Agricultural Carbon Programs

FROM PROGRAM CHAOS TO SYSTEMS CHANGE

Sierra View Solutions and American Farmland Trust

American Farmland Trust
SAVING THE LAND THAT SUSTAINS US

ABOUT AMERICAN FARMLAND TRUST

American Farmland Trust (AFT) is the largest national organization dedicated to protecting farmland, promoting sound farming practices, and keeping farmers on the land. AFT unites farmers and environmentalists in developing practical solutions that protect farmland and the environment. We work from "kitchen tables to Congress," tailoring solutions that are effective for farmers and communities and can be magnified to have greater impact. Since our founding, AFT has helped to protect more than six and a half million acres of farmland and led the way for the adoption of conservation practices on millions more. AFT has a national office in Washington, D.C., and a network of offices across America where farmland is under threat. For more information, visit us at farmland.org.

ABOUT SIERRA VIEW SOLUTIONS, LLC

Sierra View Solutions works at the intersection of agriculture, environmental markets, and policy. Our team has been involved in the development of more than 10 agriculture offset protocols and we work collaboratively with companies and organizations to implement climate-smart agriculture policies and programs. To help producers generate revenue through environmental markets, we research and advocate for practices that reduce methane emissions from dairy farms and the cultivation of rice; reduce nitrous oxide emissions from crops including corn, almonds, tomatoes, and wine grapes; and promote practices that sequesters carbon in the soil.

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SUGGESTED CITATION

Parkhurst, R., Moore, L.A., Wright, R, and Perez, M. (2023) *Agricultural Carbon Programs: From Chaos to Systems Change* [White paper]. Washington, D.C.: American Farmland Trust.

This publication is available to the public in pdf format from: https://farmlandinfo.org/publications/ag-carbon-programs-chaos-to-systems-change

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AUGUST 2023

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ACKNOWLEDGMENTS

This white paper was produced as a collaborative effort between American Farmland Trust and Sierra View Solutions, LLC. The authors would like to thank the reviewers who provided valuable feedback. Internal reviewers at AFT included Jean Brokish, Tim Fink, Emily Liss, and Bonnie McGill. External reviewers included Max DuBuisson (Indigo Ag), Margaret Henry (PepsiCo), Nathan Fields (National Corn Growers Association), Amy Hughes (Environmental Defense Fund), Adam Kiel (Soil and Water Outcomes Fund), Bruce Knight (Strategic Conservation Solutions), Chris Kopman (Newtrient), McKenzie Smith (Climate Action Reserve), Ryan Smith (Danone North America), Thayer Tomlinson (Ecosystem Services Market Consortium), and a representative from a farm commodity trade association who wished to remain anonymous. Thank you also to Ryan Anderson (Sierra View Solutions) for the idea to use the Multi-Level Perspective theory and for coming up with the title of the report.

All errors of fact or interpretation belong to the authors.

This white paper was made possible by generous support from the Walton Family Foundation.

ABOUT THIS PAPER

In this white paper, we analyze the current state of agricultural carbon programs, explore four main reasons why farmer participation may be low, and recommend 12 strategic changes that would help these programs, which are mainly focused on cropland, to succeed. The most critical barriers that we discuss are the economics of the programs, concerns about additionality, requirements for permanence, and data and technology barriers for agriculture. We hope our analysis will help farm trade associations, environmental groups, carbon program developers, and policymakers better understand some of the specific barriers to enrollment that agriculture faces and identify changes that could lead to widespread adoption of farm conservation practices. If implemented, we hope the recommendations lead to systemic change that will transform agriculture from a source of greenhouse gas emissions to a sink. We also hope these changes will provide the public and producers with the assurance that the emerging agricultural carbon programs are a credible and cost-effective approach to climate mitigation and adaptation.

Executive Summary

KEVIN KEENAN

Globally, food production will need to increase more than 50% by 2050 to meet the needs of the world's projected population of 9.8 billion people. To avoid the worst effects of climate change and to protect ecosystems, increases in food production must be accompanied by sharp reductions in greenhouse gas (GHG) emissions from agriculture, increases in soil carbon sequestration on farmland, and no further conversion of natural ecosystems into agricultural land.

Over the past 28 years in the U.S., more than 20 agricultural carbon programs have been created to incentivize the adoption of agricultural practices to reduce GHG emissions and sequester carbon in the soil. These programs offer different eligibility criteria, crediting practices, data requirements, contracting obligations, costs, and potential returns, and they have continued to evolve over time. Fifteen of the programs were created in just the past five years. Recently, all the programs have increased outreach to farmers with information and calls to participate. Despite these marketing efforts, participation remains extremely low.

In this paper we analyze the current state of agricultural carbon programs and recommend strategic changes that would help these programs succeed, with a focus on cropland. This analysis will help farm trade associations, environmental groups, carbon program developers, and policymakers better understand some of the barriers to adoption and identify changes which could lead to widespread adoption of farm conservation practices.

The most critical barriers that we discuss are the economics of the programs, concerns about additionality, requirements for permanence, and data and technology barriers for agriculture.

We recommend the following changes to attract and retain producers in agricultural carbon programs:

ECONOMICS

- **Support policies that increase the price of carbon.** We discuss the steps companies, government, and agricultural carbon programs can take to send price signals and increase trust, confidence, and demand, thereby increasing the price of carbon.
- **Create data standards for agricultural carbon programs and associated data.** We identify opportunities for agricultural carbon programs and the United States Department of Agriculture's (USDA) new Partnerships for Climate-Smart Commodities program to develop and implement clear data requirements and stabilize agricultural carbon programs, which is vital for reducing producers' wariness and confusion as well as decreasing transaction costs.
- **Design and implement insetting programs that eliminate free riding and double counting.** We identify design criteria that corporate insetting programs, which are proliferating rapidly within the agricultural supply chain, should follow to ensure their integrity and success.
- **Pay early adopters to provide peer-to-peer training.** We recommend that farmers who have already adopted climate-smart practices be rewarded and paid to teach other farmers to successfully adopt and maintain these practices.

ADDITIONALITY CONCERNS

- **Improve definitions of "new" practices.** We recommend that climate-smart farm practices that were started and disadopted more than 10 years ago could be considered a new practice if the resumption of that practice can be shown to decrease net GHG emissions, and it can be determined the disadoption did not happen merely to join an agricultural carbon program. This will expand the pool of farms that can participate in programs and generate new GHG reductions.
- **Adopt crediting practices that account for the variability in agriculture.** We discuss approaches to setting baselines and issuing credits in ways that encourage long-term adoption of climate-smart practices.
- **Eliminate common practice ceilings.** We call for agricultural programs to stop capping participation once adoption of a practice reaches a certain threshold in a given area.
- **Create additional opportunities to reward early adopters.** In addition to recommending that early adopters be paid to provide farmer-to-farmer education, we encourage these producers to participate in other programs, such as the USDA's Conservation Stewardship Program.

PERMANENCE REQUIREMENTS

- **Include buffers for intentional reversals in agricultural carbon programs.** We recommend that agricultural carbon programs expand their current buffer pools to cover both unintentional and intentional reversals for agricultural carbon projects.

DATA AND TECHNOLOGY BARRIERS FOR AGRICULTURE

- **Expand producers' broadband access.** We support investments in high-speed internet access for producers in rural and tribal areas, to make it easier for them to participate in agricultural carbon programs.
- **Modernize USDA data collection and management systems and create a national model calibration dataset.** We suggest upgrades and safeguards to agricultural data infrastructure that will make it easier for farmers to participate in carbon programs and for researchers to improve the agronomic, climate, and economic models that underlie the programs.
- **Adopt national agricultural data policies.** We call on public, private, and nongovernmental stakeholders to develop clear guidance, regulations, and standards on the privacy, portability, and interoperability of agricultural data.

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Introduction

The current agricultural system will need to fundamentally transform within the next decade to produce food, mitigate and adapt to climate change, protect water resources, and support producers in the process. Over the past 28 years, 22 programs have been created and expanded (see Box 1) to incentivize the adoption of agricultural practices to reduce greenhouse gas (GHG) emissions, such as methane (CH_4) and nitrous oxide (N_2O), and to sequester carbon dioxide (C_2O) from the air as organic carbon in the soil. Throughout this paper we will collectively refer to carbon sequestration and avoided emissions of CH_4 and N_2O as GHG reductions. We also use the umbrella term agricultural carbon programs to describe carbon registries, carbon offset markets (both compliance and voluntary), carbon inset programs, and other emerging programs are that incentivizing or rewarding farmers for implementing practices that reduce GHG emissions from agriculture.

Though these programs have many motivations and goals, there is hope they will play a role in transforming agriculture into a more sustainable sector—one that uses fewer resources to produce food, fiber, and fuel, improves soil health, protects water resources and biodiversity, and reduces GHG emissions. These programs have different eligibility criteria, crediting standards and practices, data requirements, contracting obligations, costs, and potential returns, and they have continued to evolve over time. More than half of the programs were created in just the past five years. All the programs recently increased solicitations to farmers with information and calls to participate.

To help cut through the confusion and assist producers in sorting through a chaotic array of opportunities, many organizations have created producer-focused guides to agricultural carbon programs.[1] Despite marketing and

BOX 1. THE 22 AGRICULTURAL CARBON PROGRAMS REVIEWED FOR THIS PAPER

COMPLIANCE OFFSET MARKETS	
LAUNCH YEAR	PROGRAM
2009	Regional Greenhouse Gas Initiative (RGGI)—1 agricultural (ag) protocol*
2010	California Air Resources Board's (CARB) Cap & Trade Program—2 ag protocols*
2024	ICAO for CORSIA—ag protocols under ACR, CAR, & Verra are included

VOLUNTARY OFFSET MARKETS	
LAUNCH YEAR	PROGRAM
1995	American Carbon Registry (ACR)—3 active ag protocols*
2003	Chicago Climate Exchange (discontinued in 2010)
2006	Verra's Verified Carbon Standard (VCS) Program—8 active ag protocols*
2007	Climate Action Reserve (CAR)—6 ag protocols*

AGRICULTURAL CARBON PROGRAMS**		
LAUNCH YEAR	PROGRAM	TYPE OF PROGRAM
2016	CIBO	Both offset & inset
2016	Truterra	Both offset & inset
2018	Corteva	Offset
2018	Nori	Offset
2019	Carbon by Indigo Ag	Offset
2019	Indigo Ag: Market+Source	Inset
2020	Soil & Water Outcomes Fund (SWOF)	Inset
2021	Agoro Carbon	Offset
2021	Cargill RegenConnect	Inset
2021	Locus Ag's CarbonNOW	Offset
2022	ADM re:generations	Inset
2022	Bayer Carbon Program	Offset
2022	Ecosystem Services Markets Consortium's (ESMC) Eco-Harvest	Inset
2022	Nutrien	Offset
2022	PepsiCo-PCM	Inset

* See Appendices E and F for more details about active and discontinued agricultural protocols.

**Source: ISAP. (2023). An Overview of Voluntary Carbon Markets for Illinois Farmers. Illinois Sustainable Ag Partnership. https://ilsustainableag.org/ecomarkets

1. These include Illinois Sustainable Ag Partnership (ISAP, 2023), Farm Foundation (Farm Foundation, 2022), Farm Journal (Farm Journal Editors, 2021) (Farm Journal, 2020), Iowa State University (Iowa State University Extension and Outreach, March 2023), Progressive Farmer (Clayton, 2022), Purdue University (Thompson, et al., 2021), and the Carbon Tool Box (United Soybean Board, n.d.).

educational outreach efforts, participation remains extremely low. Of the more than 1.7 billion tonnes[2] of credits generated in voluntary carbon markets through the four largest voluntary offset organizations (ACR, VCS, CAR, and Gold Standard[3]) from 1996 through the end of 2022, merely 1% came from agricultural projects (So, Haya, & Elias, 2023). Even when including agricultural carbon programs that operate outside of the established compliance and voluntary carbon markets, there is huge untapped potential in the agricultural carbon space.

While many websites, articles, and webinars have compared the different programs and identified challenges with implementing and scaling up these programs, no organization has provided a systematic review with recommendations to modify existing and emerging programs to meet the unique challenges agriculture faces in implementing conservation practices.

In this paper we analyze the current state of agricultural carbon programs and recommend selected strategic changes that would help these programs succeed. We focus this paper on cropland and grassland practices because they have the smallest adoption rate and have had challenges scaling up. Significant reductions from the livestock sector are critical to avoid the worst impacts of climate change because the livestock sector produces large amounts of CH_4, a very powerful GHG (Box 2). However, the solutions for the livestock sector are significantly different than for croplands and grasslands and deserve a separate paper focused on their unique challenges.

This analysis will help farm trade associations, environmental groups, carbon program developers, and policymakers better understand some of the barriers to adoption and identify changes that could lead to the widespread adoption of farm conservation practices. Four of the most critical barriers that we identify and discuss in this paper are the economics of the programs, requirements for additionality,[4] requirements for permanence, and the immaturity of the technology and associated data protections necessary to quantify and monitor the GHG fluxes from implementing agricultural conservation practices.

BOX 2. U.S. AGRICULTURAL GHG EMISSIONS

According to the U.S. Environmental Protection Agency (USEPA), agriculture is the fifth largest source of GHG emissions in the U.S., with 9.4% of the nation's emissions (598.1 million tonnes ($MtCO_2e$)), behind the residential sector with 17% of the emissions, commercial with 17%, transportation with 32%, and industry with 34% of GHG emissions (USEPA, 2023).

Within the agriculture sector, on a CO_2-equivalent basis, 52% of emissions originate from N_2O, 46.5% come from CH_4, and just over 1% are from CO_2. The CO_2-equivalent basis takes into account the very high global warming potentials of N_2O and CH_4; that is, compared to one tonne of CO_2 over the first 20 years after their release, one tonne of N_2O has 273 times, and one tonne of CH_4 has 82.5 times, the impact on warming (Forster, et al., 2021). Hence, strategies to reduce N_2O and CH_4 emissions are among the largest opportunities for the agriculture sector to make an immediate impact on addressing climate change.

Furthermore, among the various types of agricultural activities that release GHGs, agricultural soil management and manure management on farmland emitted the most N_2O, followed by CH_4 emissions from enteric fermentation, manure management, and rice cultivation. CO_2 emissions from urea fertilization and liming activities on farmland come in last (USEPA, 2023). Thus, the reduction of N_2O and CH_4 emissions from agriculture is critical to reducing overall GHG emissions in the U.S.

