne, 2022, p. 133). Obtaining public sector compensation for carbon sequestration is at odds with the post-Brexit objectives of using 'public money for public goods' and ensuring social benefit returns to public spending (Bateman and Balmford, 2018).

Farmers are unwilling to sign carbon project contracts perceived as equating to intergenerational commitments to implementing soil health practices during the contract period and, thereafter, maintaining carbon stocks 'permanently'. The extent to which legal liability associated with contract noncompliance constitutes a barrier to farmers' participation in carbon markets has been documented, including by Thompson et al. (2022). The results of this study underscore that permanence requirements are perceived by farmers as 'a cumbersome and unrealistic expectation' and suggest that 'there is need for timely translation of scientific knowledge of soil C longevity to inform effective policy' (Dynarski et al., 2020, p. 5).

Currently, policy and science-based definitions regarding the permanence of newly sequestered soil carbon do not align (Dynarski, Bossio and Scow). The results of this study demonstrate that there is also a gap between farmers' expectations and the demands of the carbon market regarding permanence. This indicates that there is a need for policymaking and the development of carbon codes (outlining rules regarding permanence) and minimum standards aimed at regulating the carbon market to be informed by farmer consultation. As Krzywoszynska (2019, p. 160) notes, social learning underpinned by two-way communication between the scientific community and farmers, and the emergence of a shared language around sustainable soil management, is key to ensuring that knowledge is co-produced, 'collective meanings' regarding best practices are co-created, and 'shared visions of agrarian futures which put soils at their heart' are co-produced.

4.5. Implications of findings for policymakers and practitioners in governing the emerging agricultural soil carbon market

Regulatory frameworks are currently being developed to establish carbon removal certification schemes, including the EU-wide voluntary framework which envisages benchmarking carbon removals against a proposed set of criteria titled 'QU.A.L.ITY: Quantification, Additionality and baselines, Long-term storage and Sustainability' (European Commission, 2022a). Creating performance-based incentive systems through standards, however, is contingent on 'establishing sufficient checks and balances in developing methodologies and their use, keeping track of [carbon certificates] issuance, ownership, and transactions' (Runge-Metzger et al., 2022, p. 2). The results of this study suggest that translating the vision of regulatory frameworks into practice may not be straightforward and will likely hinge on policymakers and practitioners addressing farmers' concerns regarding their ability to meet terms and conditions specified in carbon project contracts aimed at ensuring the additionality and permanence of carbon sequestered. Farmers' willingness to participate in the agricultural soil carbon market, for example, risks being undermined by a current lack of clarity in discourse relating to the determination and benchmarking of standard and project-specific carbon baselines.

Farmers' expectations of the market do not currently align with the reality and demands of the market. The findings of this study underscore the importance of policymakers and practitioners recognising that innovative farmers currently believe that there is scope to benefit from the market. Paradoxically, however, the terms and conditions associated with carbon contracts - specifically, those related to additionality – currently undermine their ability to participate in the market. Given that innovative farmers are likely to play a key role in instilling confidence among subsequent market entrants, it is imperative that farmers' expectations – and, in particular, innovative farmers' expectations – are reconciled with the demands of the carbon market.

Policymakers and practitioners must recognise and appreciate the important role that farmers play in underpinning the agricultural sector's contribution to achieving the SDGs and the goals of the UNFCCC Paris Agreement, as well as driving the global economy towards net zero. Farmers who are interested in participating in SCS schemes should not be penalised for being either early or late adopters of soil health practices. It is imperative that the market compensates both potential early and subsequent market entrants accordingly and that the terms and conditions associated with market participation are deemed acceptable and attractive by all farmers.

The results of this study suggest three pathways for scaling up the adoption of soil health practices and incentivising farmers' participation in SCS schemes that are available to policymakers and practitioners in the UK and other countries where an environmental policy framework has not yet emerged and carbon codes have, to date, played a key role in shaping the development of the carbon market.

Policymakers and practitioners could pay farmers for carbon stored in their soils relative to a reference baseline reflecting soil carbon stocks of farmers in similar social, economic, environmental and technological circumstances, with the carbon market paying for the additional SCS resulting from continued implementation of practices or adoption of additional practices. This could be a solution to the current paradox that policymakers and practitioners face in facilitating innovative farmers - who may be ineligible based on additionality criteria - to participate in the market. It would also be in line with emerging environmental policy frameworks such as the European Commission's framework which proposes that carbon removal certifications could be issued to regulate 'carbon farming' activities (European Commission, 2022).

Public sector funding could be used to protect existing soil carbon stocks by incentivising innovative farmers to continue implementing and adopting additional soil health practices. This would pave the way for private sector funding to support segments of the farming population that have not yet adopted practices or are late adopters of certain practices in changing their farming strategies and participating in the carbon market as subsequent entrants. Moreover, it would facilitate the bundling and stacking of ecosystem service payments and blending of public finance with multiple coordinated private schemes, thus ensuring public funding is reserved for landscapes and services not paid for by the market (Reed et al., 2022).

