Bipartisan Policy Center

Farm & Forest Natural Carbon Solutions Initiative

PRELIMINARY MATERIALS

The Bipartisan Policy Center's Energy Project is focused on the development of pragmatic, evidence-based energy and climate policies that can make meaningful progress towards a low-carbon future. BPC's Farm & Forest Natural Carbon Solutions Initiative aims to identify the most promising opportunities to enhance the economic and environmental well-being of our nation's natural resources. It will seek the implementation of strategic programs that support the agricultural and forestry sectors and reward practices that enhance carbon sequestration and storage. These efforts can benefit the local environments and improve the bottom line of participating companies, while providing valuable climate mitigation services.

The BPC Energy Project has been working with a variety of technical experts to examine these opportunities and compiled a set of short working papers that create a foundation for a new federal initiative, geared toward the development of more targeted and ambitious natural carbon storage programs.

We believe these working papers create an important starting point for a new congressional focus on natural carbon storage opportunities and intend to build on this initiative in 2020. BPC will publish these materials in a compendium in early 2020 and will pursue many of these concepts in greater detail afterward. In the meantime, the working papers are packaged here for preliminary review.

DECEMBER 2019

Table of Contents

BPC Summaries of Working Papers 1

Federal and State Efforts to Encourage Carbon Sequestration in Agricultural Soils and Forests 11
Eric Washburn, Windward Strategies

Federal Policy Options for a "Carbonshot" in Natural and Working Lands 26
Alex Rudee and James Mulligan, World Resources Institute

Overarching Issues in the Design of Climate Mitigation Policy for Agriculture and Forestry 40
Robert Bonnie, Duke University

Perennializing Grain Crop Agriculture: A Pathway for Climate Change Mitigation & Adaption 50
Fred Iutzi and Timothy Crews, The Land Institute

The Ecosystem Services Market Consortium: Ecosystem Services Markets Conceived and Designed for Agriculture 72
Debbie Reed, Ecosystem Services Market Consortium

Bipartisan Policy Center

Federal and State Efforts to Encourage Carbon Sequestration in Agricultural Soils and Forests

Summary of Paper by Eric Washburn, President, Windward Strategies

Changing agricultural and forestry practices can result in annually sequestering many gigatons of carbon in soils and forests, offsetting emissions, and reducing atmospheric concentrations of carbon dioxide. To achieve this goal, Congress should consider modifying existing federal agricultural and forest management programs and explore legislative concepts pioneered by federal and state lawmakers.

The summary below provides a brief outline of the paper's topics.

U.S. practices for accelerating carbon sequestration in farms and forests

Summarizes actions that have the potential to increase carbon sequestration on agricultural lands and in forests.

Market for agriculture and forestry offsets through mandatory state climate programs, voluntary GHG reduction programs, and corporate commitments

Compares regulatory and voluntary programs that include carbon offsets, which could come from agricultural or forest carbon sequestration projects.

Existing Federal USDA/ Farm Bill Programs that Encourage Carbon Sequestration

Identifies the existing Farm Bill programs that promote soil-based carbon sequestration on agricultural lands, and those that promote long-term stewardship of private forestland.

Current State Soil and Forest Carbon Sequestration Programs

Identifies relevant examples of state soil and forest health programs that could be replicable in other states or at the federal level to increase carbon sequestration.

Federal Legislative Proposals

Summarizes key provisions of several bills related to carbon sequestration that have been introduced in the 116th Congress.

State Legislative Proposals

Summarizes key provisions of several bills related to carbon sequestration that were introduced in various states in 2019.

@BPC_Bipartisan
facebook.com/BipartisanPolicyCenter
instagram.com/BPC_Bipartisan

bipartisanpolicy.org | 202 - 204 - 2400
1225 Eye St NW, Suite 1000 | Washington, DC 20005

Bipartisan Policy Center

Federal Policy Options for a "Carbonshot" in Natural and Working Lands

Summary of Paper by Alexander Rudee and James Mulligan, World Resources Institute

Carbon dioxide can be captured naturally in forests and agricultural soils. Enhancing carbon removal and storage in these natural and working lands could contribute meaningfully to climate change mitigation efforts while creating economic opportunities in rural communities.

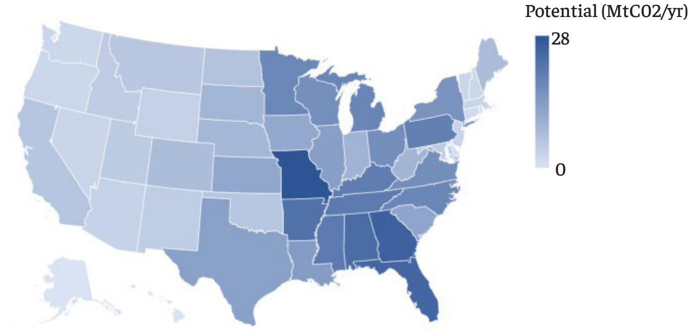
An assessment by World Resources Institute identifies two priorities for this enterprise:

- Restoring trees to the landscape in ways that improve the health of eastern timberlands, create new sources of revenue for agricultural producers, and improve the livability and character of urban and suburban communities.
- Building soil health in the nation's farms and ranches in ways that increase farm profitability while sequestering carbon.

Restoring Trees to the Landscape

- **Achievable Scale:** 360 million metric tons of carbon dioxide per year
- **Suitable Area:** 330 million acres
- **Land Types Benefitting:** Existing forest (especially eastern timberlands), pastureland, developed open space, some cropland, urban neighborhoods

Tree Restoration Potential By State



- **Major Policy Options:** Federal subsidy (cost-share, tax credit, or state grant program)
- **Cost per Ton:** ~$10/tCO2
- **Initial Federal Investment:** $1-4 billion per year

Building Soil Health

- **Achievable Scale:** 200 million metric tons of carbon dioxide per year
- **Suitable Area:** One billion acres (all agricultural land)
- **Land Types Benefitting:** Cropland, ranchland
- **Major Policy Options:** Extend on-farm innovation trials program to 10 million acres
- **Cost per Ton:** ~$40/tCO2
- **Initial Federal Investment:** $500 million per year

@BPC_Bipartisan
facebook.com/BipartisanPolicyCenter
instagram.com/BPC_Bipartisan

bipartisanpolicy.org | 202 - 204 - 2400
1225 Eye St NW, Suite 1000 | Washington, DC 20005

Bipartisan Policy Center

Overarching Issues in the Design of Climate Mitigation Policy for Agriculture and Forestry

Summary of Paper by Robert Bonnie, Nicholas Institute for Environmental Policy Solutions, Duke University

OVERARCHING OBSERVATIONS

- Command and control regulations for agriculture and forestry will not work.
- Instead, climate policy should enhance agriculture and forest profitability.
- Carbon offsets can work but are likely to need considerable assistance in the form of government insurance, guarantees, and/or other assistance to work at the scale needed.
- Both private and public investment will be needed to generate the types of changes to agricultural and forestry practices needed to sequester carbon at scale. Locally-led, collaborative projects should be encouraged.
- The Department of Agriculture should take the leading role.

POLICY MECHANISMS TO ACHIEVE CARBON SEQUESTRATION AT SCALE

- **Carbon Offsets for Compliance Markets** – Benefits of offsets include accountability for ensuring real GHG reductions and encouraging private investment into conservation practices. To work at scale, however, offset policy must provide assurances that landowner/producer investments will create returns, insure environmental integrity of offsets, and minimize transaction costs.

