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Reconciling farmers' expectations with the demands of the emerging UK agricultural soil carbon market

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Abstract

This paper explores farmers' and land managers' perceptions of the emerging agricultural soil carbon market in the UK and examines their willingness to adopt soil health management practices to enhance and/or maintain soil carbon stocks and enthusiasm for and interest in participation in soil carbon sequestration schemes. Data were collected through online questionnaires administered to 100 farmers and six organisations responsible for the operationalisation and development of carbon codes in the UK using online questionnaires. The results indicate that farmers' prior adoption of practices that promote soil health does not necessarily translate into a willingness to adopt additional practices and/or "buy into" soil carbon sequestration schemes. Farmers have reservations about planning and implementing soil carbon projects due to the terms and conditions associated with participation in the emerging UK agricultural soil carbon market. Although the carbon market may attract new entrants, early adopters of soil health management practices are likely to be excluded from soil carbon sequestration schemes established by public and private sector actors based on additionality criteria. The results of this study also suggest early adopters' expectations regarding their scope to derive benefits from participation in the carbon market are at odds with the demands of the carbon market as articulated by the carbon codes driving the development and growth of the market. These results highlight that the key role that early adopters may play in encouraging new entrants to engage with the carbon market should not be underestimated. It contends that enhancing the transparency, robustness, and integrity of the carbon market hinges on incentivising early adopters to adopt additional practices that promote soil health and facilitate their participation in the market, alongside new entrants. The paper argues that kick-starting and supporting the growth of the agricultural soil carbon market is contingent on reconciling farmers' expectations with the demands of the market, during an initial transition period, through flexible implementation of rules and regulations outlined by carbon codes regarding soil carbon sequestration and storage in agricultural soils.

1. Introduction

The potential for sequestering carbon in agricultural soils has been widely advocated by global initiatives such as the '4 per 1000 Initiative: Soils for Food Security and Climate' which aims to increase soil organic carbon (SOC) by 0.4% annually and, thereby, contribute to efforts to keep global warming below 1.5 degrees above a pre-industrial baseline (Rumpel et al., 2020; Soussana et al., 2019; Minasny et al., 2017). Soil carbon sequestration is considered part of the solution to drive the global economy towards net zero, and achieving the goals of the UNFCCC Paris Agreement. In line with its objective of being net zero by 2050, the UK government has committed to a drastic cut in greenhouse gas (GHG) emissions from all sectors, including those from agricultural activities. A reduction in GHG emissions is essential to meet net zero targets, however, greenhouse gas removal (GGR) will be essential to balance residual emissions in hard-to-abate sectors in 2050, such as aviation, agriculture, and certain heavy industries (BEIS, 2021b). The UK has in recent years explored and invested in different solutions to capture and ensure long-term storage of greenhouse gases (GHG) from the atmosphere, including Nature Based Solutions (NBS). NBS have the potential to contribute to both climate change mitigation and adaption while delivering multiple benefits for nature and people (Seddon et al., 2020). To date, the UK discourse related to NBS has been dominated by narratives around peatland, woodland, and salt marsh protection, restoration, and creation (Bradfer-Lawrence et al., 2021). However, carbon sequestration in agricultural soils is increasingly recognised by UK academics, policymakers and practitioners alike as constituting a viable NBS and an important GGR option and, therefore, a climate change mitigation strategy (Wentworth and Tresise, 2022; Stafford et al., 2021). This shift in the NBS discourse is a reflection of a growing consensus among scientists, policymakers, public and private investors, and civil society actors globally that management of soil organic carbon (SOC) constitutes a 'natural climate solution' and that the SOC climate mitigation opportunity has not yet been realised (Bossio et al., 2020, p. 391).

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 NBS, including carbon sequestration in agricultural soils. Although only 10% of total GHG emissions in the UK are estimated to stem from the agricultural sector (DEFRA, 2021), it is envisaged that the current development of a policy framework by DEFRA for ecosystem market development and an agricultural soil carbon market could catalyse the broader land use change required to realise net zero emission targets outlined by the UK government in its landmark strategy published in 2021 (BEIS, 2021a). Globally, there are growing calls for concerted action to bring soils to the forefront of the carbon agenda for climate change and adaptation (Amelung et al., 2020; Minasny et al., 2017) and for improved soil management to be scaled up through soil carbon sequestration schemes (Vermeulen et al., 2019).

In the UK, academics, policymakers, and practitioners alike are increasingly regarding soil carbon sequestration schemes as key to securing the provision and regulation of ecosystem services associated with the global carbon cycle (e.g., carbon sequestration and greenhouse gas and climate regulation) (Lal et al., 2021). These schemes reward farmers and farm managers (hereafter referred to as farmers) for their adoption of soil carbon management practices (Mills et al., 2020). Farmers do not adopt practices explicitly to increase soil organic matter and enhance soil carbon stocks, rather they adopt management practices that promote soil health (Miner et al., 2020). Their motivation to implement such practices (e.g., planting cover crops, establishing herbal leys, etc.) stems from a desire to improve soil functioning and properties, and safeguard the ecosystem services provided by soils (Lehmann et al., 2020), address agricultural production constraints (e.g., declining soil fertility, soil erosion, soil degradation, etc.) (Henderson et al., 2022; Dumbrell, Kragt and Gibson, 2016). In addition to generating private benefits for farmers - reduced productions costs due to reduced need for and use of external agricultural inputs, (e.g., synthetic fertiliser and pesticide) labour, and energy (Tiefenbacher et al., 2021), the adoption of soil health management practices, importantly, can deliver public goods societal co-benefits (e.g., increased soil water holding capacity, reduced water-and wind-induced soil erosion, reduced nutrient runoff, improved hydrological function and water quality, biodiversity, and climate change mitigation, etc.) (Banwart et al., 2014; Mooney and Williams, 2007).

Farmers' decision-making as regards which practices to adopt is nuanced and context-specific, with their preference typically being to adopt practices that can be incorporated with relative ease into their agricultural production systems under existing conditions rather than practices that necessitate a major change to their farming strategies (Henderson et al., 2022). Farmers are not a homogenous population and their choice of practices not only reflects their ability to navigate social and political barriers faced in making changes to their farming strategies but also their access to financial and other resources (e.g., labour, information, knowledge, and skills) (Henderson et al., 2022; Lal, 2021; Mills et al., 2020). The extent to which practices are deemed cost-effective hinges on associated upfront investment costs, ongoing maintenance costs, and opportunity costs; the likely impact of practices on farm profitability and productivity; and the likely time-lag as regards benefits derived (Henderson et al., 2022; Lal. 2021; Mills et al., 2020; Dumbrell, Kragt and Gibson, 2016).

In the UK, as in other countries, transforming soil carbon sequestration from an aspirational to a widely implemented, mainstream climate mitigation strategy (Amelung et al., 2020) hinges on addressing carbon accounting issues currently undermining farmers' willingness to participate in soil carbon sequestration schemes and the agricultural soil carbon market (Keenor et al., 2021; Kreibich and Hermwille, 2021). A proliferation of farm-focused greenhouse gas emissions calculators has reduced the transaction costs associated with direct measurement or empirical and process-based modelling of changes in soil carbon stocks (Paustian et al., 2019). Confidence in the robustness, transparency, and integrity of the carbon market, however, continues to be undermined by the issuance of non-equivalent credits, reflecting the continued pervasiveness of carbon accounting issues relating to the additionality and permanence of carbon sequestered in agricultural soils, leakage, and the perceived risk of reversals (Oldfield et al., 2022).

Addressing farmers' perception of soil carbon sequestration and participation in the carbon market as entailing risk (Buck and Palumbo-Compton, 2022) necessitates policymakers adopting an innovative and responsive science-based approach to developing institutional agreements, processes, and arrangements governing the production, trade, and/or direct sale of soil carbon credits to public and private sector actors (Dynarski, Bossio, and Scow, 2020; Rodríguez de Francisco and Boelens, 2015). Beyond considering, for example, whether ecosystem service payments should be bundled/stacked and public finance should be blended with multiple, co-ordinated private schemes to ensure that public funds are reserved for landscapes and services not paid for by the market (Reed et al., 2022), it is imperative that policymakers determine terms and conditions associated with market participation deemed acceptable and attractive by farmers. In the absence of farmers' enthusiasm for and willingness to "buy into" soil carbon sequestration schemes, 'the market for soil carbon offsets can be expected to remain thin or not function at all' (Gramig and Widmar, 2018, p. 518).

In the UK, the emergence of an agricultural soil carbon market has led to calls for its regulation and the development of minimum standards – with a recommendation for these standards recently developed by 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). The standards are aimed at governing the operations and actions of carbon codes (i.e., organisations mandated with monitoring and verifying changes in soil carbon stocks and/or reductions in soil-derived GHG emissions and overseeing the production of soil carbon credits) and all other individuals and entities participating in the market (i.e., farmers, public and private sector actors) (Black et al., 2022). The development of context-specific guiding principles for the market is in line with broader global demands for context-specific, rigorous, and transparent protocol standards for measuring, reporting, and verifying soil carbon sequestration and/or reductions in soil-derived GHG emissions resulting from the adoption of soil carbon management practices in line with soil carbon sequestration schemes (Beka et al., 2022; Jackson Hammond et al., 2021; Alexander et al., 2015).

Taking the UK as a case study, this paper aims to elicit farmers' perceptions of the emerging UK agricultural soil carbon market and compare their expectations with the demands of the market as articulated by the carbon codes driving its development and growth. The first hypothesis of this study is that farmers' adoption of soil carbon management practices does not necessarily translate into a willingness to adopt additional practices and "buy into" soil carbon sequestration schemes. Indeed, farmers have reservations about planning and implementing soil carbon projects due to the associated terms and conditions with participation in the carbon market. Recent international studies have explored farmers' motivation to engage with the global agricultural soil carbon market and, based on an analysis of barriers faced, examined the extent to which participation in the market constitutes an opportunity for new entrants (Buck and Palumbo-Compton, 2022; Davidson, 2022; Fleming et al., 2019). However, we are not aware of any study, either in the UK or elsewhere, that has explored how, alongside new entrants to the carbon market, early adopters of soil carbon management practices - excluded from soil carbon sequestration schemes established by public and private sector actors based on additionality criteria - might be incentivised to adopt additional practices and participate in the carbon market. Anecdotally, farmers' expectations regarding their scope, as early adopters of practices, to derive benefits from participation in the carbon market are conceptualised as being at odds with the demands and reality of the market as articulated by the carbon codes driving its development and growth. The second hypothesis of this study is, thus, that a discrepancy exists between early adopters' expectations and the demands of the carbon market. Early adopters of practices are expected to play a key role in encouraging new entrants to engage with the carbon market, by transmitting information and reducing the level of uncertainty surrounding agricultural technologies and practices, and promoting individual and social learning (Chavas and Nauges, 2020). The third hypothesis of this study is, therefore, that incentivising early adopters to adopt additional practices and facilitating their participation in the market, alongside new entrants, is contingent on reconciling farmers' expectations with the demands of the market.

2. Methodology

2.1 Sampling strategy and study area

This study was conducted in the UK, with data collected from farmers through a self-administered online questionnaire which was available for completion by potential participants between March and June 2022. The use of an online rather than a face-to-face questionnaire facilitated data collection, within a relatively short period of time, from a large and geographically distributed target population of farmers and rendered the process less costly and time-consuming and, arguably, more cost-effective than traditional data collection methods (e.g. face-to-face, postal or telephone surveys) (Wright, 2017; Regmi et al., 2016; Lefever, Fal, and Matthíasdóttir, 2006). An online questionnaire benefits the respondent who can choose to answer questions at a convenient time and take as much time as they need to respond to questions (Regmi et al., 2016). Equally, it benefits the researcher who, while waiting for the desired number of responses to accumulate, can engage in preliminary analysis of data already collected (Wright, 2017). As data collection is automated (i.e. answers to questions are saved as a respondent progresses through the pages of an online questionnaire) and data is compiled into a database that can be downloaded easily and quickly for data analysis purposes, data entry costs are eliminated, and data management is convenient and reliable (Wright, 2017; Regmi et al., 2016).

A purposive and convenience sampling strategy was used to select individuals from the target population of farmers in the UK. Although the objective was to draw a diverse and representative population sample, in the end, self-selection bias led to the majority of respondents sampled (90%) being located in England. The counties of Gloucestershire, Devon, Yorkshire, Cambridgeshire, Cornwall, Norfolk, Cumbria, Lincolnshire, North Yorkshire, and Worcestershire accounted for approximately two-thirds of the final sample drawn from the target population (Fig. 1). Respondents located in Scotland accounted for 6% of the sample, while respondents in Wales and Northern Ireland each accounted for 2%, respectively.

