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Building trust and understanding at the intersection of agriculture and society.

ISSUE REPORT

The U.S. Voluntary Agricultural Carbon Market: Where to From Here?

While carbon dioxide (CO_2) is a necessary gas to sustain life on Earth as a feedstock in the photosynthesis process, excessive amounts of CO_2 in the atmosphere creates a greenhouse effect that accelerates global warming.

Mounting pressure from consumers, investors, the green finance movement, and international leaders to reduce the levels of CO_2 and other greenhouse gasses (GHGs) in the atmosphere has prompted a growing number of entities to pledge to become carbon neutral or carbon negative over the next decades.[1]

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About this Issue Report

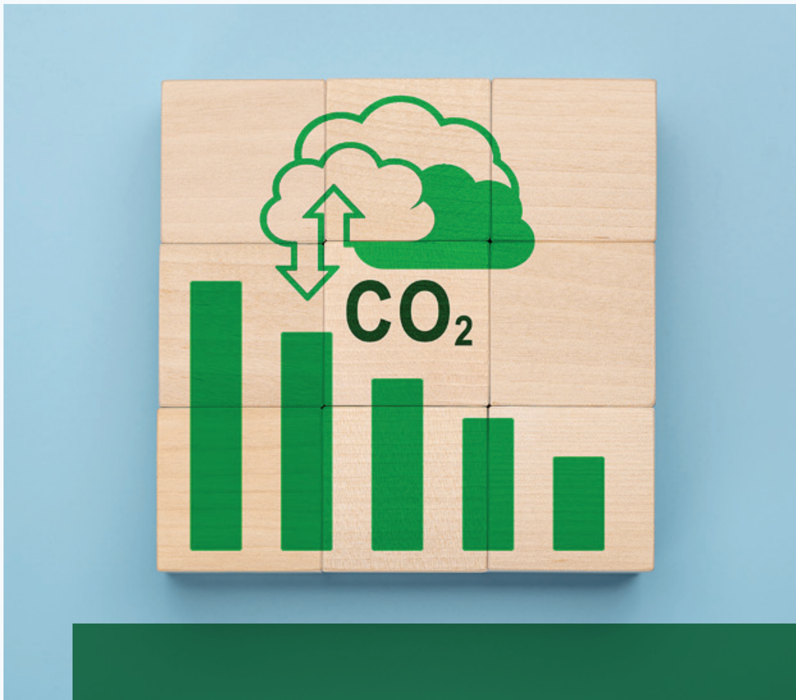
This Farm Foundation Issue Report seeks to shed light on multiple voluntary agricultural carbon programs and the contractual implications for participating farmers; discuss current and potential barriers to the development of a voluntary market for agricultural carbon credits, and steps to overcome them; and presents a simplified analysis of four possible scenarios for voluntary agricultural carbon markets and their implications for farmers and society.

These pledges typically consist of promises to reduce GHG emissions and to implement practices that remove GHGs from the atmosphere so that net GHG emissions become zero or negative. Goals are stated in terms of carbon equivalent (CO_2e) units, based on the comparative global warming potential of each GHG with respect to that of carbon dioxide over extended periods of time (usually 100 years). For example, the global warming potential of nitrous oxide, the most prevalent GHG emission in crop production, is 298 times the potential of CO_2 over 100 years.[2]

Some corporations face costly long-term investments in lower GHG emission technologies to deliver on their pledges. Until affordable low-emission technologies become available to them, entities can reduce their GHG footprint by purchasing carbon credits and using them to offset their own GHG emissions (Scope 1 emissions) or those from their supply chain (Scope 3 emissions). A carbon credit is an intangible asset that represents a claim that one metric ton of CO_2e emissions has been avoided or removed from the atmosphere, with respect to a baseline. For example, an entity with increasing Scope 1 emissions can claim in its environmental, social, and governance (ESG) report to have reduced its net emissions if it can show that the total units of CO_2e in the carbon credits used to offset Scope 1 emissions exceeded the additional units of CO_2e emitted by the entity. If sufficient credible information is available to evaluate the quality of carbon credits at low cost, a voluntary emissions trading system (ETS) could help entities achieve their carbon-neutral or carbon-negative goals, help consumers and investors assign their resources according to their climate beliefs, help suppliers of carbon credits earn additional revenue, and help society slow down global warming more efficiently than under alternative carbon pricing schemes (such as carbon taxes or a mandatory ETS).

What Is Carbon Farming?

Carbon farming refers to the implementation of agricultural practices to remove GHGs from the atmosphere while sequestering carbon into the soil, as well as practices to avoid or reduce GHG emissions during the agricultural production process. For example, planting winter cover crops could remove CO_2e from the atmosphere, while reducing the rate of nitrogen fertilizer in the production of corn could avoid CO_2e emissions. The goal of carbon farming is to generate carbon credits that can be sold to GHG emitters for offsetting their emissions. Carbon farming can become an important source of carbon credits for the nascent voluntary U.S. GHG ETS. For example, Microsoft has announced an agreement with Truterra, a company that sells carbon credits generated in the agricultural sector, to achieve its carbon emission goal. Meanwhile, IBM, JP Morgan Chase, Boston Consulting Group, Dogfish Head Craft Brewing, Shopify, Anheuser-Busch, and Barclays announced agreements with Indigo Ag, another company that sells agricultural carbon credits.



According to IHS Markit,[3] U.S. farmers have the potential to generate $5.2 billion dollars in annual revenues from carbon farming. According to a 2019 report by the National Academy of Sciences, agricultural practices to enhance soil carbon storage could sequester 250 million tons of carbon dioxide annually in the US, equivalent to around 4% of the country's emissions.

The goals of the present report are three-fold: it sheds light on the functioning of multiple voluntary agricultural carbon programs and the contractual implications for participating farmers; it discusses current and potential barriers to the development of a voluntary market for agricultural carbon credits, and steps to overcome them; and it presents a simplified analysis of four possible scenarios for voluntary agricultural carbon markets and their implications for farmers and society. The report concludes with an assessment of the most likely scenario and a summary of the recommendations to improve the prospects for success of the nascent voluntary agricultural carbon market in the United States.

Voluntary Carbon Farming Programs

Although farmers could generate and sell carbon credits directly to a public or private entity, the transaction costs associated with negotiating and enforcing individual contracts, and producing the measurement and verification documentation necessary to support GHG removal or emission avoidance claims, are typically prohibitive. Multiple private initiatives or "carbon programs" have developed to serve as intermediaries between farmers and buyers of carbon credits. This section characterizes nine carbon faming programs: Agoro Carbon, Bayer Carbon, CIBO Impact, Corteva Agriscience, Ecosystem Services Market Consortium (ESMC), Gradable Carbon, Indigo Ag, Nori, and the Soil and Water Outcomes Fund (SWOF). It extends the previous works[4,5] by highlighting the most salient similarities and differences across programs and by providing a list of clarifying questions that farmers would benefit from asking before signing a carbon farming contract. It must be noted that based on the nascent nature of carbon farming programs and the interaction of the author of this report with representatives from multiple carbon programs, the reader is advised to consider this section illustrative of the large menu of options that farmers need to consider rather than as an exhaustive and stable description of representative carbon programs.

The role of carbon programs is to enhance the efficiency of the supply chain of carbon credits by exploiting economies of scale: aggregating projects across farms, streamlining the measurement, reporting, and verification system (MRV) of carbon credits, and offering large pools of carbon credits to buyers. More than a dozen distinct carbon farming programs are currently available across the United States, and they share the following characteristics:

- *Farmers enter into a contract with a carbon program to receive compensation in exchange for implementing a detailed plan to change one or more farming practices over a certain period of time.*
- *Farmers share information on the contracted farming practice changes with the carbon program through an online data platform.*
- *The carbon program uses the data to calculate the amount of the compensation.*

Each agricultural carbon program attempts to differentiate itself from the rest to capture a larger share of the market. Major differences across carbon programs include (also see Table 1 on page 7):

- ***Covered practices.*** *While cover crops and conservation tillage are practices accepted by all carbon programs, the full list of covered practices varies across programs. For example, while the list of covered practices in the Agoro Carbon program also includes nitrogen management, management of pasture, degraded and livestock lands, and agroforestry, the list of covered practices in the SWOF includes land retirement, conversion to pasture, and extended rotations.*

- ***Payments per practice versus payments per outcome.*** *Except for Bayer Carbon, all other programs calculate the expected compensation to farmers at the beginning of the contract based on the difference in GHG emissions between a projected baseline reflecting the continuation of business as usual, and a projected scenario with at least one farming practice changed. The actual compensation per outcome is calculated after the change in practices has been implemented and verified. The potential discrepancy between projected and actual compensation is a source of risk for farmers.*

- ***Credit issuance and registration.*** *Registries are private entities that assign a unique serial number to issued carbon credits, and serve as clearinghouses of information on transactions involving those credits to avoid double counting and enhance transparency. When an owner of a carbon credit uses it to offset emissions of* CO_2*e, the serial number is retired from the registry and the transaction is transparent to the clearinghouse. Voluntary market registries include the American Carbon Registry (ACR); the Gold Standard Registry and the Climate Action Reserve (CAR) managed by APX Inc.; the Social Carbon Registry and the Plan Vivo Registry managed by Markit; the Verified Carbon Standard (VCS) Registry (now Verra), and the Climate, Community, and Biodiversity Standards (CCBS) Registry, managed by Verra. Some carbon programs rely on external registries to guide the issuance of carbon credits and to keep track of their status (sold, unsold, or retired), while other programs have developed their own internal protocols for these purposes. For example, ESMC and Indigo Ag are collaborating with external registries (ESMC with the Gold Standard, and Indigo Ag with Verra and the CAR), while CIBO Impact, Gradable, Nori and the SWOF serve as their own registries.*