2. By tonne, we mean metric tons, which is approximately 2,205 pounds.

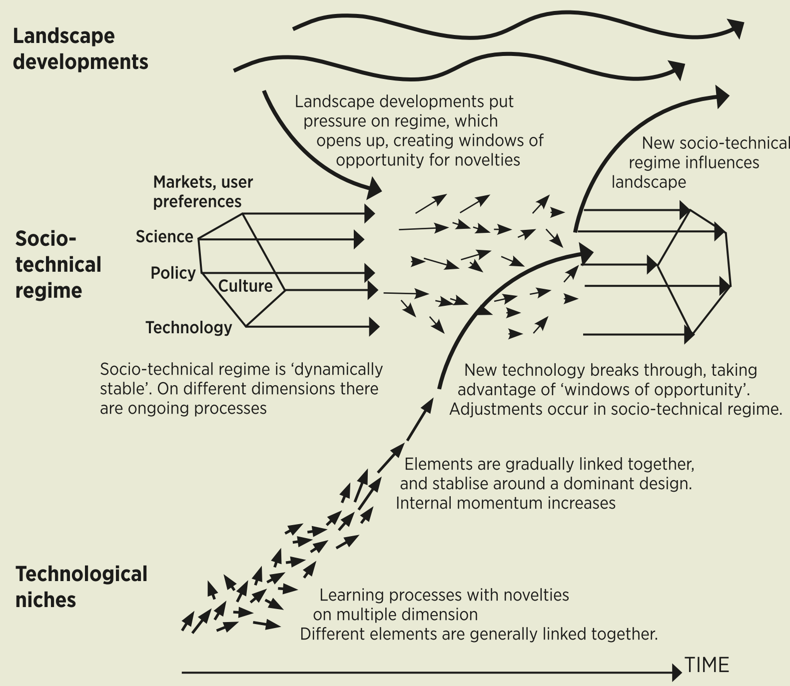
3. A fourth voluntary offset organization, the Gold Standard, has generated more than 238 $MtCO_2e$ worth of GHG credits from 2900 projects in over 100 countries (Gold Standard, n.d.). However, only 13,150 tCO_2e of credits have been issued in the United States and none of them for agricultural practices (So, Haya, & Elias, 2023).

4. Though there are varying interpretations of additionality, one of the most accepted definitions is that additionality is the implementation of climate-smart practices that would not have occurred in the absence of the incentive provided by a carbon program. This is because practices that have already been implemented are already mitigating climate change by reducing GHG emissions or sequestering carbon. What is needed is additional behavior change, additional practice adoption, and additional overall reductions in total net GHG emissions.

Methods

For our analytical framework, we used multi-level perspective (MLP) theory to analyze the current state of agricultural carbon programs and develop recommendations. MLP theory was developed by Arie Rip and René Kemp in 1998 and refined by Frank Geels and Johan Schot in the mid-2000s (El Bilali, 2019). It is a prominent framework used to describe societal transitions that include changes in consumer practices, market behaviors, business models, and technologies. MLP theory organizes transitions as interactions within and between three analytical levels: landscapes, regimes, and niches (Figure 1). The transition to a more sustainable system occurs within existing regimes as a result of external pressure at the landscape level combined with innovations that occur through niches (Konefal, 2015).

FIGURE 1. AN EXAMPLE OF MULTI-LEVEL PERSPECTIVE (MLP) THEORY (GEELS & SCHOT, 2007)



Landscape developments consist of the overarching market trends and systemic pressures on the agricultural supply chain. These include the impacts of climate change, macroeconomic drivers, and consumer preferences. Mitigation activities taken today will help reduce climate change impacts in the future, but in the short term, producers will need to continue to adapt to the changing climate with or without carbon programs while economic drivers and consumer preferences can provide price premiums that support carbon programs.

Regimes reflect the traditional and established institutions that comprise the current food and agriculture supply chain. The current regimes maintain the status quo and can hinder the transition to new practices and markets. Existing U.S. Department of Agriculture (USDA) programs, such as the Environmental Quality Incentives Program (EQIP); university research programs; complex corporate supply chains for feed and fuel; and current farming practices, such as conventional tillage, are all examples of existing regimes within the agriculture sector (Borsellino, Schimmenti, & El Bilali, 2020).

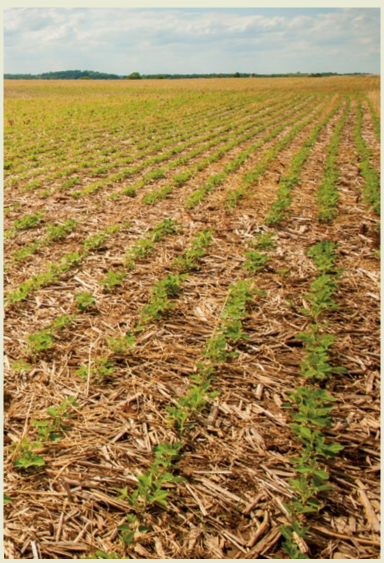
Niches are new technologies, new rules and legislation, new organizations, and new programs, projects, concepts, or ideas. Markets are a central part of developing emerging niches, and carbon programs are a prime example of a niche supporting regenerative agricultural practices (Borsellino, Schimmenti, & El Bilali, 2020). Niches are where innovation and disruption of current regimes take place and where the traditional rules can be broken. The more a niche matures and is adopted within the agricultural regime, the more likely it will scale up and contribute to regenerative agriculture transitions.

The following sections will use MLP theory to describe the current state of agricultural carbon programs. After laying the foundation of the MLP levels, we analyze the current challenges of carbon programs and provide selected recommendations on how to transform carbon programs in ways that will accelerate adoption of climate-smart practices (Box 3).

BOX 3. CLIMATE-SMART FARMING PRACTICES

In February 2022, in its National Funding Opportunity for the Partnerships for Climate-Smart Commodities (PCSC) program, the USDA provided the following list of climate-smart agricultural practices that have been identified by USDA's Natural Resource Conservation Service (NRCS) for their ability to reduce or avoid emissions of GHGs such as CH_4 and N_2O and remove CO_2 from the atmosphere through soil carbon sequestration (USDA, February 2022). In addition to reducing GHG emissions, the climate-smart practices offer a variety of co-benefits, which, depending on the practice can include increasing soil health, improving water quality, reducing input costs, increasing resilience to climate change, and supporting biodiversity. These practices include:

- Cover crops
- Low-till or no-till
- Nutrient management
- Enhanced efficiency fertilizers
- Manure management
- Feed management to reduce enteric emissions
- Buffers, wetland, grassland management, and tree planting on working lands
- Agroforestry and afforestation on working lands
- Afforestation/reforestation and sustainable forest planting for high carbon sequestration rate
- Maintaining and improving forest soil quality
- Increasing on-site carbon storage through Forest Stand Management
- Alternate wetting and drying on rice fields
- Climate-smart pasture practices, such as prescribed grazing or legume interceding
- Soil amendments, like biochar


EDWIN REMSBERG/USDA-SARE


RON NICHOLS/USDA


USDA/NRCS

Landscape

EDWIN REMSBERG/USDA-SARE

The current landscape has a direct impact on the design and operation of carbon markets. Three landscape components are included in our analysis of agricultural carbon programs: 1) climate change; 2) economic drivers; and 3) consumer food preferences.

CLIMATE CHANGE

Climate change is a driver for the development of agricultural carbon programs. The anthropogenic increase in atmospheric CO_2 and other GHGs has resulted in global warming and increasingly extreme weather events. It has also increased the daily minimum and maximum temperatures and altered precipitation frequency and volume worldwide. Across the globe terrestrial temperatures have risen by 1.32 ± 0.04 °C compared to the 1951–1980 average (Malhi, Kaur, & Kaushik, 2021). July 3 to 5 of 2023 were the hottest on Earth in more than 150 years (Plummer & Shao, 2023). To meet the Intergovernmental Panel on Climate Change (IPCC) pathway to limit warming from pre-industrial levels to no more than 1.5°C, global CO_2 emissions must decline by about 45% from 2010 levels by 2030 and reach net zero around 2050 (Masson-Delmotte, 2018).

As the impacts of climate change increase, agriculture will struggle to meet the needs of a growing population. The Food and Agriculture Organization estimates that yields of maize, wheat, and soybeans could decrease between 20 to 45%, 5 to 50%, and 30 to 60%, respectively, by 2100 (Vos & Cattaneo, 2016). At the same time, the global population reached 8 billion in November 2022 (United Nations, n.d.), up from 7 billion in 2010 and 6 billion in 1998 (Gu, Andreev, & Dupre, 2021). By 2050 production in developing countries needs to rise by 77% and by 24% in developed countries to meet these increased food and nutritional requirements (Malhi, Kaur, & Kaushik, 2021). Agricultural practices supported by carbon markets have the potential to reduce the negative impacts resulting from an increase in GHG emissions and promote the resilience necessary to produce food under more extreme weather events.

ECONOMIC DRIVERS

Margins for farmers have historically been low. To make a living, many producers must seek off-farm income. In 2021, the mean income for U.S. producers was $135,281 with $104,460, or 77%, coming from off-farm sources (USDA Economic Research Service, 2022). The need to generate additional income from off-farm sources may increase the interest and attractiveness of carbon programs. However, growers need economic support to offset the costs and risks associated with implementing new practices. These can include large upfront costs for equipment as well as agronomic (and associated financial) risks during the learning phase. Although the costs often decrease over time, there can be a gap between the upfront costs and long-term returns from participating in carbon programs. It is important to offer innovative financial mechanisms to help farmers bridge that gap (Field to Market, 2021).

CONSUMER FOOD DEMAND AND ENVIRONMENTAL IMPACTS

Over the past decade, the impacts of food production on climate, water quality, wildlife habitat, and animal welfare have been of increasing concern for consumers (Tuorila & Hartmann, 2020). A meta-analysis of 80 studies from around the world found that 29.5% of consumers are willing to pay a premium for sustainably produced products (Li & Kallas, 2021). In the U.S., 92.8% of Gen Z consumers (i.e., those born after 1994) consider the environmental characteristics of their purchasing decisions (Su, Tsai, Chen, & Lv, 2019).

Meat production is a significant climate concern given that nearly half of all direct agriculture GHG emissions come from livestock and poultry (USEPA, 2023). Furthermore, approximately 40% of all U.S. corn and 70% of all U.S. soybeans are grown to feed livestock, annually (USDA Economic Research Service, n.d.; USDA, 2015). Because of this impact, many organizations are focused on reducing meat consumption through programs like Meatless Mondays (GRACE Communications Foundation, n.d.).

However, only about a quarter of consumers are aware of the impacts or willing to stop or reduce meat consumption for environmental reasons (Sanchez-Sabate & Sabate, 2019), and the U.S. is not decreasing its consumption of animal products. Beef, pork, poultry, and dairy are all expected to increase through 2032, according to the latest data from USDA. In particular, beef production is expected to increase at an average rate of 1% annually (USDA, 2023), thus making it even more important for meat producers, and the growers farming millions of acres to produce feed and fodder crops, to adopt practices that reduce GHG emissions and increase resilience to climate change.

Though the scale of the challenge is hard to fathom, food production globally will need to increase by more than 50% by 2050 to meet the needs of the world's projected population of 9.8 billion people. This must be done with no expansion of agricultural land if we are to protect natural ecosystems. To put that in perspective, if current agricultural practices are employed globally, an additional 1.5 billion acres will be converted by 2050. From a GHG perspective, this trajectory will result in 15 billion tonnes ($GtCO_2e$) of emissions per year in 2050. To meet the Paris Agreement of holding global warming below to less than 2°C above pre-industrial temperatures, GHG emissions from agriculture must be reduced by 75% to just 4 $GtCO_2e$ per year (Searchinger, Waite, Hanson, & Ranganathan, 2019). To avoid the worst impacts of climate change, temperature increases need to be limited to no more than 1.5°C above pre-industrial temperatures, which will require reducing emissions well below 4 $GtCO_2e$ per year. Agricultural carbon programs could be an important mechanism to meet this goal.

Regimes

USDA/NRCS

For more than 90 years, there have been efforts to implement conservation practices on farmland in the U.S. The resource concerns driving these efforts initially focused on reducing soil erosion, then water quality and wildlife habitat improvement, and now climate change mitigation. USDA and universities have been the dominant regimes historically leading this work. More recently, corporations and investors are recognizing the need to reduce GHG emissions from agriculture.

USDA

The devastation of the Dust Bowl, starting in 1932, was the primary driver for the development of U.S. federal farm conservation programs. In response to the Dust Bowl, Congress enacted Public Law 74-46, which established the Soil Conservation Service, the predecessor to USDA's NRCS (USDA, n.d.). NRCS has an array of financial and technical assistance programs available to producers, which are described in more detail in Appendix A.

Despite significant investment in conservation over the last three decades, only 132 million acres, out of almost 900 million farmland acres reported to the Farm Service Agency, have participated in the largest and most popular USDA programs—EQIP, Conservation Reserve Program (CRP), and Conservation Stewardship Program (CSP). The majority of U.S. states have had less than 20% of their agricultural land participating in these conservation programs (Newton, 2019). Part of the reason for this is that annual spending for USDA's conservation programs remained constant for most of the past decade, at slightly more than $6 billion per year (Wallander, 2019).[5] Most programs receive more applications than they have funding to award. For example, USDA received approximately 125,000 national applications to EQIP but funded less than 50,000 (Happ, 2021). More details about the states where USDA programs have the highest enrollment are located in Appendix A.

Two farm conservation practices that USDA has supported over the years are getting the largest attention

5. Expenditures and enrollment are not measures of actual changes in sustainability, which are much harder to quantify.

in carbon programs: cover crops and the reduction of tillage events. These are the go-to practices that have been promoted by the agency for decades to address water quality by reducing soil erosion and nutrient loss. However, between 2006 and 2011, under $335 million, on average per year, was spent by 40 of USDA's programs on nutrient and sediment practices on cropland (Perez, Reytar, Selman, & Walker, 2014). In 2018 alone, out of a total budget for EQIP of $1.76 billion (Claassen, Hellerstein, & Wallander, 2019), USDA committed only $155 million in planned payments toward cover crops (Wallender, Smith, Bowman, & Claassen, 2021).

Two recent changes to USDA could dramatically change the impact of USDA's programs and put them more in the category of niches, rather than regimes. The first is the creation of the Partnerships for Climate-Smart Commodities program, which was designed to spend $3 billion over five years via 141 projects and over 1,000 partners to create new market opportunities for climate-smart commodities produced by farmers, ranchers, and forest owners (USDA, February 2022).[6] The Partnerships program is one of the niches that has the potential to transform the agricultural sector. The second change is the signing of the Inflation Reduction Act (IRA), which will provide $19.5 billion for conservation programs over a five-year period (Cosby, 2023). The Partnerships program and the injection of IRA funds could affect conservation outcomes in profound but as-yet poorly understood ways.

UNIVERSITIES

Universities provide both the science and technical assistance supporting agricultural conservation practices. They are the bedrock of the four regimes. Agricultural conservation practices, such as nutrient management, cover crops, and reduced tillage, trace their roots to the 1862 Morrill Act (Association of Public & Land Grant Universities, n.d.), which created land-grant universities (National Research Council, 1995). Subsequent legislation expanded the number of land grant universities to include historically black and tribal institutions as well as the scope of land-grant universities to conduct research, fund agricultural experiment stations, and establish cooperative extensions (National Research Council, 1995). It is this combination of basic research, applied research at the experiment stations, and local support through cooperative extensions that has created the foundational understanding of the science and economics underpinning current agricultural conservation practices.