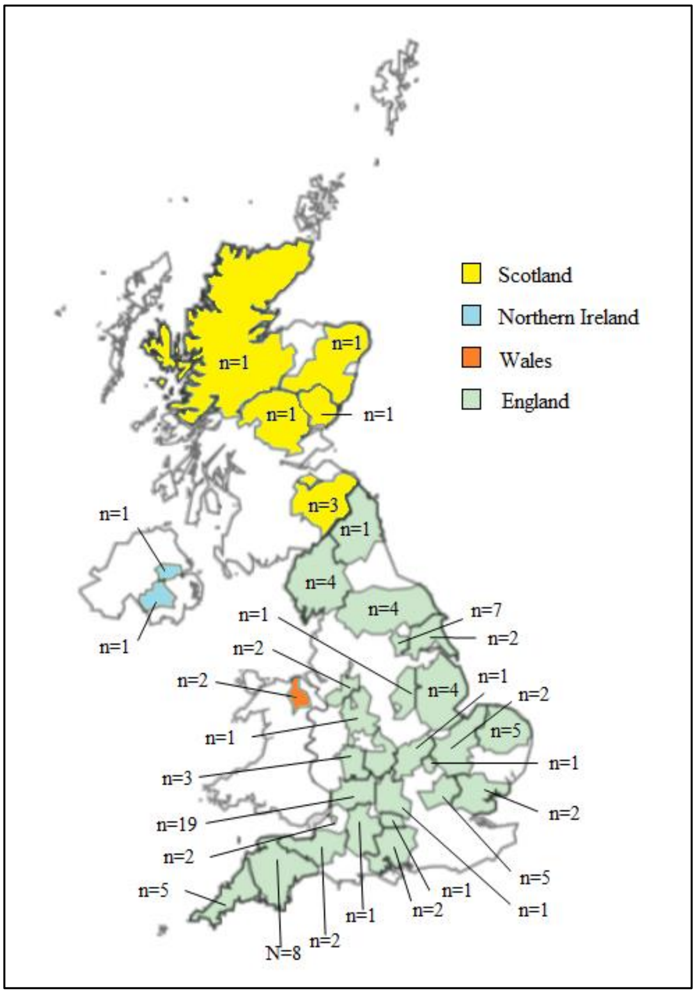

Figure 1: Map of the study area showing the number of respondents by county

2.2 Contents and structure of the online questionnaire

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

The questionnaire comprised 18 close-ended questions related to farm type; land ownership; source(s) of income; soil carbon management practices already implemented and motivation for and impact of the practice(s) adopted on farm productivity and profitability; willingness to adopt additional practices; interest in obtaining payment in exchange for providing the ecosystem service of soil carbon sequestration and participating in the emerging agricultural soil carbon market; willingness to accept terms and conditions associated with implementing a soil carbon project (Annex 1). In moving from one question section to the next, farmers were required to provide an answer to each question displayed, unless in-built skip patterns were activated. Recognising that this limited farmers' ability to refrain completely from answering a given question, answer options such as "I don't have a preference", "I don't know" and "I don't agree with any of these statements" were included. The majority of questions were multi-choice questions, with respondents ticking a box or number of boxes to indicate that they were selecting a pre-determined response option or set of options from a given list, respectively. In answering several of the questions, respondents were asked to select up to three options or permitted to select a maximum of three options only. Although this inhibited farmers' ability to select all answers deemed relevant, it reduced the likelihood of farmers selecting all options in answering questions (e.g., questions related to motivation to adopt and benefits derived from adopting management practices promoting soil health) and facilitated the identification and subsequent ranking of the most-selected options. In addition, the questionnaire comprised two questions that asked farmers to provide written answers in free text boxes. These questions were included to reduce the risk of fraudulent, inattentive, and/or implausible responses being recorded and facilitated such responses being identified and removed from the database during the subsequent data cleaning process. To contextualise the data collected, the questionnaire also comprised four additional close-ended questions to capture the respondents' socio-demographic characteristics (e.g. age, gender, level of education, and years of farming experience).

2.3 Process by which the online questionnaire was administered

The questionnaire was pilot-tested by six farmers to ensure that it would facilitate the collection of reliable and valid data. Skip patterns were built in to ensure that it was user-friendly in design and layout, enabling respondents to provide answers to individual follow-up questions or sections of the questionnaire that were not relevant. The pilot farmers were asked whether the instructions provided regarding the objective of the research were clearly worded and easily understood. Moreover, they were asked whether the questions that they had answered were appropriate, comprehensive, and ordered in a logical sequence and whether it did not take too much time to respond to each question. It took the pilot farmers on average ten mins to complete the questionnaire.

Research participants were recruited to complete the questionnaire, which was revised based on the feedback received during the piloting stage, through social media platforms (e.g. Twitter and LinkedIn). Furthermore, they were recruited through a link to the questionnaire circulated via an email to self-registered stakeholders of the UKFSCC project, providing information about the study and its context within the broader UKFSCC project. This information and a link to the questionnaire was also shared via online newsletters by several organisations (e.g. NGOs, private sector actors) providing extension services and advice to farmers across the UK.

In total, 170 farmers started filling out the questionnaire, but only 100 farmers completed it; a total of 70 farmers who did not provide full responses to Q1-Q24 were removed from the final dataset. A total of 57 respondents who indicated that they were not farmers or farm managers (Annex 1, Q1) were automatically excluded from the study.

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

To compare farmers' expectations of the carbon market with the demands of private sector actors driving the development of the carbon market, data were also collected through a short online questionnaire (Annex 2) sent by email to 10 organisations responsible for the operationalisation or development of carbon codes in the UK. Six organisations responded to the call for participation in the research, with the data that they provided anonymised to protect their commercial interests. The questionnaire comprised 23 close-ended questions related to the codes and their scope; carbon project eligibility, rules, and administration; approaches to determining soil carbon sequestration; and the carbon market.

2.5 Data management and analysis process

The 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.

3. Results

3.1 Demographic characteristics of farmers sampled

Table 1 presents the demographic characteristics of the farmers who completed the questionnaire. Respondents who completed the questionnaire were predominantly male; aged between 35-64 years; had completed formal education related to farming and had extensive farming experience - more than 60% of the sampled population had >20 years of experience. Approximately one-quarter of farmers had not completed any formal agriculture-related education. The majority of respondents (85%) engaged in agricultural production on land that they owned, however, more than a third of farmers also rented land under a short-term or long-term farm business tenancy agreement. Most respondents were farmers who had landholdings of less than 500 hectares. Nevertheless, several respondents were farmers who had large farms (i.e., 500-1000 hectares) and several respondents were farm managers responsible for managing estates of more than 1000 hectares on behalf of a land manager or an agribusiness company. Half of the farmers derived their income solely from mixed crop-livestock production, livestock (e.g., beef and/or sheep production in lowland and/or less-favoured areas), or crop production (e.g., potatoes, beet, peas, beans, cereal, and oilseed crop production). Two-fifths of the respondents, however, reported that they also derived a source of income from off-farm activities; this is a high proportion of farmers given that many owned >100 ha of land from which they derived a farm-related income.

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

			n
Gender (Q19)	Male		78
	Female		19
	Prefer not to say		3
Age (Q20)	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 (Q21)	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 (Q22)	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 (Q6)	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 (Q4)	Own land		85
	Land rented under a short-term agreement		29
	Land rented under long-term FBT		9
	Share farm (arable) land		2
Farm size (ha) (Q5)	0-50		28
	51-100		14
	101-200		18
	201-500		19
	501-1000		10
	More than 1000		8
Type of farm (Q3)	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

3.2 Soil health management practices adopted and drivers of adoption at farm level

Table 2 presents an overview of the wide range of soil health management practices that farmers are already implementing on their farms. Moreover, the table outlines the range of factors which motivated them to adopt these practices, such as declining soil fertility and high production costs associated with the use of agrochemicals and/or synthetic fertilisers, and their perception of the benefits derived from these practices, beyond the primary benefit of improved soil health.

Table 2: Type of practices adopted, factors influencing adoption of these practices, and willingness to adopt additional practices (n = 100), (respondents were asked to indicate the three most important options in answering Q8 and Q9 and as many as applicable in Q7)

		N
Adopted practices (Q7)	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 (Q8)	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 from adopted practices (other than soil carbon sequestration) (Q9)	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	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

practices and/or interest in ‘carbon payment’ (Q10)	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

The majority of respondents (63%) regarded reducing tillage as the single most important step they could take to enhance and/or maintain soil health. Respondents primarily adopted in-field practices, such as incorporating legumes and herbs into grasslands and managing livestock stocking rates and introducing cover crops (e.g. mixed winter forage crops) and leys in rotations, incorporating straw into the soil, and applying biologically-complete composts. However, providing optional ‘other’ responses (to Q7), respondents indicated that they also sought to manage field margins by establishing hedges, taking margins out of cropping, and allowing margins to re-vegetate naturally or sowing wildflower species and/or cover crops. Approximately one-fifth of respondents (19%) reported that they 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 management practices, listed in Table 1, on their farms. Thus, 94% of farmers had already adopted multiple practices (Figure 1) with a view to improving soil health, addressing soil fertility decline, and reducing production costs. In the context of calls for farmers in the UK to adopt practices that result in carbon sequestration in agricultural soil and participate in the carbon market, it is noteworthy that farmers’ adoption of soil health management practices could lead to an increase in soil carbon stocks; however, it could, concurrently, undermine their future ability to satisfy one of the key principles underpinning participation in the emerging UK agricultural soil carbon market, namely, the principle of additionality.

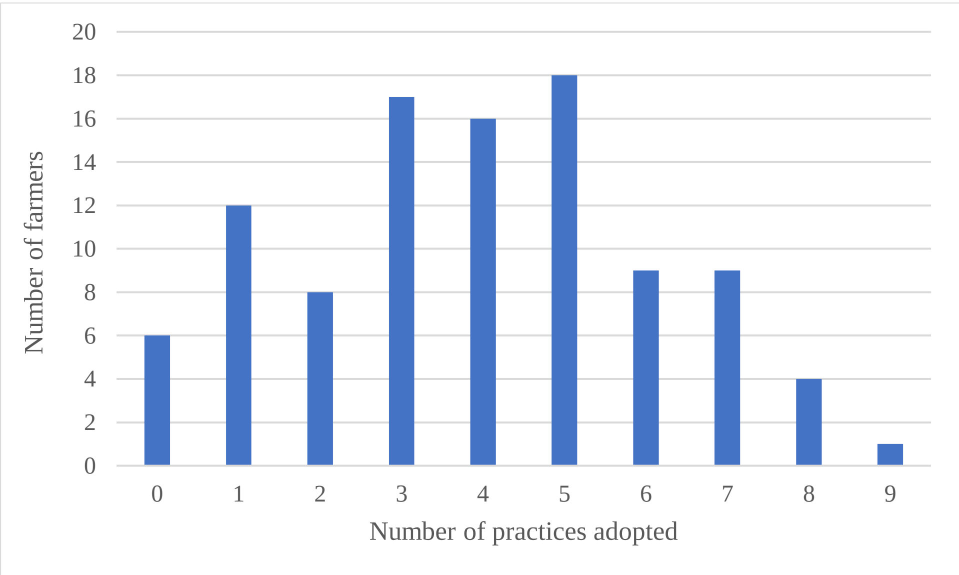

Figure 1: Number of practices adopted by farmers (n=100); on average, farmers had adopted 3.9 practices

Respondents were driven to implement soil health management practices for a variety of reasons. The majority of farmers (71%) selected three of the given options in explaining their motivation to adopt practices. Several farmers (7%) indicated that just two of the given options had informed their adoption of practices, while a minority of farmers (2%) cited a single given option as underpinning their decision to adopt practices. Respondents recognised that soil fertility was declining and reported that high input costs had led them to explore strategies to improve soil fertility that did not involve relying on agrochemicals and/or synthetic fertilisers. Although respondents were cognisant of the impact of extreme weather events on agricultural production, only a minority of farmers (12%) perceived a responsibility to contribute to climate change mitigation, recognising the importance of and the potential for their adoption of soil health management practices to contribute to soil carbon sequestration and, therefore, to building carbon stocks. Electing to solely provide an optional 'other' response (to Q8), 8% of farmers indicated that they had not necessarily been motivated by any particular reason to adopt practices. Farmers who chose to provide an optional 'other' response in addition to either one of the given options (1% of farmers) or two of the given options (6% of farmers), primarily referenced 'tradition' as the main reason for their adoption of soil health management practices, asserting that they 'ha[d] always farmed this way'.

