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Farmer perspectives on carbon markets incentivizing agricultural soil carbon sequestration

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Climate change mitigation efforts to achieve net-zero emissions require not only decreasing current greenhouse gas emissions, but also the deployment of negative emissions technologies. Soil organic carbon sequestration in agricultural lands is one such negative emissions strategy, currently being incentivized predominantly through voluntary carbon offset markets. Through semi-structured interviews, we assess both conventional and organic farmer perspectives on soil carbon offset programs that have been created in the United States since 2017. The perspectives of farmers both participating and not participating in agricultural soil carbon markets were similar and consistent. Farmers in both groups expressed concerns about the convoluted, burdensome and unpredictable nature of receiving offset credits and emphasized that they were implementing practices for their own business interests and sustainability concerns, not the financial incentive of the generation of carbon credits. Based on our research, carbon offset credit payments for agricultural soil carbon sequestration are largely reaching farmers who were already implementing these beneficial practices or were already strongly interested in implementing these practices, and the payments for the offset credits are seen as a 'gravy on top', suggesting that these offset markets face strong challenges of ensuring true additionality essential to effective climate mitigation.

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INTRODUCTION

Humanity continues to face the impacts of the climate crisis: extreme heat, increased rainfall, increased severity of tropical storms, increased prevalence of wildfire, sea level rise, and increased severity of droughts[1]. While it is fundamentally necessary to drastically reduce current and future anthropogenic greenhouse gas emissions to mitigate the climate crisis, pathways to avoid catastrophic climate change and hold warming below 2 °C also necessitate the implementation of negative emissions technologies (NET) that remove greenhouse gases from the atmosphere[2,3]. NETs include afforestation, reforestation, forest management, coastal and marine carbon sequestration, and soil carbon sequestration in agricultural lands[4].

Even though agricultural lands generally hold less soil organic carbon than wild lands[5], agriculture has the capacity to be a major source of negative emissions because of the sheer size it covers: almost 50% of potentially vegetated land surface has been converted to crop and pasture land[6]. Soil carbon sequestration refers to the accumulation of soil organic carbon (SOC) in terrestrial soils. Soil organic carbon accumulates as a result of the balance between carbon inputs to the soil – like biomass – and pathways for losses of carbon from the soil, such as respiration, decomposition and erosion[7]. When carbon inputs to soils exceed losses from decomposition and erosion, SOC accumulates and soils are a net carbon sink. Soil carbon sequestration on agricultural lands requires increasing carbon inputs and/or decreasing carbon losses, which can be accomplished through a variety of activities, including conservation tillage, mulching, cover-cropping and integrated nutrient management[7], as shown in Fig. 1. Conservation tillage reduces soil disturbance and the soil organic matter decomposition rate[8], while cover crops provide additional biomass inputs[9]. These soil management strategies seek to increase the concentration of SOC and can be accompanied by co-benefits in overall soil quality and disease resistance, decreased erosion, and increased productivity. Because of the substantial SOC storage potential of agricultural soils as a key component of natural and working lands-based negative emissions strategies, there has been increasing attention, by both governments and the private sector, toward incentivizing farmers to adopt beneficial cultivation practices to enhance carbon sequestration as part of climate change mitigation strategies.

Globally, national-level and subnational climate policies have increasingly included a variety of incentive programs to encourage farmers to undertake on-farm activities that sequester soil carbon[10]. For such incentives to be effective in inducing farmers to implement on-farm activities, they need to be functional for farmers who are implementing them. Previous survey and interview-based research has examined the facilitators of farmers and other landowners adopting these activities. These studies identified local environmental co-benefits and soil health benefits, rather than climate mitigation services, as primary drivers for practice adoption[11–14]. Taken as a whole, there is consistent social-scientific evidence that farmer motivations for adoption of carbon sequestering activities on their land are driven by perceptions about the co-benefits of such activities, rather than by financial returns or the idea of sequestering carbon.

Previous work has also identified numerous barriers to farmer adoption of soil carbon sequestering activities, despite financial incentives in place. These barriers include unfamiliarity with and lack of information about practices, and concerns about the costs of implementing new activities, despite financial incentives[13–16].

Much of the previous research has been conducted not with row-crop farmers, but with rangeland and other landowners who have participated in biodiversity conservation programs that have additional climate benefits.