- ***Agronomic plans.*** *Plans to change farming practices can be developed according to publicly available guidelines compiled by external registries, or according to proprietary guidelines developed by a carbon program. While the former method should facilitate the comparison of projects and carbon credits quality by credit buyers, the latter should provide more flexibility in the production of carbon credits to participating farmers at the expense of reducing the comparability of carbon credits across projects. Currently, all voluntary agricultural carbon programs are evaluating protocols to generate, verify, and issue carbon credits based on agricultural practices, but only Indigo Ag has methodologies approved by voluntary market registries—the Methodology for Improved Agricultural Land Management (VM0042), approved by Verra, and the Soil Enrichment Protocol (SEP), approved by the CAR.*

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- ***Additionality criteria.*** *Additionality means that the GHG mitigation would not have occurred without the compensation from the sale of carbon credits, and it implies that the timing of practice changes matters. For example, farms that have already adopted no-till practices will typically not qualify to generate carbon credits from no-till. While all programs require that carbon credits be generated through new or "additional" changes in agricultural practices, some programs define additionality with respect to past practices in the same farm, while others define additionality with respect to typical farming practices in the county or similar area (even if the farm has been implementing a specific conservation practice for multiple years). For example, while the discrepancy between modeling projections of soil organic carbon sequestration above business as usual is the defining characteristic of additionality for Nori, Indigo Ag requires projects to demonstrate that carbon farming practices are not already being implemented on more than half of the land area containing a project to be considered additional under the SEP or twenty percent of the land area under VM0042.*[6]

- ***Estimation methods.*** *Carbon programs use different methods to estimate the tons of CO_2e removed from the atmosphere and the tons of CO_2e emissions avoided, reflecting the lack of consensus on the linkages between agricultural practices, soil dynamics, and GHG emissions from soil. For example, while CIBO Impact uses the system approach to land use sustainability (SALUS) model to calculate carbon credits, Nori and the SWOF use the COMET-farm model, and the ESMC uses the DeNitrification-DeComposition (DNDC) model and the operational tillage information system (OpTIS). Other carbon programs such as Agoro, Indigo Ag, and Gradable use their own proprietary models to estimate carbon credits. Furthermore, except for Nori, all carbon programs analyzed in this report use soil test sampling to assist in the estimation of the volume of carbon credits generated in each project. These different approaches to CO_2e estimation result in different estimated numbers of carbon credits (and compensation) across carbon programs stemming from a specific practice change on a particular farm at one point in time.*

Table 1. How Voluntary Agricultural Carbon Programs Address Critical Structural Considerations

	Agoro	Bayer	CIBO	Corteva	ESMC	Gradable	Indigo	Nori	SWOF
PAYMENTS: Per output	✓		✓	✓	✓	✓	✓	✓	✓
Per practice		✓							
CREDIT ISSUANCE AND REGISTRATION External Registry	✓	✓		✓	✓		✓		
Own Registry			✓			✓		✓	✓
AGRONOMIC PLANS Approved methodology by external registries				D*			✓		
Methodology under consideration by external registries	✓	✓		D*	✓				
ADDITIONALITY Practices not previously implemented in farm	✓	✓	✓	D*	✓	✓		✓	✓
% Project area in new practices < threshold				D*			✓		
ESTIMATION METHODS SALUS model		D*	✓						
COMET-farm model		D*						✓	✓
DNDC model		D*		D*	✓				
OpTIS model		D*		D*	✓				
Own proprietary model	✓			D*		✓	✓		
Soil Tests	✓	✓	✓	✓	✓	✓	✓		✓
PRACTICE VERIFICATION Remote sensing	✓	D*	✓	✓	✓	✓	✓		
Random site visits		D*		D*	✓				
Integration with farm machinery		D*		D*			✓		
Third-party verification	✓	✓		✓	✓		✓	✓	
Internal verification			✓			✓			✓
Verification paid by farmers								✓	
PURCHASE AGREEMENT Pre-Issuance of credit		D*		D*	✓				✓
Post-Issuance of credit	✓	D*	✓	D*		✓	✓	✓	
CREDIT BUFFERS < 100-year buffer								✓	
≥ 100-year buffer		D*		D*		✓	✓		
LOOK-BACK PAYMENT		✓				✓		✓	

*D = The answer depends on the registries ultimately used to issue carbon credits.

- ***Verification.*** *Carbon programs apply different procedures to verify that the contracted changes in agricultural practices have been implemented according to plan. For example, while Bayer Carbon, Gradable, and CIBO Impact rely solely on remote technologies, Indigo Ag and Corteva also use, respectively, integration with farm machinery systems and random site visits to verify and validate practices. Also, while Agoro, Bayer, Corteva, ESMC, Indigo Ag, and Nori contract third-party verifiers to audit the implementation of practice changes, CIBO Impact, Gradable, and the SOWF conduct internal audits instead. Finally, only Nori requires that participating farmers pay for the verification process out-of-pocket. All other carbon programs cover the verification costs out of their own budget.*

- ***Purchase agreement.*** *While some carbon programs finance the generation of carbon credits through emission reduction purchase agreements (ERPAs) signed prior to project implementation and carbon credit issuance (Agoro, ESMC, Gradable, and the SWOF), and other programs sell issued carbon credits to end users or brokers (CIBO Impact, Indigo Ag, Nori), Bayer Carbon and Corteva use both financing sources to pay farmers. Purchasers of credits via ERPAs are exposed to higher risks than buyers of issued credits, as weather, pests, and timeliness of practice changes could affect the volume, quality, and timing of carbon credit generation. Consequently, credits purchased through ERPAs would typically collect lower prices than carbon credits already issued.*

- ***Credit buffers.*** *Permanence is a key attribute of carbon credits, and it refers to the duration of the carbon removal or emission avoidance. Agricultural carbon credits face natural risks such as fire, disease, pest outbreaks, and other natural disasters, as well as avoidable and unavoidable human-induced risks. Carbon reversals occur when stored carbon or avoided emissions are released into the atmosphere before the conclusion of the target permanence period. For example, tilling a farm to reduce weed pressure in the fifth year of a 10-year no-till carbon farming contract generates a carbon reversal. Furthermore, the disadoption of conservation practices such as no-till and cover crops is not uncommon.[7] Some carbon programs have developed protocols to create carbon credit reserves or "buffers" from which issued carbon credits could be drawn to offset carbon reversals within the program and secure the permanence of carbon sequestration or emission avoidance embedded in the credits outside the buffer. For example, Indigo Ag holds 5 to 20% of the credits issued in each project permanently in a credit buffer, and Nori withholds an undisclosed portion of the credits for 10 years.*

- ***Look-back payment.*** *While all carbon programs require the implementation of new changes in practices to generate carbon credits, some programs offer a one-time payment "signing bonus" based on carbon farming practices implemented in the recent past but prior to the launching of carbon programs. For example, during their pilot programs, Nori offered look-back payments for up to 5-years of carbon farming practices (with practice change date after January 1, 2010), Bayer offered to pay up to 5-years of past practices (with practice implementation starting after January 1, 2012), and Gradable pays for practices adopted on a field two years before entering into the program.*

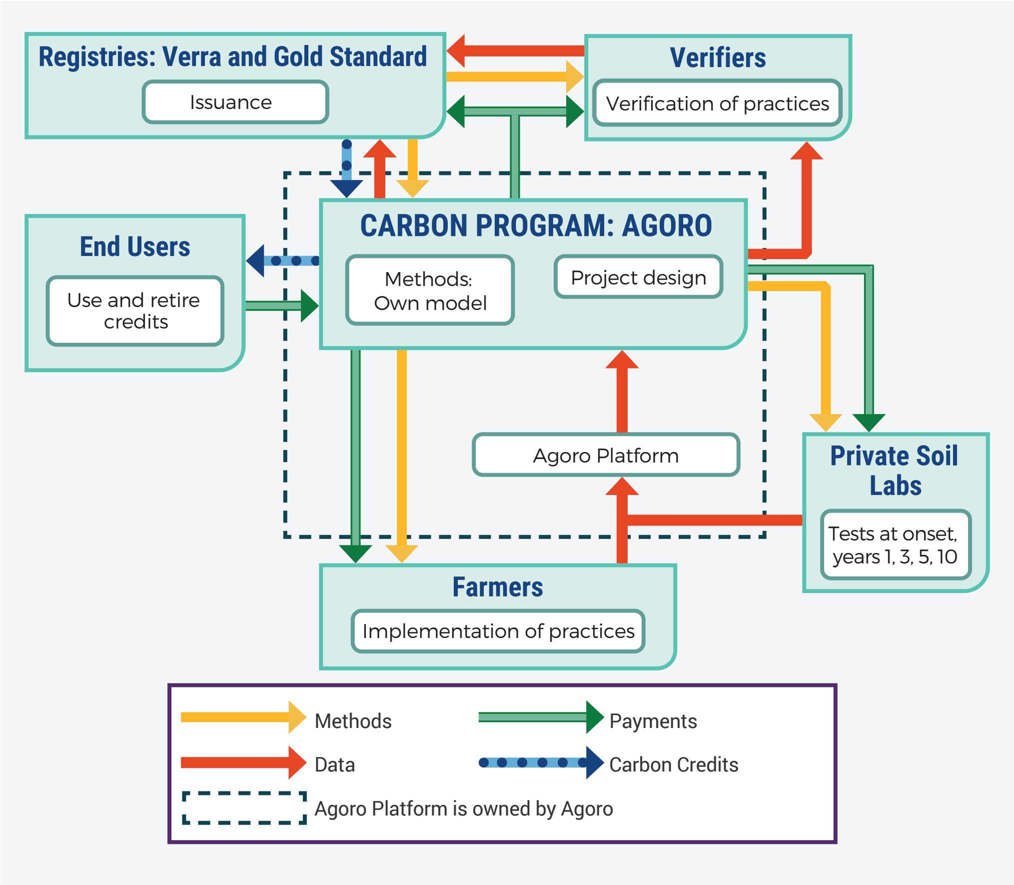
Other relevant differences across carbon programs include contract length (varying from 1 to 10 years), geographical coverage, timing of payments, and minimum enrollment area.[5]

A Characterization of Nine Carbon Farming Programs

1. Agoro Carbon Alliance

The Agoro Carbon Alliance contracts and supports farmers with free local agronomic consultants to generate carbon credits through regenerative practices, including reduced tillage and no-till, planting cover crops, pastureland management, and nitrogen management, with further methodologies under review. Its methodologies to translate agricultural practices into carbon credits are based on protocols from the Verra and Gold Standard registries (Figure 1). Practices implemented by farmers must be entered online into the Agoro Platform and independently checked by accredited verifiers. Soil tests are mandatory and paid for by Agoro Carbon. The external registries will eventually issue serial numbers for carbon credits to Agoro, which in turn will transfers them to buyers post-sale. Farmers have two payment options: after verifications in years 1, 2, 3, 5, and 10, or annual forward payments based on estimates that are adjusted after verification. Farm production data are shared with project developers, Agoro, verifiers, and the registries. To participate in the Agoro Carbon Alliance, farmers must enroll at least 500 acres in the program for 10 years.