Beyond improved soil health, respondents indicated that they had derived multiple benefits from the adoption of practices. The majority of respondents (71%) selected three of the given options in detailing the benefits of practices. Several farmers (7%) indicated that they had derived two of the given benefits, while a minority of farmers (2%) were of the opinion that they had derived just one of the given benefits. Respondents reported 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 were of the opinion that the condition of their soils had improved as a consequence of practices adopted, they did not consider practices to have translated into increased crop yields. Few respondents reported that the implementation of practices had led to direct economic benefits (e.g., higher prices for produce), enabled them to gain access to new markets for their produce (e.g., certification), or led them to receive compensation from an entity within their supply chain (e.g., payment for providing soil-related ecosystem services). Electing to solely provide an optional 'other' response (to Q9), 10% of farmers indicated that it was 'too early to say at this stage' what the impact of practices had been on farm profitability and productivity and they were unsure as the 'tools to measure soil improvements are not reliable or easily available'. Farmers who chose to provide an optional 'other' response in addition to either one of the given options (4% of farmers) or two of the given options (2% of farmers), primarily cited personal 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%) indicated they were willing to adopt practices additional to those which they were already implementing on their farm to improve soil health. Most respondents (61%) stated that their adoption of additional practices would be contingent on being paid to do so, however, several farmers (11%) indicated that they were willing to adopt practices in the absence of a 'carbon payment', indeed, they did not want to receive any form of monetary compensation. Approximately one-fifth of respondents (19%) asserted 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 that 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 (Figures 2-6).

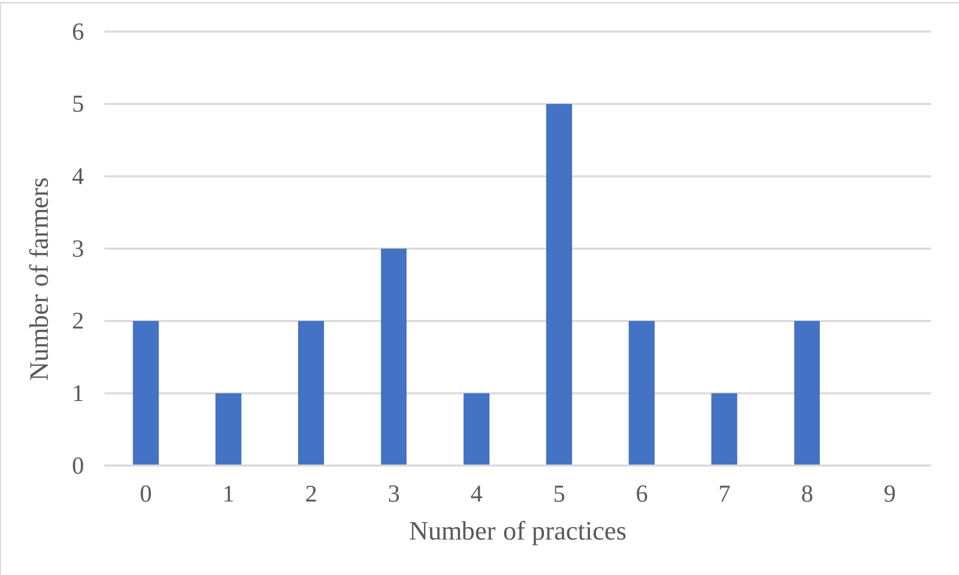

Figure 2: Number of practices already adopted by farmers who did not want to adopt additional practices but wanted to be paid for existing carbon stocks (19% of farmers); on average, these farmers had adopted 4.1 practices (more than the average for the whole sample of farmers, i.e., 3.9 practices)

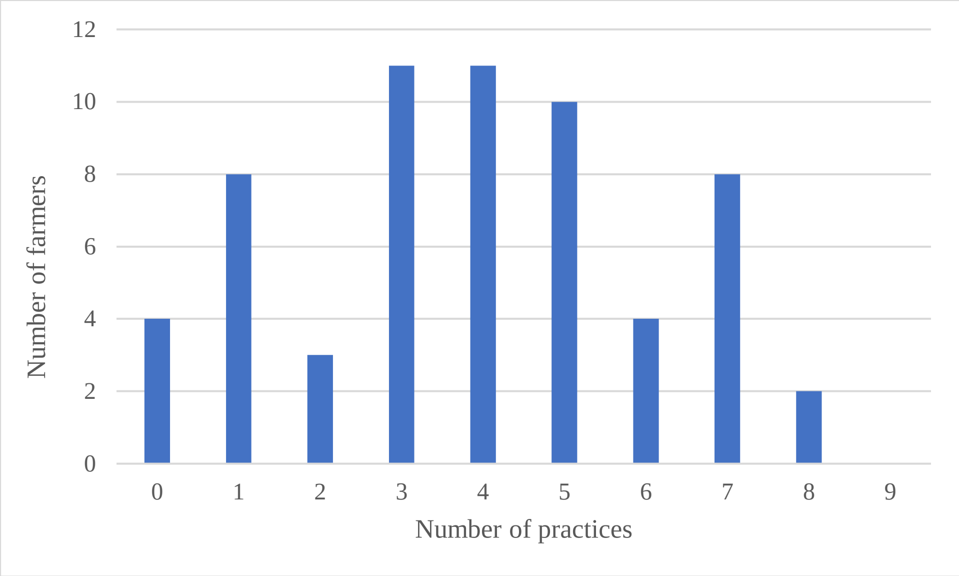

Figure 3: Number of practices adopted by farmers who were willing to adopt additional practices if paid to do so (61% of farmers); on average, these farmers had adopted 3.9 practices (equivalent to the average for the whole sample of farmers, i.e., 3.9 practices)

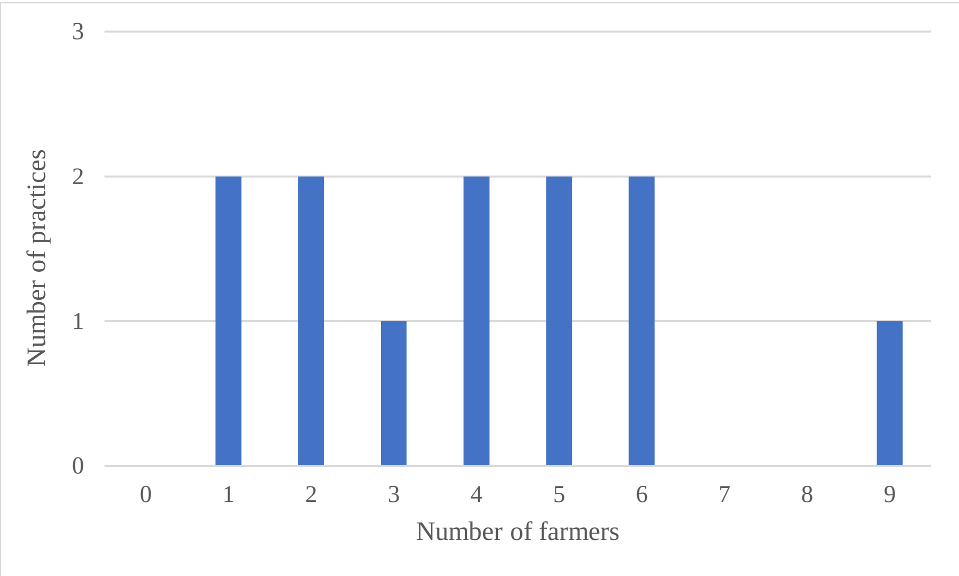

Figure 4: Number of practices adopted by farmers who had adopted practices but were willing to adopt additional practices but had no interest in 'carbon payment' (11% of farmers); on average, these farmers had adopted 4.4 practices (more than the average for the whole sample of farmers, i.e., 3.9 practices)

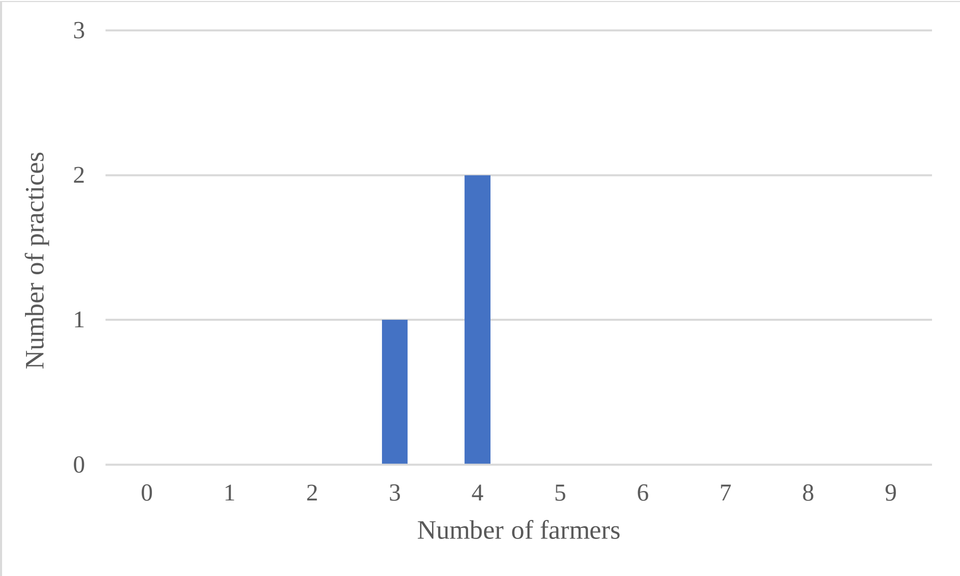

Figure 5: Number of practices adopted by farmers who were not sure about whether they were willing to adopt additional practices and/or receive a carbon payment (3% of farmers); on average, these farmers had adopted 3.5 practices (less than the average for the whole sample of farmers, i.e., 3.9 practices)

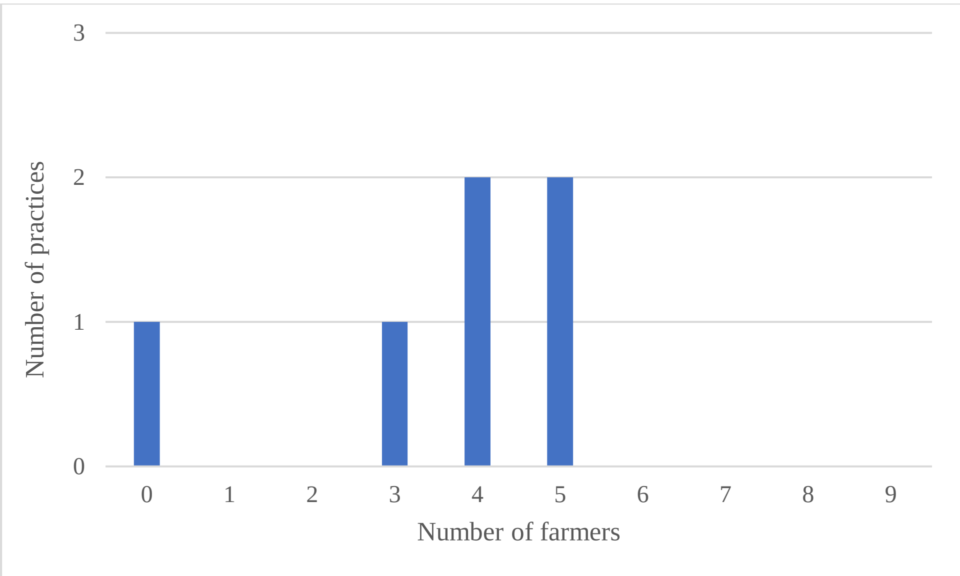

Figure 6: Number of practices adopted by farmers who were not interested in adopting additional practices and/or getting a carbon payment (6% of farmers); on average, these farmers had adopted 3.7 practices (less than the average for the whole sample of farmers, i.e., 3.9 practices)

3.3 Preferences and opinions regarding soil carbon sequestration schemes and the carbon market

As indicated by Table 2, a subset of farmers (i.e., 80 of the 100 farmers) was willing to participate in soil carbon sequestration schemes; these farmers were interested in either receiving a ‘carbon payment’ for adopting additional practices (61% of farmers) or as compensation for already adopted practices (19% of farmers). Table 3 presents an overview of this subset’s preferred source of ‘carbon payment’; preferred partner in planning and implementing a soil 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.