Since 2017, voluntary carbon offset developers have emerged that seek to incentivize U.S. farmers to change on-farm practices

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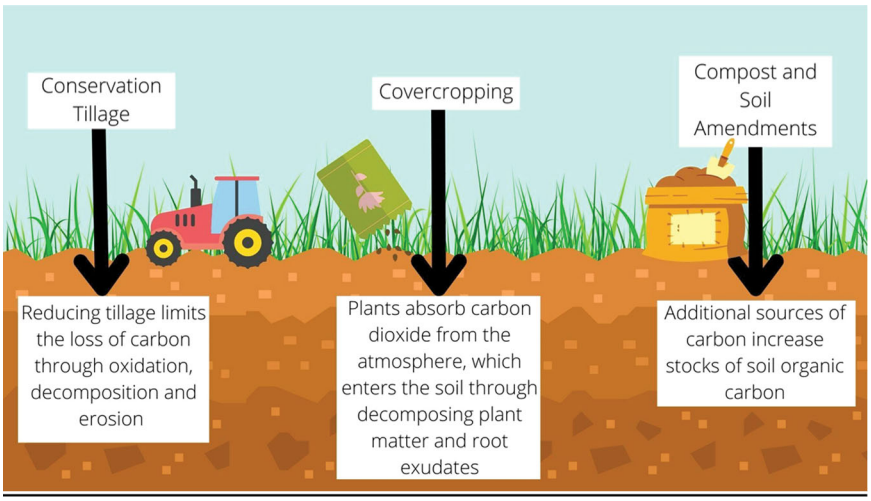

Fig. 1 Activities that enhance carbon sequestration in agricultural soils. This figure shows on-farm activities that can enhance soil carbon sequestration. In some circumstances. types of activities can be implemented to generate carbon credits under voluntary market carbon offset protocols.

to sequester soil carbon through payments for the farmers' generation of voluntary carbon credits that can subsequently be used by emitters to offset existing sources of anthropogenic emissions, as actors seek to reduce the climate impacts of their operations. Two corporations – Nori and Indigo – are the two primary offset project producers for agricultural soil carbon offsets for the voluntary market currently in operation in the United States. Indigo began its carbon market program in 2019 and Nori in 2017. Building on previous research which largely presented work from other countries, this study seeks to understand the motivations and concerns of both participating and non-participating farmers about agricultural soil carbon markets that have developed in the United States since 2017. Understanding their perspectives and lived experiences can help further inform the literature on farmer perceptions of market-based mechanisms for soil carbon sequestration and, can also help evaluate these emergent markets to assess of their effectiveness for achieving climate mitigation. Based on the core assumption of additionality–that activities that enhance carbon sequestration among conventional farmers should be credited because the financial incentive of the offset credit induces greater participation and increases total carbon sequestration from what would have happened in the absence of the offset credit – and on the existing literature about farmer adoption of soil carbon sequestering practices, we hypothesize that the farmers participating in carbon markets had adopted the practices for both perceived environmental co-benefits and for financial reasons associated with credit payments, while organic farmers who are not participating in these markets would adopt these practices solely due to the perceived environmental co-benefits.

Voluntary offset project developers face several challenges: one is to ensure that the amount of carbon estimated to be sequestered through the implementation of on-farm activities is real and accurate. Voluntary carbon credit markets for agricultural soils require exact measurements or estimation for the quantity of carbon sequestered in order for offset buyers to subtract these credits from their emissions. To facilitate verification and estimation of the amount of carbon sequestered, both Nori and Indigo use carbon offset 'protocols' that were developed by non-profit organizations known as registries. The protocols in most common use are those developed by Verified Carbon Standard, by the Climate Action Reserve and by American Carbon Registry[17]. They also restrict eligibility only to conventional row-crop agriculture in the Midwest and South where measurements of soil carbon changes in response to on-farm beneficial activities has been demonstrated.

The other challenge faced by these markets is to ensure that the carbon sequestered is 'additional' to what would have otherwise occurred. This need for additionality arises because the carbon credits will be sold to 'offset' existing sources of emissions. Additionality refers to a sequestration project being *caused* by the credit incentive – that it would not have gone forward without the incentive's support[18]. Both Nori and Indigo's certification protocols include eligibility requirements to ensure additionality. Indigo uses the Climate Action Reserve (CAR) Soil Enrichment Protocol, which 'strives to register only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of a carbon offset market'[19]. The CAR protocol requires that farmers change their soil management practices relative to an established baseline, regardless of motivation, and it allows for the stacking of incentives, including NRCS subsidies, without disqualifying farmers from eligibility. Zelikova et. al. (2021) found that CAR's protocol creates the false appearance of additionality standard while actually treating all practices as additional[17]. Nori has developed its own protocol, which is not directly available to the public. Nori's website stipulates that carbon credits that carbon credits are only issued for 'a discrete and verifiable activity or practice change that is reasonably expected (given the scientific evidence available at the time) to result in a new net CO_2 removal and C retention'[20]. Both Nori and Indigo's additionality standards will allow practice changes that were initiated for reasons other than the market's payment.

METHODS

Study populations and interview solicitation

To assess farmer perspectives on the current state of markets for agricultural soil carbon offsets in the United States now that voluntary offset markets have become established, we examined the perspectives of two groups of farmers: conventional row-crop farmers who are eligible and actively participating or seeking to participate in voluntary carbon markets, and organically certified row-crop farmers who are engaging in soil carbon sequestration practices but are not participating, nor eligible to participate in existing carbon markets. The reason for the selection of these two groups is to assess whether perspectives on these offset programs are shared between groups of farmers who are all engaged in carbon sequestering activities, but only some of whom are

Table 1. Semi-structured interview guide.