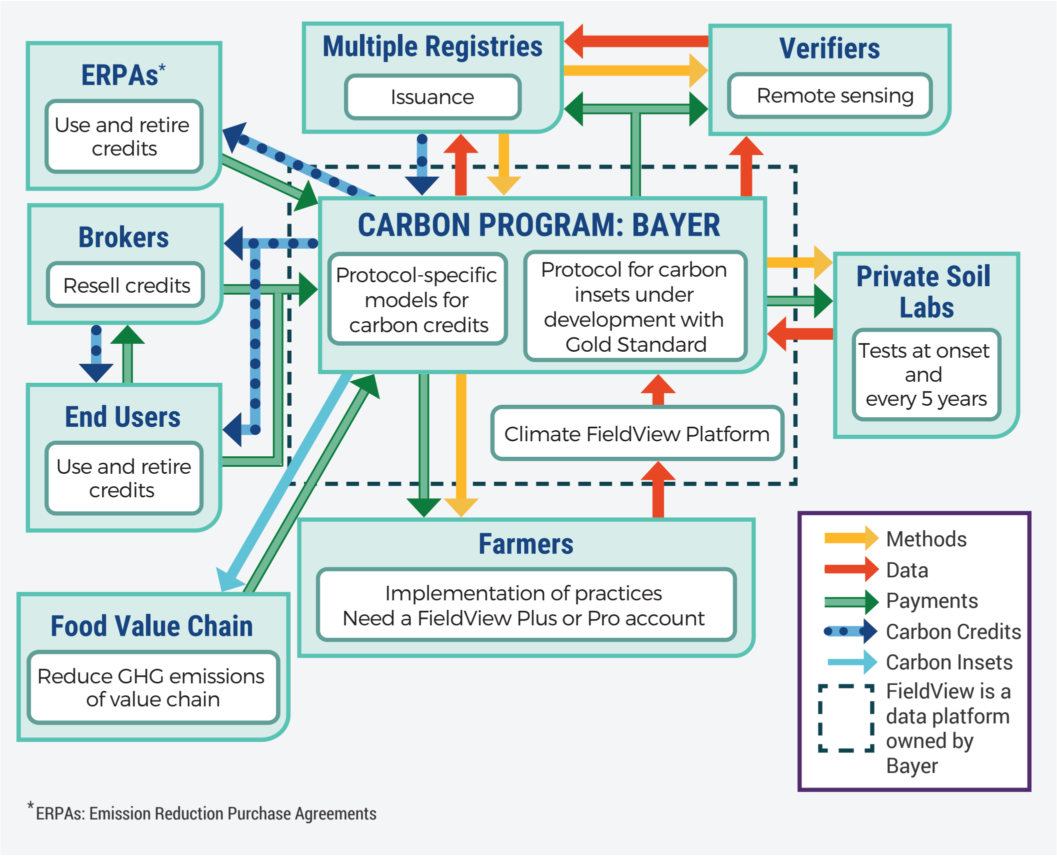
FIGURE 1. CARBON CREDIT GENERATION THROUGH AGORO CARBON ALLIANCE



2. Bayer Carbon

Bayer Carbon finds investors to finance projects through ERPAs and will sell carbon offsets and insets to end buyers and brokers. It pays farmers $3 per acre per year to implement no-till/strip-till, $6 per acre per year to plant cover crops, and $9 per acre per year to implement both practices. Payments for implemented practices could increase (not decrease) depending on revenue obtained at credit sale. Bayer Carbon offers a signing bonus based on up to five years of verified and validated cover cropping and conservation practices implemented after January 1, 2012. The methodology to quantify and issue carbon credits is under development, in collaboration with multiple registries (Figure 2). Farmers contract directly with Bayer Carbon and share their production data through the Climate FieldView Platform (owned by Bayer). Farmers must have a Climate FieldView PLUS subscription, which is available free of charge via BayerPLUS. Soil tests are mandatory at the time of enrollment and every five years for the majority of the acres, and test costs are covered by Bayer Carbon. Depending on the final institutional arrangement for credit issuance and practice verification, production data may or may not be shared with actors external to Bayer Carbon only for purposes stated in the agreement, on a need-to-know basis. Payments are made on an annual basis after remote verification and validation, within one year of practice completion. Bayer Carbon offers participating farmers access to premium low-carbon grain markets. To participate in Bayer Carbon, farmers must enroll at least 10 acres in the program for five years.

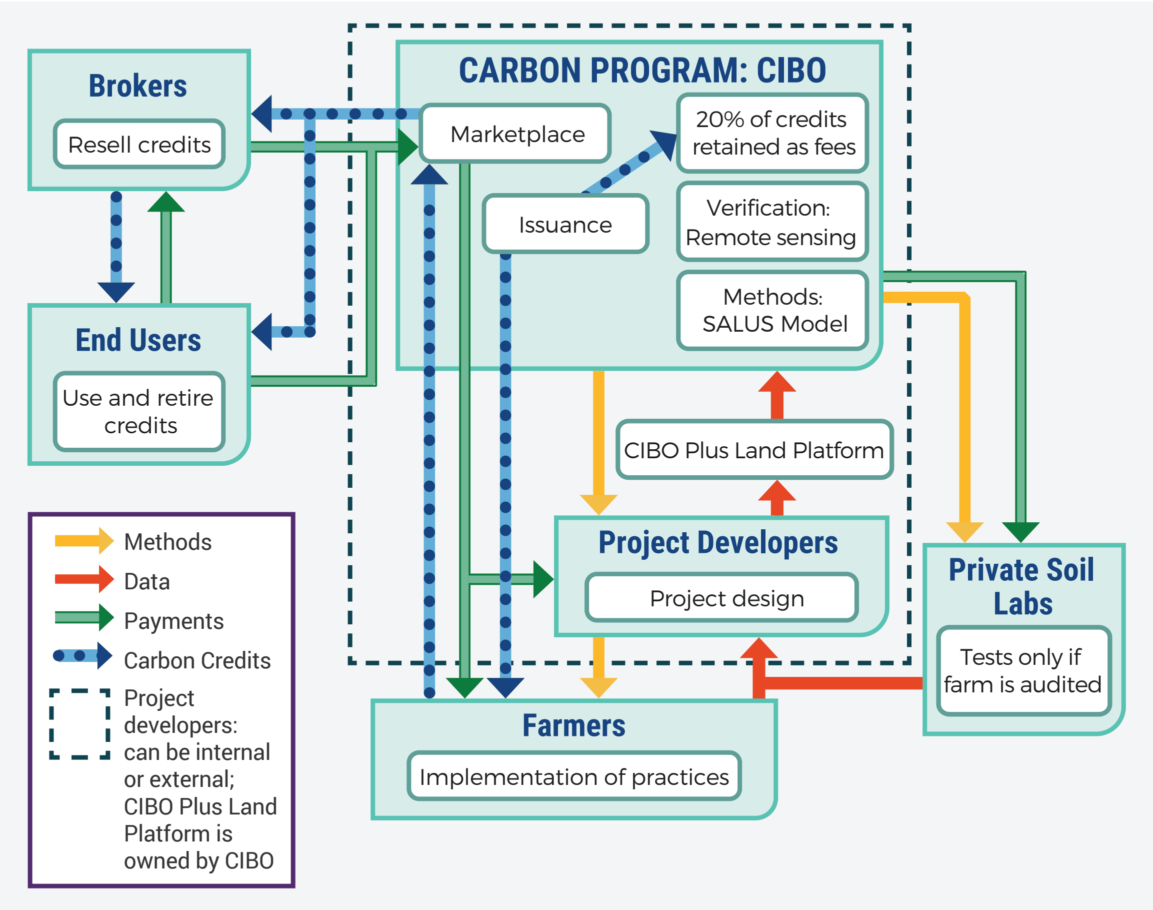
FIGURE 2. CARBON CREDIT GENERATION THROUGH BAYER CARBON



3. CIBO

CIBO is its own registry and marketplace and applies a methodology to translate agricultural practices into carbon credits that is based on the SALUS model (owned by Michigan State University). Project developers can be internal or external to CIBO (Figure 3). Practices implemented by farmers are registered online in the CIBO Plus Land Platform. Verification relies on remote sensing and is internal to CIBO. Soil tests are required only if the farm is audited, and CIBO issues the payments to soil labs. CIBO issues a serial number for carbon credits generated in a project and assigns 80% of the credits to the farmer and retains 20% of the credits as fees. Farmers sell their carbon credits through CIBO's online marketplace to end-users and brokers (who ultimately resell them to end users) and receive full monetary compensation from which fees to external project developers (if any) are paid. Farm production data are shared with project developers and CIBO. Payments start flowing into the system when a sale of (issued) carbon credits occurs. CIBO offers annual contracts, as well as five-year and 10-year contracts to farmers, and does not require a minimum enrollment acreage.