- **USDA Carbon Bank** – USDA could use the Commodity Credit Corporation to buy, insure, or provide price guarantees for carbon credits from farmers, ranchers, and forest owners.
- **Use of Existing Incentive Programs in the Farm Bill** – Congress could dramatically increase funding for Farm Bill programs such as the Conservation Reserve Program, the Environmental Quality Incentive Program, and others, though these programs aren't currently designed to optimize climate benefits.
- **Tax Incentives** – Policymakers could consider either expanding existing tax credits or creating new ones that can prevent land conversion and encourage carbon sequestration practices.
- **Research and Development** – Precision farming techniques, nitrogen inhibitors, changes in livestock feed mixes, genetic tree improvement, more efficient wood utilization, and many other new technologies can produce significant climate benefits.
- **Investments in Climate-Related Rural Jobs and Infrastructure** – Providing direct grants, low-interest loans, and other assistance to kickstart new and expanded markets for agriculture and forestry products that deliver real climate benefits.
- **Bioenergy** – Increased use of low-carbon biofuels and expanding markets for low-value wood can reduce GHG concentrations.
- **Public Lands Management** – Management to restore natural conditions and prevent intense wildfires, forest restoration, and planting trees can reduce GHG emissions and create rural jobs.

@BPC_Bipartisan
facebook.com/BipartisanPolicyCenter
instagram.com/BPC_Bipartisan

bipartisanpolicy.org | 202 - 204 - 2400
1225 Eye St NW, Suite 1000 | Washington, DC 20005

Bipartisan Policy Center

Perennializing Grain Crop Agriculture: A Pathway for Climate Change Mitigation & Adaption

Summary of Paper by Fred Iutzi and Timothy Cruz, The Land Institute

INNOVATIONS, STRATEGIES, AND POLICIES PROPOSED

- Soil carbon sequestration is the most beneficial source of negative emissions for the U.S. climate change mitigation portfolio, and current grain crop production acreage is the prime candidate for major sequestration opportunities.
- U.S. grain crop agriculture is based on crops that are shallow-rooted, annual plants, grown in low-diversity monocultures that have lost the majority of the soil carbon. The native grasslands that sequestered carbon—prior to settlement and cultivation—were composed of deep-rooted, perennial plants, growing in high-diversity mixtures of multiple species.
- While discussions of soil carbon sequestration often emphasize uncertainty, the scientific literature shows that the highest levels of carbon sequestration achievable occur when lands—previously planted to annual crops—are converted to continuous, perennial vegetation.
- In other words, perennializing the agricultural landscape is the single most effective thing we can do for carbon sequestration.
- Perennial, polyculture grain cropping systems have the potential to substantially reduce emissions of nitrous oxide—a potent greenhouse gas—from agricultural soils. It can also reduce carbon dioxide emissions from farm equipment operations and the synthesis of inputs, especially nitrogen fertilizers.

- Perennial grain crops can also make major contributions to increasing agriculture's adaptation to climate change by reducing soil degradation, reducing negative water quality impacts, and reducing agricultural pesticide use.
- The Land Institute and its network of global research collaborators have recently achieved proof-of-concept with their perennial grain crops research efforts. The world's first two perennial grain crops are now in pilot-scale commercial production: Kernza® perennial grain and perennial rice. Other perennial grain crops are under development.
- To date, results demonstrate that a suite of perennial grain crops can be developed to replace the bulk of current U.S. and global grain crop production, leading to transformational increases in carbon sequestration. However, at current levels of investment, full deployment is decades away.
- Decisive action by the federal government is now warranted to accelerate perennial grain crop R&D by increasing public funding and stimulating private investment.

@BPC_Bipartisan
facebook.com/BipartisanPolicyCenter
instagram.com/BPC_Bipartisan

bipartisanpolicy.org | 202 - 204 - 2400
1225 Eye St NW, Suite 1000 | Washington, DC 20005

Bipartisan Policy Center

The Ecosystem Services Market Consortium: Ecosystem Services Markets Conceived and Designed for Agriculture

Summary of Paper by Debbie Reed, Executice Director, ESMC

The Ecosystem Services Market Consortium is launching the first ecosystem service market program dedicated exclusively to agricultural lands. The program is currently in full pilot and demonstration mode with more than 40 members from across the agricultural supply chain, and the full-scale market will launch in 2022. The ESMC operates at the national scale, and was conceived of, and designed for, US farmers and ranchers. ESMC's program provides outcomes-based, quantified, salable credits. These credits represent improvements in soil carbon sequestration and retention, net GHG mitigation, water quality impacts, and water use efficiency. ESMC's approach was designed to incorporate the successful elements of previous ecosystem service trading markets, while overcoming the mistakes and pitfalls that plagued them. ESMC's market will incorporate these lessons and drive technological R&D. To date, ESMC has developed new agriculture-focused market rules that accommodate the needs of buyers and sellers. The new rules also develop social capital and systems connecting every corner of the market to reduce market failure risks.

Recommendations for Congress

ESMC's market has been designed to not require any policy changes, due to its private free-market approach. However, there are a few policies that could help undergird its approach:

- Federally fund research to improve the state of monitoring, reporting, and verification of ecosystem services assets, including through the development of new and improved technologies.

- Fund R&D into distributed technologies to provide rapid and accurate in-field soil carbon testing and more accurate and repeatable soil bulk density tests. Fund R&D into satellite and drone remote sensing technologies that are capable of feeding into quantification models. Fund databases that can improve the rigor of ecosystem services asset quantification, monitoring, reporting and verification.
- Update and make databases, such as the SSURGO database maintained by USDA, available with updated soils information at a more granular scale across agricultural lands and more accurately reflect soil carbon content at different depths, by region and production system.
- Continually update conservation practice standards to reflect new, improved regional or production-system specific variations. This will ensure standards remain current and reflect new regenerative and sustainability practices being adopted.
- Improve the understanding of the economics of adoption of various practices and systems approaches that improve ecosystem services outcomes at the field, farm, and regional and production scale.
- Improve accessibility of research data collected by USDA and other federal agencies.
- Provide greater clarity around credit or asset ownership and stacking, to facilitate inter-sectoral credit trading. All federal agencies should adopt USDA's long-standing policy position that producers own the environmental assets or credits they generate, regardless of whether cost-share from public conservation programs helped them achieve the credited environmental outcomes.
- Clarify that the same land can generate multiple ecosystem assets at the same time, such as carbon, water quality, and water use credits, to achieve outcomes-based impacts at scale.

@BPC_Bipartisan
facebook.com/BipartisanPolicyCenter
instagram.com/BPC_Bipartisan

bipartisanpolicy.org | 202 - 204 - 2400
1225 Eye St NW, Suite 1000 | Washington, DC 20005

Federal and State Efforts to Encourage Carbon Sequestration in Agricultural Soils and Forests

Eric Washburn, President, Windward Strategies

1. Introduction

As state and federal policymakers have searched for solutions to climate change, attention has increasingly focused on opportunities in the agriculture and forestry sectors to accelerate carbon sequestration in soils and trees. This helps to mitigate climate change if the soils and trees function as net carbon sinks, taking up more carbon annually from the atmosphere than they release. Policies in support of net carbon sinks complement traditional greenhouse gas (GHG) reduction strategies and are considered key to both reversing near-term emissions growth reduction growth rates and meeting long-term climate goals, especially net-zero emissions or carbon neutrality goals. Climate has been a focus in recent state efforts to implement soil and forest health programs and in several state and federal legislative proposals that are under active consideration. This paper, which was compiled from summaries of work going on in this field, provides an overview of practices that can accelerate carbon sequestration in agricultural lands and forests, current carbon offset programs in the United States, current state and federal programs that encourage the use of practices that sequester carbon, and state and federal legislative proposals.