6. It should be noted that this program was created using the Secretary's discretionary authority through the Commodity Credit Corporation and is not a permanent program.

Since their founding, the land-grant universities[7] have evolved and in the past decade, many of these universities have created departments or initiatives that focus on improving and expanding carbon markets. Examples include but are not limited to institutions like the University of Illinois, the University of New Hampshire, Michigan State University, Cornell University, and Colorado State University (CSU). In addition to providing training, these and other universities have developed tools for quantifying GHG fluxes from agriculture. Details on two illustrative examples (CSU's COMET-Farm tool (Miller, 2013) and Cornell University's agricultural carbon-focused programs) are in Appendix B.

CORPORATIONS AND INVESTORS

Corporations and private investors are important regimes in the food supply chain. Corporations not only send the demand signal for what crops should be produced but are increasingly adding climate and other environmental criteria to their procurement decisions. A recent survey of 100 senior decision-makers at food and agriculture companies found that their supply chains will face long-term challenges in adapting to the impacts of climate change (WTW, 2023). Investors extend between the regime and niche levels.

Corporations

U.S.-based food and agriculture companies are under increasing pressure to set GHG reduction targets. One example of the pressure corporations face is the Science Based Targets Initiative (SBTi), a partnership between the Carbon Disclosure Project (CDP), United Nations Global Compact, World Resources Institute (WRI), and World Wildlife Fund (WWF), which was founded to define and promote best practice in emissions reductions and net-zero targets in line with climate science.

According to the SBTi, 68 food and agriculture companies in the U.S. have either committed or set science-based targets, including Cargill, PepsiCo, and General Mills (Science Based Targets Initiative, 2023). Other companies have initiated and invested in internal programs that promote regenerative agriculture and lowering emissions. Examples of corporate SBTi goals of a variety of food and agriculture companies as well as descriptions of illustrative carbon programs can be found in Appendix C.

Companies are responding to more than just social pressure to set reduction targets; they are also investing in climate-smart agriculture to ensure security of supply in the face of climate change. The Covid-19 pandemic was a vivid demonstration of the impact of supply chain disruption and its costs, so there is more impetus than ever for food and beverage companies to focus on ensuring secure supply.

Investors

Investors are strategically investing in agricultural technology (ag tech) start-ups. In 2022, there were at least 89 ag tech deals totaling just under $1 billion in 2022, including climate monitoring and carbon trading. Ag tech has also proven more resilient than the overall venture market. While the overall funding for startups decreased by 35% between 2021 and 2022, ag tech funding only decreased by 13% (Welborn, 2023). Two examples of venture-backed ag tech investments can be found in Appendix D.

PRODUCERS

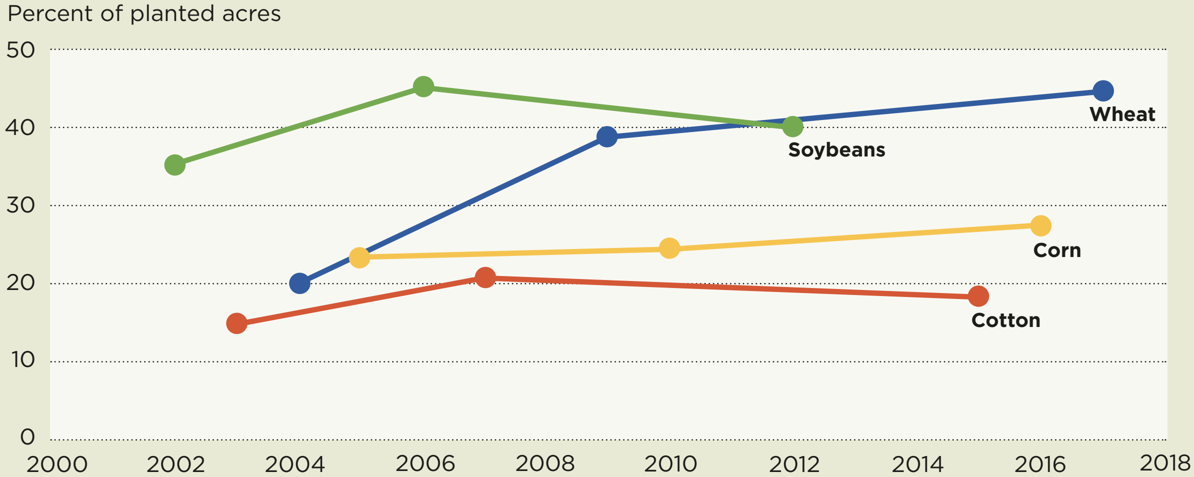
Without the implementation of agricultural conservation practices by producers, there would be no agricultural carbon programs. The practices listed in the USDA Notice of Funding Availability (Box 3) are examples of climate-smart practices included in many programs. Two agricultural conservation practices are getting significant attention in carbon programs: the reduction of tillage events and the planting of cover crops. They are the practices that the majority of agricultural carbon programs are supporting (ISAP, 2023), and the two practices that have attracted attention by market participants because of their ability to sequester carbon and provide climate resilience (Huang, et al., 2020).

No-Till

A 2020 study found that no-till or strip-till is practiced on 30% of cropland in the U.S. (Pannell & Claassen, 2020). Specific no-till adoption rates for 2002–2017 by crop are shown in Figure 2; adoption ranged from as low as 19% for cotton in 2015 to more than 40% for wheat in 2017. Additionally, adoption rates can vary widely based on geography, even with the same crop. These statistics obscure an important challenge—producers who implement no-till do not always maintain the practice. For example, between 2012 and 2017, although the overall no-till adoption rate increased across the country, no-till was discontinued on more than 5 million acres (Sawadgo & Plastina, 2022). One of the key challenges in adopting no-till is that it disrupts current farming norms, such as the perception of "clean" fields and the timing of planting in the spring (Kawa, 2021). A potential factor in discontinuing no-till may be that funding for participants

7. The 52 land-grant universities represent almost 11 million acres of Indigenous land once inhabited by approximately 250 tribes, bands, and communities. Today less than 0.5% of the enrollment at these universities comes from Indigenous people (Lee, et al., n.d.).

FIGURE 2. NO-TILL ADOPTION IN THE U.S. 2002–2017 BY COMMODITY CROP (CLAASSEN, 2018)



Note: No-till is based on the absence of tillage operations reported in the Agricultural Resource Management Survey (ARMS).
Source: USDA Agricultural Resource Management Survey data for 2002–2017.

in cost-share programs can decrease or even disappear after a certain amount of time in the program (Sawadgo & Plastina, 2022).

Cover Crops

Cover crop adoption in the U.S. is significantly lower than no-till. Cover crops are a key focus of state, regional, and federal conservation programs. They are also an important strategy encouraged by the federal-state Gulf of Mexico Hypoxia Task Force to address poor water quality conditions in the Mississippi River and Gulf of Mexico associated with agricultural runoff (USEPA, 2023). Despite the importance and support given to producers to plant cover crops, only 5.1% of harvested cropland planted cover crops in 2017, totaling 15.4 million acres, a 50% increase over the 10.3 million acres planted in 2012 (Wallender, Smith, Bowman, & Claassen, 2021). As with no-till, producers may not reliably plant cover crops every year, or after every crop in the rotation.

According to the USDA Agricultural Resource Management Survey (ARMS) nationwide survey, only one-third of cover crop acres in the U.S. were planted with a financial incentive program, meaning two-thirds were planted without financial support (Wallender, Smith, Bowan & Claassen, 2021). Similarly, the Sustainable Agricultural Research and Education (SARE) National Cover Crop Survey found that nearly 50% of the 1,172 farmers respondents did not receive incentive payments (SARE, CTIC, & ASTA, 2020). Thus, financial support remains important for about half of producers in providing a safety net support as they start adopting cover crops (Wiercinski, Yeatman, & Perez, 2023a) as upfront and agronomic costs can be high in the early stages of adoption (Field to Market, 2021).

Between 2012 and 2017, although total cover crop adoption increased overall, almost a million acres stopped planting cover crops (Sawadgo & Plastina, 2022).

Significant adoption challenges surround cover crops, including but not limited to the difficulty in timing the planting and termination of crops, challenges in implementing more diverse crop rotations, and the fact that cover crops do not work in the same way for all cropping systems and all regions (Roesch-McNally, Basche, Arbuckle, Tyndall, & Miguez, 2017). For producers who do plant cover crops, payments from cost-share programs can decrease or disappear after a certain amount of time in a program (Sawadgo & Plastina, 2022), and state and federal cost-share payments may be insufficient to cover producer costs, according to research on adoption in Iowa (Plastina, Liu, Sawadgo, Miguez, & Carlson, 2018).

For conservation practices such as no-till and cover crops to be more broadly adopted, the challenges of cost and yield impacts need to be overcome. Agricultural carbon programs can play a pivotal role in the expansion of these practices.

Niches

BRANDON O'CONNORUSDA-NRCS

More than 90 years after the founding of NRCS and implementation of the voluntary federal financial and technical assistance programs, 28 states have less than 20% of agricultural land participating in EQIP, CRP, and CSP, the three largest NRCS programs, by expenditures (Newton, 2019). More information on each of these programs is provided in Appendix A. Clearly, the status quo has not been enough to scale up conservation practices. Agricultural carbon programs are starting—and, with strategic modifications, have even greater potential—to disrupt the existing regimes by offering new incentives and support for the adoption of conservation practices. There are four categories of programs pioneering new approaches to reducing GHG emissions from agriculture. They are the offset markets, inset programs, corporate programs, and the USDA Partnerships for Climate Smart Commodities.

OFFSET MARKETS

Carbon offset markets were first developed in the late-1990s as an opportunity for companies wanting to balance out their GHG emissions by paying entities, mainly in developing countries, to reduce GHG emissions or maintain carbon in native forests. This has evolved into two primary markets—the compliance offset market and the voluntary offset market. Since 1996, more than 1.7 billion credits ($GtCO_2e$) have been generated through approximately 70 different standards including energy efficiency, refrigerant destruction, and cookstoves. The annual volume of credits has substantially increased since 2016—growing from about 52 million to almost 300 million in 2022 (So, Haya, & Elias, 2023).

Unfortunately, carbon offsets from agriculture remain elusive. At the Agri-Pulse Communications annual Ag & Food Policy Summit in March 2021, USDA Secretary Tom Vilsack said that the "carbon market is not designed and set up for farmers" (Tomson, 2021). Through the end of 2022, only 21.7 million offset market credits, or 1.3%, came from agricultural projects. Of those agricultural projects, 77% of those credits came from manure management systems (So, Haya, & Elias, 2023), which is important because CH_4 emissions from livestock account for 44% of the GHG emissions from the agriculture sector (Box 2). One of the significant barriers faced by agricultural carbon projects is high transaction costs, particularly the independent verification and sampling required by many carbon programs. There are two types of markets for agricultural offset projects: compliance markets and voluntary markets.

Compliance Offset Markets

The three compliance markets that operate in the U.S. are California's Cap-and-Trade program, the Regional Greenhouse Gas Initiative (RGGI) in the northeast, and the International Civil Aviation Organization's Carbon Offset Reduction Scheme for International Aviation. Each of these markets is discussed briefly below.

California's Cap-and-Trade program has generated 9.6 $MtCO_2e$ of offsets from agriculture. California's market will allow the use of 107 $MtCO_2e$ of offsets between 2023 and 2030 (California Code of Regulations, n.d.). This means that carbon-emitters in the state of California, such as food processors and electric utilities, can choose to buy a limited number of carbon offsets from producers nationwide to offset their emissions rather than reduce their own emissions, use existing allowances, or purchase allowances. The offset credits approved by the California Air Resources Board (CARB) for use in California have been generated under the livestock CH_4 digester protocol by paying dairy producers to install equipment that traps CH_4 from leaving manure lagoons. The captured CH_4 can be flared, with no additional energy value, or it can be used to generate electricity or as compressed natural gas for transportation. The other agricultural carbon protocol, the rice protocol, adopted in 2015, has not generated any credits (So, Haya, & Elias, 2023). More background on California's Cap-and-Trade program is in Appendix E.

The **Regional Greenhouse Gas Initiative (RGGI)** is a market-based cap-and-trade program for the power sector in the Northeast U.S. The program started in 2009 and by 2021, eleven states were participating in the program: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia (RGGI, n.d.). RGGI allows for five types of offset projects and only one, avoided agricultural CH_4, applies to agriculture (RGGI, n.d.). Furthermore, since its start in 2009, RGGI has only generated about 50,000 tCO_2e of credits, none from agricultural standards, and there does not appear to be any interest by the program to expand to include additional agricultural carbon offset protocols (RGGI, n.d.). Part of the reason for the lack of interest in the development of offsets under RGGI is that the price of allowances in the program was below \$10 per $MtCO_2e$ through the first half of 2021 (U.S. EIA, 2022) and was \$12.73 per $MtCO_2e$ at the June 2023 auction (RGGI, 2023). In comparison, California's Cap-and-Trade program started at \$10 per $MtCO_2e$ in 2013 and was \$30.33 per $MtCO_2e$ after the May 2023 auction (CARB, 2023).

The **International Civil Aviation Organization (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)** has approved eight registries to supply credits to the program. In the U.S., they include the American Carbon Registry, Climate Action Reserve, and Verra (ICAO Environment, n.d.). The CORSIA program is being implemented with a pilot phase from 2021 to 2023, the first phase from 2024 to 2026, and a second phase from 2027 through 2035 (ICAO Environment, n.d.).

The airline industry estimates that without CORSIA, the GHG emissions from international aviation would increase from 600 $MtCO_2e$ in 2020 to nearly 900 $MtCO_2e$ by 2035 (IATA, n.d.). The program has approved the use of all the agriculture focused protocols from the above registries for use under the program. Demand for credits is expected to increase as the program enters its first phase in 2024 (UNDP, 2022). For details on the protocols, see their descriptions in the following section. Additional background information on the CORSIA program is in Appendix E.

Voluntary Offset Markets

There are three voluntary offset organizations, also called carbon offset registries, that issue the majority of carbon credits in the U.S. They are the American Carbon Registry (ACR), Climate Action Reserve (CAR), and Verra.[8]

ACR was founded in 1995 and was the first private voluntary GHG registry in the world. Today, ACR has 18 approved standards. It has an additional 17 protocols[9] that have been discontinued due to lack of use. There are currently three active and eight inactive protocols that reward agricultural practices. A list of the protocols can be found in Appendix F. The active and inactive protocols have generated 269,472 tCO_2e since 2014 and involve practices such as reducing CH_4 releases from manure storage, reducing CH_4 emissions from rice cultivation and wetlands by using water more precisely, and decreasing N_2O emissions via precision fertilizer applications (So, Haya, & Elias, 2023).