1. Tell me a little bit about your farm and what you do.
2. What do you think about your farming as it relates to climate change? In what ways does climate change affect you?
3. What practices are you using to sequester carbon in your soils? What factors drove your decision to implement these practices?
4. Hypothetically, if you were not already implementing these practices, what regulations, incentives or programs do you think would allow you or encourage you to implement soil carbon sequestration practices?
5a. (if not participating). How would you feel about a carbon farming add-on to the organic certification label? What about a program that paid you for the practices themselves?
5c1. (if participating) How were you farming before you got involved with selling carbon credits and how do you reflect on these practices now? 5c2. (if participating) What has been your experience with the program thus far?
6. Overall, what do you think would make carbon credit programs work better for farmers?
7. How do you think agriculture needs to adapt to address climate change?
8. Where do you see carbon markets for soil carbon sequestration in five years from now? Where would you like to see markets in five years?

participating in carbon markets. By interviewing farmers in both groups, we were able to identify universally held perspectives on motivations for adopting beneficial practices and on concerns about existing agricultural soil carbon market mechanisms. In particular, by interviewing farmers who had all chosen to adopt at least some of these practices, we could develop a typology of both the facilitators of practice adoption and concerns about markets and compare whether incentives from voluntary offset payments shaped adoption pathways for eligible farmers, compared to non-participating farmers.

The participating farmers interviewed for this study came from a pool of carbon credit sellers listed on Indigo and Nori's websites. Participants were solicited by email or by phone using the contact information listed either directly on carbon market websites or on other farm websites. Because Nori publishes each participating farm as its own carbon sequestration project, we were able to view on its website every farm that has ever sold credits through the marketplace. This allowed us to solicit interviews from nearly every participating Nori farmer (except 3 that we could not find contact information for). As Indigo does not release the same data broken down by individual farm project, we do not know how many farmers are participating in their carbon sequestration program, and consequently what percentage of them we reached.

The non-participating farmers interviewed for this study came from a pool of certified organic vegetable producers in New York State. Because they are organic famers operating in a region for which soil carbon credits are ineligible, we could ensure that they were both adoptive of beneficial practices and not participating in carbon markets. Specifically, farmers were selected from a publicly available registry of farmers certified through the Northeast Organic Farming Association of New York (NOFA-NY), one of the largest organic certifiers in New York State. Participants were solicited by email at the email address listed either directly on the registry or on farm websites.

Semi-structured interviews and coding

After receiving ethics approval from the Hamilton College Institutional Review Board, author CTB conducted seventeen individual, semi-structured interviews between January 2021 and February 2022, for a total of seventeen semi-structured interviews. All interviews were conducted with informed consent for participants. Confidentiality was maintained for all research participants. Semi-structured interviews lasted between 30 min and 1.5 h in length and conducted on Zoom or over the phone. All interviews were recorded and then electronically transcribed using automated voice-to-text software, after which transcripts were manually corrected for minimal transcription errors. Semi-structured interview questions centered on farming practices and farmer perspectives about carbon markets and other incentives to undertake activities that enhance soil carbon sequestration. The interview guide for semi-structured interviews is shown in Table 1 below.

Interview transcripts were qualitatively analyzed using a modified grounded-theory approach[21] – an inductive method to assign codes to recurring themes across interviews. In this method, we first established two goals: (1) developing a typology of categories and subcategories of that led to farmer adoption of on-farm carbon sequestering activities and (2) developing a typology of categories and subcategories of concerns about currently functioning offset markets. We then sought to define whether these categories and subcategories were unique to one of our two study populations or were shared across them.

To develop the codebook of categories and subcategories, we first conducted iterative readings of the transcripts by both authors CTB and ALS to develop an initial list of categories and subcategories of responses. We then refined this grounded, inductive list of categories by comparing our categories and subcategories with identified factors that constituted barriers and facilitators from the literature, in particular from Buck and Palumbo-Compton's 2022 review paper[14]. Using this information, we refined our coded categories to develop the two-level code book of categories shown in Fig. 2 below. Readings of transcripts began after twelve interviews had been completed, and we conducted five further interviews from the same previously identified subject pool before determining that no new codes were being developed and we had achieved saturation within the structure of our code book. After saturation and with our developed codebook, all coding was redone using a combination of Nvivo software (Nvivo Version 12 for Mac) and manual coding of anonymized transcripts. Coding was done first by author CTB, then transcripts were re-coded by ALS to ensure intercoder reliability. Re-coded transcripts had a percentage agreement of 91%.