2. An Overview of U.S. Agriculture and Forestry Practices for Accelerating Carbon Sequestration

2.1 Carbon Sequestration in Agricultural Soils

For decades, researchers in soil science have studied the potential to increase carbon sequestration in soil organic matter. The premise makes sense: thousands of years of cultivating land for agricultural production have dramatically reduced the stocks of carbon in soils. Tilling and plowing expose soil to air and sunlight, causing carbon to oxidize and leave the soil. Avoiding these practices, by contrast, allows soil carbon stores to grow as organic material from roots and leaves decomposes. Thus, changing agricultural techniques has been proposed as a means to restore and maintain carbon in domesticated soils. Estimates of the potential of soils to sequester vary. The World Resources Institute projects that the U.S. could sequester 200 million tons of carbon dioxide equivalent per year. Specific types of agricultural practices that have been proposed to enhance soil carbon sequestration include cover crops, switching from annuals to perennials, and no-till cultivation.

Cover Crops: According to Sustainable Agricultural Research and Education (SARE), planting cover crops can be an important soil carbon sequestration strategy. The roots and shoots of cover crops feed bacteria, fungi, earthworms, and other organisms, which increases soil carbon levels over time. Typical cover crops can be annual or perennial and include cereals, brassicas, legumes, and other broadleaf species. For example, cereal rye, crimson clover, and oilseed radish are popular cover crops. Familiar small-grain crops, such as winter wheat and barley, can also be adapted for use as cover crops to fit almost any production system. The use of cover crops is slowly growing in popularity, and it is estimated that 20 million acres across the United States are planted in such crops today. However, with about 267 million acres planted in row crops, cover crops remain a small part of the overall U.S. agriculture system. And while research has addressed the impact of cover crops on carbon sequestration at a global scale, the potential within the United States has not been thoroughly assessed. A literature review and meta-analysis of five existing studies that included data from 26 separate research trials estimated that planting cover crops on 20 million acres could sequester approximately 60 million metric tons of CO_2-equivalent per year—enough to offset annual emissions from 12.8 million passenger vehicles[i]. Meanwhile, planting practices are changing so that cover crops can be grown for longer periods of time with increased biomass accumulation. Practices such as inter-seeding cover crops into standing cash crops or "planting green" (planting a cash crop directly into a living cover crop) can extend the growing season for cover crops, allowing for greater root and biomass growth. As cover crop acreage increases and more farmers adopt practices that maximize cover crop growth and ground coverage, the potential for biological carbon sequestration will grow.

Perennialization of Grains: According to The Land Institute, which has pioneered this work, switching from annual to perennial grains could dramatically increase the storage and retention of carbon in agricultural soils. Historically, native grasslands and forests accumulated high levels of soil carbon precisely because their roots were able to grow year after year. When agriculture replaced native ecosystems composed on grasslands and forests, perennial plants were largely eliminated in favor of annual grains like corn and wheat. Research has substantially improved our understanding of the linkages between carbon sequestration and specific functional characteristics of perennial vegetation like large root systems. The Land Institute has been developing perennial grains such as Kernza to replace some annuals. So called "perennializing" our agriculture landscape would be a dramatic departure from current agricultural practice but would be a very effective means of increasing soil carbon sequestration.

No-Till Cultivation: Some have suggested that no-till cultivation might be able to increase soil carbon content. In traditional tillage, the soil is turned to a depth of 8 to 12 inches with a plow. Subsequently, the soil is disked at least twice more to prepare the seedbed before planting takes place. In no-till cultivation, however, these steps are avoided. Instead, seeds are deposited directly into untilled soil. Studies have shown relatively little or no soil carbon benefits from conventional no-till practices. For example, a 2014 study by Powelson, *et al.* found that the quantity of additional organic carbon in soil under no-till is relatively small.[ii] A 2010 study by Luo, *et al*. found that cultivation with conventional tillage and no-tillage resulted in comparable soil carbon loss comparing with adjacent natural soils.[iii] Moreover, in many cases, no-till agriculture is practiced using herbicides to control weeds that would otherwise be controlled by ploughing and other more intensive tillage techniques, manual weeding, and crop rotations that include forage legumes, which are known to suppress weeds and fix nitrogen. However, the heavy use of herbicides can kill beneficial sinks for soil carbon like microorganisms.

Combinations of Practices: The most significant steps to reduce atmospheric concentrations of greenhouse gas concentrations are likely to come from combinations of practices. For example, planting cover crops + nutrient management + manure management + crop diversity could maximize greenhouse gas (GHG) reduction benefits, including through carbon sequestration, nitrogen dioxide (NO_2) reductions, and possibly methane reductions. Promising systems for soil carbon sequestration may be a combination of crop rotation with low or no inputs of pesticides, herbicides, and industrial fertilizers. Long-term studies by the Rodale Institute and others suggest that such systems build (and don't simply conserve) significant quantities of organic carbon in the soil through a variety of mechanisms[iv].

Costs: The cost of sequestering carbon in soil through existing USDA Natural Resources Conservation Service (NRCS) programs is estimated to be between $32 and $442 per ton of carbon dioxide, with an average cost of $183 per ton. However, it is important to note that these programs provide other environmental benefits as well.[v]

Challenges: While the potential for carbon sequestration in soils is indeed high, in the United States, cultural, economic, and physical barriers present challenges to creating a robust national soil carbon sequestration program. Renters typically have less financial incentive to invest in conservation programs that deliver long-term payoffs or benefits. Absentee, offsite and older landowners may see little reason to invest in long-term soil carbon management. In fact, adoption rates for U.S. Department of Agriculture (USDA) programs related to soil health (which have carbon sequestration benefits) are relatively low: only 2%–5% of U.S. cropland is enrolled in the two largest conservation programs, Environmental Quality Incentives Program (EQIP) and Conservation Technical Assistance (CTA). Moreover, farmers with annual income above $900,000 are excluded from receiving conservation support under some programs. New, more robust financial incentives will likely be necessary to significantly expand participation in soil carbon-building programs. Communicating the numerous agronomic and ecological benefits of healthy soils may also encourage greater adoption of soil carbon-building practices.[vi]

2.2 Carbon Sequestration in Forests

According to the World Resources Institute, there are about 330 million acres in the United States that could host new tree plantings, and collectively could sequester about 360 million tons of carbon dioxide equivalent per year. Management options include:

- **Avoided deforestation** involves the protection of existing forests, typically (in the U.S. context) by placing conservation easements on forestlands to restrict development, tree harvesting, and other forms of forest management.

- **Reforestation** involves restoring forests on land that was once forested. Planting trees to replace trees and forests that have been cleared in the past can create carbon sinks that sequester carbon dioxide for decades.

- **Afforestation** differs from reforestation in that it involves cultivating forest on land that was previously unforested, typically for longer than a generation. As with reforestation, this practice can lead to long-term, year-on-year improvements in carbon sequestration.

- **Changes in forest management,** such as forest thinning, may help forests adapt to a hotter drier climate while also increasing their value in terms of long-term carbon storage, wildlife habitat, and potential timber production. Understory thinning can also have co-benefits by reducing the risk that high-intensity wildfires will ignite on the forest floor and spread into and through the tree crowns.

Costs: The marginal cost of sequestering carbon in forests has been estimated at $10-$100/ton[vii].

Challenges: Challenges related to forest-based carbon sequestration in the U.S. largely stem from the fact that forests are natural resources typically managed for multiple uses (e.g., commercial timber production, recreation, wildlife habitat, watershed management etc.) and are vulnerable to natural and human-caused disturbances, including harvest, wildfire, wind, insect damage, disease, and land use conversion from forested to non-forested uses. Forest disturbances are evaluated as one of a larger set of factors under various carbon accounting frameworks and, depending on the circumstances, may result in net carbon loss to the atmosphere. Most forest carbon accounting protocols include mechanisms to protect against potential carbon losses—for example, requiring a forest project buffer pool, which holds a portion of a project's carbon credits in reserve (based on a project-level risk assessment) to draw from in the event of an unexpected disturbance.