CAR began as the California Climate Action Registry (CCAR) in 2001, which was set up by the State of

8. A fourth voluntary offset organization, the Gold Standard, has generated more than 238 $MtCO_2e$ worth of GHG credits from 2900 projects in over 100 countries (Gold Standard, n.d.). However, only 13,150 tCO_2e of credits have been issued in the U.S. and none of them for agricultural practices (So, Haya, & Elias, 2023). Therefore, they are not included in our analysis.

9. Where possible, we refer to the documents to credit GHG reductions as protocols. However, different organizations refer to them as protocols, standards, and methodologies. The differences between these designations are insignificant.

California for the voluntary reporting of emissions from California companies. In 2007, CCAR was rebranded as CAR and refocused on the development of offsets throughout North America and Central America. It is in the process of expanding globally. Today, CAR oversees 22 protocols spanning the region. Of the 22 approved protocols, six are applicable to agricultural practices in the U.S.—Grassland, Nitrogen Management, Organic Waste Digestion, Rice Cultivation, Soil Enrichment, and U.S. Livestock (CAR, n.d.). CAR is also developing a protocol for the production and use of biochar. Since 2014, CAR has generated slightly over 1 $MtCO_2e$ of agriculture-related credits for the voluntary market with 98% of the credits generated by reducing CH_4 emissions through the building of anaerobic digesters under the U.S. Livestock Protocol (So, Haya, & Elias, 2023). The Soil Enrichment Protocol (SEP), which was adopted in 2020, is starting to generate a significant volume of credits. As of June 2023, Indigo Agriculture has created 133,614 tCO_2e from nearly 430 producers across 22 U.S. states under the SEP (Indigo Agriculture, 2023).

Verra runs the Verified Carbon Standard (VCS) Program, with over 1,600 certified projects and more than 1 $GtCO_2e$ generated worldwide. The VCS program was launched in 2006 and has 47 approved protocols and four inactive protocols. Eight of the approved protocols and two of the inactive protocols are applicable to U.S. agricultural practices. A list of the protocols is in Appendix F. Verra has issued more than 250,000 tCO_2e offset credits from these protocols since 2014 with more than 200,000 coming from anaerobic digester projects (So, Haya, & Elias, 2023).

BOX 4. THE DIFFERENCE BETWEEN OFFSETS AND INSETS

In the most basic sense, the difference between an offset and an inset is that an offset is a reduction in GHG emissions that occurs outside of the direct supply chain of a company, and an inset is an emissions reduction within a company's supply chain. There are three primary differences between offsets and insets.

The first main difference is that offsets are reductions in GHG emissions not directly related to the business of the company purchasing them. They are typically used to offset direct, or Scope 1, emissions from the companies. The purchases are often from different sectors than the business of the company. For example, Microsoft's purchase of carbon credits from Land O'Lakes is an example of a company purchasing reductions from a different sector than their business (Ellis, 2021). Insets are reductions of the indirect GHG emissions that are outside the company's direct control but are part of a company's supply chain and customer emissions, also known as their Scope 3 emissions. Insetting is an important part of companies' commitment to address the emissions in their supply sheds, which customers, consumers, shareholders, and environmental groups view as their responsibility.

The second difference is that, because the inset reductions are part of a company's supply chain and there may be a relationship between the supply chain company and the company creating the inset project, these projects are inherently more collaborative than offset projects.

The third difference is that the rules for insets are still being defined. Many inset programs are being designed with more flexible and less rigorous measurement, monitoring, reporting, and verification (MMRV) requirements (Tipper, Coad, & Burnett, 2009).

An example of a potential insetting project is Mondelēz, the makers of Triscuit crackers, paying wheat producers in its supply chain to reduce fertilizer use. In contrast, an example of a potential offsetting project is Delta Air Lines purchasing credits for the use of efficient cookstoves in Kenya, which reduce the amount of fuel needed for cooking. While the wheat is part of Mondelēz's supply chain, Delta is not responsible for the emissions from rural cooking in Kenya.

CARLY WHITMORE/USDA-NRCS

INSETTING PROGRAMS

Carbon insetting has recently become attractive to food, beverage, and apparel companies interested in reducing the emissions associated with the goods and services they purchase, which is typically one of the largest sources of a company's Scope 3 GHG emissions.[10] By developing deeper relationships with the entities in their supply chain, both corporations and their suppliers have a mutual interest in the security of production and the success of farmers who are at the heart of their business. One of the benefits of insetting is that because there is a relationship between the farmers and the food companies, the approach has the opportunity to be more collaborative.

In some cases, independent third-party verification may not be pursued since the entities have a relationship built on trust (Tipper, Coad, & Burnett, 2009). The organizations designing insetting programs may also reduce the stringency of the requirements for the measurement, monitoring, and reporting of the GHG reductions implemented by the producer compared to those used in offset markets, which is the approach of the Value Change Initiative (VCI) (Tufinio, Bloch, & Streicher, 2021). It is still too early to determine if the reduction in MMRV requirements will significantly reduce the transaction costs of implementing agricultural conservation practices or if it will translate into larger payments to producers.

The views on and understanding of insetting programs are in flux because these programs were launched in 2016 or later and most are still in their pilot phase. At the publication date of this white paper, we are observing that the terms "insetting" is evolving as an umbrella term that covers two different activities:

- Some companies are paying farmers who have already implemented practices, such as no-till and cover crops, to reward the producers for doing so and to help the food company minimize their Scope 3 GHG emissions baseline. This approach is referred to as the inventory method to GHG accounting under the draft Land Sector and Removals Guidance from the GHG Protocol[11] (WRI & WBCSD, 2022b). According to GHG Protocol definitions, this method does not need to achieve additionality.[12]
- In contrast, accounting for credited emissions reductions and removals requires companies to credit new practices. This guidance is used when a company has established its Scope 3 GHG emissions baseline and set a Scope 3 GHG emissions reduction target (e.g., net-zero targets by 2050 or percent reduction goals). To make progress towards that emissions reductions goal, these companies can incentivize farmers to begin adoption of new climate-smart practices and claim those reductions through the crediting method because they are additional, as called for by Section 13 of the draft Land Sector and Removals Guidance (WRI & WBCSD, 2022b).

An advantage of both variants of insetting programs is that they keep emissions reductions by farmers within the agricultural sector and they can be claimed by multiple companies that use or process the agricultural commodity. In that way, Scope 3 emissions are associated with a product throughout the supply chain. For example, if a producer implements nutrient management on a corn field that is in the geography purchased by a food company (also called the company's supply shed), those GHG reductions travel with the corn to the mills it uses, the food processing plants, storage warehouses, and retail stores.

Any downstream company that can demonstrate a relationship with the climate-smart management practices can claim reductions within its supply shed. This can be done without tracking the exact bushel of corn where those benefits were generated. Separate guidance from the GHG Protocol acknowledges and allows for this approach (WRI & WBCSD, 2022a).

Several corporations are piloting the draft Land Sector and Removals Guidance, published by the GHG Protocol in September 2022, as they develop and implement their insetting programs (WRI & WBCSD, 2022b).

One of the challenges with insetting, however, is that, even with the draft guidance from the GHG Protocol, there are few standards for such programs. A 2022 report by the United Nations Food and Agriculture Organization and the European Bank found that "Several initiatives have attempted to develop standards for insetting, but resulting standards diverge in recommended approaches and definitions" (Santos, di Sitizano, Pedersen, &

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10. Scope 3 emissions are the indirect emissions that occur in a company's value chain. These are different than the direct (Scope 1) emissions that are emitted by the company's own facilities under their direct control, and the GHG emissions associated with the purchase of electricity for use in their operations (Scope 2 emissions). Examples of Scope 3 emissions other than purchased goods and services include business travel, transportation and distribution of products, and use of sold products.

11. The GHG Protocol was jointly developed in 1998 by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) and is seen as the authoritative guidance on GHG accounting.

12. Additionality is the implementation of a practice that would not have happened without the incentive provided by a program (WRI & WBCSD, 2004). See the "Additionality Concerns" sections below for more detail.

Borgomeo, 2022). Without independent and consistent standards, companies may develop weak programs that do not reduce GHG emissions or credit practices that are not new.

There are significant challenges in developing these programs, which is demonstrated by there being no publicly available information on the volume of GHG reductions the programs have generated to date. Three organizations are adding their perspective to the design and implementation of insetting programs: SBTi, the Value Change Initiative (VCI), and the International Platform for Insetting. These organizations will have a significant impact on the development of insetting programs, but it is too early to analyze their impact as many are still developing or piloting their standards and requirements.

OTHER CARBON PROGRAMS

Recognizing the limited production and high cost of generating agricultural carbon credits over the last 28 years in the compliance and voluntary offset markets, some companies and nonprofit organizations are working to disrupt the offset and inset markets by developing their own programs. These programs combine aspects of compliance and voluntary offset markets as well as insetting programs. Some programs have expanded their scope to credit co-benefits such as water quality and biodiversity. Because of the evolution in this space, it is hard to differentiate between inset and other carbon programs. Since 2016, 15 agriculture-focused carbon programs have been developed by companies and nonprofits (Box 1); and are marketing themselves as offset or inset programs, or as providing both options (ISAP, 2023).

While many of these efforts were launched as standalone programs, an increasing trend for these programs is to align themselves with the more traditional carbon offset organizations. This alignment allows programs to have an independent body assessing the rigor of the credits and providing services such as developing and updating protocols, managing verification body approval, and issuing and retiring credits. These agricultural carbon programs can then spend their time on producer enrollment and technical assistance.

One goal of many of these programs is to spur innovation faster than through the traditional offset or emerging inset programs. Like the inset programs, most of these other programs are still in their infancy and are piloting the initial protocols or projects. The next several years will be pivotal in the development of these programs.

USDA PARTNERSHIPS FOR CLIMATE SMART COMMODITIES

The most recent development in the niches is the launch of the USDA Partnerships for Climate-Smart Commodities (Partnerships program), which was announced in February 2022. The program will finance up to 141 pilot projects with more than $3.1 billion of taxpayer support to produce, sell, and promote climate-smart commodities over the next five years.

This program is expected to reach more than 60,000 farms operating more than 25 million acres and generate more than 60 $MtCO_2e$ of GHG reductions over the five years of the program (USDA, n.d.). The pilot projects will investigate a variety of approaches to create climate-smart commodity markets, including the development of offset and inset programs. One of the key components of the Partnerships program is the quarterly collection and analysis of data from the projects (USDA, n.d.). This has the potential to bridge gaps between traditional USDA conservation programs and agricultural carbon programs. In addition, the Partnerships program's focus on MMRV could help reduce one of the largest costs to the development of agricultural carbon projects.

Analysis

LANCE CHEUNG/USDA

MLP theory helps frame the challenges underlying and influencing the agricultural carbon markets. The theory recognizes that regime change, and social and technical transitions require changes in practices, policies, infrastructure, and business models, which can be tested at smaller scales in the technological niches (Geels & Schot, 2007; El Bilali, 2019). Incredible amounts of change throughout all levels of society are needed to keep global warming to 1.5°C or less and will require reducing GHG emissions 45% from 2010 levels by 2030 (United Nations, n.d.).

In 2020, U.S. agriculture generated about 598 $MtCO_2e$ of emissions or about 9.4% of total national GHG emissions (USEPA, 2023). Climate change is forecast to decrease crop yields between 20 to 60% by 2100 (Vos & Cattaneo, 2016). In 2022 alone, citrus growers in Florida lost 50–90% of their crop to high winds and rain, and in the Plains and Midwest, drought reduced the winter wheat harvest by 25% and caused growers to abandon 43% of cotton acres in New Mexico (Sorensen, Murphy, & Nogeire-McRae, 2023).

At the same time, improved cropland and grassland management practices has the potential to store more than 250 $MtCO_2e$ annually in the U.S. alone; equal to about 4% of total annual U.S. GHG emissions (Chambers, Lal, & Paustian, 2016). In addition, the Biden Administration has a plan to reduce agricultural CH4 emissions by more than 150 $MtCO_2e$ by 2035, which stem from manure and enteric fermentation and account for 37% of all CH4 emissions in the U.S. (White House Office of Domestic Climate Policy, 2021). Because the adoption of many climate-smart practices, including reduced tillage and cover crops, is low in more than half of U.S. states, there is a significant potential to expand practices through agricultural carbon programs.

We have identified four primary reasons that help explain limited producer participation in agricultural carbon programs for croplands: economics of programs, additionality concerns, permanence requirements, and data and technology barriers.

ECONOMICS OF PROGRAMS

The success of voluntary conservation programs in the U.S. has been limited by available funding, which is in part why 28 states have 20% or less of their agricultural land participating, at some point, in federal conservation programs (Newton, 2019), including the top 10 agricultural states as measured by gross receipts (USDA Economic Research Service, 2023).

One of the significant challenges in adopting climate-smart practices, including participation in agricultural carbon programs, is that when financial assistance is not available or the program payments do not cover the full cost of adoption, the producers cannot fully recover their investments and may experience reduced yields in the early years after adoption, further enlarging the economic impact (West & Post, 2002; Saak, et al., 2021; Deines, Wang, & Lobell, 2019). In some cases, farmers attribute increases in yield to their use of no-till, cover crops, and nutrient management or net income improvements due to reductions in input costs, though results are not always positive (Wiercinski, Yeatman, & Perez, 2023b).

Farmers do receive several economic benefits which may go unquantified (e.g., resilience to weather extremes, pest and disease control, and improved nutrient cycling), and society also benefits from resulting soil carbon sequestration and reduced impacts on water quality and biodiversity (Rejesus, et al., 2021). Some programs recognize and reward holistic environmental benefits from new practices; for example, the Soil and Water Outcomes Fund makes joint carbon and water payments.

Producer payments are insufficient to gain participation. A recent study by McKinsey & Company found that approximately 50% of producers are not participating in carbon markets because the return on investment is not high enough (McKinsey & Company, 2022). One of the reasons producers may not see the financial benefits is that 59% have never calculated the economic benefits of adopting conservation practices (Slattery D., 2022). Another possible deterrent is that it can take years for carbon benefits to accrue with practices such as cover crops and reduced tillage (White, Brennan, Cavigelli, & Smith, 2020; West & Post, 2002).

Some of the highest paying carbon programs and pilots (such as Indigo Ag, Soil and Water Outcomes Fund, and the Corteva pilot) have paid producers up to $30 per acre for implementing practices, although average payments are lower (ISAP, 2023). This is in contrast to typical EQIP payments for cover crops averaging $50 to $54 per acre and state programs, such as those in Maryland seeking to improve water quality the Chesapeake Bay, that pay as much as $55 to $95 per acre for cover crops (Myers, Weber, & Tellatin, 2019; Keppler, Maryland's 2022–2023 Cover Crop Program, 2022). If producers grow cover crops, in between commodity crop rotations, on the same field for three consecutive years, they can earn as much as $160 per acre (Keppler, Cover Crop Plus, n.d.).