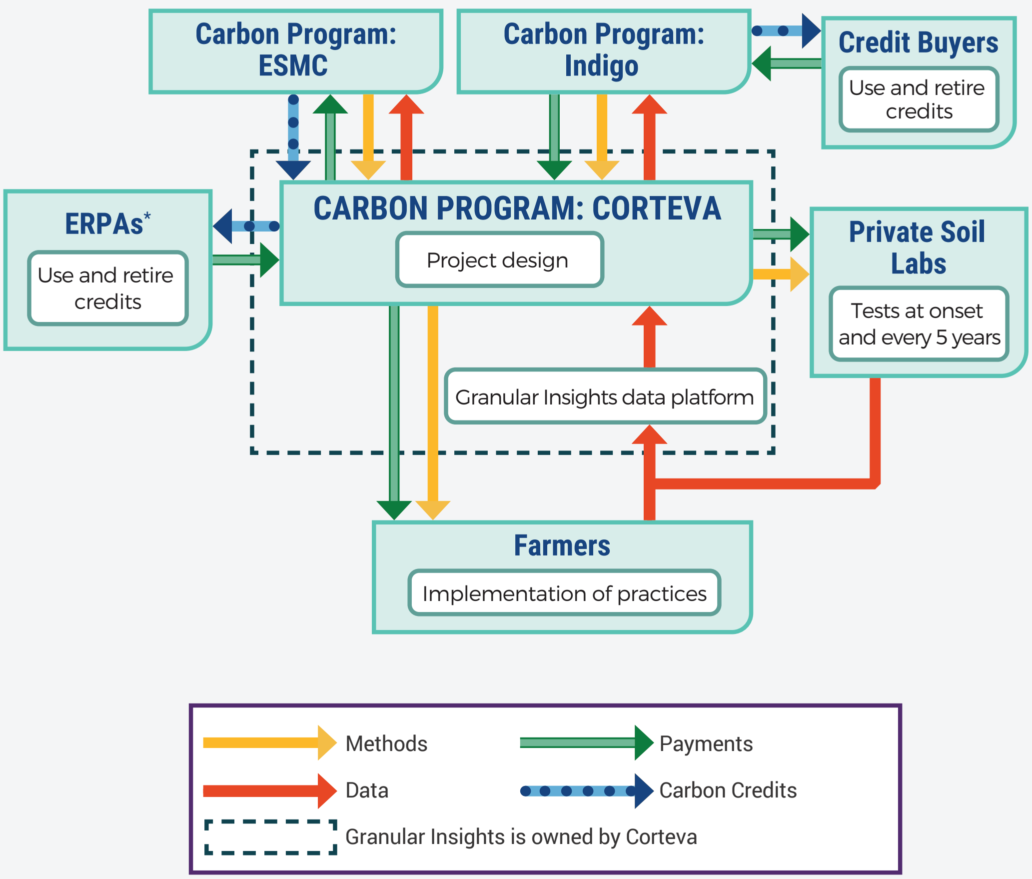
FIGURE 3. CARBON CREDIT GENERATION THROUGH CIBO



4. Corteva Agriscience

Corteva Agriscience contracts directly with farmers to produce carbon credits (Figure 4). Corteva partners with MRV companies, such as ESMC and Indigo Ag, to quantify and certify carbon credits through registry-approved protocols, including SustainCERT (ESMC) or Verra/CAR (Indigo). Farmers input their practices into Granular Insights, Corteva's free digital tool. These practices are submitted to carbon registries for certification and are verified through remote sensing and random site visits. Soil tests are mandatory every five years. Verifiers issue carbon credits to ESMC and Indigo, who sell credits to investors. Corteva transfers 75% of carbon credit sale revenue to farmers, and payments are distributed over the life of the project. Corteva Agriscience offers five-year contracts, with an annual option to opt out, and does not require a minimum enrollment acreage.

FIGURE 4. CARBON CREDIT GENERATION THROUGH CORTEVA AGRISCIENCE

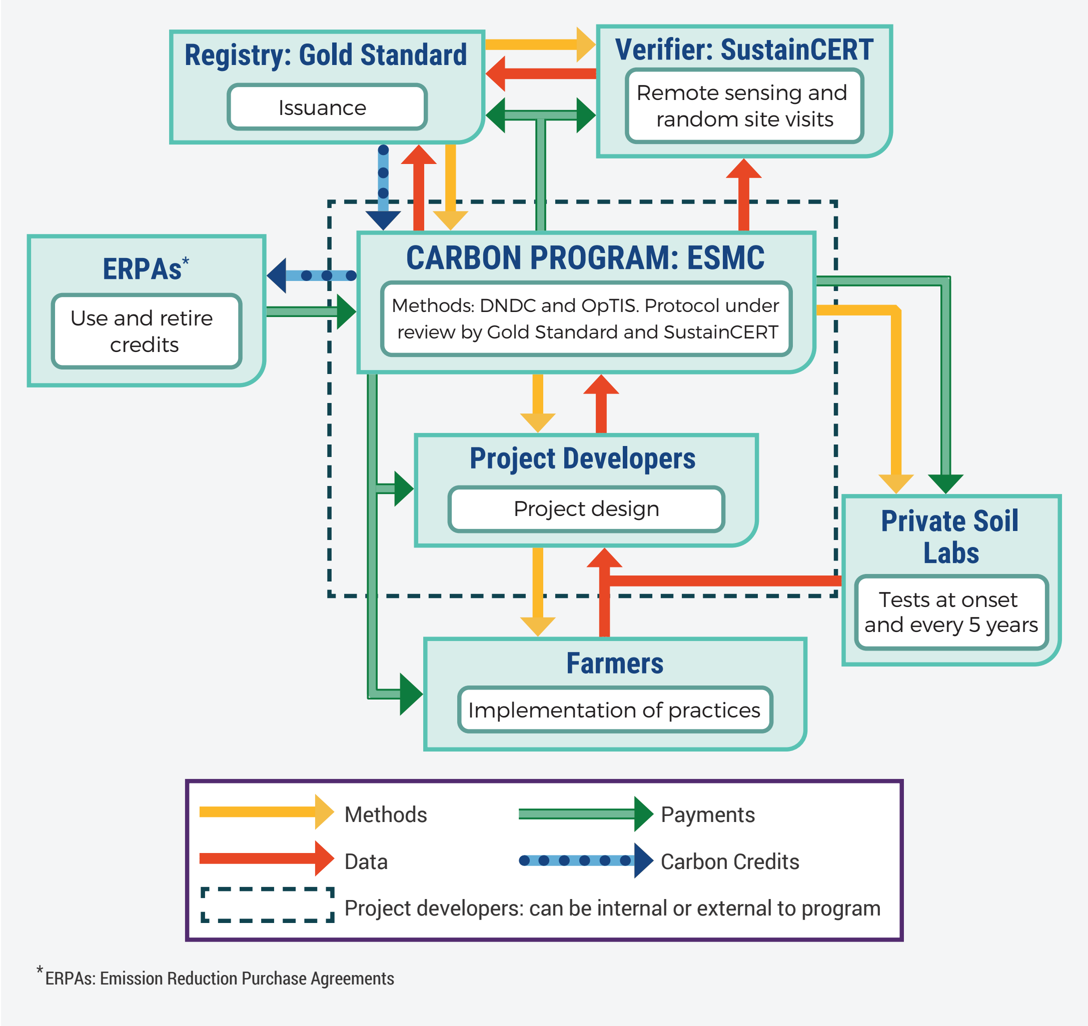


*ERPAs: Emission Reduction Purchase Agreements

5. Ecosystem Services Market Consortium (ESMC)

ESMC finds investors to finance projects through ERPAs (Figure 5). Its methodology to translate agricultural practices into carbon credits is based on the DeNitrification-DeComposition (DNDC) and the Operational Tillage Information System (OpTIS) models, which are publicly available. ESMC's methodology is under review by the Gold Standard registry and SustainCERT. Project developers can be internal or external to ESMC. Practices implemented by farmers are independently verified by SustainCERT. Soil tests are mandatory at the time of enrollment and then every five years. The Gold Standard registry issues serial numbers for carbon credits to ESMC, which in turn transfers them to investors. Farm production data are shared with project developers, ESMC, SustainCERT, and the Gold Standard registry. Payments to all actors in the process are distributed over the life of the project. ESMC offers 10-year contracts, and does not require a minimum enrollment acreage.