Table 3: Preferences regarding the design and implementation of soil carbon projects (n = 80)

		n (%)
Preferred source of ‘carbon payment’ (Q11)	From several different sources (e.g. public funding sources and p rivate 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 ‘soil carbon project’ contract (Q12)	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 (Q17)	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 (Q18)	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)

Few respondents appeared to have confidence in planning and implementing a carbon project in conjunction with a government department or entity from their supply chain, instead expressing their preference to work with a project developer or not-for-profit NGO, which would likely allow them to assert a greater degree of control over the project design and implementation process. Nevertheless, one-fifth of farmers indicated that their preference was to receive a ‘carbon payment’ from a public source of funding. Although one-fifth of respondents did not want to sign up for contracts longer than five years, almost one-third of respondents were willing to accept a contract of 5-10 years duration. 80% of respondents were unwilling to commit to maintaining soil carbon stocks post-contract beyond a period of 10 years.

Table 4 presents an overview of farmers' positions on the agricultural soil carbon market as indicated by their agreement with pre-formulated statements and their preferences regarding soil 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 4: Agreement with statements about the agricultural soil carbon market and preferred soil carbon project contract terms and conditions (n = 100), (respondents were able to choose three answers and up to three options only in answering Q13 and Q14, respectively)

		n
Agreement with statements about the emerging soil carbon market (Q13)	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’ (Q14)	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’ (Q15)	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	Less than 5%	28
	5-10%	43
	11-20%	18
	More than 20%	2

contribute to a buffer (Q18)	I don’t know	9

Regardless of their interest in implementing a soil carbon project and participating in the emerging soil carbon market, respondents were of the opinion that the emerging soil carbon market should be governed by certain conditions to generate economic and non-economic benefits. One-third of respondents took the view that there should be two rates of payment to acknowledge that farmers had historically adopted different approaches to managing their land and that this had resulted in differences in SOC stocks between farms (i.e., farms will have different SOC baselines depending on past management). One-fifth of respondents opined that farmers should be paid solely if they adopted new, additional practices. Only a minority of respondents (8%) thought that farmers should not be paid for existing soil carbon stocks.

Half of the respondents believed that 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 soil carbon sequestration, many respondents took the view that carbon payments should be provided where farmers reduced their on-farm use of synthetic fertiliser (46% of farmers) or increased their use of renewable energy (25% of farmers), resulting in avoidance of emissions associated with on-farm use of fossil fuels. One-third of respondents thought that carbon payments should be provided when farmers reduced their use of fossil fuels, while one-third of respondents thought that those who reduced soil erosion on their farms 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 that carbon payments should be received in instalments throughout a carbon contract rather than upfront, at the start of a contract, 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 leakages; 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 equivalent to more than 20% to a buffer.

3.4 Terms and conditions of six UK carbon codes sampled

Table 5 provides an overview of the six soil carbon codes and the conditions for carbon project ownership. Distinct in their design and scope, the carbon codes were found to differ in the criteria they imposed on farmers as regards monitoring, reporting and verification of soil carbon sequestration and/or GHG emissions reductions.

Table 5: Overview of six carbon codes sampled and their respective terms and conditions for soil carbon projects

	Carbon Code A	Carbon Code B	Carbon Code C	Carbon Code D	Carbon Code E	Carbon Code F
Owner organisation (Q1)	Not-for-profit	Commercial	Not-for-profit	Commercial	Commercial	Commercial
Quantification approach (Q2)	Modelling and in-situ measurement	Modelling and in-situ measurement	Modelling, in-situ measurement and/or use of emissions factors	Modelling, in-situ measurement and/or use of emissions factors	Modelling and in-situ measurement	Modelling and in-situ measurement
Carbon project owner (Q3)	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer
Entity that can register a carbon project (Q4)	Carbon project developer	Farmer	Farmer/ Carbon project developer	Farmer/ Carbon project developer	Farmer/ Carbon project developer	Farmer
Legal rights to land required (Q5)	Yes	Yes	Yes	Yes	Yes	Yes
Registration costs (Q6)	Yes	Yes	No	Yes	Yes	Yes

All of the carbon codes that completed the online questionnaire stipulated that carbon projects could only be initiated by farmers with a legal right to land. The codes did not specify that those implementing projects should be land-owning farmers, yet the condition around legal rights favours those who are pursuing agricultural production on their own land. In the case of tenant farmers, their capacity for initiating a soil carbon project hinges on their relationship with the landowner and the conditions of their tenancy agreement. Some of the codes indicated that farmers themselves were permitted to develop and register carbon projects, while other codes only accepted projects being registered by carbon project developers contracted by farmers and/or farm managers. This increases the costs associated with initiating a soil carbon project and also has implications for farmers' capacity to participate in the carbon market. Although most codes require farmers to monitor changes in soil carbon stocks change through modelling or in-situ measurement, two of the codes additionally permit farmers to use GHG emissions factors in calculating and reporting reductions in GHG emissions.

Table 6 presents an overview of the land use types and management practices stipulated by carbon codes currently operating in the UK as eligible for inclusion in soil carbon projects. All of the carbon codes regard cropland and grassland as eligible land use types. However, two of the codes exclude permanent pasture, one excludes permanent crop production (i.e. orchard production) and another code excludes land used for root vegetable production from being used in the generation of carbon credits. Most carbon codes have predefined lists of practices that farmers can choose from and implement on their farms to sequester carbon in the soil and/or reduce soil-derived GHG emissions. One code does not specify which agricultural practices farmers should adopt; however, like the other carbon codes, it mandates that practices should be 'additional' and outlines several additionality-related criteria that should be met for practices to be deemed eligible for inclusion in a soil carbon project.

Table 6: Types of land use and practices permitted for inclusion in soil carbon projects

	Carbon Code A	Carbon Code B	Carbon Code C	Carbon Code D	Carbon Code E	Carbon Code F
Eligible land use (Q7)	Crop/grassland	Cropland	Crop/grassland	Crop/grassland	Crop/grassland	Cropland
Ineligible land use (Q8)	No response	Permanent pasture, woodland/forest, permanent crop production (e.g. orchard crops)	No response	No response	No response	Permanent pasture, woodland/forest, peatland, mineral soils, production of root vegetables
Eligible carbon sequestering practices (Q9)	No predefined list of practices	Predefined list of practices	Predefined list of practices	Co-developed, pre-defined list of practices	Practices must meet specified criteria	Predefined list of practices
Additionality criteria (Q10)	• Practices adopted must not be 'common' (i.e. widely adopted) in a region • Practices adopted must be 'new' to a farm (i.e. not already adopted) • Practices may not be adopted in response to government subsidies • Practices may be adopted using funding from other financial sources	• Practices adopted may be 'common' (i.e. widely adopted) in a region • Practices adopted must be 'new' to a farm (i.e. not already adopted) • Practices may be adopted in response to government subsidies • Practices may not be adopted using funding from other financial sources	• Practices adopted may be 'common' (i.e. widely adopted) in a region • Practices adopted must be 'new' to a farm (i.e. not already adopted) • Practices may not be adopted using funding from other financial sources	• Practices adopted must be 'new' to a farm (i.e. not already adopted) • Practices may not be adopted using funding from other financial sources	• Practices adopted must not be 'common' (i.e. widely adopted) in a region • Practices adopted must be 'new' to a farm (i.e. not already adopted) • Practices may be adopted in response to government subsidies • Practices may be adopted using funding from other financial sources	• Practices adopted must not be 'common' (i.e. widely adopted) in a region • Practices adopted must be 'new' to a farm (i.e. not already adopted)

Table 7 presents an overview of the conditions that project participants are expected to satisfy as regards soil carbon project contract length; soil carbon stocks permanence, the establishment of 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. The carbon codes differ in their conceptualisation of permanence and expectations of the length of time that soil carbon stocks should be maintained after a carbon project contract has ended, with permanence timeframes stipulated ranging from 5-25 years. Two of the codes did not provide information regarding the length of time that they envisaged carbon stocks should be maintained. Most carbon codes stipulate that 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 in soil carbon stocks and/or reductions in GHG emissions over the contract period. Two of the carbon codes take 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 regard 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 varies by code. While all of the carbon codes expect that modelling takes place on an ongoing yearly basis, the frequency of measuring soil carbon stocks and/or reductions in soil-derived GHG emissions varies by code.

Table 7: Permanence, baselines and reporting of modelled/measured changes in soil carbon stocks

	Carbon Code A	Carbon Code B	Carbon Code C	Carbon Code D	Carbon Code E	Carbon Code F
Contract commitment (Q11)	Project duration	No response	No response	Project duration and permanence period	No response	No response
Permanence duration (Q12)	25 years	10 years	No response	5 years	No response	25 years
Historic data required to establish a baseline (Q13)	No response	No response	Less than 3 years	3-5 years	10 years	No response
Type of baseline (Q14)	Dynamic	No response	Dynamic	Dynamic	Fixed average	Fixed average
Frequency of reporting in-situ measured changes in SOC stocks (Q15)	2-5 years	No response	Yearly	2-5 years	6-10 years	Yearly
Sampling strategies for measuring SOC stocks (Q16)	No response	20cm	No response	30-60cm	30cm	No response
Frequency of reporting modelled changes in SOC stocks / GHG emissions reductions (Q17)	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly
GHG emissions covered (Q18)	CO_2, N_2O, CH_4	No response	No response	CO_2, N_2O, CH_4	CO_2, N_2O, CH_4	CO_2, N_2O, CH_4

Table 8 presents an overview of the conditions associated with carbon payments. The majority of carbon codes permit 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 allow for stacking of payments, facilitating blended finance (i.e., public and private funding of practices resulting in soil carbon sequestration). All codes require farmers to contribute a share of carbon credits generated to a buffer fund; in the case of one code, a share of 20% of carbon credits is required. Most carbon codes do not offer a guaranteed carbon floor price (i.e., a binding minimum price for future carbon sequestered and/or GHG emission reductions to reduce carbon price volatility and the level of risk faced by carbon credit producers and buyers); however, three of the codes have put discounting arrangements in place in anticipation of contingencies and developments in the carbon market (e.g., ensuring that the carbon price is equivalent to ~70% of the agreed sales price for one tonne carbon dioxide equivalent).

Table 8: Carbon payment conditions

	Carbon Code A	Carbon Code B	Carbon Code C	Carbon Code D	Carbon Code E	Carbon Code F
Retrospective crediting permitted (Q19)	Yes	Yes	Yes	No	Yes	No
Stacking of carbon payments with other payments permitted (e.g. subsidies) (Q20)	Yes	No response	No response	Yes	Yes	No response
Buffer funds required (Q21)	Yes	Yes	Yes	Yes	Yes	Yes
Guaranteed carbon floor price (Q22)	No	Yes		No	No	No
Discounting arrangements in place (Q23)	Yes	Yes	Yes	No response	Yes	No response

4. Discussion

The following section discusses the results with regard to the study hypotheses (farmers' adoption of soil carbon management practices does not necessarily translate into a willingness to adopt additional practices and "buy into" soil carbon sequestration schemes; a discrepancy exists between early adopters' expectations and the demands of the carbon market; and incentivising early adopters to adopt additional practices and facilitating their participation in the market, alongside new entrants, is contingent on reconciling farmers' expectations with the demands of the market).

4.1 Farmers' adoption of soil health management practices

The results of this study show that farmers in the UK are actively adopting practices that promote soil health and, in doing so, may increase the carbon content of their soils. These practices are known to promote the recycling of carbon-containing biomass and reduce 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., 2020; Alexander et al., 2015). Soil carbon sequestration and/or a reduction in soil-derived GHG emissions may be realised 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 are thought to be enhanced and/or GHG emissions reduced through practices ranging from 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, Kragt and Gibson, 2016; Aertsens et al., 2013). Moreover, carbon stocks can also be enhanced and GHG emissions reduced through grazing land management (optimised stocking density, restoration of pastureland, 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).