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

RESULTS

Response rates

Out of thirteen solicitations for interviews for farmers from both Nori and Indigo, we received nine positive responses, a response rate of 69%. These farmers were all farming in the United States: six in the Midwest and three in the Southeast. Of the farmers we interviewed, four were growing only field crops (including corn, soybeans, cotton and winter wheat), and four were growing field crops and raising livestock in mixed operations. Six of the

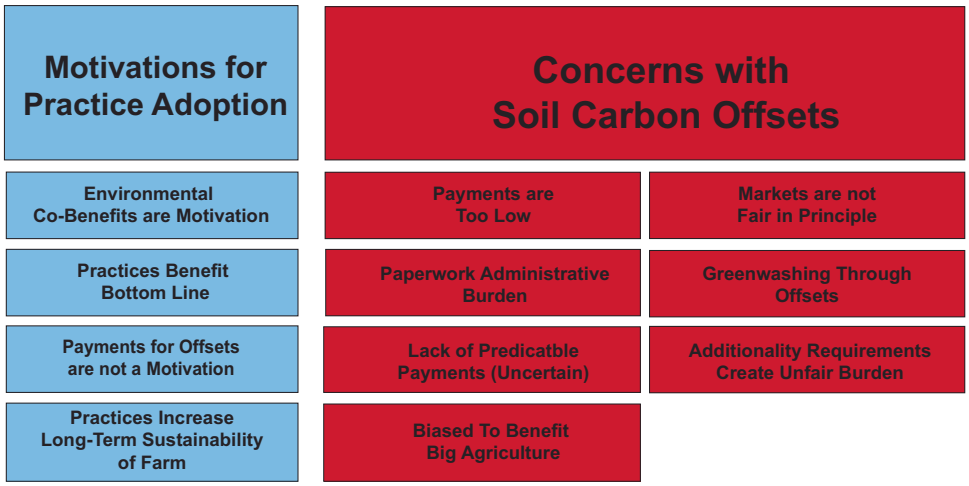

Fig. 2 Code book. This figure depicts the two level code book used in analyzing qualitative semi-structured interview transcripts.

individuals we interviewed had successfully received payments from carbon credits from Nori or Indigo, while three were farmers working with Indigo and Nori, but had not directly received payments yet. Two farmers identified as female and seven as male. The potential population of eligible farmers to interview was limited by the low number of total farmers actively participating in these programs. While exact figures have not been published, 23 farmers were listed on the two company's websites and in other available documentation, however we were not able to find contact information for them. Thus, our thirteen solicitations represented 57% of the population of farmers whom we could identify. For the organic farmer pool, out of twenty requests for interviews sent, we received nine positive responses, a response rate of 45%. Of the farmers we interviewed, three were growing only vegetables and six were growing vegetables and raising livestock in mixed operations. These farmers were all farming in New York State: three in Western New York, one in Central New York, three in the North Country, and two in the Hudson Valley. None of them were participating in active carbon markets. Four farmers identified as female and five identified as male.

Motivations for practice adoption

Across both groups of farmers – those participating in carbon markets and those not – the primary motivations to adopt beneficial farming practices were the same: (1) overall economic profitability and (2) intergenerational resilience due to maintaining healthy soils. As a whole, all farmers were motivated to adopt practices that sequestered carbon because of interests in long-term sustainability, crop health, and farm profitability.

Farmers who were actively participating in carbon markets for soil carbon sequestration or who had attempted to utilize such carbon markets adopted practices for a number of reasons, but the ability to participate in a carbon market was not the primary reason. As one farmer said of the practice changes encouraged by carbon markets, which he had implemented years before being approached by carbon markets:

> We made all those changes to cover crops, no till, and all the things that they want you to do. We did that just for our own profitability and survival, you know? It's a better way to farm.

Roughly a third of large-scale commodity crop farmers interviewed expressed that more conventional practices had brought them into situations of economic hardship that made alternative practices that enhance soil health more appealing, because soil health practices made farmers more resilient. While participating farmers were aware that these practices made them eligible to receive carbon credit payments, participating farmers' decision to adopt these practices were universally driven by on-farm concerns. Most (seven of nine) were multi-generation farmers who expressed explicit concerns with maintaining long-term profitability for many years into the future. As one participating farmer said:

> Our goal is that we're constantly looking at the future of our operation, and how we can make sure that we're maintaining the soils and the land that we have, so that they're in very high fertility rates, as well as we're building the organic matter on the farm. So as we start to continue to see, and we have in our area, our weather patterns change, that we can combat by, with hopefully, you know, really, really fertile, healthy soil.

Organic farmers also discussed soil and crop health, economic productivity, and adapting to extreme weather events for future generations. While some of these practices were required for organic certification, most organic farmers had gone beyond the bare minimum requirements for cover cropping and crop rotation because of some other motivator. In general, they were concerned with maintaining the health of microbiotic communities and the whole farm ecosystem, and the corresponding impact on plant health and productivity. One farmer noted the benefits of these practices:

> Obviously sequestration is great for [climate mitigation],[but it's] even better for the soil.