3. The Market for Agriculture and Forestry Offsets

3.1 Offsets as a Compliance Option in Mandatory State Climate Programs

A few state-based climate change programs in the United States allow for terrestrial offsets as a compliance option.

California and The Western Climate Initiative. California implements a cap-and-trade program for reducing greenhouse gas emissions from large sources, including industrial facilities, fuel distributors, and power plants. California and the province of Quebec operate in a linked emissions allowance trading market administered by the non-profit Western Climate Initiative, Inc. Nova Scotia is developing its own market that could potentially be linked in the future.[viii] Each jurisdiction sets its own rules and regulations regarding compliance for its program and approved types of carbon offsets that can be used for compliance. Quebec's program does not have an approved protocol for forest or soil-based carbon offsets at this time. California's program includes a forest-based offset scheme and a "Forest Protocol" that sets forth requirements and methods for quantifying the net climate benefits of activities that sequester carbon on forestland. The California forest protocol describes offset project eligibility rules, methods for calculating net effects on GHG emissions and removals of carbon dioxide from the atmosphere (removals), procedures for assessing the risk that carbon sequestered by a project may be reversed (i.e. released back to the atmosphere), and approaches for long-term project monitoring and reporting, including procedures for filing Offset Project Data Reports.[ix] The protocol is designed to ensure that net GHG reductions and climate benefits from an offset project are accounted for in a complete, consistent, transparent, accurate, and conservative manner and thus qualify for registry offset credits, which are issued by the California Air Resources Board (CARB). Forest offset projects must submit to independent verification by CARB-accredited verification bodies.

The Regional Greenhouse Gas Initiative. RGGI is a cap-and-trade program jointly implemented by the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont to reduce carbon dioxide emissions from the power sector.[x] RGGI includes a forest offset program and individual states determine eligible project types, including reforestation projects, improved forest management projects (defined as activities that increase carbon stocks on forested land relative to baseline levels of carbon stocks), avoided conversion projects – that is, specific actions that prevent the conversion of privately-owned forestland to a non-forest uses (for example, dedicating land to preserve continuous forest cover through a conservation easement or transfer to public ownership).[xi]

To ensure that carbon dioxide offsets used in RGGI represent permanent carbon sequestration, the states participating in RGGI require relevant state agencies to approve legally binding permanent conservation easements for the land covered by the offset project. Such easements must: (1) be granted by the owner to a qualified holder of a conservation easement in accordance with the conservation easement enabling statute of the state in which the project is located; (2) be perpetual in duration; and (3) expressly acknowledge that the participating state is a third-party beneficiary of the conservation easement with the right to enforce all obligations under the easement and all other rights and remedies conveyed to the holder of the easement (these rights include standing as an interested party in any proceeding affecting the easement).

3.2 Offsets in Voluntary GHG-Reduction Programs

Voluntary GHG-reduction programs and corporate commitments, such as Nori (https://nori.com/) and Puro (https://puro.earth/), create another market for agriculture and forestry offsets. The idea is that businesses, governments, NGOs, and individuals can use offsets to count against their direct and indirect carbon emissions. Offsets for this purpose may be created through the Kyoto Protocol's Clean Development Mechanism (CDM) or other voluntary efforts (the latter are called VERs for "verified" or "voluntary" emission reductions). Compared to the offsets market for compliance purposes, where demand is created by a regulatory mandate, trading volumes in the voluntary market are much smaller because demand is created only by voluntary buyers (corporations, institutions, and individuals). Given lower demand and the fact that VERs cannot be used to demonstrate compliance in mandatory programs, VERs tend to be cheaper than credits sold in the compliance market (e.g. CERs).

Unlike government-led carbon credit programs, the voluntary carbon offset market is not regulated and is not required by law to meet consistent standards; however, various widely accepted third-party project-level standards and certification programs exist for carbon offsets sold to voluntary buyers. Standards include the Verified Carbon Standard, Climate Action Reserve, American Carbon Registry, and Gold Standard, and certification includes Green-e® Climate.

An advantage of the voluntary offset market is that it can serve to test new procedures, methodologies, and technologies that may later be included in regulatory schemes. Voluntary markets also allow for experimentation and innovation because projects can be implemented with fewer transaction costs than under CDM or other compliance markets. Voluntary markets also provide niche demand for micro projects that are too small to warrant the administrative burden of CDM, or for projects that are currently ineligible for recognition in mandatory compliance schemes. On the negative side, a lack of quality control has led to the production of some low-quality VERs, such as emission reductions claimed for actions that likely would have happened anyway.

4. Federal and State Programs that Encourage Carbon Sequestration

4.1 Federal Farm Bill Programs

A number of existing Farm Bill programs promote soil-based carbon sequestration on agricultural lands.

- **Environmental Quality Incentives Program (EQIP):** This program provides financial and technical assistance for activities that benefit air quality, water quality, soil and water conservation, and wildlife habitat. By improving soil quality, EQIP can promote soil carbon sequestration.
- **Conservation Stewardship Program (CSP):** This program helps farmers and ranchers maintain, improve, and expand activities that benefit natural resources (including soil, water, air, and

wildlife habitat) or conserve energy. Payments are based on performance. As with EQIP, CSP can promote carbon sequestration by improving soil health.

- **Conservation Reserve Program (CRP):** CRP is a land conservation program administered by the Farm Service Agency (FSA). In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve ecosystem health and quality. Contracts for land enrolled in CRP are 10–15 years in length. Planting grasses on formerly farmed lands promotes soil carbon sequestration.
- **Agricultural Conservation Easement Program (ACEP):** ACEP helps landowners, land trusts, and other entities protect, restore, and enhance wetlands, grasslands, and working farms and ranches through conservation easements. In this way, the program prevents development that would otherwise lead to losses of terrestrial carbon.
- **Regional Conservation Partnership Program (RCPP):** RCPP engages landowners and agricultural producers in conservation activities that improve water, soil, wildlife habitat, or other natural resources on a regional scale. The Secretary of Agriculture also designates eight 'critical conservation areas' that receive priority funding. By supporting projects that improve soil quality, this program may accelerate carbon sequestration in soils.

Other Farm Bill programs promote carbon sequestration in forests.

- **Community Forests Program:** This grant program authorizes the U.S. Forest Service to provide financial assistance to local governments, Tribal governments, and qualified nonprofit entities to establish community forests that provide continuing and accessible community benefits.
- **Forest Legacy Program:** This Forest Service program is supported by the Land and Water Conservation Fund. It protects private forests by purchasing conservation easements or land from forest owners, who participate voluntarily. According to Forest Service guidance published in 2015 "the purpose of the Forest Stewardship Program is to encourage the long-term stewardship of important State and private forest landscapes, by assisting landowners to more actively manage their forest and related resources."
- **Healthy Forests Reserve Program:** The Healthy Forests Reserve Program (HFRP) assists private landowners to restore, enhance and conserve forests through the use of easements and by providing financial assistance. Among the purposes of the program are aiding the recovery of endangered and threatened species, improving plant and animal biodiversity and enhancing carbon sequestration.

4.2 State Soil Health and Carbon Sequestration Programs

This section draws from existing summaries of state soil health programs compiled by Regeneration International to highlight programs supporting soil-based carbon sequestration on agricultural lands. This is not meant to be a comprehensive list of all state healthy soil programs, but rather identify relevant examples that could be replicable in other states or at the federal level.