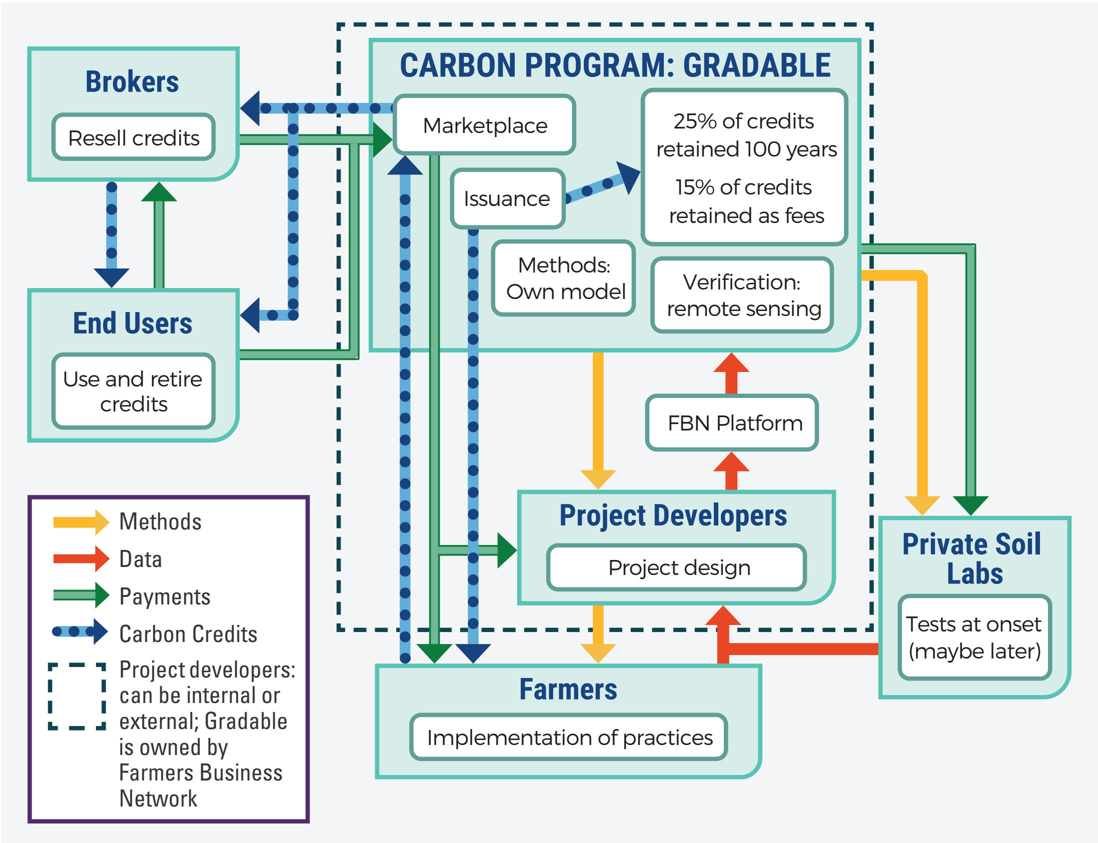
FIGURE 5. CARBON CREDIT GENERATION THROUGH ESMC



6. Gradable

Gradable is its own registry and marketplace, and it develops its own methodology to translate agricultural practices into carbon credits based on a proprietary model (Figure 6). Project developers can be internal or external to Gradable. Practices implemented by farmers are registered online in the Farmers Business Network (FBN) Platform. Verification relies on remote sensing and is internal to Gradable.[8] Soil tests are required at the time of enrollment and, if the optional add-on Gradable Plan to receive tailored agronomic recommendations is selected, also every three or four years (depending on the geographical location). Gradable issues a serial number for carbon credits generated in a project and assigns 60% of the credits to the farmer, retaining the remaining 40%: 25% of the credits are retained to cover avoidable and unavoidable losses of carbon over a 100-year period and the remaining 15% are retained as fees. Farmers sell their carbon credits through Gradable's online marketplace to end users and brokers (who ultimately resell them to end users), and receive full monetary compensation from which fees to external project developers (if any) are paid. Gradable issues payments to soil labs. Farm production data are shared with project developers and Gradable. Payments start flowing into the system when a sale of (issued) carbon credits occurs. Gradable requires that at least 250 acres be enrolled in the program (although minimum area requirements vary by tier) for five years.

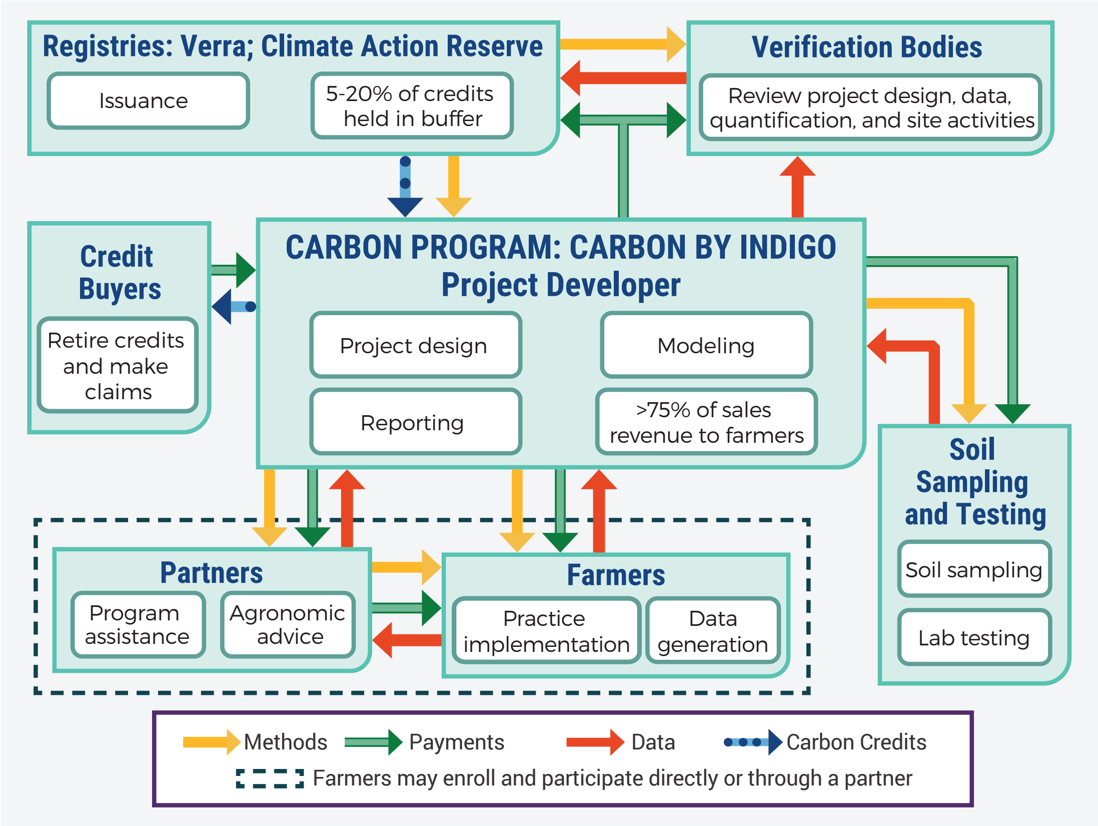
FIGURE 6. CARBON CREDIT GENERATION THROUGH GRADABLE



7. Indigo

Indigo develops carbon projects under standards developed by independent, nonprofit standards organizations, with credits issued and tracked on public registries (Figure 7). They currently work with the Soil Enrichment Protocol, adopted by the Climate Action Reserve, and the Methodology for Improved Agricultural Land Management (VM0042), coauthored by Indigo and approved by Verra. Indigo works either directly with farmers or through partner organizations (e.g., Corteva) to enroll in the carbon project and adopt new practice changes. Management data collection occurs through a proprietary software platform, as well as through remote sensing and farm management system (i.e., software used by farmers to manage data) integrations. Prior to each issuance by the registry, Indigo hires an independent, accredited verification body that conducts limited site visits and in-depth reviews of all documentation, reporting, and quantification. The program is certified Ag Data Transparent and farm data are not shared beyond the registry and verification body. A portion of credits (5 to 20%) are permanently held by the registry in a buffer pool to protect against future carbon reversals. The balance of credits is issued to Indigo and then either transferred to or retired on behalf of the credit buyers. At least 75% of the proceeds from credit sales are paid directly to farmers. If an unavoidable reversal of stored carbon occurs, the registry uses an equivalent amount of credits from the buffer pool to compensate for the loss. Indigo requires farmers to enroll at least 150 acres for five years to participate in the program.

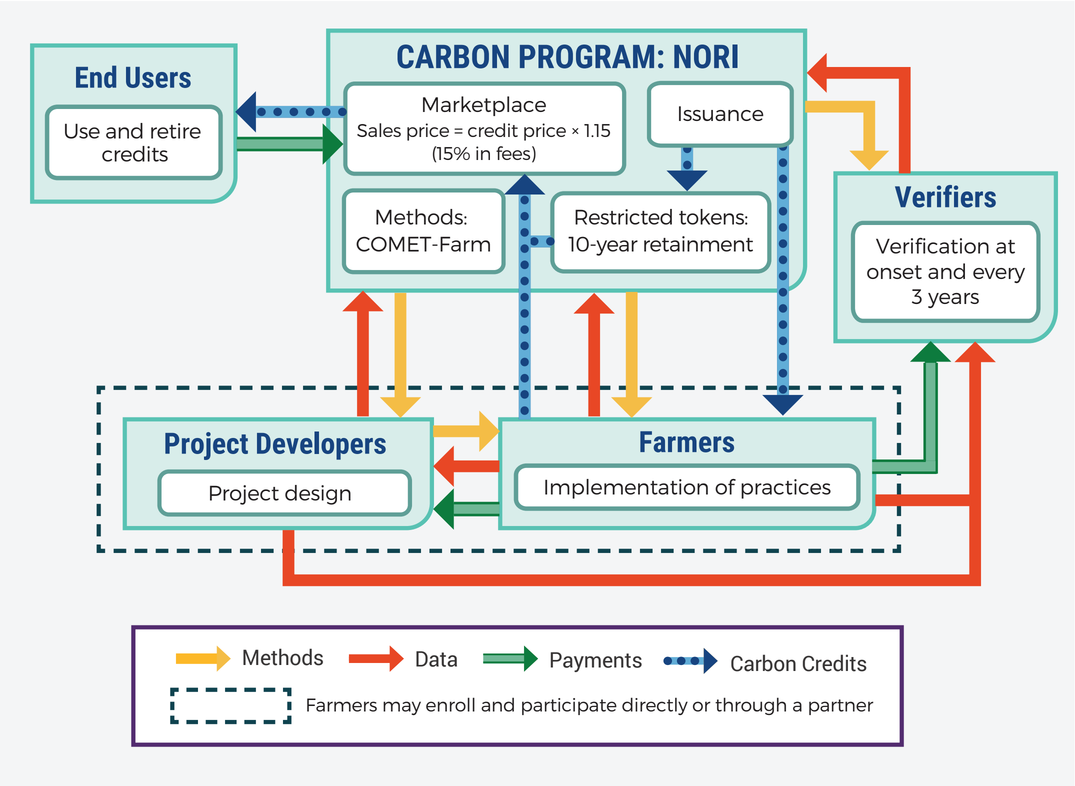
FIGURE 7. CARBON CREDIT GENERATION THROUGH INDIGO