While the majority of farmers were implementing tillage-, grassland sward-, and grazing management-related practices, other practices, such as agroforestry production or biochar application, were less widely adopted as a strategy to promote soil carbon sequestration and/or reduce soil-related GHG emissions. It is important to note, however, that Table 2 must be interpreted with caution as the results are not indicative of farmers' uniform conceptualisation of practices and understanding of the impact of these practices on soil carbon stocks and/or GHG emissions. In an agricultural research context, there is, equally, disagreement around the exact definition of practices, with terms used broadly to describe practices adopted by farmers to manage production systems without consideration of perspective-specific and context-specific variations characterising their implementation of these practices (Derpsch et al., 2014). In the case of tillage-related practices, this has resulted in confusion as to the 'true' effect of tillage systems on crop production and environmental outcomes (Derpsch et al., 2014). The extent to which soil carbon sequestration is attributed to reduced tillage and/or no tillage under experimental conditions is typically determined by the depth of sampling, with minimal tillage changing the soil profile distribution for SOC and not total carbon stock (Sun et al., 2018), and the concentration of SOC along a soil profile rather than overall SOC content thought to reflect soil disturbance or lack thereof (Baker et al., 2007). Similarly, the use of a variety of terms to describe grazing-related practices - reflecting different philosophical and physical approaches to grassland management - has led to confusion (Fielding, 2022; Garnett et al., 2017). The inconsistent and interchangeable use of terms by farmers, as well as practitioners and scientists, has rendered 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

Farmers are adopting soil health management practices to address the issue of declining soil fertility and reduce production costs associated with the use of external inputs such as fertilisers. Although they are not necessarily adopting practices to sequester carbon in the soil and build carbon stocks, their motivation for practices (Table 2, Q8) suggests an awareness of the adverse impacts of historical land use patterns on soils (e.g., declining soil fertility), as does their perception of benefits derived from the adoption of practices (e.g., improved soil health; reduced soil erosion) (Table 2, Q9). 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). The results of this study suggest that approximately one-quarter of farmers are aware that their farming strategies and those of previous generations have rendered soils and, by extension, agricultural production, vulnerable to the impacts of extreme weather events (Table 2, Q8). The 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, Kragt and Gibson (2016).

The importance placed by farmers on adopting practices that promote soil health suggests that they recognise that soils have become degraded due to intensive farming strategies and that by adopting soil health management practices they can maintain and build soil organic matter and increase the organic carbon content of soils. Beyond improving soil fertility and reducing soil erosion, farmers may be aware that the adoption of soil health management practices deliver tangible, co-benefits such as improved food and nutritional quality, improved water quality and availability, and increased biodiversity. In contrast, the results of this study suggest that an awareness of the non-tangible co-benefits of soil carbon sequestration and climate change mitigation do not currently underpin farmers' adoption of soil health management practices. From a soil carbon sequestration and net zero perspective, this is noteworthy given that farmers who are well-informed about the agricultural soil carbon market yet choose not to adopt practices that promote soil carbon sequestration may be incentivised to do so, to a greater extent, by information regarding these co-benefits rather than information relating to the market opportunities to earn financial compensation (Dumbrell, Kragt and Gibson, 2016). The results of this study, however, suggest that farmers in the UK are neither fully aware of the soil carbon-related co-benefits of practices nor the opportunities to augment their income through the adoption of additional practices (which promote soil carbon sequestration) and participation in the carbon market.

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

Intrinsically motivated to adopt practices to improve soil health and reduce production costs rather than implementing practices in response to extrinsic rewards (e.g. government subsidies, incentives from within the supply chain), farmers appear to be willing to adopt additional practices if paid to do so (Table 2, Q10). Given that studies have shown economic incentives can crowd out intrinsic motivations for providing social goods such as soil carbon sequestration (Buck and Palumbo-Compton, 2022), it is encouraging 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, including those that promote soil carbon sequestration. However, there are nevertheless several challenges associated with public and private sector incentivisation of farmers' adoption of soil health management practices and participation in the emerging agricultural soil carbon market in the UK.

Beyond access to information regarding the carbon-related co-benefits of soil health management practices and opportunities to derive personal benefits from participation in the emerging UK agricultural soil carbon market, several factors may currently be contributing to the reluctance of one-third of farmers, despite their adoption of practices, to engage with the market (Table 2, Q10). It is important to differentiate between barriers to the adoption of practices that promote soil carbon sequestration and barriers to participation in the carbon market (Kragt, Dumbrell and Blackmore, 2017). Although farmers - particularly those who own their land or have an additional, off-farm source of income - may not face barriers in adopting practices, their capacity to engage with the carbon market may nevertheless be undermined by the conditions associated with participation in soil carbon sequestration schemes. Their willingness to engage with the market may be eroded, for example, by conflicting information regarding practices and carbon sequestration schemes and uncertainty related to changes in climate change- and carbon-related policies and carbon prices. Furthermore, it may be undermined by perceptions of carbon credit buyers; carbon calculators and methodologies currently used to verify changes in carbon stocks; intergenerational implications of carbon project contracts and commitments to 'permanently' maintain carbon stocks (Kragt, Dumbrell and Blackmore, 2017; Rochecouste, Dargusch and King, 2017); and perceptions that regulations may change and that they may, in the future, be expected to be carbon neutral themselves before trading and/or selling carbon credits (Fleming et al., 2019). Education and training may also play a key role in undermining farmers' willingness to adapt practices and participate in soil carbon sequestration schemes, with farmers who have the skills and knowledge required to adapt to changing circumstances finding themselves in a better position to survive in an ever-evolving sector (Augère-Granier, 2017)

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

The results of this study (Table 6, Q9) underscore that, although farmers may, in theory, be willing and have the resources to adopt practices beyond those already implemented, their scope to do so may, in effect, be curtailed by UK carbon codes' stipulation that they adopt practices from a predefined list of practices deemed scientifically sound in terms of their potential to enhance soil carbon stocks and/or reduce soil-derived GHG emissions. 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); this reflects a degree of autonomy and independence which is at odds with the demands of private and/or public sector actors. Although two-thirds of farmers were willing to adopt additional practices if paid to do so, the results of this study regarding practices adopted (Table 6, Q7) highlight and affirm the fact that the crucial carbon market principle of additionality constitutes a barrier to participation in the market, as also reported by Blum (2009). Farmers' ability to participate in the market may be undermined by a 'common practice test' (whereby a given farmer is compared to similar peers); 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) (Rochecouste, Dargusch and King, 2017).

Many UK carbon codes require that farmers select practices from pre-defined lists (Table 6, Q9). 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, as also outlined by Renwick and Wreford (2011). The results of this study also highlight a disconnect between expectations regarding the opportunities for deriving compensation from participation in the agricultural soil carbon market and the actual compensation offered by the market. Whereas farm and farm managers anticipate that they will be compensated for historically sequestered soil carbon as a result of already-adopted practices and continued maintenance of soil carbon stocks (Table 2, Q10; Table 3, Q13), UK carbon codes permit retrospective crediting only for a short period of time prior to the start of a soil carbon project (Tables 8, Q19). Albeit offering a value proposition similar to international carbon codes (Black et al., 2022), the results suggest that, in compensating farmers for their soil stewardship, there is currently a failure among private and public sector actors to recognise and appreciate that new entrants to the carbon market start from different positions in terms of SOC stocks and potential to sequester more SOC. Moreover, there is a failure to fully acknowledge that this may, perversely, incentivise farmers to lower soil carbon stock baselines before initiating a soil carbon project, for example, by refraining from practices or reverting from minimal tillage or direct drilling back to conventional tillage. The results of this study underscore the imperative to address the risk of such perverse incentives being created and avoid the release of carbon from soils before entering into a soil carbon sequestration scheme, as has also been argued by Oldfield et al. (2022).

Farmers' preference to receive a carbon payment from several different sources rather than a single source (Table 3, Q11); this is in agreement with the UK carbon codes' willingness, in principle, to permit stacking (Table 8, Q20). However, in reality, stacking is complex; albeit recognising the interconnectedness of ecosystem services on a landscape level (Deal, Cochrane and LaRocca, 2012), it constitutes a challenge for all actors participating in the carbon market, with the risk of double counting of carbon credits undermining policymakers and carbon buyers confidence in the market, and farmers potentially facing high transaction costs in participating in the market and trading and/or directly selling carbon credits to different buyers (Duguma et al., 2018).

The results of this study suggest there are gaps between farmers' expectations and the demands of the market regarding the conditionality of carbon payments. Farmers' preference is to obtain public sector compensation for carbon sequestration, for example, through the soil standards of the Sustainable Farming Incentive (SFI) component of the new Environmental Land Management Scheme (ELMS) in England. This is not in line with post-Brexit political pressure to both use 'public money for public goods' and ensure good value for money and social benefit returns to public spending (Bateman and Balmford, 2018). Although the results of this study suggest that farmers prefer public to private funding or blended finance, there is 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).

Farmers' preference to sign carbon contracts that stipulate they contribute a share of 5-10% of carbon credits to a buffer is also at odds with the demands of carbon codes that request farmers to contribute as much as 20% of credits to a buffer. Moreover, farmers are unwilling to sign carbon project contracts perceived as equating to intergenerational commitments to implementing soil carbon management 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 indicate that 80% of farmers want contracts of <10 years, while only 9% of farmers were willing to sign up to >20 years contract, perceiving such a contract as a lengthy commitment given that they would also have to respect an agreed-upon permanence period. Such a permanence period could potentially transform a farmer's commitment into >40 years and, therefore, equate to an intergenerational commitment. 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, Bossio and Scow, 2020, p. 5).

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. 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 to by farmer consultation.

4.5 Implications of findings for carbon market development: incentivising early adopters, alongside new entrants, to adopt additional practices and participate in the carbon market

As the agricultural soil carbon market continues to develop in the UK, it will likely be possible to classify farmers who are interested in establishing soil carbon sequestration schemes and participating in the market along a continuum, with one segment of the farming population classified as early adopters of soil carbon management practices and the other segment identified as late adopters of practices and, consequently, as new entrants to the carbon market. The majority of farmers (94%) who completed the online questionnaire and participated in this study had already adopted practices and can, therefore classified as early adopters of practices. The willingness of 80% of farmers to participate in soil carbon sequestration schemes and either receive a 'carbon payment' for adopting additional practices (61% of farmers) or compensation for already adopted practices (19% of farmers) has implications for the continued development of the carbon market. The results of this study indicate that rules and regulations outlined by current carbon codes in the UK, regarding issues such as additionality and permanence of sequestered carbon, do not line up with farmers' expectations and, in particular, do not facilitate the participation of early adopters of management practices that promote soil carbon sequestration. Moreover, carbon contract conditions undermine early adopters' willingness to participate in the carbon market. Given that early adopters are likely to play a key role in instilling confidence among late adopters of practices and incentivising their participation in the market, the results of this study suggest that there is an imperative to reconcile farmers' expectations with the demands of the carbon market.

Specifically, the results of this study imply that a transition period is required during which carbon codes relax their rules and regulation to kick-start and support the growth of the agricultural soil carbon market, enabling early adopters to enter the market and encouraging others farmers to follow. During this transition period, there is an imperative to encourage farmers along the adoption continuum to adopt soil health management practices that are known to promote soil carbon sequestration and sensitise farmers to the importance of soil carbon sequestration, the UK's Net-Zero targets and the conditions associated with participation in the carbon market to the demands of the market as expressed by carbon codes operating in the UK. Farmers should neither be penalised for being early or late adopters of soil health management practices that promote soil carbon sequestration nor perversely incentivised to reverse carbon stocks. In this context, there is an imperative for public sector funding to protect soil carbon stocks by incentivising early adopter to continue implementing practices that sequester carbon in the soil, and for private sector funding to support a transition by late adopters towards adoption of practices that promote soil carbon sequestration. This will also ensure that there is no competition between public and private sector funding for incentivising farmers' contribution to the UK's Net-Zero targets and compensating them accordingly. A transition period could serve to maintain carbon stocks and facilitate early adopters in shifting towards additional practices where possible, while also encouraging late adopters that there is a rationale and evidence base for managing soil carbon stocks and a business case for adopting practices that sequester carbon in the soil. Alternatively, early adopters could be paid for the carbon their land stores compared to farmers in similar social, economic, environmental and technological circumstances (i.e. the difference between their baseline and a peers' reference baseline) with carbon markets paying for the additional uptake of carbon above the baseline resulting from a farmer's continued implementation of practices or adoption of additional practices. This would be in line with the recent proposal for carbon removal certifications published by the European Commission to regulate 'carbon farming' activities in the European Union.

The challenge facing the public and private sector actors who are expected to provide carbon payments is to incentivise soil carbon sequestration by the UK farming population as a whole in a manner which does not disincentivise early adopters who are further along their journey towards achieving carbon-neutral status and/or have historically contributed to a greater extent to the UK's Net-Zero targets than their peers. Ensuring that farmers are not discouraged from participating in a carbon market hinges on the flexible or gradual implementation of rules and regulations aimed at addressing carbon accounting issues relating to additionality and permanence, leakage (associated with a change in farm strategies), and the perceived risk of reversal of carbon sequestered. There is an imperative to incentivise carbon capture and storage in agricultural soils by farmers who may currently not be interested in adopting practices and/or receiving a carbon payment due to their perception that the terms and conditions associated with soil carbon sequestration schemes are too restrictive. Conversely, it is important that carbon codes' contribution to developing the carbon market is not undermined and that the transparency, robustness, and integrity of carbon credits generated and traded or sold directly to public and private sector actors is enhanced.