A few farmers were also concerned about improving their resiliency in the face of increasingly severe flooding and drought, and thus were interested in building their soil's erosion resistance and water-holding capacity. The majority of organic farmers believed that these practices were chosen out of enlightened self-interest, meaning that they were better for plant health and overall system sustainability, as well as farm income (self interest). Farmers participating in carbon markets shared this perspective. As one carbon markets farmer described:

> Well, you're looking at the wrong way, you should put your cover crop out, because it was the right thing for you to do for your operation…Stack the carbon program on top of that.

Non-participating and participating farmers shared very similar views on carbon market payments for beneficial activities. Collectively they viewed the payments as helpful, especially for those who were already doing the on-farm activities. In terms of their perspectives on receiving payments for 'what they were going to do anyway', farmers participating in carbon markets expressed positive sentiment about being paid for their practices. The view was summed up by one farmer:

> Why not take the money while it's there?

Another reiterated that carbon payments were a clear benefit to their operation:

> If I've gotten an installment today, that's something I can make a difference to my family and my business today.

Non-participating farmers also acknowledged the benefits of providing farmers with another source of income. For a group of farmers who were already farming in a way that sequestered carbon, it seemed like a clear benefit to receive payment without having to put much money or time into changing their methods or doing anything new. They also seemed optimistic about the long-term success of a program that compensated farmers, over one that relied simply on education or shifting ideologies.

Additionally, a few organic farmers reported that a financial incentive might be a good way to convince conventional farmers, who they saw as less ideologically driven than they are, to adopt beneficial practices. Farmers from both groups agreed that farmers tend to be underpaid and overworked, and were appreciative of any incentive that gave them additional income, especially one that supported soil management practices that provide other co-benefits to their operations. One organic farmer spoke positively of carbon markets:

> [A]nything that has any sort of monetary value attached to it, I think is gonna be what works in the long run.

All farmers who were participating saw carbon market programs as an avenue to get compensated for practices they were already looking to adopt, and which they saw as benefits to their farm operations. One farmer reflected:

> The carbon credit thing is just sort of gravy on top of what we already do, and what we think is the right thing to do.

One farmer reflected on the carbon credit payment:

> I think it's sort of an added bonus.

And another farmer encapsulated this same view:

> Like, we don't (want to) farm differently to sequester carbon. We are farming differently because it's the better thing to do. So whatever system whatever carbon credit market or system lets us, y'know, pays us to do what we were already going to do anyway.

Of course, when farmers are paid for doing what they are already doing, low compensation may still be viewed generally positively. One farmer said:

> I didn't change anything to do it, you know what I mean? … You're doing this, you're doing a really good job. Here's almost a half a million dollars. Is that okay? I go, Yeah, that's fine.

Four participating farmers were also open about the fact that they were choosing carbon markets based on which quantification systems would compensate them for practices they were already using.

Concerns about soil carbon markets

Farmers from both subject pools expressed numerous concerns about and frustration with existing carbon markets. These concerns included (a) compensation being too low, (b) substantial burdens of paperwork, (c) a lack of predictability and the 'black box' of credit calculations, (d) frustration that the markets were skewed to benefit larger-scale agriculture, and (e) concerns about both greenwashing and additionality. We present evidence for each of these concerns below.

The most consistent complaint that participating farmers raised about carbon markets was that the payment was simply too low. While the universal view was that money for 'doing nothing new' was great to receive, farmers viewed the payments as too low to incentivize new activities that a farmer was otherwise not inclined to adopt. There was complete agreement from every participating farmer we interviewed that the carbon credit payments available currently are too low to drive substantial practice changes on their own farms that they were not planning to adopt for other reasons, and are too low to drive practice changes for non-participating farmers. They expect that carbon credit programs will not be appealing enough to farmers who are not already interested in practice changes until the value of credits increases substantially. One farmer said of the roughly $15 per acre payment that most farmers receive:

> No, that's not going to change anybody, nobody's gonna quit doing the way they've always done it, try over something new for that.

Non-participating farmers felt that carbon markets were built for large, conventional farmers who were not using many beneficial practices already, and they felt that carbon markets would result in little profit for them. One interviewee said:

> From what I have seen in carbon markets that have been established, um, cap and trade has not paid enough to fund those so that a smaller scale would get enough to even pay for the time they have to spend applying.

Despite the ease of getting paid for doing 'nothing new', both groups of farmers saw the paperwork associated with tracking on-farm activities as a frustrating component of carbon markets. Participating farmers expressed concern that carbon market payments were made more difficult to access because of the hardship of gathering all of the required records and inputting their data into the carbon market system. They complained of the complexity of digitizing older paper-based records, getting records to mesh over the years as fields changed, and converting their data into a precisely specified format. One farmer said of this process:

> The data, the data part was, is ridiculous. I mean, everything that you do on every acre for the last 10 years, is what you have to do…you get back to 2010 - one, I wasn't even here, and records were mostly like little scribbly notes on notebook paper. So…maybe you weren't even farming the same fields then or you called them something different, or it used to be six fields, and now you made it one.