A choice experiment involving hundreds of corn and soybean producers in Indiana concluded that farmers who have never tried any form of reduced tillage would require nearly $40 per acre of additional revenue to implement no-till, compared to about $11 per acre for producers who have implemented conservation tillage (Gramig & Widmar, 2018). This makes sense as farmers are more likely to reduce tillage in stages rather than change immediately from conventional to no-till. Furthermore, producers indicated that they preferred flexibility: on average, they wanted an additional $10.57 per acre to enter into a multi-year contract to maintain conservation tillage. Finally, the farmers preferred government payments over agricultural carbon programs (Gramig & Widmar, 2018).

A carbon program payment of $30 per acre is a fraction of the revenue a corn producer receives for growing corn. Assuming the average 2022 yield of 172 bushels of corn per acre (Schnitkey, Paulson, Baltz, & Zulauf, Weekly Farm Economics: Corn and Soybean Yields in 2022, 2022) and an average price of $6.86 per bushel (Schnitkey, Paulson, Baltz, & Zulauf, 2022 Harvest Prices: Payments for 2022 and Indications for 2023 Projected Prices, 2022), the gross revenue per acre for a corn producer is approximately $1,180. A carbon payment of $30 per acre is only an additional 2.5% of gross revenue per acre. If implementing the practices reduces yield by more than 4 bushels per acre, producers lose revenue.

Depending on GHG, per acre outcome generation and payment opportunity can be small. The amount of GHG emissions that can be reduced per acre for some conservation practices is low. The first project to generate GHG reductions from nutrient management practices was verified in 2014 and resulted in 2 tCO_2e on a 40-acre field (ACR, n.d.). At a price of $40 per tCO_2e, that only generates $2 per acre gross revenue for the producer. This is one of the reasons why protocols such as Changes in Fertilizer Management, Compost Additional to Grazed Grasslands, and Rice Management Systems were moved to inactive status by ACR (ACR, n.d.). Since 2010, eight projects have been listed for CH_4 and N_2O reductions from croplands. Of these projects, five generated a modest 672 tCO_2e and three did not generate any credits at all (So, Haya, & Elias, 2023).

More recently developed programs, such as CAR's Soil Enrichment Protocol (SEP) and ForGround by Bayer and VCI, credit the soil carbon sequestration practices of no-till and cover crops. This is because these practices generate more GHG reductions per acre under the current protocols than nitrogen management practices. This is evident when looking at the volume of credits generated by the projects. Three projects using improved nitrogen management protocols generated only 75 tCO_2e between 2011 and 2023, whereas two projects under the CAR SEP generated 111,677 tCO_2e between 2018 and

2023 (So, Haya, & Elias, 2023). However, programs that include no-till and cover crops are only cost-effective for developers when they enroll a large number of producers. For example, one of the CAR SEP projects has issued 111,645 tCO_2e to a project developed by Indigo Ag that includes 430 producers in 22 states. Producers were paid up to $30 per tCO_2e per year for their involvement in the project (Indigo Agriculture, 2023).

Agricultural soil carbon sequestration prices are forecast to increase. In 2021, the global voluntary carbon market was valued at more than $2 billion and generated almost 300 $MtCO_2e$ of reductions, meaning that the average credit sold for about $6.66 per tCO_2e (Research and Markets, 2022). Based on average emissions reductions generated in Indigo Ag projects, which pay producers up to $30 per tCO_2e (DuBuisson, 2023), most producers could not generate enough credits to reach the $40 per acre threshold that Gramig & Widmar (2018) found that Indiana corn-soybean producers wanted to receive in order to adopt reduced tillage. Thus, these producers are not likely to be interested in carbon programs at current prices.

A recent Bloomberg New Energy Finance forecast that the price for high-quality credits from nature-based solutions will reach $38 per tCO_2e by 2039. The forecast also included an unlikely scenario where prices would increase above $250 per tCO_2e if the market were limited to carbon removals (such as soil carbon) and prohibited avoidance credits (such as avoided deforestation) and clean energy projects. This scenario could run the risk of driving companies away from setting sustainability goals at all, due to the cost (BloombergNEF, 2023). However, a six-fold increase in average credit price could improve the attractiveness of carbon markets to agricultural producers.

Transaction costs minimize value for market providers and payment to producers. Even if prices rise dramatically, the transaction costs associated with MMRV requirements are limiting the development of projects. According to conversations with carbon credit developers, the cost of verification alone can be as high as $40,000 per project, 50% of the total development cost (Parkhurst, 2023). One of the primary drivers of this cost is the number of sites that offset protocols require verifiers to visit. The good news is that verification costs do not necessarily scale with the size of a project (DuBuisson, 2023).

An additional significant development cost is soil carbon sampling. If a project is doing extensive sampling, sampling costs can equal or even exceed the costs of verification (Parkhurst, 2023). This is because soil carbon content varies widely between and within fields and it changes very slowly, requiring a lot of sampling to statistically detect a change over time. It is important for agricultural carbon programs to find ways to reduce such costs while maintaining the quality and rigor of their credits; one should not come at the expense of the other.

The inset market was designed to address these transaction costs. As one example, the VCI developed guidance for the verification of Scope 3 GHG impacts. ESMC completed VCI validation and verification for a subset of their enrolled producers, laying a foundation for scaling verification across their broader portfolio of projects in future cycles. The first five producers participating in ESMC's program farm more than 550 acres and have implemented practices including conservation tillage, nutrient management, cover crops, and/or irrigation management. The results of this pilot will provide an important early indication of whether and how this insetting approach can reduce MMRV costs.

If insetting programs can significantly reduce the MMRV costs, producers could be paid more for implementing practices because less is spent on activities such as measurement and verification. The goal of some programs is to ensure that at least 75% of the money goes directly to farmers, with the remainder spent on MMRV and technical assistance (Henry, 2023). A possible drawback of insetting is that these less rigorous approaches could be viewed as producing lower quality emission reductions with higher degrees of uncertainty in the reductions, which could potentially hurt the value to growers in the long term. As with all carbon programs, insetting programs must continuously seek to balance quality and rigor.

Insetting rules may allow free rides by companies along the supply chain. As described in the niche section, insetting programs allow each company in the supply chain of a food ingredient to claim the reduction implemented by the producer (WRI & WBCSD, 2022a). The challenge with this approach is that if a company pays for an insetting credit and publicly reports this information, for instance in their annual corporate social responsibility report, then other companies in the supply chain could also claim that reduction without paying for any of the credit. This double claiming, while allowed in all insetting programs, could lead to a volunteer's dilemma where one company pays for the benefits and other companies upstream and downstream of that company can make the same claim for no cost (Campos-Mercade, 2021). It is important for companies to develop transparent approaches that allow double claiming, the assertion of Scope 3 emission reductions throughout the supply chain, while avoiding multiple companies counting the same reductions, also known as double counting. In addition, these programs should be designed to avoid free rides of companies that do not contribute to the reductions in the supply chain.

Program instability and uncertainty undermine participation interest. A persistent challenge with carbon markets is their lack of stability. One of the earliest agricultural carbon programs was the Chicago Climate Exchange. Between 2003 and 2010, the program generated approximately 84 $MtCO_2e$ of carbon credits (Lavelle, 2010). When the program ended in 2010, many producers were left with credits they could not sell (Gronewold, 2011). This closure came at a great cost to producers who invested time and money in the program in anticipation of generating carbon credits (Swette Center for Sustainable Food Systems, 2020).

Our analysis considered 22 programs in various stages of development (Box 1). Nine of these programs were launched after 2020. In that short period of time, there have already been significant changes. For example, Farmers Business Network's Gradable Carbon program launched its program in 2021 and discontinued it in 2022; the pilot program by Corteva and ESMC was dissolved; and new partnerships were launched between Nori and Bayer, and between Corteva and Indigo Ag (Iowa State University Extension and Outreach, March 2023). The uncertainty caused by the frequent changes in programs exacerbates producer reluctance to commit to the requirements of a program.

ADDITIONALITY CONCERNS

One of the most important, controversial, and difficult characteristics of any environmental program, not just an agricultural carbon program, is additionality. In the simplest of terms, additionality is the implementation of a practice that would not have happened without the incentive provided by a program (WRI & WBCSD, 2004). The complexities of additionality are reflected in the differing rules employed by different agricultural carbon programs, and in some cases these approaches could lead to perverse outcomes.

Changing practices or habits is difficult for people and industries. Significant research has been conducted in this space to identify helpful "nudges" to encourage behavior change, especially when the future is at stake (Thaler & Sunstein, 2021). Social factors matter in farming and barriers to widespread change can include not just financial considerations but also social norms, peer pressure, and farmer identity (Field to Market, 2021; Lequin, Grolleau, & Mzoughi, 2019; Liu, Bruins, & Heberling, 2018). As a result, accelerating adoption of climate-smart practices is likely to require a comprehensive approach that provides producers not just financial incentives but also social and technical support. Some carbon programs attempt to address these multiple barriers.

We focus our analysis and recommendations primarily on economic incentives, but we also identify some opportunities for carbon programs to provide valuable social support and nudges to producers. We acknowledge the complex nature of farmer decision making and the importance of a holistic approach to driving change.

Early adopters are not included in most agricultural carbon programs. Though there are many differences between the voluntary and compliance offset markets, insetting programs, and other agricultural carbon programs, the majority of 22 programs listed in Box 1 uphold additionality and exclude early adopters (individuals who are already using a climate-smart practice). The objective of additionality is that a buyer is paying for an outcome where the payment was the incentive for the producer to implement the practice and track its outcome. Because the buyer is paying for a behavior change and the new outcome associated with that change, anyone who began implementation of the practice historically (an early adopter) is typically not allowed to participate in these programs. These early adopters—e.g., the producers using no-till on 30% and cover crops on 5% of cultivated acres—are excluded from most programs focused on no-till and cover crops. As long as they continue to use no-till and cover crops, they will continue to enjoy the soil health, economic, water quality, and climate resilience benefits of their ongoing practice use, and society is better off because of their ongoing investment in soil health.

As mentioned earlier, some corporations are rewarding these early adopters by including them in their Scope 3 GHG emissions inventories, which allows the corporations to minimize the emissions they are associating with their baseline. Government programs such as the USDA's CSP also reward producers for their existing use of conservation practices and attainment of stewardship management thresholds for resource concerns (e.g., water quality-nitrogen, water quality-sediments, etc.) but do so in exchange for new, additional practice adoption that is also financially supported (USDA NRCS, 2021).

Careful design of agricultural carbon programs must evaluate whether and how to incorporate early adopters and whether they should get paid for continuing existing behavior. See Box 5 for a discussion of how current additionality bottlenecks could be alleviated by programs shifting their focus towards other priority climate-smart practices.

BOX 5. EXPANSION OF THE MARKET OFFERINGS FOR REDUCTIONS IN N_2O AND CH_4 MAY HELP AMELIORATE CURRENT ADDITIONALITY BOTTLENECKS

One current challenge with additionality stems from the fact that most of the emerging programs for cropland management are focused on soil carbon sequestration and limit payment to two practices: cover crops and no-till (ISAP, 2023). Though all but two of the 15 programs reviewed by ISAP do offer a third or a fourth eligible practice (mostly some form of nitrogen management), the bulk of the focus and the net GHG emissions reductions are expected to come from just cover crops or some form of reduced tillage (ISAP, 2023). And these important practices offer a plethora of climate resilience, water quality, and soil health-building benefits as well.

However, focusing primarily on cover crops and no-till rather than practices that generate large-scale reductions in N_2O and CH_4 emissions, which have higher global warming potentials than CO_2, delays generation of critical reductions from the agriculture sector. Though compliance and voluntary offset markets for the livestock sector have focused on CH_4 largely via manure digesters, which have yielded climate and water quality benefits, they have paid less attention to the large emissions reduction opportunities available via non-digester manure management practices and feed additives for enteric fermentation. Attention to CH_4 and N_2O will require the development of additional agricultural carbon program offerings inviting more (and more types of) producers to participate, thereby lowering the problems of additionality caused by focusing primarily on just two cropland practices.

Carbon programs do not adequately define what constitutes a new practice. Carbon offset protocols and most carbon programs define additionality as the implementation of practices for the first time. For example, the CAR SEP requires "one or more changes in pre-existing agricultural management practices" (CAR, 2022). This limits the potential involvement of a producer's fields to those where a carbon-sequestering or GHG emissions-reducing conservation practice has not yet been implemented.

The challenge with this otherwise good definition of additionality is that there is no time limit associated with it. A strict reading of the protocols would only allow "brand new" practices to be credited. The conundrum is "what does *new* mean?" For example, consider a producer who tried a climate-smart practice in the past, stopped using it prior to the historic baseline of a carbon project (typically three to five years), has since been using practices that do not reduce GHG emissions, but is now interested in trying the climate-smart practice again. Would that producer be allowed to participate in a carbon program because the climate-smart practice would be "new-ish"? The language in most programs is unclear.

Annual crop producers such as corn and soybean farmers only have 40 to 50 harvests in their careers, and agronomic decisions are often made to minimize risk and maximize yield (Peterson & Tomel, 2001). This may be why producers with nearly 1 million acres in cover crops and more than 5 million acres of no-till stopped implementing those practices between 2012 and 2017 (Sawadgo & Plastina, 2022). At the same time, the logic of additionality is to pay for practices that would not have otherwise occurred, rather than practices that have already been adopted, even if those practices were stopped for a significant period of time.

However, scenarios are possible where implementation of these disadopted practices should qualify as additional. For example, if a practice was stopped and significant time has passed so that less carbon is sequestered in the soil, the resumption of practices could be credited. Or, if a producer planted cover crops more than 10 years ago and has not used them since that time, the soil carbon sequestered by cover crop usage should have decreased. Thus, in both cases, there could be a net increase in soil carbon sequestration from starting no-till and/or cover crops again. The critical consideration is avoid creating perverse incentives, e.g., for the producer to till up their fields only to implement no-till a few years later. The time between conservation practices needs to be long enough, such as 10 years, to prevent these adverse outcomes.

When used as a floor by offsetting markets to reward early adopters, "common practice baselines" violate additionality. Some protocols, such as the archived ACR Rice Management Systems (ACR, n.d.), use a common practice baseline to pay early adopters in order to promote the program to others who have not yet adopted the practice. That is, if most producers in a region have not implemented a practice, a producer that has historically implemented the practice can generate carbon offsets under the protocol, such as ACR's Rice Management Systems. For example, if a protocol sets a common practice baseline as 5% adoption in a county, any producer in that county with less than 5% adoption can generate offset credits for the practice that they initiated decades ago and are continuing currently. The objective of this approach is to encourage the adoption of practices by rewarding early adopters who implemented practices, paying them, and promoting their participation to encourage other producers who have not adopted to participate in the program. This approach rewards producers who already implemented practices, which is inconsistent with established definitions of additionality.