8. Nori

Nori is its own registry and marketplace, and its methodology to translate agricultural practices into carbon credits is based on the publicly available COMET-Farm model. Farmers can either enroll directly with Nori or through a project developer. Practices implemented by farmers are verified by independent third-parties. Farmers must pay out-of-pocket for the verification process at the beginning of the contract and at least every three years thereafter. Nori uses a digital ledger based on Blockchain technology to issue and track serial numbers for carbon credits and to maintain a transparent and inalterable record of the transactions related to each serial number. Nori adds 15% to the price of carbon credits as fees, charged to the buyer (not the supplier). In the pilot phase of the Nori program, each supplier will be issued Nori tokens, a type of cryptocurrency, equal to the number of carbon credits generated. Those tokens will be restricted over the life of the 10-year contract. If there are reversals during that time, Nori will use the restricted tokens as insurance to purchase more recent carbon credits. After the pilot phase, Nori will have its own reserve or buffer of tokens and will still restrict a percentage of tokens from suppliers to use in case of carbon reversals. If farmers avoid carbon reversals for 10 years following the sale of the unrestricted tokens, Nori removes restrictions from the remainder of the farmer's tokens. Nori claims that it will never own farmer data or use them for anything other than running the carbon model. Any data sharing agreements outside of Nori are made directly between the farmer and project developer or verifier. Payments start flowing into the system when a sale of (issued) carbon credits occurs.

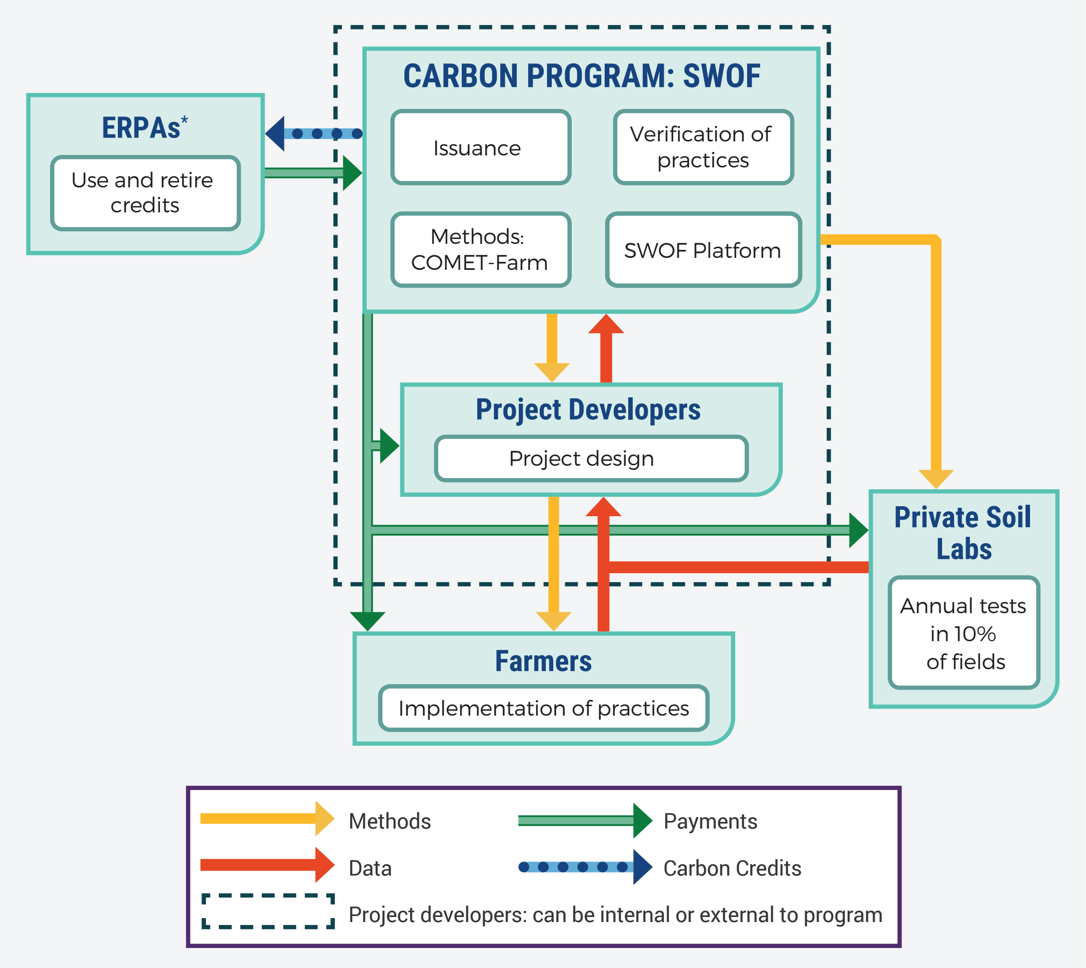
FIGURE 8. CARBON CREDIT GENERATION THROUGH NORI



9. Soil and Water Outcomes Fund (SWOF)

SWOF finds investors to finance projects through ERPAs and acts as its own registry. Its methodology to translate agricultural practices into carbon credits is based on the publicly available COMET-Farm model (Figure 9). Project developers can be internal or external to SWOF. Practices implemented by farmers are verified internally by SWOF, and soil tests are mandatory. SWOF issues the serial number for carbon credits generated in a project, transfers ownership of the serial number to the investor, and makes payments to all actors in the process. Farm production data are shared with project developers and collected through an online platform owned by SWOF. Payments are distributed over the life of the project. SWOF offers annual contracts with no minimum enrollment area requirements, and payments are based on implemented practices that remove carbon and provide environmental co-benefits (improvements in water quantity and quality, biodiversity, and pollinator habitat).

FIGURE 9. CARBON CREDIT GENERATION THROUGH SWOF



*ERPAs: Emission Reduction Purchase Agreements

Clarifying Questions for Farmers

Farmers interested in carbon farming should consider asking multiple questions to program representatives to evaluate the suitability of each program for their own operation. Beyond specific contract details such as covered farming practice changes, definition of additionality and permanence, expected payments and out-of-pocket costs, contract length, and exit clauses, farmers should understand the details of how carbon removal and emission reductions are measured through the life of the contract, the circumstances that trigger temporary or permanent breach of contract and their associated penalties, any special requirements based on land ownership and tenure or leasing agreements, and whether free agronomic guidance to implement practice changes will be available to them.

Since all programs rely on data sharing and verification, farmers need to be clear about the exact type of records they must collect and report, the frequency of the reporting, the platform through which data are to be reported, who has access to the data, what cybersecurity measures are implemented to protect the privacy of their data, what kind of customer support is provided to help organize and complete the data submission, the expected number of hours involved in data entry over the course of the year, and any other responsibilities resulting from program participation (such as allowing the collection of soil samples from the enrolled farms or scheduling site visits for verifiers).

Farmers are advised to consider the opportunity cost of signing a carbon farming contract. One type of opportunity cost could arise from the potential ineligibility from or for current programs incentivizing the adoption of conservation practices, such as cost-sharing programs and crop insurance discounts. For example, the USDA Natural Resources Conservation Service (NRCS) offers qualifying farmers assistance with soil health testing and acquiring cover crop seeds through the Environmental Quality Incentives Program (EQIP) that are not related to carbon sequestration or emission avoidance. While participation in carbon programs does not render farms ineligible for EQIP, farmers must understand whether participation in EQIP makes their farms ineligible for the carbon program.

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Another type of opportunity cost could emerge if the carbon farming contract imposes limitations on future owners of the land (such as a restriction on the sale of conservation easements), or on present or future landlord-tenant relationships or borrower-lender relationships.[9]

A third type of opportunity cost could arise if enrollment in a carbon program today precludes a farm from becoming eligible for other (potentially more suitable) carbon or conservation programs in the future.

Finally, interested farmers are advised to exercise due diligence and consult with their trusted advisors, attorneys, and family members before signing a carbon contract, and to keep in mind that these contracts "are written by the attorneys for the aggregators, the brokers, or the sponsoring organizations" and they "will be written in the best interest of those parties."[9]

A multiplicity of factors are hindering the development of a robust market for agricultural carbon credits, and most of them are rooted in the fact that carbon credits are a credence good. Credence goods are those with product characteristics that cannot be ascertained by consumers even after consumption.[11]

Overcoming Barriers to Market Development

While the number of carbon programs is increasing rapidly, a well-functioning voluntary market for agricultural carbon credits has proven elusive. This section, based on an article entitled "Challenges to Voluntary Ag Carbon Markets,"[10] highlights major barriers to market development and presents suggestions on how to overcome them.

A multiplicity of factors are hindering the development of a robust market for agricultural carbon credits, and most of them are rooted in the fact that carbon credits are a credence good. Credence goods are those with product characteristics that cannot be ascertained by consumers even after consumption.[11] Agricultural carbon credits represent claims that farmers have removed GHGs from the atmosphere or have avoided GHG emissions through changes in agricultural practices, and the credibility of those claims cannot be assessed in the absence of an MRV system.