4.6 Limitations of the study

The results of this study indicate that there is scope, interest, and willingness among farmers - in particular, those less than 65 years of age - to contribute to the UK's Net-Zero targets by adopting practices that have been shown to increase SOC stocks. However, it is important to note that the sample of farmers drawn for the study may not be representative of the target population due to the limitations associated with the data collection method (i.e., an online questionnaire). This non-representativeness is underscored by two key demographic characteristics (i.e. age and farm size). Namely, farmers in England represented 90% of study participants and the majority of farmers (82%) who participated in this study were less than 65 years of age, despite the most recent agricultural census indicating that, in 2016, a third of farmers in England were over the age of 65 years (DEFRA, 2021). Moreover, the average farm size managed by questionnaire respondents was 413 hectares, whereas the average UK farm size in 2019 was 81 hectares (DEFRA, 2021). Although many farmers rented land under short-term or long-term farm business tenancy agreements, the majority of respondents owned the land on which they were pursuing mixed crop-livestock, crop, or livestock production. Consequently, tenancy did not emerge as an issue that could undermine a transition towards the UK's Net-Zero goals, despite often being regarded as a potential barrier to farmers' participation in the carbon market (Coulson and Milbourne, 2022; Reed et al., 2022; Mills et al., 2019; Ingram et al., 2014).

This study did not explore whether the fees associated with initiating a soil carbon project were perceived by farmers as prohibitive and whether the costs associated with soil testing and establishing a soil carbon stocks baseline could serve to disincentivise their participation in the carbon market. Moreover, perceptions of the market as an opportunity or risk and exploring farmers' confidence in market developments and issues such as the uncertainty around carbon prices were deemed to be beyond the scope of this project. Given that such issues may influence farmers' willingness to participate in soil carbon sequestration schemes and the emerging agricultural soil carbon market, further research must be conducted.

5. Conclusion

This paper concludes that farmers' adoption of soil health management practices does not necessarily translate into a willingness to adopt additional practices and "buy into" soil carbon sequestration schemes. This is likely due to the fact that they are motivated to 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 or perceived pressure to contribute to climate change mitigation and the UK's Net-Zero targets. Farmers have reservations about signing up for soil carbon sequestration schemes, and planning and implementing soil carbon projects, due to the current terms and conditions associated with participation in the emerging UK agricultural soil carbon market but also their expectation that these terms and conditions may change over time as the market evolves and minimum standards regulating the market are developed and adopted by carbon codes. Although the carbon market may attract new entrants, early adopters of soil carbon management practices are likely to be excluded from soil carbon sequestration schemes established by public and private sector actors based on additionality criteria, and a gap between their expectations and the carbon codes' demands regarding the permanence of soil carbon storage, and length of carbon project contracts and commitments. Early adopters' expectations regarding their scope to derive benefits from participation in the carbon market are at odds with the demands of the carbon market as articulated by the carbon codes. As early adopters are likely to play a key role in encouraging new entrants to engage with the carbon market, this paper contends that incentivising early adopters to adopt additional practices and facilitating their participation in the market, alongside new entrants is paramount to the development and growth of the market. Consequently, there is much at stake; without farmers' buy-in to soil carbon sequestration schemes and adoption of soil health management practices that capture and store carbon, the climate change mitigation potential, and associated ecosystem services, of sequestering carbon in agricultural soils across the UK 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.

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References

Aertsens, J., De Nocker, L., Gobin, A., 2013. Valuing the carbon sequestration potential for European agriculture. Land use policy 31, 584–594. https://doi.org/10.1016/j.landusepol.2012.09.003

Alexander, P., Paustian, K., Smith, P., Moran, D., 2015. The economics of soil c sequestration and agricultural emissions abatement. Soil 1, 331–339. https://doi.org/10.5194/soil-1-331-2015

Amelung, W., Bossio, D., de Vries, W., Kögel-Knabner, I., Lehmann, J., Amundson, R., Bol, R., Collins, C., Lal, R., Leifeld, J., Minasny, B., Pan, G., Paustian, K., Rumpel, C., Sanderman, J., van Groenigen, J.W., Mooney, S., van Wesemael, B., Wander, M., Chabbi, A., 2020. Towards a global-scale soil climate mitigation strategy. Nat. Commun. 11, 5427. https://doi.org/10.1038/s41467-020-18887-7

Baker, J.M., Ochsner, T.E., Venterea, R.T., Griffis, T.J., 2007. Tillage and soil carbon sequestration-What do we really know? Agric. Ecosyst. Environ. 118, 1–5. https://doi.org/10.1016/j.agee.2006.05.014

Banwart, S., Black, H., Cai, Z., Gicheru, P., Joosten, H., Victoria, R., Milne, E., Noellemeyer, E., Pascual, U., Nziguheba, G., Vargas, R., Bationo, A., Buschiazzo, D., De-Brogniez, D., Melillo, J., Richter, D., Termansen, M., van Noordwijk, M., Goverse, T., Ballabio, C., Bhattacharyya, T., Goldhaber, M., Nikolaidis, N., Zhao, Y., Funk, R., Duffy, C., Pan, G., la Scala, N., Gottschalk, P., Batjes, N., Six, J., van Wesemael, B., Stocking, M., Bampa, F., Bernoux, M., Feller, C., Lemanceau, P., Montanarella, L., 2014. Benefits of soil carbon: report on the outcomes of an international scientific committee on problems of the environment rapid assessment workshop. Carbon Manag. 5, 185–192. https://doi.org/10.1080/17583004.2014.913380

Bateman, I.J., Balmford, B., 2018. Public funding for public goods: A post-Brexit perspective on principles for agricultural policy. Land use policy 79, 293–300. https://doi.org/10.1016/j.landusepol.2018.08.022

BEIS, 2021a. Net Zero Strategy: Build Back Greener, Gov.Uk.

BEIS, 2021b. Greenhouse gas removal methods and their potential UK deployment: a report published for the Department for Business, Energy and Industrial Strategy by Element Energy and the UK Centre for Ecology and Hydrology.

Beka, S., Burgess, P.J., Corstanje, R., Stoate, C., 2022. Spatial modelling approach and accounting method affects soil carbon estimates and derived farm-scale carbon payments. Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2022.154164

Black, H., Reed, M., Kendall, H., Parkhurst, R., Cannon, N., Chapman, P., Orman, M., Phelps, J., Rudman, H., Whaley, S., Yeluripati, J.B., Ziv, G., 2022. What makes an operational Farm Soil Carbon Code ? Insights from a global comparison of existing soil carbon codes using a structured analytical framework. Carbon Manag. 1–39.

Blum, M., 2020. The legitimation of contested carbon markets after Paris–empirical insights from market stakeholders. J. Environ. Policy Plan. 22, 226–238. https://doi.org/10.1080/1523908X.2019.1697658

Bossio, D.A., Cook-Patton, S.C., Ellis, P.W., Fargione, J., Sanderman, J., Smith, P., Wood, S., Zomer, R.J., von Unger, M., Emmer, I.M., Griscom, B.W., 2020. The role of soil carbon in natural climate solutions. Nat. Sustain. 3, 391–398. https://doi.org/10.1038/s41893-020-0491-z

Bradfer-Lawrence, T., Finch, T., Bradbury, R.B., Buchanan, G.M., Midgley, A., Field, R.H., 2021. The potential contribution of terrestrial nature-based solutions to a national ‘net zero’ climate target. J. Appl. Ecol. 58, 2349–2360. https://doi.org/10.1111/1365-2664.14003

Bradford, M.A., Carey, C.J., Atwood, L., Bossio, D., Fenichel, E.P., Gennet, S., Fargione, J., Fisher, J.R.B., Fuller, E., Kane, D.A., Lehmann, J., Oldfield, E.E., Ordway, E.M., Rudek, J., Sanderman, J., Wood, S.A., 2019. Soil carbon science for policy and practice. Nat. Sustain. 2, 1070–1072. https://doi.org/10.1038/s41893-019-0431-y

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

Chavas, J., Nauges, C., 2020. Uncertainty, Learning, and Technology Adoption in Agriculture. Appl. Econ. Perspect. Policy 42, 42–53. https://doi.org/10.1002/aepp.13003Coulson, H., Milbourne, P., 2022. Agriculture, food and land: Struggles for UK post-Brexit agri-food justice. Geoforum 131, 126–135. https://doi.org/10.1016/j.geoforum.2022.03.007

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

DEFRA, 2021. Agri-climate report 2021.

Derpsch, R., Franzluebbers, A.J., Duiker, S.W., Reicosky, D.C., Koeller, K., Friedrich, T., Sturny, W.G., Sá, J.C.M., Weiss, K., 2014. Why do we need to standardize no-tillage research? Soil Tillage Res. 137, 16–22. https://doi.org/10.1016/j.still.2013.10.002

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

Dynarski, K.A., Bossio, D.A., Scow, K.M., 2020. Dynamic Stability of Soil Carbon: Reassessing the “Permanence” of Soil Carbon Sequestration. Front. Environ. Sci. 8. https://doi.org/10.3389/fenvs.2020.514701

Fielding, D., 2022. Climate-positive farming reviews: Unravelling the terminology and impacts of rotational grazing – what evidence is there for environmental benefits ?

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

Frank, Dorothea, Reichstein, M., Bahn, M., Thonicke, K., Frank, David, Mahecha, M.D., Smith, P., van der Velde, M., Vicca, S., Babst, F., Beer, C., Buchmann, N., Canadell, J.G., Ciais, P., Cramer, W., Ibrom, A., Miglietta, F., Poulter, B., Rammig, A., Seneviratne, S.I., Walz, A., Wattenbach, M., Zavala, M.A., Zscheischler, J., 2015. Effects of climate extremes on the terrestrial carbon cycle: Concepts, processes and potential future impacts. Glob. Chang. Biol. 21, 2861–2880. https://doi.org/10.1111/gcb.12916

Garnett, T., Godde, C., Muller, A., Röös, E., Smith, P., Boer, I. De, Ermgassen, E., Herrero, M., Middelaar, C. Van, Schader, C., Zanten, H. Van, 2017. Grazed and confused? Summary 1–127.

Gramig, B.M., Widmar, N.J.O., 2018. Farmer preferences for agricultural soil carbon sequestration schemes. Appl. Econ. Perspect. Policy. https://doi.org/10.1093/aepp/ppx041

Henderson, B., Lankoski, J., Flynn, E., Sykes, A., Payen, F., Macleod, M., 2022. Soil Carbon Sequestration by Agriculture: Policy Options, OECD Food, Agriculture and Fisheries Paper.