When used as a ceiling to exclude late adopters, common practice baselines prevent progress towards climate goals. On the opposite end of the spectrum, some programs cap participation once adoption of a practice reaches a certain threshold. In the CAR SEP protocol, once the adoption of no-till, reduced-till, cover crop adoption, rotational grazing, and intensive grazing reach an "uptake rate of more than 50% of either total cropland area, or total pasture operations," they are considered ineligible for crediting under the protocol (CAR, 2022). This approach is problematic because there are often agronomic, technological, or financial reasons why a producer has not implemented a practice when many of their neighbors have, such as specific soil types or slope conditions, access to equipment, or inability to afford upfront costs such as new equipment. This approach to additionality prohibits the full uptake of practices that are critical to stabilizing global temperatures at less than 1.5°C.

The nature of agriculture makes the determination of additionality challenging. Additionality is more straightforward in carbon credit programs outside of agriculture, where the options are more black-and-white—e.g., are the trees still standing, were they planted, were the solar panels installed, were the refrigerants destroyed, or was the CH_4 captured and destroyed from the mine. Unlike those carbon credit programs and practices, the challenges associated with agricultural practices are unique. Every year, producers decide what to plant, when to plant it, how much fertilizer to apply, and make many other choices. This is because producers are operating in shifting conditions that change over time and space, such as temperature, rainfall, and soil type. All these variables complicate decisions for the producer; as a result, determining additionality for agriculture practices has been a particularly complex challenge in designing carbon programs.

Additionality definitions are becoming standardized, but they do not adequately address agricultural challenges. Many organizations are working to standardize the definition of additionality. Overall, this is a good thing, but the organizations are not considering the challenges associated with agriculture. Regardless of the organization or approach taken to develop additionality rules, the challenges associated with the implementation and maintenance of agricultural conservation practices must be considered.

Examples of organizations setting market-wide additionality rules for carbon programs are:

- **The Integrity Council for the Voluntary Carbon Market.** Their Core Carbon Principles define additionality to be when the practices "would not have occurred in the absence of the incentive created by carbon credit revenues" (ICVCM, n.d.).
- **Voluntary Carbon Markets Initiative.** VCMI's Provisional Claims Code of Practice states that practices are "additional to those that would occur in the absence of demand for carbon credits" (Voluntary Carbon Markets Integrity Initiative, 2022).
- **Carbon Credit Quality Initiative.** This effort was founded by the Environmental Defense Fund, World Wildlife Fund, and Oeko-Institut provides a transparent score on the quality of carbon protocols. Their methodology includes criteria on additionality related to the time period without revenues from carbon credits (EDF, WWF, Oeko-Institut, 2022).

While the Carbon Credit Quality Initiative considers a time limit for program eligibility, none of the organizations considers the unique situations in agriculture where a producer stopped a practice but is interested in trying to make it work again. This underscores one of the core challenges with the current market approach. This problem will persist until the unique aspects of agriculture are incorporated into additionality definitions.

PERMANENCE REQUIREMENTS

Soil carbon sequestration is easy to reverse, so it is essential that conservation management practices be maintained. For example, in one study, a single application of inversion tillage eliminated the soil organic matter that had accumulated over 20 years of minimal tillage (Stockfisch, Forstreuter, & Ehlers, 1999); a more recent global meta-analysis concluded that occasional tillage within otherwise no-till systems reduces soil carbon over time (Peixoto, et al., 2020).

Despite the importance of permanence, its definition, interpretation, and associated rules are controversial and difficult characteristics of carbon programs. The most basic definition of permanence is the prevention of emission reductions or removals from being re-released into the atmosphere over 100 years (Goodward & Kelly, 2010). This definition creates a significant contracting challenge for producers. For example, the common law concept of the "rule against perpetuities" prevents people from using legal instruments, such as a deed or a will, to control the ownership of property indefinitely (Waggoner, 1986). To address this contracting problem, carbon programs have adopted specific timeframes for permanence.

The requirement to maintain sequestered carbon for 40 to 100 years is problematic for producers. A common approach to permanence (as used in many of the protocols by CAR, Verra, and ACR) is the requirement for carbon sequestration to be maintained for up to 100 years. A significant challenge with this approach is that approximately 39% of farmland in the U.S. is rented (USDA Economic Research Service) and many producers have one-year, "handshake" agreements with landowners. Some non-operating landowners are beginning to modify lease terms for producers who want to invest in soil health, for example by adopting climate-smart practices like no-till, cover crops, nutrient management, and conservation crop rotations in order to build in flexibility for equitable sharing of risks and rewards (Ranjan, et al., 2019). Most producers who do not have access to such favorable lease terms are reluctant to enter into multi-year contracts; in one study, farmers indicated that they would want an additional $10.57 per acre to enter into such contracts (Gramig & Widmar, 2018). Finally, 100-year permanence spans multiple lifespans, which requires creative legal instruments to pass the requirements between generations.

Tonne-year accounting eliminates permanence requirements. The tonne-year accounting approach calculates the quantity of GHG emission reductions that are physically equivalent to avoiding the emissions over a single year (CarbonCredits.Com, 2022). This approach was originally developed by the IPCC and published in their Special Report on Land Use, Land-Use Change, and Forestry. This report states that "projects must be maintained until they counteract the effect of an equivalent amount of GHGs emitted to the atmosphere" (Watson, et al., 2000). The tonne-year accounting approach allows producers to participate in carbon programs without having to sign long-term agreements binding them to the practices. However, it significantly reduces the number of credits generated, and no projects have been developed using this approach.

Project developers are considering the creation of private buffer pools for intentional reversals. Loss

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of permanence happens in two ways—unintentional and intentional releases of stored carbon, referred to as “reversals.” An unintentional reversal results from something out of the control of the producer, such as a drought, flood, or fire, also called a “force majeure” event. Carbon offset registries administer and collect credits into a buffer pool for such unavoidable reversals. The other type of reversal is an intentional reversal. This is when the producer stops or reverses a conservation practice, such as tilling a no-till field. To address the issue of intentional reversals, some agricultural carbon programs have considered holding onto additional credits to insure against intentional reversals. These private buffer pools allow producers who need to temporarily stop a practice to still participate in the program. The problem with these intentional buffer pools is that there is no transparency in the number of credits they include.

DATA AND TECHNOLOGY BARRIERS FOR AGRICULTURE

The ability to quantify the changes in agricultural GHG emissions associated with the carbon and nitrogen cycles through the interaction of soil, weather, crop growth cycles, and human activities requires the collection of significant amounts of data from producers, which can pose several challenges. To determine the baseline level of GHG emissions for a field, most carbon programs require three to five years of cropping history, including planting and harvesting dates, fertilizer type, application dates and rates, tillage practices, and irrigation dates and amounts.

Lack of broadband hinders the adoption of farm management systems. The significant amount of data necessary to participate in agricultural carbon programs is an obstacle for the 79% of producers who collect information using non-structured data management systems (which can be as simple as paper logbooks or as advanced as macro-enabled Excel spreadsheets) rather than farm-management software (Fiocco, Ganesan, Lozano, & Sharifi, 2023). Lack of rural internet is one of the significant reasons why producers may not have adopted farm-management software. The Federal Communications Commission estimates that 17% of Americans in rural areas and 21% of Americans living on tribal lands lack access to broadband. Some studies have found that up to 50% of rural Americans lack broadband in some areas (Lee, Seddon, Tanner, & Lai, 2022).

Agricultural data policies are unclear and discourage producer participation in agricultural carbon programs. Some producers may be able to get the necessary historic data from their agricultural retailer (Skernivitz, 2022). Agricultural retailers are companies that supply producers with products and services. Products include seed, nutrients, equipment, and technology. Services include field mapping, custom planting and application, and the development of nutrient management plans and conservation plans (Ag Retailers Association, n.d.). Several of these companies, such as Winfield and GROWMARK, are developing systems that can collect this information and allow producers to participate in carbon programs.

Even if an agricultural retailer or input company has a digital data collection system, many producers are reluctant to adopt technology because there is a lack of clarity about how the data will be used and managed. These concerns include data ownership, privacy, portability, and liability. The crux of the problem is a lack of trust by producers about the companies that collect, manage, aggregate, and share their data (Wiseman, Sanderson, Zhang, & Jakku, 2019). Data ownership and privacy are important, and unfortunately the current approach to data collection in the U.S. has no standards, best practices, legal frameworks, or regulations (Kaur, Fard, Amiri-Zarandi, & Dara, 2022).

The privacy concerns extend to carbon programs. At a 2021 U.S. House Committee on Agriculture hearing, producers raised concerns about data privacy in carbon market programs (Joiner, 2021). A recent study found that while producers are willing to share their data with private organizations, they are reluctant to share their data with government entities (Niles & Han, 2022).

Data portability is critical to agricultural carbon market expansion. Because carbon programs are rapidly changing and because producers may be interested in participating in different carbon markets over time, data portability is an important concern when producers decide to share their data with a third party. Data portability avoids the lock-in problems required by some technologies or companies. A good example of the impacts of lock-in challenges are the trade-offs required in selecting an iPhone or Android phone. The most robust form of portability allows the transfer or waiving of portability rights. It also specifies if the portability is of just the raw data or if it includes any derived data (Atik, 2022). The inability to transfer data between platforms inhibits some producers from participating in carbon programs.

Lack of data standards creates uncertainty. One of the largest challenges with data management in the U.S. is that there are limited regulations protecting producers. This is not the case worldwide. The European Union (EU) is exploring data standards for agriculture. In 2021, the EU held a workshop to develop a common European agricultural data space (European Commission, 2021).

Recommendations

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Transforming agriculture into a more climate-resilient and environmentally sustainable sector by reducing GHG emissions is a multi-faceted challenge. Multi-level perspective (MLP) theory provided the framework to facilitate a discussion of the complex societal transitions to identify the barriers and obstacles to implementing agricultural carbon programs. Using MLP we analyzed the current state of agricultural carbon programs and key reasons why producers are not participating in those programs at scale in order to develop recommendations to support the expansion and scale-up of these programs. This approach facilitated the structured review of the transitions amongst stakeholders in the regimes and niche levels necessary to accelerate farmer adoption of climate-smart agricultural practices. The analysis and recommendations in this paper include important changes in program rules, stakeholder behaviors, business models, and technologies.

To prevent global emissions from increasing by more than 1.5°C above pre-industrial temperatures, GHG emissions must be reduced by more than 75% compared to projected 2050 levels (Searchinger, Waite, Hanson, & Ranganathan, 2019). Agricultural carbon programs could play a critical role in making progress towards that target, but agricultural carbon reductions currently represent just 1% of the global carbon market (So, Haya, & Elias, 2023). Below are recommendations to address each of the four barriers to producer participation in agricultural carbon programs.

A. ECONOMICS OF PROGRAMS

1. Support policies that increase the price of carbon. The most significant change to attract and retain producers is to increase the price of carbon. This could be achieved through increasing the demand for GHG reductions from agriculture. Internationally, over 500 food and agriculture companies have set or committed to setting science-based targets through SBTi. As these companies develop and implement their goals, there will be increased demand for GHG reductions from agricultural producers, which will send a strong price signal.

Governments could also set a price signal for reductions. In November 2022, the USEPA proposed to set the social cost of carbon at $190 per tCO_2e. While the social cost of carbon is helpful, it may only have an indirect impact on agricultural carbon programs because it is used primarily as a policy tool to weigh different regulatory proposals (Asdourian & Wessel, 2023). Even if the social cost of carbon is limited to policy decisions, it could still be used as a target or benchmark for agricultural carbon programs.

Finally, strengthening the integrity of the voluntary carbon market could increase trust, confidence, and demand, thereby increasing the price of carbon. At least two efforts are underway to do this (Voluntary Carbon Markets Integrity Initiative, 2023; The Integrity Council for the Voluntary Carbon Market, 2022).

2. Create data standards for agricultural carbon programs and associated data. Having a stable number of programs with clear data requirements is vital for attracting and retaining producers and creating the business models to decrease the transaction costs to develop projects and pay producers. The 15 agricultural carbon programs that have been created since 2016 with differing rules and standards, with many of those programs being merged or discontinued soon after launch, have created uncertainty and wariness among producers. Each of these programs requires different types of data collected for different time periods. While some resources provide guidance and criteria for quantifying GHG fluxes from agriculture (e.g., the recently released Greenhouse Gas Protocol's Land Sector and Removals Guidance (WRI & WBCSD, 2022b) and the SBTi Forest, Land and Agriculture Guidance (SBTi)), they do not provide clear or consistent guidance or criteria for what data elements should be collected from farmers and over what timeframe they should be collected.

While it is still too early to tell, the USDA Partnerships program could create stability in the market and develop more standardized MMRV approaches, including more cost-effective soil testing standards. A supplement to the Partnership contracts is a data dictionary that details the type and frequency of the data that must be reported by funded projects. The 84-page data criteria document specifies what data must be collected (such as the GHG reductions that will be generated; the method, approach, or equipment involved in MMRV and the cost of MMRV; and how the climate-smart commodities will be promoted), how often it must be reported, the format and units for the data, and the allowed values for the report.

There are more than 1,000 organizations participating in the Partnerships program. Creating this uniform reporting approach could become the standard format for agriculture carbon program reporting with consistent data elements, values, units, and format making it easier to move data from different data collection systems into GHG quantification and crediting systems. As an additional benefit, the analysis of this data by USDA could result in the identification of opportunities to reduce or streamline MMRV approaches thereby reducing transaction costs. Finally, the data collected through this program will help USDA and the researchers who have access to the dataset identify the practices that generate the largest volume of reductions at the lowest cost. This will allow USDA and agricultural carbon programs to further target the commodities, practices, and geographies that generate the largest GHG benefits in the most cost-effective way possible and provide producers with higher payments for implementing climate-smart practices.

3. Design and implement insetting programs that eliminate free riding. Insetting programs are still nascent—there is no publicly available information of inset projects generating GHG benefits. However, ESMC has 16 pilot projects in development that are expected to generate credits in the future (ESMC, n.d.). As these programs are refined and as more join the pipeline, it is important that the role of each step in the supply chain is considered. If programs are not designed so that companies at each step of the supply chain are encouraged or incentivized to participate, the program will not scale up and will suffer from a free rider problem.

For example, each node of the supply chain, the grain mills, transporters, food manufacturers, warehouses, food brands, and retail stores all need to be considered in the design and implementation of inset programs. Each of these entities benefits from the reduced GHG footprint of the climate-smart agricultural commodity and they should be encouraged to pay for that benefit. If only one node in the supply chain participates, insetting programs will be no different than offset programs—one company paying a producer for GHG benefits. If the entire supply chain invests in generating reductions, every company can claim the reductions and pay a smaller per-tonne price, while producers get larger per-acre payments due to the number of participants in the supply chain. These concepts are currently being piloted by PepsiCo and ESMC, and other organizations should be encouraged to follow their lead (Henry, 2023; Tomlinson, 2023).