Robust MRV systems are key to convincing buyers that the implemented changes in agricultural practices actually removed carbon from the atmosphere or avoided carbon emissions, and that carbon credits are additional (generated by new changes in practices), permanent, real, and steps have been taken to prevent increases in GHG emissions outside of the project area in response to decreases in production within the project area (leakage avoidance).

One of the current challenges to the development of a voluntary agricultural carbon market is the absence of standard technical specifications for carbon credits, and the resulting lack of clear, consistent, and uniform guidelines across MRV systems to assess their quality. This can result in high "search costs" to identify the appropriate type of carbon credits for a buyer. Moreover, the presence of difficult-to-verify claims, misunderstood or poorly worded labels, and label proliferation (the existence of too many labels in a market or on a good leading to confusion about competing claims) can decrease the effectiveness of the MRV system and result in market failure. The standardization of technical specifications for carbon credits and guidelines across MRV systems would address this challenge. Some lessons from the U.S. organic markets before and after certification can be applied to the discussion on how to overcome barriers to carbon farming: prior to the development of specific standards for production, the market for organics was very small and lenders were reluctant to finance operations; once standards were set and claims were verified, many farmers overcame their reluctance to join the industry, consumers overcame their distrust of product claims, wholesalers overcame their reticence to broker the goods, retailers devoted shelf space to the items, lenders had a greater understanding of the needs of producers in this new market, and risk management tools were developed for some organic commodities. The Growing Climate Solutions Act of 2021 (GCSA), passed by the U.S. Senate on June 24, 2021, would provide the U.S. Department of Agriculture (USDA) authority to create a GHG Technical Assistance Provider and a Third-

party Verifier Certification Program, and instruct the Secretary of Agriculture to provide necessary definitions of the markets and determine the rules for the certification program.[12]

Another challenge is that robust MRV systems are complex and costly to implement, creating a gap between prices paid for carbon credits by end users and prices received by farmers. Large fixed costs in the MRV system could prove cost-prohibitive for small scale projects, effectively skewing the supply of voluntary carbon credits towards large scale farms in detriment of small and medium-scale farms.[13]

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Changing farm management practices is a costly process that usually involves a steep learning curve for farmers, depending on a diverse combination of economic and agronomic factors, social norms, perceptions of government programs, farm characteristics, land tenure factors, and knowledge-related factors.[14,15,16,17] For example, farmers in Indiana who have never adopted conservation tillage or no-till would require almost a $40 per acre increase in net revenue to implement no-till, and an additional $10.57 per acre would be required to enter into a multi-year contract that does not allow farmers to change their tillage practices over the life of the contract.[18] Fair compensation to carbon farmers will be needed to induce widespread participation in agricultural carbon programs. Not only prices for carbon credits received by farmers would have to cover all extra costs, but also provide sufficient cushion to deal with multiple risks, as described below.

Sources of Risk for Farmers

One source of risk for farmers is the way carbon programs estimate the number of carbon credits generated by a particular project. Currently, it is impossible for farmers to assess the amount of carbon credits that one change in practices in one farm can generate across multiple carbon programs (Table 1). For example, while CIBO Impact uses the SALUS model to calculate carbon credits, Nori and the SWOF use the COMET-farm model, and ESMC uses the DNDC model and the OpTIS model to calculate carbon credits. Since contracts are signed based on the projected volume of carbon credits, but paid on the actual volume of credits generated, uncertainty in projected volumes translates directly into uncertainty in revenues for farmers. The agricultural carbon industry needs research-based guidelines on how to compare the potential to generate carbon credits across programs to reduce uncertainty for credit buyers and farmers.

Additional uncertainty stems from the quantification of actual or realized carbon removal or emission avoidance, which can entail costly processes. On the one hand, soil tests can produce more accurate measurements than remote sensing, but they are cost-prohibitive at large scale. As discussed in the previous section, most carbon programs currently rely on soil tests to establish a baseline and some programs also plan to use soil tests to assist in the determination of the actual number of carbon credits produced. However, since soil tests are too costly and time-consuming to be widely used,[19] sampling is often limited to small areas of each project. The NRCS currently offers assistance to farmers for soil health testing through the 216 Soil Health Testing Conservation Evaluation and Monitoring Activity,[20] and does not restrict the producer from utilizing the results for a carbon program. On the other hand, remote sensing technologies could be less expensive but produce very uncertain estimates of actual changes in GHG emissions at the farm level scale.[21] A lack of scientific consensus on the linkages between soil dynamics, agricultural practices, and GHG dynamics at farm level makes the coordination of multiple technologies to measure the actual production of carbon credits very challenging and can undermine the viability of an agricultural carbon market. More research is needed to develop a consensus on the appropriate mix of technologies to measure actual carbon removal or avoidance at farm, project, and regional scales.

As of 2021, voluntary carbon credits issued in the agricultural sector accounted for less than one percent of all voluntary carbon.[23]

Temporary or permanent disadoption of contracted changes in farming practices due to avoidable or unavoidable causes, can generate carbon reversals that could trigger penalties for disadopting farmers. Some carbon programs make provisions to deal with reversals through credit reserves or buffers (as discussed above), but information on the penalties that could be imposed to farmers is not publicly available. Increased transparency on how carbon programs plan to address carbon reversals is needed to foster the development of an agricultural carbon market.

Another risk for participating farmers is the potential for data breaches in the MRV system and unauthorized access to and use of private farm and farmer data. Increased transparency on data management and security measures could mitigate this risk, although not completely eliminate it.

A source of uncertainty for the voluntary agricultural carbon industry is competition from other carbon credit suppliers, such as forestry and renewable energy—the top two sectors in terms of carbon credits issued around the world.[22] As of 2021, voluntary carbon credits issued in the agricultural sector accounted for less than one percent of all voluntary carbon.[23] Strategic considerations of capacity, scale of operation, break-even prices and other factors affecting competition and market structure on the supply side of the market, are necessary to assess the potential for development and success of an agricultural carbon market.

On the demand side, pledges of carbon neutrality by large corporations place their target date a decade or more into the future, but details about short- and medium-term plans to purchase carbon credits are kept under wraps. For example, Microsoft and Smithfield Foods pledged to become carbon negative by 2030, while Kraft Heinz, Ford and Exxon pledged to become carbon neutral by 2050. The uncertainty about potential demand for carbon credits in the short and medium term can increase perceived risks for farmers, who are typically required to sign multi-year carbon farming contracts.

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Corporations could help mitigate this uncertainty by providing more detailed information on their plans to purchase carbon credits and following them.

The overall carbon footprint of the whole carbon farming system (accounting for both negative CO_2e emissions from changes in farming practices, plus the positive CO_2e emissions from MRV, project financing, and credit trading) could become a barrier to the development of a voluntary agricultural carbon market if the carbon intensity of the carbon farming system is higher than the corresponding intensity of other sectors. Research-based comparative analysis of the overall carbon footprint of competing carbon suppliers would be needed to assess the viability of carbon farming as an industry.

Perceived differences in carbon credit quality across agricultural carbon programs (related to additionality, permanence, realness, and leakage avoidance, among other characteristics) could lead to some existing programs losing market share and even exiting the market. Such a structural change in the carbon program environment could increase the exposure of farmers and credit buyers to uninsured systemic risks. Developing equivalencies across protocols to facilitate the transfer of credits across programs and the comparison of credits generated by practice changes across programs should reduce the risk of losing some of the investments in carbon farming if a carbon program exits the market.

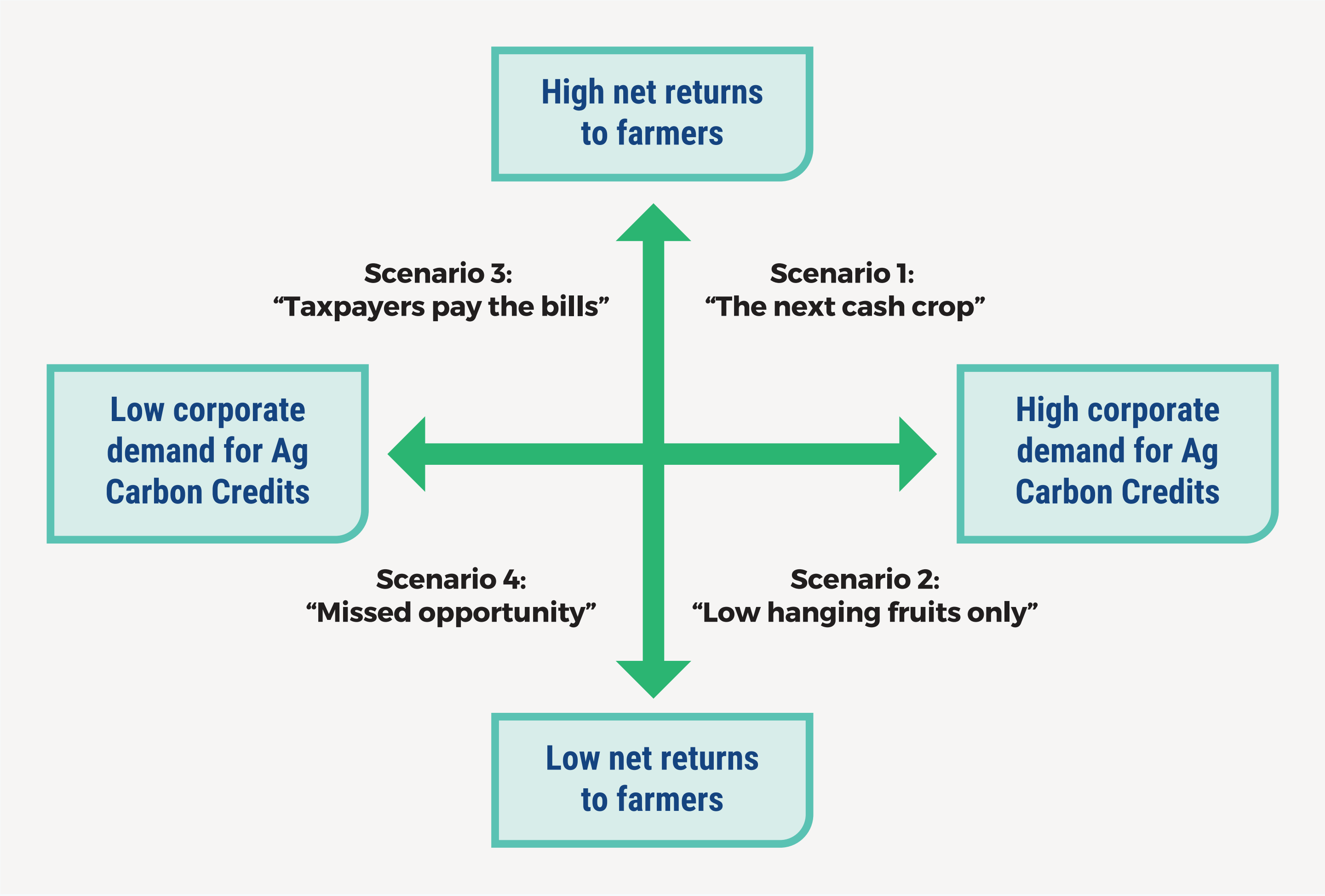
An additional risk in the carbon farming industry stems from the lack of transparency in the price discovery mechanism for carbon credits. Although a handful of futures contracts on carbon emission offsets are currently traded,[24,25] they apply to a narrowly defined set of credits and cannot be construed to serve as a pricing benchmark for voluntary agricultural carbon.[26] A quarterly survey of prices paid for voluntary agricultural carbon credits organized by an independent agency or a land-grant university would help mitigate this risk.