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

Jackson Hammond, A.A., Motew, M., Brummitt, C.D., DuBuisson, M.L., Pinjuv, G., Harburg, D. V., Campbell, E.E., Kumar, A.A., 2021. Implementing the Soil Enrichment Protocol at Scale: Opportunities for an Agricultural Carbon Market. Front. Clim. 3, 1–8. https://doi.org/10.3389/fclim.2021.686440

Keenor, S.G., Rodrigues, A.F., Mao, L., Latawiec, A.E., Harwood, A.R., Reid, B.J., 2021. Capturing a soil carbon economy. R. Soc. Open Sci. 8. https://doi.org/10.1098/rsos.202305

Kreibich, N., Hermwille, L., 2021. Caught in between: credibility and feasibility of the voluntary carbon market post-2020. Clim. Policy 21, 939–957.

https://doi.org/10.1080/14693062.2021.1948384

Krzywoszynska, A., 2019. Making knowledge and meaning in communities of practice: What role may science play? The case of sustainable soil management in England. Soil Use Manag. 35, 160–168. https://doi.org/10.1111/sum.12487Lal, R., 2021. Soil management for carbon sequestration. South African J. Plant Soil 38, 231–237. https://doi.org/10.1080/02571862.2021.1891474

Lal, R., Monger, C., Nave, L., Smith, P., 2021. The role of soil in regulation of climate. Philos. Trans. R. Soc. B Biol. Sci. 376, 20210084. https://doi.org/10.1098/rstb.2021.0084

Lefever, S., Dal, M., Matthíasdóttir, Á., 2007. Online data collection in academic research: Advantages and limitations. Br. J. Educ. Technol. 38, 574–582. https://doi.org/10.1111/j.1467-8535.2006.00638.x

Lehmann, J., Bossio, D.A., Kögel-Knabner, I., Rillig, M.C., 2020. The concept and future prospects of soil health. Nat. Rev. Earth Environ. 1, 544–553. https://doi.org/10.1038/s43017-020-0080-8

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

Minasny, B., Malone, B.P., McBratney, A.B., Angers, D.A., Arrouays, D., Chambers, A., Chaplot, V., Chen, Z.-S., Cheng, K., Das, B.S., Field, D.J., Gimona, A., Hedley, C.B., Hong, S.Y., Mandal, B., Marchant, B.P., Martin, M., McConkey, B.G., Mulder, V.L., O'Rourke, S., Richer-de-Forges, A.C., Odeh, I., Padarian, J., Paustian, K., Pan, G., Poggio, L., Savin, I., Stolbovoy, V., Stockmann, U., Sulaeman, Y., Tsui, C.-C., Vågen, T.-G., van Wesemael, B., Winowiecki, L., 2017. Soil carbon 4 per mille. Geoderma 292, 59–86. https://doi.org/10.1016/j.geoderma.2017.01.002

Miner, G.L., Delgado, J.A., Ippolito, J.A., Stewart, C.E., 2020. Soil health management practices and crop productivity. Agric. Environ. Lett. 5, 1–8. https://doi.org/10.1002/ael2.20023

Mooney, S., Williams, J., 2007. Private and Public Values from Soil Carbon Management, in: Kimble, J.M., Rice, C.W., Reed, D., Mooney, S., Follett, R.F., Lal, R. (Eds.), Soil Carbon Management: Economic, Environmental, and Societal Benefits. CRC Press, Taylor & Francis Group, Boca Rton, Florida, pp. 1–284.

Oldfield, B.E.E., Eagle, A.J., Rubin, R.L., Rudek, J., Gordon, D.R., 2022. Regional consistency is necessary for carbon credit integrity. Science (80-.). 375.

Oldfield, E.E., Eagle, A.J., Rubin, R.L., Rudek, J., Sanderman, J., Gordon, D.R., 2022. Crediting agricultural soil carbon sequestration. Science (80-.). 375, 1222–1225. https://doi.org/10.1126/science.abl7991

Paustian, K., Collier, S., Baldock, J., Burgess, R., Creque, J., DeLonge, M., Dungait, J., Ellert, B., Frank, S., Goddard, T., Govaerts, B., Grundy, M., Henning, M., Izaurralde, R.C., Madaras, M., McConkey, B., Porzig, E., Rice, C., Searle, R., Seavy, N., Skalsky, R., Mulhern, W., Jahn, M., 2019. Quantifying carbon for agricultural soil management: from the current status toward a global soil information system. Carbon Manag. 10, 567–587. https://doi.org/10.1080/17583004.2019.1633231

Reed, M.S., Curtis, T., Gosal, A., Kendall, H., Andersen, S.P., Ziv, G., Attlee, A., Fitton, R.G., Hay, M., Gibson, A.C., Hume, A.C., Hill, D., Mansfield, J.L., Martino, S., Olesen, A.S., Prior, S., Rodgers, C., Rudman, H., Tanneberger, F., 2022. Integrating ecosystem markets to co-ordinate landscape-scale public benefits from nature. PLoS One. https://doi.org/10.1371/journal.pone.0258334

Regmi, P.R., Waithaka, E., Paudyal, A., Simkhada, P., van Teijlingen, E., 2016. Nepal Journal of Epidemiology Guide to the design and application of online questionnaire surveys. Nepal J Epidemiol 6, 640–644.

Renwick, A., Wreford, A., 2011. Climate change and Scottish agriculture: an end to the freedom to farm? Int. J. Sociol. Agric. Food 18, 181–198. https://doi.org/10.48416/ijsaf.v18i3.243

Rochecouste, J.F., Dargusch, P., King, C., 2017. Farmer perceptions of the opportunities and constraints to producing carbon offsets from Australian dryland grain cropping farms. Australas. J. Environ. Manag. 24, 441–452. https://doi.org/10.1080/14486563.2017.1379037

Rodríguez de Francisco, J.C., Boelens, R., 2015. Payment for Environmental Services: mobilising an epistemic community to construct dominant policy. Env. Polit. 24, 481–500. https://doi.org/10.1080/09644016.2015.1014658

Rumpel, C., Amiraslani, F., Chenu, C., Garcia Cardenas, M., Kaonga, M., Koutika, L.-S., Ladha, J., Madari, B., Shirato, Y., Smith, P., Soudi, B., Soussana, J.-F., Whitehead, D., Wollenberg, E., 2020. The 4p1000 initiative: Opportunities, limitations and challenges for implementing soil organic carbon sequestration as a sustainable development strategy. Ambio 49, 350–360. https://doi.org/10.1007/s13280-019-01165-2

Saco, P.M., McDonough, K.R., Rodriguez, J.F., Rivera-Zayas, J., Sandi, S.G., 2021. The role of soils in the regulation of hazards and extreme events. Philos. Trans. R. Soc. B Biol. Sci. 376. https://doi.org/10.1098/rstb.2020.0178

Smith, P., Soussana, J.F., Angers, D., Schipper, L., Chenu, C., Rasse, D.P., Batjes, N.H., van Egmond, F., McNeill, S., Kuhnert, M., Arias-Navarro, C., Olesen, J.E., Chirinda, N., Fornara, D., Wollenberg, E., Álvaro-Fuentes, J., Sanz-Cobena, A., Klumpp, K., 2020. How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. Glob. Chang. Biol. https://doi.org/10.1111/gcb.14815

Soussana, J.-F., Lutfalla, S., Ehrhardt, F., Rosenstock, T., Lamanna, C., Havlík, P., Richards, M., Wollenberg, E. (Lini), Chotte, J.-L., Torquebiau, E., Ciais, P., Smith, P., Lal, R., 2019. Matching policy and science: Rationale for the ‘4 per 1000 - soils for food security and climate’ initiative. Soil Tillage Res. 188, 3–15. https://doi.org/10.1016/j.still.2017.12.002

Stafford, R., Chamberlain, B., Clavey, L., Gillingham, P.K., McKain, S., Morecroft, M.D., Morrison-Bell, C. and Watts, O., 2021. Nature-based Solutions for Climate Change in the UK: A Report by the British Ecological Society, British Ecological Society. London, UK.

Subedi, A., Franklin, D., Cabrera, M., Dahal, S., Hancock, D., McPherson, A., Stewart, L., 2022. Extreme Weather and Grazing Management Influence Soil Carbon and Compaction. Agronomy 12. https://doi.org/10.3390/agronomy12092073

Sun, R., Li, W., Dong, W., Tian, Y., Hu, C., Liu, B., 2018. Tillage Changes Vertical Distribution of Soil Bacterial and Fungal Communities. Front. Microbiol. 9, 1–13. https://doi.org/10.3389/fmicb.2018.00699

Sustainable Soils Alliance (2022) Report and recommendations on minimum requirements for high-integrity soil carbon markets in the UK - Version 1.0. [Report on recommendations on minimum requirements for high-integrity soil carbon markets in the UK, published December 2022. Available at: https://sustainablesoils.org/images/pdf/Framework_Requirements_for_High-Integrity_Soil_Carbon_Markets.pdf].

Thamo, T., Pannell, D.., Pardey, P.G., Hurley, T.M., 2004. Private Incentives for Sustainable Agriculture: Soil Carbon Sequestration, Agricultural and Resource Economics. Crawley, Australia.

Tiefenbacher, A., Sandén, T., Haslmayr, H.-P., Miloczki, J., Wenzel, W., Spiegel, H., 2021.

Optimizing Carbon Sequestration in Croplands: A Synthesis. Agronomy 11, 882. https://doi.org/10.3390/agronomy11050882

Vermeulen, S., Bossio, D., Lehmann, J., Luu, P., Paustian, K., Webb, C., Augé, F., Bacudo, I., Baedeker, T., Havemann, T., Jones, C., King, R., Reddy, M., Sunga, I., Von Unger, M., Warnken, M., 2019. A global agenda for collective action on soil carbon. Nat. Sustain. 2, 2–4. https://doi.org/10.1038/s41893-018-0212-z

Wentworth, J., Tresise, M., 2022. Restoring Agricultural Soils. London.

Wright, K.B., 2017. Researching Internet-Based Populations: Advantages and Disadvantages of Online Survey Research, Online Questionnaire Authoring Software Packages, and Web Survey Services. J. Comput. Commun. 10, 00–00. https://doi.org/10.1111/j.1083-6101.2005.tb00259.x

Zaralis, K., 2015. SOLID participatory research from UK: Mob Grazing for Dairy Farm Productivity. Sustain. Org. Low Input Dairy. (SOLID). Org. Res. Centre. SOLID Proj. (Agreement no. 266367 (http//www. solidairy. eu/) 266367.

Annex 1

UK 'Farm Soil Carbon Code' (FSCC) questionnaire

Introduction

Thank you for your interest in completing this questionnaire and participating in a research study being undertaken by the University of Leeds and a consortium of partners to develop a UK ‘Farm Soil Carbon Code’ (FSCC). This Code will outline minimum standards that can regulate the emerging UK agricultural soil carbon market and the production, verification and trade or sale of ‘carbon credits’ generated by farmers adopting alternative management practices on their farm. It will complement the existing Woodland and Peatland Carbon Codes that have already been operationalised.

The purpose of this questionnaire is to gain insight into your knowledge of the agricultural soil carbon market; elicit your views of the proposed FSCC; and gauge your willingness and capacity to adapt your farming strategy as appropriate to include practices that store carbon in the soil. The questionnaire should take you **approximately 15 minutes** to complete.

Confidentiality, Data Use, and Anonymity

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You may request that your answers be withdrawn up to 30 days after your interview by contacting the email address above. We will then destroy and not use your responses. If you contact us after the 30 days have passed, we will not be able to delete all your responses.

This research is funded by the Environment Agency’s Investment Readiness Fund and iCASP. It has been approved by the Ethics Committee of the University of Leeds.

Please tick below to confirm that you have understood the above information and that you consent to take part in this questionnaire.

- ○ I consent to take part in this study

Q1. Which best describes you? (please select one option)

- ▢ Farmer
- ▢ Agronomist
- ▢ Allied agricultural business
- ▢ Researcher
- ▢ Government/policy-maker
- ▢ Charity worker
- ▢ Other

Q2. Where are you based? (please provide the first half of the postcode of your farm)

____

Q3. What type of farm are you managing? (tick all that apply)

- ▢ Arable farm
- ▢ Horticulture farm
- ▢ Specialist pig farm
- ▢ Specialist poultry farm
- ▢ Dairy farm
- ▢ LFA grazing livestock farm
- ▢ Lowland grazing livestock farm
- ▢ Mixed farm

Q4. Do you...? (tick all that apply)

- ▢ Own land
- ▢ Rent land under a short-term rental agreement (≤ 5 years)
- ▢ Other (please specify) ____

Q5. How much of your land (in hectares) is...? (please put 0 in categories not applicable)

- ▢ In agricultural production (including grassland) ______________________
- ▢ In fallow, not in use ______________________
- ▢ In other use ______________________

Q6. Are you...?

- ▢ Earning sole source of income from farming
- ▢ Earning income from farming, but also an additional off-farm source of income
- ▢ Earning income by managing a farm holding on behalf of a company
- ▢ Other (please specify) ____

Q7. Which of the following practices are you implementing on your farm? (please tick **<u>all answers</u>** that apply)

- ▢ Low intensity/rotational/mob grazing
- ▢ No/low/minimal/conservation tillage
- ▢ Cover crops
- ▢ Incorporation of organic amendments into soils
- ▢ Introducing leys in crop rotations
- ▢ Incorporation of a mix of legumes and herbs into grasslands
- ▢ Agroforestry
- ▢ Management of field margins
- ▢ Application of biochar
- ▢ Other (please specify) ____
- ▢ I am not implementing any of the above practices on my farm

Q8. What motivated you to adopt these particular farming practices? (please indicate the **<u>three most important</u>** factors)

- ▢ Government subsidies/payments
- ▢ High production costs
- ▢ Exposure to extreme weather events
- ▢ Declining soil fertility
- ▢ Desire to reduce reliance on agrochemicals and/or synthetic fertilisers
- ▢ Pressure to align practices with certification standards
- ▢ Pressure from customers/consumers to change farming strategy
- ▢ Pressure to contribute to climate change mitigation
- ▢ Desire to gain respect in the community
- ▢ Desire to express my pro-environmental identity
- ▢ Other (please specify) ____

Q9. What benefits have you derived from your adoption of these farming practices? (please indicate the **<u>three most important</u>** benefits derived)

- ▢ Improved soil fertility
- ▢ Improved soil health
- ▢ Reduced soil erosion
- ▢ Increased crop yields
- ▢ Increased biodiversity on farm
- ▢ Increased resilience to extreme weather events
- ▢ Reduced production costs
- ▢ Improved standing in the community
- ▢ Access to new markets for my produce
- ▢ Other (please specify) ____

Q10. In the future, farmers may be paid to increase the amount of carbon in their arable soils and/or reduce their greenhouse gas emissions from cultivation. Would you be willing to adopt **<u>additional</u>** practices (to those you mentioned implementing on your farm in Q7) if you were offered a 'carbon payment' to do so?