Farmers who were participating in carbon credit markets generally felt that their own records were better than most, and

that this was part of what allowed them to succeed, but they were concerned that the older or smaller-scale farmers would not be prepared for the level of detail that was required to participate in these programs. They expressed worry that this would limit the adoption of carbon credit programs. One farmer suggested that other farmers may be unprepared for the paperwork burden:

> It is a ton of paperwork and a ton of like, proving what you had to do. Yeah, it's pretty extensive…I think the farmers that are looking into these programs are prepared. I think the farmers that maybe are a few steps behind the curve are not prepared.

The main things that participating farmers said helped them overcome the record-keeping and data entry hurdle was having spare time to keep records or having someone on staff whose job was predominantly to keep records, using a digital record-keeping system that was compatible with their carbon market's software and having someone at their carbon market helping them through the data entry process to clarify what was required. The farmers who had the easiest time submitting records to carbon markets were those who were using digital record-keeping systems administered by Indigo or by Truterra, which has partnered with Nori.

Farmers participating in carbon markets also expressed frustration that the eventual payouts from these markets were difficult to predict. The uncertainty of the payment made the work of changing practices and inputting data seem far less worth it. One farmer suggested that other farmers would be unwilling to take the step to participate in the market (and the associated paperwork burden) just for an uncertain payment:

> So nobody's gonna do that - they're not going to do all that work on the chance they might not get paid.

Farmers felt that it was risky to put effort into substantially changing practices solely to participate in a carbon credit program because of the chance that they would not receive any money. The cost of changing practices, they felt, should be compensated no matter what, or else farmers would be hesitant to take a 'leap of faith' on a carbon market.

> I mean, it's gotta be something that's a for sure thing if they make the changes. That's the other thing that's always frustrated me. You might make all the changes and then not get paid? That's crazy.

Farmers' perception that carbon markets were unreliable was heightened by the fact that payouts were calculated differently from program to program, generally totally out of the view of the farmer. This uncertainty put farmers in the situation of inputting data into a 'black box' and hoping that it would result in a payout, a risk that they recognize others might not be willing to take, hindering wider adoption of carbon market programs.

One farmer summarized other farmers' worry about how opaque carbon markets are:

> It makes people a little nervous, because it's not a tangible thing. And then, like the model that they're using is very complicated. It's kind of a black box. So you don't know what's actually happening. So there's some distrust going on.

In order to avoid the distrust and confusion bred by the unpredictability of payouts, the majority of farmers participating in carbon markets voiced support for a more standardized system, with clearer and more consistent rules for setting the value of a credit. One farmer said simply:

> I would like to see one standardized set of rules. So it wasn't such a wild wild west.

Beyond the barriers of predictability and paperwork, all farmers expressed some concerns that existing voluntary carbon markets contain biases and are poorly structured to try to incentivize non-optimal activities or for the benefit of other actors. They viewed market operators skeptically and thus these concerns about bias can represent a form of barrier to participation. Some of these concerns focused on concerns that markets would incentivize activities that required heavy chemical inputs, which a farmer would have to purchase from a chemical company. Chemical companies tend to emphasize the role of no-till in sequestering carbon above other practices like cover cropping and nutrient management, because no-till often requires heavy pesticide and herbicide inputs to replace the disruption of weed root systems and pest life cycles that normally occurs through tillage[22]. Participating farmers expressed concern that these companies could be involved in setting national government standards for carbon markets, which would then skew all carbon markets toward a specific style of farming and ignore other beneficial practices for carbon sequestration.

One farmer spoke negatively about other programs that were closely associated with chemical companies:

> If a large chemical dealer wants to sell you a chemical that if you use, they promise you'll sequester more carbon, and then they're going to pay you for that carbon, but you can only get that payment if you buy their chemical…like it's pretty obvious what's happening there. And you know, it's just another way for farmers to be taken advantage of by input dealer you're basically sequestering carbon with the intent that this company is going to buy your credit to offset the cost of producing the chemical that they sold you to sequester the carbon that's dumb. I'm not interested in that at all.

Organic farmers were especially concerned about carbon markets privileging a specific style of large-scale monocrop farming. They worry that many currently active carbon markets are rooted in models based on pilot phase testing on large-scale commodity crop farms. An industrial-scale model would put small-scale, diversified organic farms at the disadvantage of entering an incentive structure that was not built to adequately capture or account for the way their farms operate and the practices that they're using. Organic farmers were even more concerned than participating farmers that carbon markets would narrowly support only a subset of valuable farming practices, but both groups of farmers frequently raised concerns that carbon markets would inadequately support a full range of beneficial soil management practices. Farmers from both groups expressed that it was a priority that carbon markets be protected from unfair industry bias.

> I can see already that…there's already the major ag players that are kind of trying to write the rules for the programs and design the standards…around…no till and that approach to farming is where it will get tilted towards… because their incentive is to sell…seed and chemicals and fertilizers.