4. Pay early adopters to provide peer-to-peer training. Farmer-to-farmer education provides a way to overcome many adoption barriers by having a fellow producer with firsthand experience share both the benefits and challenges of practice adoption. In so doing, those fellow producers can address the perceived risks to yield, labor costs, and product quality concerns that can prevent farmers from trying a new practice. Farmer-to-farmer learning is also a crucial part of a comprehensive approach to providing culturally tailored technical assistance for historically underrepresented and marginalized communities (AFT, 2023). Whether they participate in a federal conservation program or a private agricultural carbon program, farmers who have already adopted climate-smart practices should be encouraged and could be paid to teach other farmers to successfully adopt and maintain these practices.

B. ADDITIONALITY CONCERNS

Traditional additionality approaches need to be tweaked if agricultural carbon programs are to succeed. No-till is only practiced on about 30% of croplands and producers have planted cover crops on about 5% of U.S. cropland acres. Agricultural carbon programs have the opportunity to increase that practice uptake. It is also important to reward farmers who have already adopted climate-smart practices and incentivize them to adopt additional practices.

1. Improve definitions of "new" practices. Agricultural carbon programs focus their definition of additionality on new practices, but not all programs define what a new practice is. Producers who once implemented practices but stopped them for long enough that the GHG benefits have since dwindled—i.e., the past and disadopted practices are in fact "old"—should be allowed to participate in carbon programs. Allowing these producers to participate in programs if the practices have not been in place for a significant time, such as 10 or more years, will yield net new GHG reductions and expand the pool of farms that can participate in programs. This time period is also long enough to discourage any perverse and unintended outcome wherein farmers stop using a practice simply to join a carbon program.

2. Adopt crediting practices that account for the variability in agriculture. Agricultural production consistently involves yield fluctuations in response to swings in temperature and precipitation (Malhi, Kaur, & Kaushik, 2021). This makes generating credits challenging as there can be years when a field is a net GHG emissions source, rather than a sink, even if implementing climate-smart practices increases carbon sequestration and/or reduces GHG emissions over the long term. For most cropland management protocols, a dynamic baseline that is updated annually using weather information from the project period is the most appropriate approach. This is the approach used by CAR's SEP and Verra's Methodology for Improved Agricultural Land Management.

Alternatively, allowing programs to reward projects over longer periods of time will encourage longer-term adoption of practices. For example, credits could be calculated and issued in 5-year increments, which would allow for the annual variability of farming to be considered. Some protocols use a version of this approach in the development of a project's baseline. While most programs consider the baseline over a multiple-year period, such as a complete crop rotation, they issue credits on an annual basis. A multi-year crediting approach could be implemented for both the crediting period as well as the baseline period. This would allow more fields to generate credits because many practices, such as no-till and cover crops, can best be measured over longer periods of time (Bolinder, et al., 2020).

3. Eliminate common practice ceilings. Some programs consider practices to no longer be additional once adoption within a given region reaches a certain level. It should not matter if the adoption of a practice exceeds an arbitrary practice cap. Because we need to reduce GHG emissions and increase carbon sequestration as much as possible as quickly as possible, we need to incentivize as many producers as possible to adopt climate-smart practices. If that means 100% of producers in a county get paid for implementing a practice, then they are generating greater regional climate and soil health benefits than before and if these interventions are less costly than other interventions, overall, they are still cost-effective climate solutions.

Furthermore, widespread adoption of climate-smart practices could have numerous local and even state or regional water quality benefits because practices such as no-till, cover crops, and nitrogen management reduce nitrogen and sediment losses to waterways. Thus, the additional benefit to eliminating common practice ceilings for climate-smart practices is that it could achieve sufficiently dense practice adoption within watersheds that the impaired streams or lakes within those watersheds could become clean enough to be removed from the EPA List of Impaired Waterbodies (Perez, Water Quality Targeting Success Stories: How to Achieve Measurably Cleaner Water Through U.S. Farm Conservation Watershed Projects, 2017).

4. Create additional opportunities to reward early adopters. Producers who have historically implemented practices and maintained them, and who want to get paid for their continued use of those practices, should participate in programs such as the USDA's CSP. This program rewards producers who have adopted multiple conservation practices and have achieved stewardship levels of management addressing at least two resource concerns. The program further incentivizes adoption of additional practices or more advanced versions of the same practices on the same acres or on new acres in the operation to achieve at least one more resource concern stewardship threshold (Conservation Stewardship Program, n.d.). As discussed above, early adopters should also be encouraged or paid to provide peer-to-peer learning.

C. PERMANENCE REQUIREMENTS

The current permanence requirements were designed for forest carbon markets. Forest owners are focused on long-term decisions to maximize the timber on their land. It makes sense, therefore, to incentivize and require them to preserve their trees as long as possible. In contrast, most agricultural decisions are made throughout the year, every year—when to plant with which kind of tillage method, when to plant which cover crop after which cash crop, when and how to terminate a cover crop, how much fertilizer to apply, when to irrigate, when to harvest, how to handle post-harvest biomass, etc. There may be rational and important reasons for producers to discontinue conservation practices they implemented on a one-time or one-off basis.

1. Include buffers for intentional reversals in agricultural carbon programs. Private companies are creating intentional reversal buffer pools to address the risks of producers stopping or reversing practices. Expanding current buffer pools managed by agricultural carbon programs to include contributions to cover both unintentional and intentional reversals will create a standardized approach to this risk and create greater transparency to market participants. Maintaining private buffer pools creates standardization and transparency issues and creates a smaller buffer pool than one managed by a program with multiple projects developed by multiple private companies. If a large enough buffer pool is created, it would be possible to sign shorter contracts. Fields would still need to be monitored to ensure a net reduction in GHG emissions, but the consequences of producers stopping practices would be minimal because they would be insured through the buffer pool.

D. DATA AND TECHNOLOGY BARRIERS FOR AGRICULTURE

There is a significant amount of data necessary to participate in agricultural carbon programs. Reducing barriers to data collection is critical to the success and expansion of these programs.

1. Expand producers' broadband access. Unfortunately, less than a quarter of producers have digitized their data. One of the primary reasons is the lack of broadband access. Somewhere between 17 and 50% of producers lack high speed internet access. USDA recently announced that it is investing $401 million to provide access to high-speed internet for 31,000 rural residents and businesses in 11 states (USDA, July 28, 2022). This investment could expand the ability of producers to adopt data technology systems that will allow them to participate in agriculture carbon programs. The progress of this program should be monitored and adapted to rapidly expand access to producers in rural and tribal areas.

2. Modernize USDA data collection and management systems and create national data networks. The influx of funding from the IRA and the data, lessons, and best practices emerging from the USDA Partnerships program provide exciting opportunities to improve the collection, management, and use of agricultural conservation practice data. On July 12, 2023, USDA announced that IRA investments would be used to improve MMRV of GHG emissions including the development of a Soil Carbon Monitoring and Research Network and a Greenhouse Gas Research Network (USDA, 2023).

If set up properly, these Networks could serve many uses including as a national calibration dataset for computer modelers who could use the data to calibrate, validate, and improve their models and other tools for estimating the many agronomic, environmental, and economic outcomes of climate-smart practices, including: soil carbon sequestration, GHG emissions, nitrogen, phosphorus, and sediment loss changes, and economics. Such a calibration dataset could lead to improving the accuracy of modeled outcomes of farm conservation practice adoption and expand the geographic, production, and conservation practice scope of analysis of various outcomes estimation modeling tools. Modernizing national data infrastructure through this announcement should include making it easier for farmers to authorize third parties, including researchers, to access the data collected about their fields. As these Networks and additional use cases are developed, it will be critical to build in privacy protections at every step.

3. Adopt national agricultural data policies. Without clear guidance, regulations, and standards on the privacy, portability, and interoperability of agricultural data, adoption of climate-smart practices will remain low. Producers should be able to transition their data between an offset and inset program over time if they want to do so. Locking them into a single system or approach will discourage widespread participation. Efforts are underway to create open technology approaches through initiatives such as OpenTEAM (OpenTEAM, n.d.), but they have yet to scale up.

Through its Learning Network, the USDA Partnerships program could bring together the players and create data standards that will allow producers to seamlessly move their data across platforms and programs. In addition, USDA should modernize its data management and computing capabilities to make it easier for farmers to access and/or authorize third parties to access any data the government has collected about their fields. While legislation or regulations are unlikely in the U.S., the EU is exploring the development of data standards for agriculture. These standards could become best practices internationally. Even if they are not, they could be required for participation in agricultural carbon programs, which could signal to producers that adopting climate-smart practices and sharing their data is warranted, safe, and worth their time and efforts.

Conclusion

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In this white paper we analyzed the current state of agricultural carbon programs and some of the reasons why producer participation remains low. The most critical barriers to success are the economics of the programs, concerns about additionality, requirements for permanence, and data and technology barriers for agriculture. We identified strategic changes that would help overcome these challenges and increase producer enrollment in carbon programs. Our analysis will also help carbon programs, policymakers, farm trade associations, and environmental groups better understand some of the barriers to adoption and the roles they can play in enacting changes which could lead to widespread adoption of climate-smart practices. If improvements were made, the agricultural carbon programs have the potential to lead to systemic change that could transform agriculture from a source of greenhouse gas emissions to a sink. In so doing, these changes may provide the public and producers with the assurance that the emerging agricultural carbon programs are a credible and cost-effective approach to climate mitigation and adaptation.

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APPENDIX A

USDA Conservation Programs, Reach, and Policies on Environmental Markets and Climate Change

FEDERAL FINANCIAL SUPPORT FOR WORKING LANDS

USDA provides multiple programs to promote and incentivize agricultural conservation practices on pasture, cropland and woodlands. One of the largest federal financial assistance programs for agriculture, the NRCS Environmental Quality Incentives Program (EQIP) provides technical and financial assistance to producers to deliver environmental benefits (). EQIP offers approximately 200 unique conservation practices designed specifically for farms, ranches, and forests. Another large program is the NRCS Conservation Stewardship Program (CSP) where the NRCS helps producers design custom conservation plans that improve grazing conditions, increase crop resiliency, or develop wildlife habitat (USDA, Conservation Stewardship Program, n.d.).

In addition to EQIP, USDA also offers the Regional Conservation Partnership Program (RCPP), the Agricultural Management Assistance program (AMA), and the Agricultural Water Enhancement Program (AWEP). Since 2014, USDA has spent between $1.5 and $2.1 billion annually on these five conservation programs (Figure 3). The largest increases in spending have been the EQIP and AMA programs, which increased more than 150% between 2014 and 2022 (USDA, October 1, 2022).

REACH OF THE FEDERAL CONSERVATION PROGRAMS FOR WORKING LANDS AND RETIRED AG LANDS

Despite these significant annual investments in conservation programs, a small percent of applicable land is has participated in NRCS working lands or retired lands program. As shown in Figure 4, 20 states had more than 20% of their agricultural land participating in federal conservation programs. That means that 28 states have less than 20% of their agricultural land

FIGURE 3. ANNUAL SPENDING FOR MAJOR USDA CONSERVATION PROGRAMS 2014–2022 (USDA, OCTOBER 1, 2022)

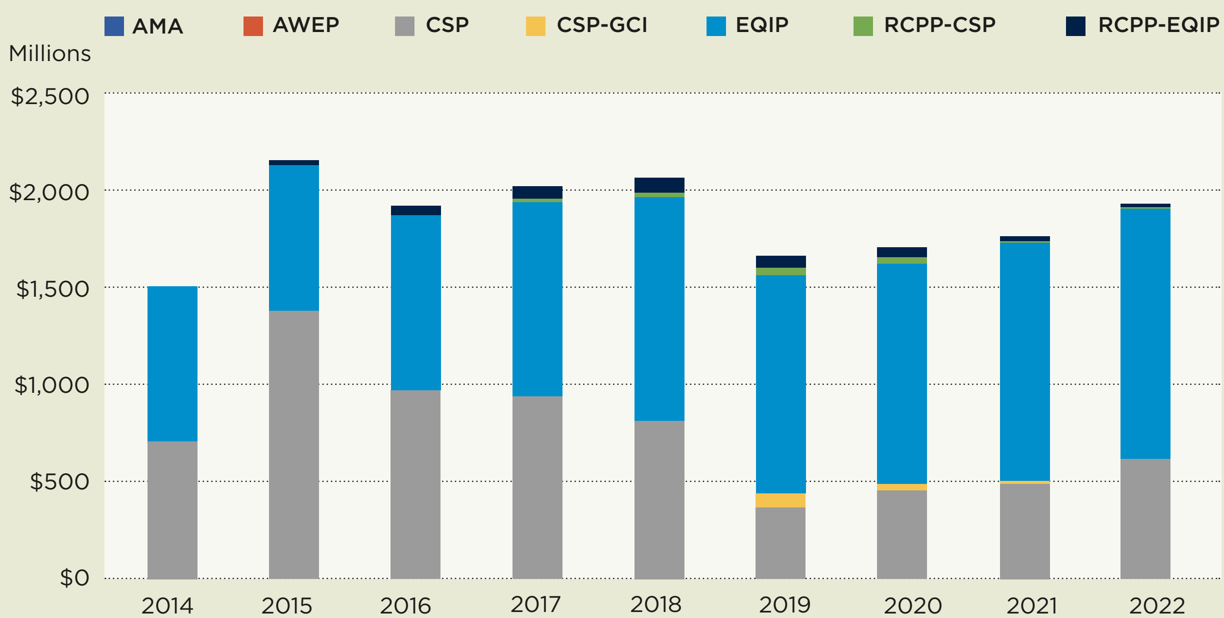
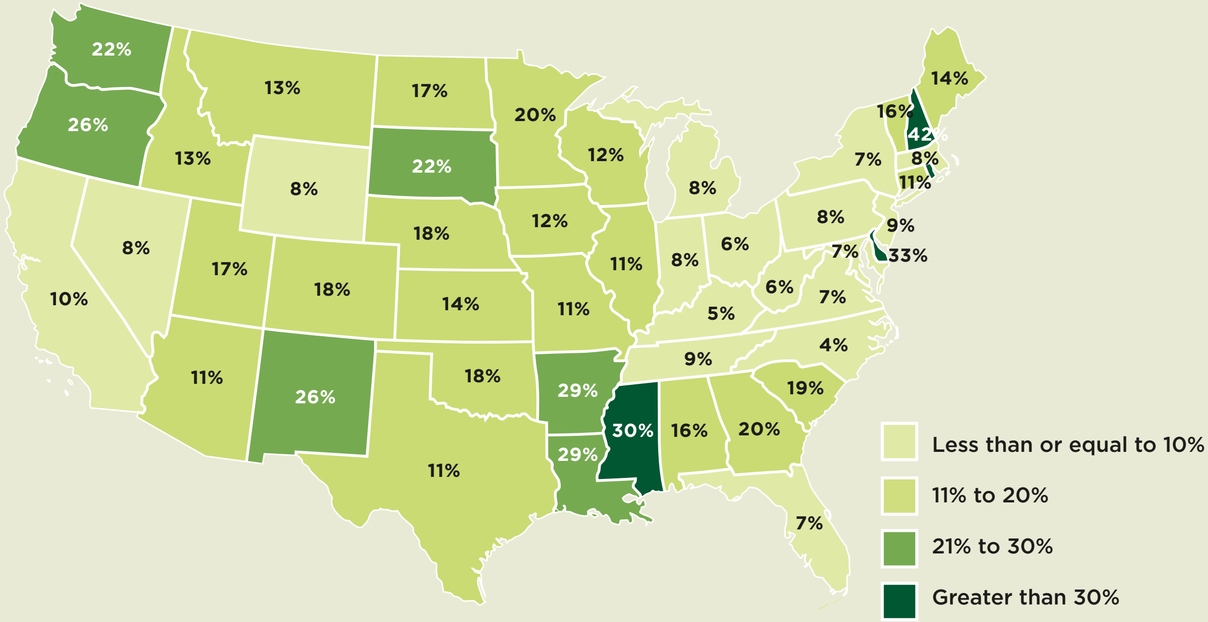


FIGURE 4. CONSERVATION ACREAGE AS A PERCENT OF TOTAL AGRICULTURAL LAND (NEWTON, 2019)



Source: Farm Bureau calculations from USDA NRCS, USDA FSA, USDA NASS Census of Agriculture and Farm Bureau calculations

engaged in the three conservation programs. The key commodity states of Iowa, Illinois, and Indiana all had 12% or less participation in EQIP, Conservation Reserve Program (CRP) and Conservation Stewardship Program (CSP). California, the largest dairy and specialty crop state, as well as the fourth largest rice growing state, only had 10% of its acres in enrolled in federal programs (Newton, 2019).