California: California's Healthy Soils Initiative (HSI) is a collaborative effort that involves a coalition of state agencies and departments and is being led by the California Department of Food and Agriculture (CDFA). It is a key part of California's strategy to reduce GHG emissions by increasing carbon sequestration in and on natural and working lands. The goal is to comprehensively look at policies that can support healthy soils through (1) improvements at governmental agencies, (2) incentives for climate-friendly ranching and farming practices, and (3) research and education. CDFA has partnered with NRCS, the California Climate Action Network (Cal-CAN), the California Association of Resource Conservation, and the Carbon Cycle Institute, as well as several universities that have helped inform the design of the program. Climate legislation (first established in 2006) set the state's GHG-reduction target at 40% below 1990 emissions by 2030. The same legislation also established a cap-and-trade mechanism for limiting emissions from the power sector and other large sources; this mechanism provides the funding for HSI. In August 2016, the California legislature approved a cap-and-trade budget that included $7.5 million in first-time funding for HSI. Half of that funding was earmarked to go directly to farmers and the other half was earmarked for demonstration projects. The COMET planning tool is being used to assess the impact of HSI-funded practices and projects.

Hawaii: In 2017, the state of Hawaii established the Carbon Farming Task Force within its Office of Planning to identify agricultural and aquacultural practices for improving soil health and promoting carbon sequestration, as well as the capture and long-term storage of atmospheric carbon dioxide. It grew directly out of a "Healthy Soils, Healthy Ranching" conference hosted by the Hawai'i Center for Food Safety (CFS) and CFS Soil Solutions in October 2016.

Iowa: In 2017, Iowa established a new program, called the "New Ground with Innovative Cover Crop Incentive," that gives farmers who plant cover crops a $5-per-acre discount on crop insurance over three years. The program is managed by the Iowa Department of Agriculture and Land Stewardship (IDALS). USDA surveys show that more farmers would consider planting cover crops if they received such discounts, especially in the Midwest where crop insurance is tremendously popular (about 80% of Iowa cropland is insured through the Federal Crop Insurance Program (FCIP)). Technically, the program doesn't reduce the cost of insurance, rather IDALS works with the USDA's Risk Management Agency (RMA), which administers FCIP, to cover part of the insurance premium. The discount applies only to crop cover on "new" acres. In addition, Unilever and PepsiCo offer cash incentives for cover crops through programs managed by Practical Farmers of Iowa (PFI). For example, Unilever's "Sustainable Soy" program for Hellman's mayonnaise offers soybean growers who are new to cover crops an incentive of $40 per acre on 40 acres. The company also offers farmers who are experienced with planting cover crops a $10-per-acre incentive on up to 160 acres or 10% of acres farmed, whichever is larger. Soybeans grown under this program are processed at the Archer Daniel Midlands's crushing plant in Des Moines, but farmers are eligible if they can deliver their soybean crop to several elevators, including all locations of Heartland, Key, Landus, Mid-Iowa, and other cooperatives. Similarly, PepsiCo sponsors a program that offers cover crop incentives to farmers who deliver corn (for use in making high-fructose corn syrup) directly to Cargill's corn processing plant in Eddyville. A key to these cover crop incentives is they can be stacked on top of other incentives offered through state and federal programs.

Maryland: Maryland's Healthy Soils Program aims to improve the health, yield, and profitability of soil, increase soil carbon sequestration, and promote more widespread use of healthy soils practices among farmers in the state. The program defines "healthy soil" in terms of the capacity to function as a biological system; increase organic matter; improve soil structure, and water and nutrient-holding capability; and sequester carbon. State law requires the Maryland Department of Agriculture to provide incentives, such as research, education, technical assistance, and (subject to funding) financial assistance to farmers to implement practices that promote healthy soils. Using monies provided by the Chesapeake Bay Restoration Fund and the Chesapeake and Atlantic Coastal Bays Trust Fund, grants are made to farmers to plant cover crops to reduce erosion, suppress weeds and pests, and improve soil health. In the 2016/2017 fiscal year, 560,000 acres of farmland in Maryland—or about 50% of eligible land in the state—were planted in cover crops. The program is seen as helping Maryland meet its aggressive state climate goal (i.e., reducing GHG emissions 40% by 2030); its adoption reflected the potential for cooperation between agricultural and environmental groups on these issues despite a history of not always getting along.

Oklahoma: The Oklahoma Carbon Sequestration Enhancement Act was signed into law in April 2001. It was subsequently amended (in 2003 and 2011) and is currently unfunded. The legislation, as amended, established a committee (with members appointed by the governor) to advise the state on carbon sequestration opportunities; it also authorized the Oklahoma Conservation Commission (a non-regulatory agency) to establish and administer a "Carbon Sequestration Certification Program." The process of developing this program, including writing the rules and developing verification methodologies, has included farmers, ranchers, conservation district directors and employees, and representatives from the ARS, NRCS, electric cooperatives, electric companies, grain and seed companies, land grant universities, the state's agriculture department, other environmental agencies and non-profits, the association of conservation districts, oil and gas professionals, and EPA Region 6. A strength of the program is that it was developed in Oklahoma, for Oklahomans, to benefit the state's land, air, and water resources. Another strength is the program's simplicity and practicality, which have been interpreted by some as a lack of rigor but which make the program user-friendly and realistic to implement by land managers. The Oklahoma program is not currently linked to a major market or trading registry and it needs more funding and staff to raise its branding profile, forge partnerships with other states and markets, and develop projects, verification methodologies (for no-till, seeded grasslands, rangeland, and soil sampling), and application materials.

Utah: The Utah legislature adopted a Concurrent Resolution on Carbon Sequestration on Rangelands that was signed by the governor in 2015. The resolution calls on federal agencies to be directed to implement management practices that increase soil carbon sequestration, to develop comprehensive plans for maximizing carbon sequestration, and to increase the economic and environmental productivity of rangelands, while also urging similar actions within each state.

4.3 State Forest and Carbon Sequestration Programs

The National Conference of State Legislatures published an overview of how state policymakers are working to maintain healthy forests, to support sustainable management practices and increase carbon sequestration and storage. Their summary is available here:
http://www.ncsl.org/research/environment-and-natural-resources/state-forest-carbon-incentives-and-policies.aspx

5. State and Federal Legislative Proposals

5.1 Federal-Level Proposals

Several bills related to carbon sequestration have been introduced in the 116th Congress. This section summarizes their key provisions.

The Climate Stewardship Act - S. 2452 and H.R. 4269; Sen. Booker (D-NJ) and Rep. Haaland (D-NM)

- Calls for planting over 4 billion trees by 2030, and 15 billion trees by 2050, on a combination of federal, state, local, tribal, and non-governmental lands.
- Calls for planting over 100 million of these trees in urban neighborhoods across America, with priority going to low-income neighborhoods and communities of color. (The bill notes that, in addition to sequestering carbon, trees also absorb harmful air pollutants and reduce temperatures in urban areas.)
- Supports voluntary climate stewardship practices on over 100 million acres of farmland, with the aim of reducing or offsetting agricultural emissions by one-third by 2025, by:
    - Providing tens of billions of dollars of supplemental funding for USDA working lands conservation programs, with new funding dedicated to stewardship practices such as rotational grazing, improved fertilizer efficiency, and planting tens of millions of new acres of cover crops.
    - Protecting millions of acres of environmentally sensitive farmland.
    - Doubling funding for agricultural research programs, including more funding for soil health demonstration trials.
    - Tripling USDA funding to provide farmers with expert technical assistance on climate stewardship practices.
    - Providing grant funding to tens of thousands of farmers, ranchers, and rural businesses for renewable energy production, such as solar panels and wind turbines, and energy efficiency improvements.
- Provides for Investments in local and regional food systems to increase resilience in rural and urban communities.
- Restores or protects over 2 million acres of coastal wetlands by 2030 to sequester carbon emissions and reduce coastal flooding (coastal wetlands act as an important sponge during extreme weather events with heavy rainfall).
- Reestablishes the Civilian Conservation Corps to provide youth from low-income communities, indigenous communities, and communities of color with skills and work experience in forestry and wetlands restoration.