The development of an agricultural carbon credit market could be fostered by a suite of risk management tools to mitigate production, legal, and price risks, including: templates with suggested language to add to contractual agreements to protect the balance of powers between carbon programs, farmers, and credit buyers; insurance policies for agricultural carbon production; hybrid compensation systems with a minimum payment per acre to enhance program participation plus transparent performance-based premiums and penalties; protocols for stacking payments from carbon programs (focused on GHGs), and environmental services beyond carbon (water quality and quantity, biodiversity, etc.); protocols for non-additional practices, since all practices considered additional today will eventually become non-additional.

Possible Scenarios for Agricultural Carbon Markets

The complexity of the nascent carbon farming industry cannot be understated. However, to organize the discussion on the possible evolution of voluntary agricultural carbon markets, this section focuses on two critical variables that give raise to four extremely simplified scenarios (Figure 10). The level of corporate demand for agricultural carbon credits and net returns to farmers for carbon credits can drive the success of voluntary agricultural carbon markets.[27] Net returns to farmers are defined as the gross compensation received by farmers minus the cost of changing farming practices and the cost of keeping records and entering data into the web-based platforms to comply with the verification process. This section expands on previous works[27] by expanding the characterization of the scenarios.

FIGURE 10. FOUR POSSIBLE SCENARIOS FOR AG CARBON MARKETS



Scenario 1: The Next Cash Crop

If corporate demand for agricultural carbon credits is high and sustained, and net returns to farmers are high, then the carbon market will generate a valuable and stable source of income for participating farmers. This scenario requires a credible MRV system for agricultural carbon credits and strong confidence that the offsets are legitimate and high quality. It also needs that competition from other sources of carbon credits be limited (via limited quantities issued at similar or lower prices, or via a segmented market for carbon credits with different prices), and that robust financing and adequate risk management tools be available for farmers and credit buyers.

In this scenario, widespread adoption of multi-year conservation practices according to production protocols that generate high-quality credits becomes the norm. A sustained demand for agricultural carbon credits and widespread farmer participation would result in liquid markets with moderate price volatility. This scenario could be reinforced by the development of complementary value chains for low-carbon commodities that trade at a premium over conventional commodities. The new USDA Partnerships for Climate-Smart Commodities program will finance partnerships to support the production and marketing of climate-smart commodities implemented on a voluntary basis on working lands.[28]

Scenario 2: Low-Hanging Fruits Only

If corporate demand for carbon credits is high but the quality of agricultural carbon credits is perceived by buyers to be low, then net returns to farmers will be low and the agricultural carbon market will likely be small and underdeveloped.

Given that forestry can produce carbon credits at a lower cost than agriculture,[29] this scenario requires the total demand for carbon credits to exceed the supply of credits from forestry and other low-cost sources (limited competition). This second scenario is likely to occur if the MRV system for agricultural carbon credits is weak and not credible, or if (cash and non-cash) participation costs for farmers are high. The expected outcome is that participants would implement only the least-cost practices to generate carbon credits or practices that farmers were planning to change even in the absence of carbon payments (but had not changed yet).

Market liquidity would be low, with high volatility around low average prices, and limited financing and risk-management services for farmers and purchasers of credits would be available.

Scenario 3: Taxpayers Pay the Bills

If corporate demand for carbon credits is low but participation in voluntary carbon programs is heavily subsidized and market prices for carbon credits become of secondary importance to farmers, then the private voluntary carbon market under analysis would transform into a government-sponsored program funded by present and future taxpayers, as well as by credit buyers. While the USDA currently offers multiple cost-share programs to incentivize the adoption of conservation practices (such as payments for retiring land from production, extra subsidies for some crop insurance policies tied to the use of cover crops, and assistance to assess soil health through soil tests), none of the existing programs target GHG removal or emission avoidance.

This scenario would require government programs to (a) absorb a substantial portion of the cost of the MRV system, (b) directly pay farmers a participation bonus on top of the price received in the private market for their credits, or (c) mitigate farmers' costs of changing practices to generate carbon credits. Option A could be implemented by centralizing the MRV system into a government-funded agency to exploit economies of scale through massive aggregation of projects. Option B would require a clearinghouse of information within a government agency to avoid double-counting of credits and would result in less government involvement than option A. Option C could be implemented through new Farm Bill programs that extend NRCS mission to incentivize carbon farming, adapting existing mechanisms to implement the additional mandate.

In this scenario, the focus of participating farmers would turn to complying with regulations to participate in the government-sponsored programs, and option A might generate incentives for rent-seeking behavior by groups representing participating farmers (such as expending efforts to lower MRV standards or granting exceptions for certain practices or farms).

A low corporate demand for carbon credits could stem from a weak MRV system or high competition from other sources of carbon credits. Market liquidity from private sources would be low, with high volatility around low average market prices, and limited private financing and risk-management services for farmers and purchasers of credits.

Scenario 4: Missed Opportunity

If corporate demand for carbon credits is low and the perceived quality of agricultural carbon credits is low, resulting in low net returns for farmers, then an agricultural carbon market might not develop at all or it might develop only to collapse later, as it was the case with the Chicago Climate Exchange.[27] A low corporate demand for agricultural carbon credits could stem from a weak MRV system or high competition from other sources of carbon credits. Limited adoption of carbon farming practices will likely generate high volatility around low average agricultural credit prices, and steer farmers away from carbon markets. There would be limited private financing and risk-management services for farmers and purchasers of credits.

Next Steps

The rise of several carbon programs, and companies that verify, buy and sell credits, is indicative of a strong corporate demand for agricultural carbon credits. However, there are no clear signals that the volume of agricultural credit generation is increasing in a meaningful way, or that prices for agricultural carbon credits are increasing or can be expected to increase in the future.

The current lack of standards and proliferation of intrinsically different agricultural carbon programs results in the co-existence of various MRV systems. Large fixed costs for the carbon farming industry and limited enrollment result in suboptimal scales of operations and large unit costs per agricultural carbon credit. Carbon programs are currently dependent on angel investors and venture capital to finance their operations, and do not derive profits from selling carbon credits. Eventually, carbon programs will have to cover operating costs and generate profits from the sale of credits. That could generate sizable wedges between prices paid by consumers and prices received by farmers. Additionally, agricultural carbon credits will continue to face competition from other sources of carbon credits (particularly forestry and renewable energy). Consequently, the most likely scenario in the status quo is the second one: "low-hanging fruits only."

In order to overcome the challenges presented in this article, and move from the "low-hanging fruits only" scenario to "the next cash crop" scenario, efforts must be devoted to:

- *Fill the science gaps generating uncertainty in the production of agricultural carbon credits;*
- *Increase the transparency of the carbon farming industry and improve the credibility of agricultural carbon credits to at least a level comparable to that of carbon credits from forestry and renewable energy;*
- *Develop and enforce minimum standards for carbon credits, promote economies of scale in the MRV system, and let the market define premiums and discounts with respect to the standard;*
- *Develop a suite of tools to manage production, price, and legal risks for participating farmers.*

This analysis does not account for the increased interest on carbon capture and sequestration ("industrial carbon sequestration") in the corn-based ethanol industry or the carbon calculation in renewable diesel production to qualify for the incentives offered by California and Oregon's low-carbon fuel standards, which could present additional opportunities for farmers to monetize the implementation of conservation practices. However, it must be noted that agricultural carbon credits cannot usually be directly sold into the markets for low-fuel standards.

While carbon credits are the major focus of this issue report, other ecosystem markets from agricultural production could develop in the future to protect water quality and quantity, wetlands, pollinators, and biodiversity. The performance of the voluntary agricultural carbon credits market will set a precedent for those other markets. The size of the market for ecosystem services related to nitrogen and phosphorous management in the US was projected by IHS Market at $8.7 billion annually.[3]

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