USDA POLICIES ON ENVIRONMENTAL MARKETS AND CLIMATE CHANGE

USDA's focus on environmental markets dates to the Food, Conservation, and Energy Act of 2008, also known as the 2008 Farm Bill. Section 2709 of the Conservation Title requires the Secretary of Agriculture to:

> Establish technical guidelines that outline science-based methods to measure the environmental services benefits from conservation and land management activities in order to facilitate the participation of farmers, ranchers, and forest landowners in emerging environmental services markets. The Secretary shall give priority to the establishment of guidelines related to farmer, rancher, and forest landowner participation in carbon markets. (USDA, n.d.)

One of those technical guidelines is "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry," published in July 2014, which is the most authoritative guidance on the quantification of GHG emissions from agriculture and forestry (Eve, et al., 2014). It was written by scientists with expertise in agricultural GHG quantification from institutions including Colorado State University, University of California at Davis, and Michigan State University.

In March 2022, USDA published its Strategic Plan for fiscal years 2022 to 2026. The first strategic goal in the plan is to "Combat Climate Change to Support America's Working Lands, Natural Resources and Communities." The objectives of the plan include "developing and implementing a comprehensive strategy to incentivize climate-smart decision-making by all agricultural and forest producers, landowners, and communities" (USDA, March 2022).

APPENDIX B

Illustrative Examples of Agricultural Carbon Programs and Tools at Universities

Universities conduct much of the research that is used to identify, quantify, pilot, and finance the practices that reduce the most GHG emissions. Just two of many examples of universities leading work studying agricultural conservation practices and designing markets are Colorado State University (CSU) and Cornell University.

COLORADO STATE UNIVERSITY

CSU was established in 1870 through the Morrill Act. CSU has been a leader in the quantification of soil carbon and research on soil biodiversity. In 1994, CSU developed the DAYCENT biogeochemical model (Parton, Ojima, Cole, & Schimel, 1994). The model was expanded to include fluxes of carbon and nitrogen between the atmosphere, vegetation, and soil between 1998 and 2001 (Del Grosso, et al., 2001; Parton, Stewart, & Cole, 1988). Under funding from USDA, a producer-friendly version of the DAYCENT model, called COMET-Farm was launched in 2013 (Miller, 2013). Since its inception, COMET-Farm has become one of the leading tools for quantifying the GHG fluxes from agriculture.

CORNELL UNIVERSITY

Cornell was founded in 1865 and is one of the few private land-grant universities. The university has two programs focused on agricultural carbon markets: Climate Smart Farming and Transition Finance for Regenerative Agriculture Systems. The Climate Smart Farming program was established in 2015 to help producers reduce GHG emissions and adapt to climate change in the Northeastern U.S. The program has three pillars, which are derived from the three pillars of climate-smart agriculture, as defined by the UN Food and Agriculture Organization (FAO, n.d.) and the USDA's Climate-Smart Agriculture and Forestry Initiative (USDA, n.d.). The pillars of the Cornell Climate Smart Program are:

- Increase agricultural productivity and farming incomes sustainably;
- Reduce greenhouse gas emissions from agricultural production through adoption of best management practices, increased energy efficiency and use of renewable energy; and
- Increase farm resiliency to extreme weather and climate variability through adoption of best management practices for climate change adaptation (Cornell Institute for Climate Smart Solutions, 2016).

The Cornell Atkinson Center for Sustainability hosts the University's Regenerative Agriculture Systems program, which has three objectives—assess innovations, co-create, and invest in growth. Cornell faculty partner with leaders in the financial industry to assess and identify innovative financial mechanisms that support producers in adopting regenerative practices. The Regenerative Agriculture program also collaborates with producers to design and implement impact-oriented regenerative agriculture projects. Finally, the program has developed the New York Outcomes Fund, which pays New York producers for the ecosystem services they provide, including clean water, carbon sequestration, and biodiversity (Cornell University, n.d.).

APPENDIX C

Illustrative Examples of Corporate SBTi Goals and Agricultural Carbon Programs

Food and agricultural corporations are increasingly setting goals and targets for GHG reductions in their supply chain. These goals are driven, in part, by participation in SBTi. Examples of corporate food and agriculture goals are listed in Table 1. Three notable corporate programs are those developed by PepsiCo, General Mills, and Unilever.

PEPSICO

PepsiCo Positive (pep+) is PepsiCo's program designed to have a positive impact on people and the planet. As part of the program, a series of goals were set in 2021, some of which relate to agriculture. By 2030, the company aims to spread the adoption of regenerative agriculture practices across 7 million acres worldwide. To meet that goal, PepsiCo has partnered with Precision Conservation Management (PCM), an Illinois-based company, to offer the Soil Health Incentive to PCM farmers, an inset program which began in 2022. PepsiCo funds payments for new and existing acres where cover crops, no-till, strip-till, and/or nitrogen reduction are being implemented. Up to three years of historic practices are eligible for the program. Payments range from $5 to $25 per acre, depending on the number and type of practices implemented. There are approximately 250 thousand acres enrolled in Illinois, as of 2023 (ISAP, 2023).

GENERAL MILLS

General Mills has a series of GHG reduction goals, set in 2019, with benchmarks in 2025, 2030, and 2050. To decrease their emissions from agriculture, they have committed to advancing regenerative agriculture on 1 million acres by 2030. They define regenerative agriculture by highlighting five core principles to implement: minimize soil disturbance (chemical and physical), maximize crop and animal diversity, keep the soil covered year-round, maintain a living root year-round, and integrate livestock.

General Mills promotes regenerative agriculture through several different partnerships. They are a founding member of the Ecosystem Services Market Consortium (ESMC), a non-profit that incentivizes farmers and ranchers to decrease GHG emissions, improve water quality, and increase ecosystem services. Additionally, General Mills has partnered with the Soil Health Academy and Understanding Ag to create programs that help farmers implement regenerative agricultural practices, by providing technical assistance and economic assessments. They also have a partnership with the National Fish and Wildlife Foundation (NFWF), whereby a regenerative agriculture focus is added to existing regional conservation programs (General Mills, n.d.). The General Mills Regenerative Agriculture Self-Assessment tool is available to help farmers assess what regenerative practices are suitable for their operations (General Mills, n.d.).

UNILEVER

In 2010, Unilever developed the Unilever Sustainable Agriculture Code (SAC) to outline best practices for farmers in their supply chain. Revised in 2017, the SAC includes an Implementation Guide. To enhance the SAC, Unilever released a set of Regenerative Agriculture Principles in 2021, which highlight four over-arching guidelines: positively impact soil health, water and air quality, carbon capture, and biodiversity; enable local communities to improve and protect their environment and wellbeing; produce enough quality crops to meet existing and future needs, with the least resource inputs; and minimize the use of non-renewable resources while optimizing the use of renewable resources (Unilever, n.d.).

Unilever has founded and partnered with various organizations to advance sustainable agriculture. They are a founding member of the Round Table on Responsible Soy (RTRS) and helped develop standards and verification systems like the Rainforest Alliance, trustea, and the Roundtable on Sustainable Palm Oil (RSPO) (Unilever, n.d.).

TABLE 1. EXAMPLE SBTI GOALS FROM FOOD AND BEVERAGE COMPANIES

COMPANY	SBTI GOAL
AB InBev	Global Brewer AB InBev, a Belgian multinational drink and brewing company, commits to reduce absolute Scope 1 and 2 GHG emissions 35% by 2025 from a 2017 base year. AB InBev commits to increase annual sourcing of renewable electricity from 7% in 2016 to 100% by 2025. AB InBev also commits to reduce emissions across the value chain (Scopes 1, 2 and 3) by 25% per beverage by 2025, from a 2017 base year. These commitments reinforce AB InBev's commitment towards mitigating the impacts of climate change.
Ben & Jerry's	Ben & Jerry's, an American ice cream company, commits to reduce Scope 1 and 2 GHG emissions 100% by 2025 from a 2015 base-year. The company also commits to reduce value chain GHG emissions (Scope 1, 2 and 3) 40% per pint of product sold by 2025 from a 2015 base-year.
Bunge Limited	Bunge, an American agribusiness and food company, commits to reduce absolute Scope 1 and 2 GHG emissions 25% by 2030 from a 2020 base year. Bunge also commits to reduce absolute Scope 3 GHG emissions from purchased goods and services, upstream transportation and distribution, and fuel and energy related activities 12.3% over the same timeframe.
Chiquita Brands International	Chiquita, a producer and distributor of bananas and other produce, commits to reduce absolute Scope 1 and 2 GHG emissions 30% by 2030 from a 2019 base year. Chiquita also commits that 90% of its suppliers (covering purchased goods and services and upstream transportation and distribution) will have science-based targets by 2025.
Coca-Cola	Coca-Cola, a drink industry company, commits to reduce absolute Scope 1, 2 and 3 GHG emissions 25% by 2030 from a 2015 base year.
Danone	Multi-national food company, Danone commits to reduce absolute Scope 1 and 2 GHG emissions 47.2% by FY2030 from a FY2020 base year. Danone further commits to reduce absolute Scope 1 and 3 Forest, Land, and Agriculture (FLAG) GHG emissions 30.3% by FY2030 from a FY2020 base year. Finally, Danone commits to no deforestation across its primary deforestation-linked commodities with a target date of FY2025.
General Mills	Multinational manufacturer and marketer of branded consumer foods General Mills commits to reduce absolute Scope 1, 2, and 3 GHG emissions 30% by FY2030 from a FY2020 base year. Within that target, General Mills commits to reduce absolute Scope 1 and 2 GHG emissions 42% by FY2030 from a F2020 base year and reduce absolute Scope 3 GHG emissions 30% over the same timeframe.
Nestlé	Nestlé, a Swiss multinational food and drink processing conglomerate, commits to reduce absolute Scope 1, 2 and 3 GHG emissions 20% by 2025 and 50% by 2030 from a 2018 base year. Nestlé also commits to increase annual sourcing of renewable electricity from 40% in 2019 to 100% by 2025.

APPENDIX D

Illustrative Examples of Venture-Backed Ag Tech Investments

Two examples of venture backed ag tech investments are S2G Ventures and Agreena. On April 6, 2023, S2G Ventures, a multi-stage venture fund focusing on investments in food and agriculture industries, announced a $300 million Special Opportunities fund to finance social and environmental impact startups focusing on land, infrastructure, and credit markets (Martson, Brief: S2G Ventures launches new fund to offer 'flexible' financing for cap-intensive climate-tech startups, 2023). Agreena, a software company that has developed a platform to help producers implement practices that store soil carbon, recently raised $50 million in Series B funding (Martson, Soil carbon startup Agreena lands $50m to tear down the financial barriers to regen ag, 2023).

APPENDIX E

Supplementary Information on Compliance Offset Markets

CALIFORNIA'S CAP-AND-TRADE PROGRAM

California's Cap-and-Trade Program was established through Assembly Bill 32, the California Global Warming Solutions Act of 2006. AB 32 requires a reduction in GHG emissions through a suite of programs, including Cap-and-Trade. The Cap-and-Trade Program establishes a declining limit on major sources of GHG emissions throughout California. The program applies to companies that generate more than 25,000 metric tons (tCO2e) emissions per year, covering approximately 80 percent of the State's GHG emissions. The California Air Resources Board (CARB) creates emission permits (allowances) equal to the total amount of permissible emissions (CARB, n.d.). CARB allows companies to meet a portion of their compliance obligation using one of six approved offset protocols, two of which are for agricultural projects: livestock digesters and rice cultivation (CARB, n.d.).

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION (CORSIA)

At its 39th triennial Assembly in 2016, ICAO adopted Assembly Resolutions A39-2 and A39-3, which set the goal for the aviation sector to achieve 2% annual fuel efficiency improvement through 2050 and capped GHG emissions from international aviation at 2020 levels. To achieve these goals, ICAO developed a series of measures to reduce emissions including aircraft technology improvements, operational improvements, sustainable aviation fuels, and market-based measures. The primary market-based measure of the program is CORSIA (ICAO, 2019).

APPENDIX F

Supplementary Information on Voluntary Offset Protocols

ACR has three approved/active and eight discontinued/inactive protocols that reward agricultural practices. The active ACR protocols are: (1) Avoided Conversion of Grasslands and Shrublands to Crop Production, (2) Restoration of California Deltaic and Coastal Wetlands, and (3) Restoration of Pocosin Wetlands (ACR, n.d.). The inactive ACR protocols are: (1) Biochar, (2) Changes in Fertilizer Management, (3) Compost Addition to Grazed Grasslands, (4) Reduced Use of Nitrogen Fertilizer on Agricultural Crops, (5) Restoration of Degraded Wetlands in the Mississippi Delta, (6) Rice Management Systems, (7) Grazing Land and Livestock Management, and (8) Methane Recovery in Animal Manure Management Systems (ACR, n.d.).

The VCS program has adopted eight protocols which are applicable to U.S. agricultural practices: (1) Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing, (2) Avoided Ecosystem Conversion, (3) Biochar Utilization in Soil and Non-Soil Applications, (4) Improved Agricultural Land Management, (5) Reduction of Enteric Methane Emissions from Ruminants through the Use of 100% Natural Feed Supplement, (6) Sustainable Grassland Management (SGM), (7) Quantifying N2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction, and (8) Revisions to the CDM methodology AMS-III.Y to Include Use of Organic Bedding Material (Verra, n.d.).

VCS has two inactive protocols applicable to agricultural practices: (1) Adoption of Sustainable Agricultural Land Management and (2) Soil Carbon Quantification Methodology (Verra, n.d.).

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