The Northwest California Wilderness, Recreation, and Working Forests Act - S.1110 and H.R. 2250, Sen. Harris (D-CA) and Rep. Huffman (D-CA)

- Provides for the restoration, economic development, and conservation of – and recreational access to – certain public lands in Northern California.
- Authorizes the use of certain forest residues for research and development of biobased products that result in net carbon sequestration.
- Authorizes initiatives to restore degraded redwood forest ecosystems in the Redwood National Forest and state parks.

- Requires studies concerning certain visitor accommodations and recreational trails in the Six Rivers, Shasta-Trinity, and Mendocino National Forests, as applicable.
- Authorizes partnerships for trail and campground maintenance, public education, visitor contacts, and visitor center staffing on federal lands in Mendocino, Humboldt, Trinity, and Del Norte Counties.
- Adjusts the boundaries of the Elkhorn Ridge Wilderness.

<u>The Study on Improving Lands Act - H. R. 4133, Reps. Neguse (D-CO) and Curtis (R-UT)</u>

- Directs the National Academies of Science to determine parameters for measuring soil health, including:
    - Measures of soil organic matter and other metrics,
    - Soil qualities that promote carbon sequestration, and
    - Soil qualities that support strong ecosystems and resilient environments.
- Directs the Secretary of Agriculture, not later than 1 year after the date of the enactment, to coordinate with the Secretary of the Interior and the National Academies of Science to:
    - Commence a study on the state of soil health on federal lands in an effort to determine impacts on grazing, wildfire, recreation, invasive species, and other relevant issues; and
    - Create a database of the information collected during the study.
- Requires an annual report to Congress on the progress and findings of the study.

<u>The Rural Green Partnership Proposal, Rep. Bustos (D-IL)</u>

In August 2019, Rep. Bustos released a set of principles and policies – called the Rural Green Partnership – to the House Select Committee on the Climate Crisis. Among other things, Rep. Bustos's proposal focuses on increasing soil organic carbon by improving soil health and promoting sustainable forest management, reforestation, and uses of forest products. Specifically, the Rural Green Partnership proposes to:

- Increase the amount of funding available and the number of acres eligible for federal assistance to incentivize the adoption and maintenance of proven, science-based, precision agriculture and conservation management farming practices that increase soil carbon, reduce runoff, and optimize fertilizer inputs This work can be done through the existing NRCS, FSA, or other federal programs, or it could entail re-envisioning federal assistance programs.
- Expand the number and availability of technical experts capable of offering customized, one-on-one conservation advice to agricultural producers.
- Streamline the process to sign up for NRCS/FSA programs.
- Facilitate widespread data collection to aid hyper-localized management strategies that increase carbon sequestration and strengthen the resilience of different U.S. geographic regions.
- Incentivize integrated crop/livestock operations to maximize the soil carbon sequestration in croplands.
- Expand grants, loans, and tax incentives for farm and ranch operations that improve energy efficiency, support energy generation, and drive down GHG emissions through technologies like methane digestors.
- Expand applied agricultural R&D into crop breeding, precision agriculture, soil health practices, extension yield trials, and other on-farm conservation research that mitigates risk and increases resilience.

- Guarantee broadband access for farms, homes, and small businesses to ensure that data related to best management practices is readily available.
- Incentivize sustainable forestry practices that sequester carbon while creating new markets for biomass to heat and power homes and business.
- Expand sustainable forestry practices such as implementing pre-commercial thinning, forest stewardship plans, and fire-resilient wildland–urban interfaces that reduce the incidence and intensity of fires and increase resources available for reforestation after catastrophic loss.

Bills related to carbon sequestration were also introduced in the 115th Congress. This section summarizes their key provisions.

The Forest Incentives Program Act of 2018 – Sen. Shaheen (D-NH)

- Would have directed USDA to create certain programs that provide incentives to reduce GHG emissions.
- Specifically, would have directed USDA to establish an incentive program to achieve supplemental GHG reductions and carbon sequestration on private U.S. forestland (eligible land) through carbon incentives contracts and conservation easement agreements.
- Under this program, would have required USDA to make payments to owners of eligible land for:
    - Certain forestry practices that increase carbon sequestration and storage over a designated period on eligible land, and
    - Conservation easements on eligible land.
- In addition, would have required USDA to establish an incentives program to achieve supplemental GHG reductions from materials in nonresidential buildings used for commercial or state or local government purposes. Under this program, USDA would have had to pay owners of such buildings for the use of eligible products that sequester carbon in those buildings, where eligible products would have included commercial or industrial products that are composed of biological products, including renewable agricultural and forestry materials.

The Conservation for Very Erodible Row Cropland (COVER) Act of 2018 – Sen. Michael Bennet (D-CO)

- Would have amended the Food Security Act of 1985 to modify USDA conservation programs to authorize additional assistance for farm practices related to soil health and carbon storage.
- Would have modified EQIP to provide payments for practices that:
    - Improve soil health,
    - Enhance farmers' ability absorb and recover from shocks and stresses to production,
    - Increase carbon storage on agricultural land, and
    - Achieve other conservation outcomes as determined by USDA.
- Would have modified the Conservation Innovation Grants program to establish a pilot program to encourage:
    - Outcome measurements related to the planting of regionally appropriate cover crops, and
    - Opportunities to increase farm income.
- Would have directed USDA, in carrying out the Conservation Innovation grants program, to prioritize projects with third-party partners such as academic entities, carbon offset protocol developers, livestock producers, and food manufacturers.

<u>The Strengthening Our Investment in Land (SOIL) Stewardship Act, Sen. Smith (D-MN) and Rep. Walz (D-MN)</u>

- Would have amended the Food Security Act of 1985 to reauthorize and modify USDA, including EQIP and CSP.
- Would have addressed requirements in these programs relating to:
  - Enrollment and funding levels,
  - The length and renewal process for contracts,
  - Payment rates,
  - Payment limits,
  - Coordination of application and enrollment processes for the two programs,
  - Set-asides and the enrollment process for beginning and socially disadvantaged farmers,
  - Soil health and carbon storage, and
  - Organic production.

5.2 State-Level Proposals

Legislation related to soil carbon sequestration that has been introduced at the state level is summarized in this section. Soil4Climate tracks these bills at its website (https://www.soil4climate.org/news/category/healthy-soils-legislation), which can be referenced for the status of these bills.

<u>Connecticut</u>: **HB6647** defines "healthy soils practices" and sets up a fund for programs; this draft legislation has not yet been filed due to a full docket. It will be submitted for the 2020 session.

<u>Illinois</u>: SB1980/HB2737 amends the Soil and Water Conservation Districts Act, providing that the purposes of soil and water conservation districts include the conservation of soil health, organic matter in soil and plants, and water quality (rather than just water); and the improvement of resilience to droughts, floods, and other extreme weather. This legislation is moving forward in both chambers and has broad support. Another bill, **HB2819**, would allow the state's Department of Natural Resources to include soil health requirements in leases of state land; this bill was tabled in committee.

<u>Iowa</u>: **HSB 78** provides for tax exemptions for planting cover crops; the bill is stalled in committee. Another bill, **HF 102**, provides "for a statewide soil resource health and recovery monitoring system." It is also stalled in committee.

<u>Massachusetts</u>: SD1438/HD3065 adds a definition for "healthy soils practices" and sets up a fund for programs; the legislation also adds an expert on healthy soils practices to the state's food policy council. This bill has broad bi-partisan support: 37% of state legislators are co-sponsors.

<u>Nebraska</u>: LB243 creates a Soil Health Task Force; it was signed into law on April 17, 2019. **LB283** provides funding to develop a climate action plan that will include improvements to soil health. The bill is stalled in committee. **LB729** provides incentives for cover crops; it too is stalled in committee.