Non-participating farmers also felt it was unfair that carbon markets were built on an industrial monocrop model that would not be easily applied to their small, diversified farms. One participant said of carbon markets:

> [S]o maybe eventually they do approach, you know, a 30 acre diversified vegetable operation, but if their data and

> their models are based on a corn and soy operation in Iowa, is that going to make sense?

Farmers were left with the perception that some carbon markets were set up just for the purpose of enriching the companies that run them. This led to a distrust of carbon markets in general, and participating farmers worry that this distrust will hinder wider adoption of these programs by other farmers. Farmers were also concerned about the involvement of large chemical companies when they look forward toward more potential government regulation of carbon markets. One farmer expressed this anxiety:

A few farmers in both groups raised concerns that companies using carbon credits from the voluntary market would use them for marketing and mislead consumers about their practices. They worried that carbon credits would be used in greenwashing campaigns by industries seeking to paint themselves as more environmentally sustainable than they are, producing more revenue for these companies without producing substantive change to address greenhouse gas emissions. One farmer participating in carbon markets offered this detailed critique of the problem of greenwashing that carbon credits facilitate:

> [T]he general public, I mean, they, they see these companies buying carbon credits, and they think it's great…but I think they also don't fully understand the whole scope of everything. Because…well take like a Delta Airlines…you buy a flight with Delta, they say we can fly, you know, carbon neutral for an additional $40, you know, and, I mean, I've seen it, there's people getting out their phones, and they're paying those 40 bucks. And they're like, Wow, this is great, you know, I flew carbon neutral. Okay, but you really didn't. Because, you know, Delta Airlines still burned the same amount of fuel, they still put the same amount of emissions out into the air…these big companies…they're using it to their advantage for marketing.

Organic farmers were concerned more broadly with the way that companies, particularly food producers, greenwash themselves as 'sustainable,' 'climate friendly,' or 'carbon neutral' and avoid accountability for their harmful practices. One interviewee worried that companies would simply use carbon credits and other market-based climate change approaches as a cover to dodge deeper changes to their practices.

> We're not going to shop our way out of industrial agriculture being bad for the climate, because these companies are uniquely gifted at greenwashing themselves.

Both groups of farmers raised concerns about the extent to which market-based solutions can truly and transparently drive climate change mitigation efforts. At the same time that they want recognition of their own climate beneficial practices, farmers worry that the flip-side of that recognition in carbon markets is the obscuring of continuing harmful practices in the industries that purchase their carbon credits. Looking at the fuller picture of carbon markets, farmers seemed concerned that their own positive practice changes might be misappropriated, making those practices a less effective climate solution.

Overall, concerns about additionality are central to an evaluation of any functioning voluntary offset program. Yet, for the participants in the program, concerns about additionality requirements centered not on concerns that sequestered carbon was non-additional and that such credits would be used to allow sources of emissions to continue. Rather, for both groups of farmers, concerns about additionality centered on the perverse incentive these requirements created to reward those who more recently adopted beneficial practices or, in some cases, to incentivize farmers to switch back to conventional tillage practices in order to enhance their eligibility for payments in the future.

Farmers participating in carbon markets generally had negative views about existing additionality requirements. They saw them as an unfair burden which prevented farmers using beneficial practices from consistently being compensated and which penalized early adopters of these practices. They generally felt that they should be paid for their beneficial practices, regardless of when they started or whether the practice was additional. One farmer said of their beneficial practices:

> I'm still doing it. So if you're gonna pay people for doing that, what difference does it make when they started?

A few participating farmers were only able to enroll a portion of their acres in carbon market programs, because fields they had been farming for a long time did not meet additionality requirements. Others were entirely excluded from carbon markets whose additionality protocols would allow them to look back only a few years. Participating farmers voiced concerns that prioritizing recent practice conversion created a perverse incentive against maintaining beneficial practices over the long term, which would be most beneficial from a climate perspective. One participating farmer said of the additionality requirement:

> It kind of is a disincentive. To me, I could see people hopping out of some of these good practices for a year or two just so they can get re-enrolled in them in the future.

Another farmer recalled a conversation with a carbon market representative in which they realized farmers could see the most money by pausing their beneficial practices and then starting over again:

> But one of our initial conversations we were kind of joking with him was like, okay, so you're telling me, we'd be better off to go back to tilling for two years? And then go back to how we were doing things? He's like well be better if you didn't. Well I know, but like this is the way this works? Like, that's kind of how it's set up.

Farmers participating in carbon markets felt that additionality requirements "punish the early adopters" and prevent them from seeing as much money as farmers who adopt practices later. Being paid less than farmers who had implemented the same practices that they were using later, most farmers felt that additionality requirements set up an unfair penalty for farmers who had been innovative and forward-thinking enough to adopt beneficial practices years before.

Organic farmers were similarly concerned about additionality, especially because they were almost always early adopters who would be ineligible for payments because they had been using beneficial practices for so long. Some expressed the perspective that a carbon market would function more as an incentive to conversion to beneficial practices for conventional farmers, rather than providing a continuation incentive for farmers already using beneficial carbon sequestration practices. Organic farmers felt that farmers should be supported for using beneficial practices regardless of when they began, in order to incentivize long-term use of good soil health practices and climate change mitigation.