- ▢ Yes, I would be open to adopting additional practices if I was paid to do so
- ▢ Yes, I would be open to adopting additional practices, but I am not interested in receiving carbon a payment for this
- ▢ No, I am not interested in adopting any additional practices or getting a 'carbon payment'
- ▢ No, I am not interested in adopting any additional practices, but I would like to be paid for those practices which I am already implementing which have increased soil carbon
- ▢ I don't know yet

Q11. Do you have a preference as regards who would provide this 'carbon payment'?

- ▢ My preference would be to receive this payment from public funding sources
- ▢ My preference would be to receive this payment from private investors (e.g. agribusinesses and/or the food industry, banks, pension funds, aviation industry)
- ▢ My preference would be to receive payments from several different sources (e.g. public funding sources and private investors)
- ▢ I don't have a preference
- ▢ I don't know yet

Q12. With whom would you prefer to design a 'soil carbon project' contract? This contract would outline the conditions for a carbon payment. (please tick **all answers** that apply)

- ☐ I am not interested in being involved in designing a contract to generate 'carbon credits'
- ☐ No one, I would prefer to do it by myself (with the help of a carbon project developer)
- ☐ An entity within my supply chain (e.g. processor)
- ☐ A not-for-profit NGO
- ☐ A government department
- ☐ I don't have a preference
- ☐ I don't know yet

Q13. Which of the following statements about carbon markets do you agree with? (please tick those statements you **most agree** with, you can tick up to **three** statements)

- ☐ Farmers should not be paid for existing carbon stored in the soil, even if they have been managing their farms 'well' and the soil is not degraded
- ☐ Farmers should only be paid if they implement new, additional farming practices
- ☐ Farmers should be paid based on in-situ measured increases in soil carbon, before and after the contract
- ☐ Farmers should be paid based on modelled/estimated changes in soil carbon
- ☐ There should be two rates of payment for farmers – one rate for farmers who have historically managed their soils 'well' and one rate for farmers who have not historically managed their soils 'well'
- ☐ I don't agree with any of these statements

Q14. What of the list below should count towards 'carbon credits'? (please tick those options you **most agree** with, you can choose up to **three** options)

- ☐ Increasing the amount of carbon stored in the soil
- ☐ Reduction in soil erosion
- ☐ Reduction in emissions resulting from reduced fuel use on farm
- ☐ Avoided emissions linked to increasing use of renewable energy on farm
- ☐ Avoided emissions from fertilizer manufacturing, linked to a reduction in on-farm use of synthetic fertilisers
- ☐ Reduction all GHG emissions from soils (i.e. carbon dioxide, methane, and nitrous oxide)
- ☐ I don't know

Q15. When do you think farmers should receive ‘carbon credits’ (and payment)? (please tick **all answers** you agree with)

- ▢ Upfront, based on predicted (modelled) carbon uptake associated with implementation of certain practices
- ▢ Retrospectively, after 5 or 10 years, based on measured and/or estimated (modelled) increase in soil carbon stock and/or GHG emissions avoided during the contract
- ▢ In several instalments during the contract, based on measurements and/or estimates of the increase in soil carbon/reduction in greenhouse gas emissions
- ▢ I don't know

Q16. For what length of time would you be willing to implement a 'soil carbon project' contract, knowing that you would have to sign a legally-binding contract indicating your commitment to implementing **specific** farming practices for the duration of the contract?

- ▢ Less than 5 years
- ▢ 5-10 years
- ▢ 11-20 years
- ▢ 21-50 years
- ▢ More than 50 years
- ▢ I don't know

Q17. A 'soil carbon project' contract will require you to legally commit to maintaining the soil carbon you sequestered (during a contract period) after the contract has ended. For what length of time would you be willing to commit to maintaining a store of carbon in the soil?

- ▢ Less than 5 years, unless I enter into a subsequent contract
- ▢ 5-10 years
- ▢ 11-20 years
- ▢ 21-50 years
- ▢ More than 50 years
- ▢ I don't know

Q18. Farmers receiving ‘carbon credits’ would be required to contribute a share to a pooled ‘buffer’ of credits to mitigate risks of unintended or unavoidable reversal/loss of carbon stored in soils or ‘leakage’ of carbon emissions elsewhere on your farm. What do you think would be **an acceptable share of ‘carbon credits’** to contribute to such a buffer?

- ▢ Less than 5%
- ▢ 5-10%
- ▢ 11-20%
- ▢ More than 20%
- ▢ I don't know

Thank you for answering our questions. For us to understand the representativeness of the responses, we would appreciate if you can tell us...

Q19. What is your gender?

- ▢ Male
- ▢ Female
- ▢ Other
- ▢ Prefer not to say

Q22. How old are you?

- ▢ 18-24 years
- ▢ 25-34 years
- ▢ 35-44 years
- ▢ 45-54 years
- ▢ 55-64 years
- ▢ 65 years and over
- ▢ Prefer not to say

Q23. What is the level of education, related to farming, that you have completed?

- ▢ I have not completed any formal training
- ▢ On-going technical/vocational training (e.g. BASIS)
- ▢ Bachelor’s degree
- ▢ Master’s degree
- ▢ Doctorate degree

Q24. How many years of farming experience do you have?

- ▢ Less than 5 years
- ▢ 6-10 years
- ▢ 11-20 years
- ▢ 21-30 years
- ▢ More than 30 years

Q25. Is there anything else related to the topics discussed (i.e. UK 'Farm Soil Carbon Code' (FSCC), carbon markets, and 'carbon credits') that you would like to share today?

Q26. How best can the University of Leeds and consortium partners support you in familiarising yourself with the proposed UK ‘Farm Soil Carbon Code’ (FSCC), drawing up ‘carbon credits’ contracts, and producing and trading 'carbon credits' in the voluntary carbon market or sell directly to private investors?

Q27. In the coming months we will be holding phone interviews and online workshops to further understand farmers’ perspectives on carbon markets and other concerns/synergies of those practices on farms. Would you be interested in participating in these interviews and online workshops?

- ☐ Yes
- ☐ No

Q28. As you answered "Yes" to the last question (about follow-up interviews and workshops), can you please give us a contact email and/or phone number:

____

Annex 2

Questionnaire for UK Carbon Codes

Introduction

Thank you for your interest in completing this questionnaire and participating in a research study being undertaken by the University of Leeds and a consortium of partners to develop a UK ‘Farm Soil Carbon Code’ (FSCC). This Code will outline minimum standards that can regulate the emerging UK agricultural soil carbon market and the production, verification and trade or sale of ‘carbon credits’ generated by farmers adopting alternative management practices on their farm. It will complement the existing Woodland and Peatland Carbon Codes that have already been operationalised.

The purpose of this questionnaire is to gain insight into the carbon code that your organization has operationalised or is currently developing for roll-out in the UK, and your experience of working with farmers and farm managers who have adopted or are interested in adopting soil carbon management practices with a view to producing, verifying, and trading or selling carbon credits to private sector investors or receiving compensation from public sector actors. The questionnaire should take you **approximately 15 minutes** to complete.

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You will not be asked any personally identifiable information, only general information about your farming activity and views. All information and data will be kept on password-protected computer systems in line with University of Leeds protocols and the UK Data Protection Act and will not be shared beyond the research team. The results of the questionnaire will be used for academic and other relevant publications. The results will only be published at an aggregated level, and it will not be possible to identify answers from any individual participant organisation. If you have any questions about this questionnaire or the research, you can contact Dr Lisette Phelan at the University of Leeds (l.phelan@leeds.ac.uk).

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Please tick below to confirm that you have understood the above information and that you consent to take part in this questionnaire.

- ○ I consent to take part in this study

Scope of Code

1. What type of organisation are you?

   - ☐ Commercial
   - ☐ National government
   - ☐ Not-for-profit
   - ☐ Research organisations
   - ☐ UN-affiliated organisation
   - ☐ Other (please specify) ________________

2. What is your approach to quantifying changes in carbon stocks?

   - ☐ In-situ measurement
   - ☐ Modelling only
   - ☐ Use of emission factors only
   - ☐ Hybrid approach of measurement, modelling and/or use of emission factors

Project eligibility, rules and administration

3. Who can register a carbon project against your carbon code?

   - ☐ Farmer (tenant or landowner)
   - ☐ Landowner
   - ☐ Project developer

4. Who is the owner of a carbon project registered against your carbon code?

   - ☐ Farmer (tenant or landowner)
   - ☐ Landowner
   - ☐ Project developer

5. Is the owner of a carbon project required to have legal rights to the land?

   - ☐ Yes
   - ☐ No

6. Are there costs associated with registering a carbon project against your carbon code?

   - ☐ Yes
   - ☐ No

7. What types of land use are eligible for inclusion in a carbon project?

- ▢ Cropland
- ▢ Grassland
- ▢ Crop and grassland

8. What types of land use are ineligible for inclusion in a carbon project?
   - ▢ Permanent pasture
   - ▢ Woodland/forest
   - ▢ Permanent crop production (e.g. orchard crops)
   - ▢ Production of root vegetables
   - ▢ Peatland
   - ▢ Mineral soils

9. Does your carbon code specify which carbon sequestration practices should be implemented?
   - ▢ Yes, there is a predefined list of practices
   - ▢ No, there is no predefined list of practices
   - ▢ Yes, there is a co-developed predefined list of practices
   - ▢ No, but practices adopted by farmers should meet certain specified criteria

10. What additionality criteria must be adhered to by those implementing carbon projects against your carbon code?
    - ▢ Practices adopted must not be ‘common’ (i.e. widely adopted) in a region
    - ▢ Practices adopted must be ‘new’ to a farm (i.e. not already adopted)
    - ▢ Practices may not be adopted in response to government subsidies
    - ▢ Practices may be adopted using funding from other financial sources

11. What period of time does a carbon project contract cover?
    - ▢ Project duration
    - ▢ Permanence
    - ▢ Fixed period not project duration
    - ▢ Other (please specify) _________________

12. What is the expected duration of permanence (number of years) for a carbon project?

_____ years

Soil carbon sequestration

13. How many years of historic data are required to establish a baseline for a carbon project?

- ☐ Less than 3 years
- ☐ 3-5 years
- ☐ 6-9 years
- ☐ 10 years
- ☐ More than 10 years

14. What type of baseline does your carbon code expect for carbon projects?

- ☐ Fixed
- ☐ Fixed average
- ☐ Dynamic
- ☐ Other (please specify) ________________

15. How often do in-situ measurements of changes in soil carbon stocks need to be reported?

- ☐ Every year
- ☐ Every 2-5 years
- ☐ Every 6-10 years

16. At what depth are soil carbon stocks measured in-situ?

- ☐ Less than 20cm
- ☐ 20-29cm
- ☐ 30-60cm
- ☐ More than 60cm

17. How often do modelled changes in soil carbon stocks and/or GHG emissions reductions need to be reported?

- ☐ Every year
- ☐ Every 2-5 years
- ☐ Every 6-10 years

18. What GHG emissions are covered by your carbon code?

- ☐ CO2 only
- ☐ CO2 and N2O
- ☐ CO2, N2O and CH4

Carbon market

19. Does your carbon code permit retrospective crediting?

- ☐ Yes
- ☐ No

20. Does your carbon code permit stacking of carbon payments with other payments?

- ☐ Yes
- ☐ No

21. Does your carbon code expect contributions to a buffer fund?

- ☐ Yes
- ☐ No

22. Does your carbon code guarantee a carbon floor price?

- ☐ Yes
- ☐ No

23. Are there discounting arrangements in place to account for changes in the carbon market?

- ☐ Yes
- ☐ No