New Mexico: SB218/HB204 sets up healthy soils program; it was signed into law on April 2, 2019.

New York: A02718 provides a tax exemption for carbon-friendly farming that is based on the economic value of the carbon sequestered; the bill is in committee.

Oregon: HB2020 proposed a cap-and-invest program that included forest and agricultural carbon offsets and funding for additional soil and forest carbon sequestration projects; it is expected that a similar bill will be introduced in the next legislative session.

Vermont: S.43 proposes "to require the Secretary of Natural Resources to establish a regenerative soils program whose purposes include increasing the carbon sequestration capability of Vermont soils, reducing the amount of sediment and waste entering the waters of the State, and promoting cost-effective and healthy soil management practices." The bill was introduced into the Senate in early 2017 and referred to the Committee on Natural Resources and Energy.

Washington: **SB 5947/HB 2095** sets up a sustainable farm and field program; as of the end of the legislative session it was still in committee.

In terms of the prognosis for further state action, it is likely that legislation to support healthy soils will be before legislatures in 2020 in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Iowa, Oregon, and Washington, and possibly in numerous other states.

Organizations Working on Issues of Soil Carbon Sequestration

- Ecosystem Services Markets Consortium (ESMC), Debbie Reed - https://www.nature.org/en-us/explore/newsroom/new-national-consortium-forms-ecosystem-services-market-program/
- Ecosystem Marketplace: https://www.cbd.int/financial/2017docs/carbonmarket2017.pdf; https://www.forest-trends.org/publications/fertile-ground/; https://www.forest-trends.org/publications/unlocking-potential/
- The Climate Trust: https://climatetrust.org/
- American Carbon Registry: https://americancarbonregistry.org/
- Verifiable Carbon Standards (VCS): https://verra.org/
- The Noble Research Institute: https://www.noble.org/
- Forest Trends: https://www.forest-trends.org/
- CarbonFund: https://carbonfund.org/
- Climate and Land Use Alliance: http://www.climateandlandusealliance.org/
- Climate Action Reserve: https://www.climateactionreserve.org/how/program/
- California ARB: https://ww3.arb.ca.gov/cc/sequestration/seq.htm; https://ww3.arb.ca.gov/cc/capandtrade/protocols/usforest/usforestprojects_2014.htm
- Soil Health Institute: https://soilhealthinstitute.org/
- Inigo/Terraton Initiative: https://www.indigoag.com/the-terraton-initiative
- Nori (https://nori.com/)
- Puro (https://puro.earth/)
- Carbon Cycle Institute: https://www.carboncycle.org/carbon-farming/
- Carbon Underground: https://thecarbonunderground.org/
- Resources for the Future: https://www.rff.org/land-water-and-nature/forest-resources/forest-carbon/
- Coalition on Agricultural Greenhouse Gases - https://www.c-agg.org/about/
- Cool Effect: https://www.cooleffect.org/?gclid=CjwKCAjwkenqBRBgEiwA-bZVtiXwNxpzaon7V1NOTyckLAk7phr64xv50_b_m-lb83PbB27yQ7alSBoCNWMQAvD_BwE
- The Nature Conservancy: https://www.nature.org/en-us/explore/newsroom/tnc-natural-climate-solutions-accelerator-awards/; https://www.nature.org/en-us/what-we-do/our-insights/perspectives/a-natural-path-for-u-s-climate-action/
- World Resources Institute: https://www.wri.org/publication-series/carbonshot-creating-options-carbon-removal-scale-united-states
- Duke University Nicholas Institute: https://nicholasinstitute.duke.edu/people/robert-bonnie

---

Endnotes:

[i] https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops/Ecosystem-Services-from-Cover-Crops/Cover-Crops-and-Carbon-Sequestration

[ii] http://virtualfarm.psu.edu/assets/uploads/content/No-till_Climate_Mitigation.pdf

[iii] https://www.researchgate.net/profile/Osbert_Sun/publication/229109635_Can_no-tillage_stimulate_carbon_sequestration_in_agricultural_soils_A_meta-analysis_of_paired_experiments/links/5c49894e299bf12be3df397b/Can-no-tillage-stimulate-carbon-sequestration-in-agricultural-soils-A-meta-analysis-of-paired-experiments.pdf

[iv] https://www.researchgate.net/publication/281511510_A_Review_of_Long-Term_Organic_Comparison_Trials_in_the_US

[v] https://food.berkeley.edu/wp-content/uploads/2016/05/GSPPCarbon_03052016_FINAL.pdf

[vi] https://food.berkeley.edu/wp-content/uploads/2016/05/GSPPCarbon_03052016_FINAL.pdf
[vii] https://www.fs.usda.gov/treesearch/pubs/45563
[viii] http://www.wci-inc.org/
[ix] https://ww3.arb.ca.gov/cc/capandtrade/offsets/offsets.htm
[x] https://www.rggi.org/
[xi] https://www.rggi.org/allowance-tracking/offsets/offset-categories/forestry-afforestation

WORLD RESOURCES INSTITUTE

FEDERAL POLICY OPTIONS FOR A CARBONSHOT IN NATURAL & WORKING LANDS

SUMMARY

Carbon dioxide (CO_2) can be captured naturally in forests and agricultural soils. Enhancing carbon removal and storage in these natural and working lands could contribute meaningfully to climate change mitigation efforts while creating economic opportunities in rural communities.

An assessment by World Resources Institute identifies two priorities for this enterprise:

1. **Restoring trees to the landscape** ("Tree Restoration") in ways that improve the health of eastern timberlands, create new sources of revenue for agricultural producers, and improve the livability and character of urban and suburban communities.
2. **Building soil health** in the nation's farms and ranches in ways that increase farm profitability while sequestering carbon.

This brief outlines the potential scale of carbon removal and specific federal policy options for driving each of these approaches forward.

RESTORING TREES TO THE LANDSCAPE

In Brief

Achievable Scale:
360 $MtCO_2$ per year[1]

Suitable Area:
330 million acres

Land Types Benefitting:
Existing forest (especially eastern timberlands), pastureland, developed open space, some cropland, urban neighborhoods

Major Policy Options:
Federal subsidy (cost-share, tax credit, or state grant program)

Cost per Ton:
~$10/$tCO_2$[2]

Initial Federal Investment:
$1-4 billion per year

Restoring trees to the American landscape could plausibly remove more than a third of a gigaton (billion tons) of CO_2 from the atmosphere per year through 2050. This potential spans across multiple land use

[1] Recognizing real barriers to restoring trees in all suitable areas due to lack of landowner capacity and some level of inevitable tree mortality, the achievable scale of carbon removal represents two-thirds of the identified "upper bound" technical potential.