Finally, policymakers and practitioners could designate a time-limited transition period during which innovative farmers are incentivised to participate in the market by a relaxation of rules and regulations outlined by environmental policy frameworks and/or carbon codes. This could serve to kick-start and support market growth and development. Moreover, it could enhance the transparency, robustness and integrity of the market by sensitising both innovative farmers and the broader farming population to the importance of SCS; the conditions associated with participation in the carbon market; and the demands of the market as articulated by carbon codes.

4.6. Limitations of the study

The descriptive case study outlined in this paper adds to the global literature on the emerging agricultural soil carbon market by highlighting the opportunities and challenges associated with incentivising farmers' participation in SCS schemes and facilitating innovative farmers' engagement with the carbon market, alongside subsequent entrants.

A self-selection bias was introduced by the use of an online questionnaire to collect data, which led to the sample not being representative of the broader UK farming population based on its geographic composition as well as two key demographic characteristics (i.e. age and farm size). In the present study, the majority of farmers were from England and aged between 35 and 64 years. This is noteworthy given that, in 2016, one-third of farmers in England were recorded as being over the age of 65 years (DEFRA, 2021). Moreover, the average farm size in the present study was 413 ha, whereas the average UK farm size was found to be 81 ha in 2019 (DEFRA, 2021). Nevertheless, the farmers recruited for this study can be regarded as representative of the target population (i.e., innovative farmers in the UK who had adopted soil health practices promoting SCS). It is noteworthy that the sample is similar in its demographic makeup to that of Jaworski et al. (2023), who explored UK farmers' adoption of sustainable soil management and regenerative agriculture practices.

Important insights may be drawn from this case study by policymakers and practitioners in the UK as regards innovative farmers' willingness to adopt soil health practices; interest in participating in soil carbon sequestration schemes; and expectations regarding their scope to derive benefits from the market. These insights may also be of interest to policymakers and practitioners globally, as the UK is an example of a region where carbon codes, rather than environmental policies, have served to shape the carbon market. Specifically, the present study may provide insights into the pathways available for scaling up adoption of soil health practices and incentivising farmers' participation in SCS schemes and, by extension, the carbon market.

This study did not explore whether fees associated with initiating carbon projects were perceived by farmers as prohibitive and whether costs associated with soil testing and establishing soil carbon stock baselines could serve to disincentivise participation in the carbon market. Tenancy did not emerge as an issue that could undermine a transition towards the UK's net zero goals, despite often being cited as a barrier to farmers' participation in the carbon market (Coulson and Milbourne, 2022; Reed et al., 2022; Mills et al., 2020; Ingram et al., 2014). Moreover, perceptions of the market as an opportunity or risk and exploring farmers' confidence in market developments and issues such as uncertainty around carbon prices were deemed to be beyond the scope of this project.

5. Conclusions

This paper concludes that innovative farmers' adoption of soil health practices does not necessarily translate into a willingness to adopt additional practices and "buy into" SCS schemes, and/or an ability to engage with the carbon market. Farmers adopt practices to address issues of declining soil fertility and to reduce production costs stemming from a reliance on agrochemicals and synthetic fertilisers. Farmers are, currently, not motivated to adopt practices by carbon payments nor do they perceive pressure to contribute to climate change mitigation and/or net zero targets. Farmers have reservations about signing up for carbon schemes, and planning and implementing carbon projects, due to the terms and conditions associated with participation in the emerging UK agricultural soil carbon market but also their expectation that these may change over time as the market evolves and regulatory minimum standards are developed and adopted by carbon codes. Although late adopters of soil health practices may be attracted to participate in the carbon market, innovative farmers are likely to be excluded from public and private sector-established carbon schemes based on additionality criteria. Farmers' expectations regarding their ability to derive benefits from participation in the carbon market are at odds with the demands of the carbon market as articulated by carbon codes. Specifically, there is a gap between innovative farmers' expectations and codes' demands regarding the permanence of soil carbon storage, and carbon project contracts' length and commitments. As innovative farmers are likely to play a key role as frontrunners in encouraging new entrants to engage with the carbon market, this paper contends that incentivising innovate farmers to adopt additional practices and facilitating their participation in the market, alongside new entrants is paramount to market growth and development. This paper underscores that there is much at stake, both in the UK and at a global level; namely, without farmers' adoption of soil health practices that capture and store carbon and committed participation in SCS schemes and engagement with the carbon market, the climate change mitigation potential, and associated ecosystem services, of sequestering carbon in agricultural soils will not be realised.

Ethical clearance

Ethical clearance for this study was obtained from the University of Leeds' School of Business, Environment and Social Services (AREA) Committee, with the ethics approval reference given as LTGEOG-065 - iCASP Farm Soil Carbon Code.

Credit author statement

LP – conceptualised and designed the study methodology, collected and analysed the study data, and prepared the manuscript. PJC – supervised the research, acquired financial support for the study, conceptualised and designed the study, and contributed to the writing and editing of the manuscript. GZ – supervised the research, acquired financial support for the study, conceptualised and designed the study, and contributed to the writing and editing of the manuscript.

Declaration of competing interest

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Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envdev.2023.100941.

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