DISCUSSION

Our results show that both groups of farmers largely shared the same motivations to undertake beneficial activities: the benefits to soil and crop health and the long-term economic sustainability garnered from those benefits. This finding matches the results of previous studies demonstrating that farmers' adoption of

environmentally beneficial practices is primarily motivated by the perceived conservation and environmental benefits of doing so[14,23].

Based on generalized assumptions of additionality requirements, however, we expected that farmers participating in carbon markets would also perceive the financial benefits of payments at least as one of their primary motivations for implementing carbon sequestering practices, but this was very clearly not the case.

Our typology of concerns with carbon markets that emerged from coded interview transcripts also demonstrates that both participating and non-participating farmers largely share the same concerns. They all are concerned that markets are structured unfairly to benefit large agricultural corporations and/or offset developers rather than farmers, and that markets are largely a wild-west of unpredictable benefits and burdensome paperwork. These results confirm findings from Kragt et al. (2017) that administrative burdens can pose real barriers to participation in carbon sequestration programs[13].

Our results also suggest that providing more information or experience with programs about programs as a way to address identified barriers around familiarity and information may not be enough not alleviate farmer concerns that are fundamentally rooted in issues of trust[14]. Even farmers participating in the carbon markets do not trust the markets nor view them as beneficial, but rather view them as a means to earn an extra buck for what they are already doing. This confirms the idea identified by Feliciano et al. (2014) that those who are most likely to participate in markets are those who are already doing on-farm activities that make them eligible, because the uncertainties and costs associated with participation are seen as lower barriers[15].

Finally, our results present evidence for how the issue of additionality is perceived by farmers participating in voluntary offset markets, with strong implications for broader concerns about the environmental integrity of voluntary soil carbon offset credits.

Farmers' perspectives were both that the carbon they were sequestering was not additional to what would have occurred without the carbon credits, but, also that that additionality restrictions are unnecessary and convoluted imply that there is a fundamental disjuncture between how carbon markets define themselves, primarily as a climate change mitigation tool built on rigorous, permanent and additional offsets, and the work that farmers want offset markets to be doing, that is, providing one more source of monetary support for soil management practices. Thus, this disjuncture may lead markets to function improperly to address climate change as they are forced by farmer (and buyer) demand to adopt less stringent additionality requirements, or to fail to catch on at all. Farmer desires for practice support also point to the unmet need for educational and monetary support for practice changes, which is now being imperfectly fulfilled by carbon markets.

Based on our research, carbon market payments through existing markets such as Nori and Indigo for soil carbon sequestration are largely reaching farmers who were already implementing these beneficial practices or were already strongly interested in implementing these practices, and that the payments for the offset credits are seen as a 'gravy on top' in the form of payments earned for what they were already doing. Given that farmers also perceived the payments as generally too low to incentivize *new* adoption of the practices, this has an effect of largely generating credits from farmers who were already and separately motivated to adopt beneficial practices.

Under the protocols used to approve offset credits, the additionality standard in practice does not assess or require an assessment of farmer motivations for implementing practices. Rather, the additionality requirement is simply that activities are newly additional relative to a pre-established baseline period – this is why some farmers joked that they should stop cover-cropping for a few years so they could re-start and earn more credits. Both Nori and Indigo's additionality protocols fundamentally require only that practice changes be reasonably expected to sequester additional carbon relative to an established baseline of original practices. While this means that farmers' primary motivations for practice adoption do not in and of themselves violate the protocol requirements, the fact that farmers perceive that they are being paid for what they were already doing or would otherwise do even if they were not being paid and that farmers themselves perceive that their credits are not additional demonstrates further disconnection about what additionality means in practice. Arcusa et al. (2022) recently summed up these issues, highlighting that there are numerous working definitions of additionality that are not shared uniformly across different stakeholders participating in carbon markets, and we see evidence for that in our results[24].

These concerns about additionality are not unique. Recent analyses of soil carbon farming the Australian Carbon Farming Initiative's performance have found significant concerns for ensuring additionality under a voluntary carbon offset protocol in that system as well[25]. As the voluntary market for agricultural soil carbon offsets expands, it is increasingly important to ensure that market programs for agricultural soil carbon sequestration are effective at sequestering additional carbon and appealing enough to incentivize farmers to adopt soil carbon sequestration practices.

DATA AVAILABILITY

The datasets generated during this study include original interview transcripts. To ensure confidentiality, we are not making these data publicly available, but data are available from the corresponding author on reasonable request.

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AUTHOR CONTRIBUTIONS

C.T.B. and A.L.S. co-designed the study. C.T.B. conducted interviews, and C.T.B. and A.L.S. analyzed the data and co-developed the code book and coded results. C.T.B. wrote the manuscript. A.L.S. edited the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

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