[2] Cost per ton reflects full funding for the direct costs of restoring trees to the landscape on all suitable acres. "Hidden costs" that may be incurred by incentivizing landowners to restore trees—such as transaction costs, monitoring costs, and opportunity costs associated with alternative land uses—are not included in this calculation.

types, but none of it would require displacing agricultural production. Major opportunities for tree restoration in the United States include:

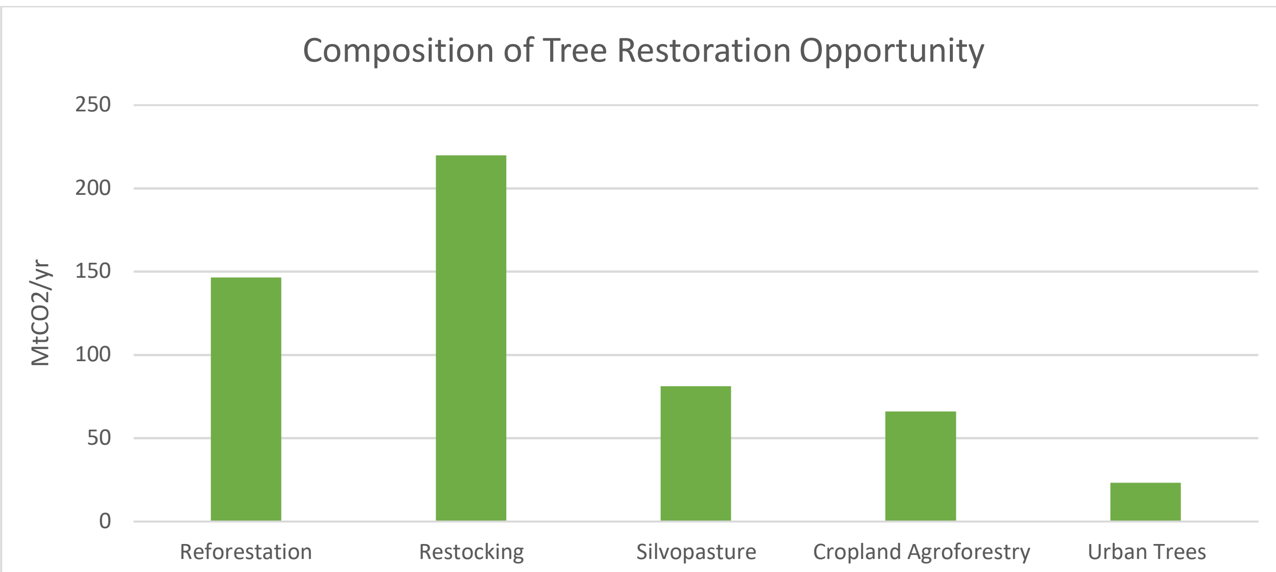
- **Improving forest health by restoring stocking levels in private and public timberlands in the eastern United States: 165 million acres; up to 220 MtCO$_2$ per year** (Hoover and Heath 2011; Oswalt et al. 2014; Sohngen 2018). Opportunities for restocking arise from tree mortality—for example due to poor harvesting practices like high-grading or selective logging, or natural disturbances like insects, disease, or wildfire—in instances where natural regeneration fails due to competition with other vegetation, herbivory, or continued natural disturbance (Vasievich and Alig 1996). Implementing sustainable harvest plans, actively regenerating land after disturbance, and reducing hindrances to growth from invasive species and herbivory can all enhance forest resilience to future stresses and disturbances.
- **Reforesting disturbed or abandoned non-agricultural land in areas that are ecologically appropriate for trees: 53 million acres; up to 146 MtCO$_2$ per year** (adapted from Cook-Patton Forthcoming; also see Fargione et al. 2018). About half of this opportunity is in lands categorized as "developed open space"—e.g., parks, roadsides, sparse suburban areas.
- **Integrating trees into pasture ("silvopasture") to provide shade, fodder, and additional revenue streams while maintaining or enhancing livestock production: 65 million acres; up to 81 MtCO$_2$ per year** (adapted from Fargione et al. 2018; Cook-Patton Forthcoming; Swan et al. 2015). These 65 million acres of pasture are in areas that historically were forested and are ecologically suited for trees.
- **Integrating trees and crops ("cropland agroforestry") to build soil health, improve water quality, and provide farmers with additional revenue streams while maintaining crop production: 39 million acres, 66 MtCO$_2$ per year** (adapted from Fargione et al. 2018; Peichl et al. 2006, Bambrick et al. 2010, and Cardinael et al. 2015). Cropland agroforestry practices that can enhance the carbon removal capacity of agriculture in the United States include alley cropping, windbreaks, and riparian buffers.
- **Expanding urban forest patches and street trees by 7-11 percent: 8 million acres; up to 23 MtCO$_2$ per year** (Fargione et al. 2018).

As a first step, allocating $1-2 billion per year to federal subsidies for tree restoration would capture low-hanging fruit opportunities, build critical implementation experience, and serve to improve characterization of the scale of opportunity and full funding need. Fully capturing the identified upper bound potential would require an estimated $4-4.5 billion per year over 20 years.

Key Barriers to Tree Restoration

The financial requirements for private and public landowners represent the primary barrier to tree restoration that can be addressed by federal policy. Although total economic benefits typically exceed total costs when fully accounting for public benefits like clean water, flood protection, and carbon sequestration (e.g. Lee et al. 2018; Vargas et al. 2007), few of those benefits accrue directly back to landowners. Costs include upfront expenses for site preparation and planting along with recurring expenses for tree maintenance (surveys, management plans, pruning, invasive plant control, and/or fire safety measures). Given the concentration of private costs and the diffusion of public benefits of tree restoration, public subsidies are warranted to achieve the socially optimal level of tree restoration in the United States.

Other barriers include transaction costs (especially on small parcels), a lack of landowner capacity to manage forests intensively, and landowners' time preference for money—since any revenues from monetizable co-benefits, like production of timber or other forest products, would not accrue for years or decades after planting. Overcoming these "hidden costs" will require an attractive financial incentive either for landowners or for intermediary project developers.



Notes: Error bars reflect published or estimated standard error for the carbon removal rate associated with reforestation and restocking, and published standard errors for both the available area and carbon removal rate for windbreaks (a component of agroforestry) and urban reforestation. For silvopasture, where an estimate of standard error was unavailable, the error was defined by the high and low carbon removal factors published in COMET Planner (Swan et al. 2015). For alley cropping (a component of agroforestry, along with windbreaks), where the published estimate was deemed inconsistent with findings in the source literature, the error was defined by extrapolating the minimum and maximum carbon removal rates found in the literature across the mean estimate of eligible acreage found by Fargione et al. (2018).

Federal Policy Design for Tree Restoration

Effectively and efficiently restoring tree cover at the scale envisioned will require several key policy features: a subsidy that exceeds the net financial costs of tree restoration on non-federal lands, safeguards for environmental integrity, the use of third-parties to streamline implementation, and technical assistance for landowners.

Subsidy to address financial barriers to tree planting

We approximate an annual federal funding need based on the estimated total cost of tree establishment and maintenance over a 20-year window in areas that have been identified in recent literature and analyses as suitable for tree restoration (Bair and Alig 2006). Assuming that future timber harvest is likely in restocked forests, and that timber or other products of similar value will be harvested in silvopasture systems, we reduce estimated total costs for these systems by the discounted value of future revenues in order to approximate federal funding need. Altogether, the estimated federal funding needed to achieve the estimated upper bound potential with safeguards for tree restoration is $4-4.5 billion per year over 20 years (Mulligan et al. forthcoming). Note that additional "hidden costs"—like landowner aggregation and other transaction costs, opportunity cost of other land uses, and monitoring costs—could raise funding needs beyond the range estimated here.

Policy mechanisms that tailor federal subsidies to closely approximate the difference between total costs (both explicit and hidden) and potential private benefits—including co-payment for these services by state, local, and private sector entities—will make more efficient use of federal resources than mechanisms to provide flat cost-share rates regardless of the circumstances. Policy options for tailoring subsidy rates include competitive bidding processes, tailored cost-share rubrics, and increasing rates over time to enable price discovery.

A federal subsidy for tree restoration could be administered through a tax credit program or a direct payment program. A tax credit program would be akin to other major federal climate policies enacted to-date—including the investment tax credit (ITC) for solar, the production tax credit (PTC) for wind, and the 45Q tax credit for carbon capture, utilization, and storage. In this structure, eligible project operators or sponsors would receive a credit for trees planted and maintained—or the corresponding carbon sequestered.

A direct payment program would be a natural extension of existing conservation incentives authorized under the Farm Bill and administered by USDA. Payments could be structured as either a cost-share or pay-for-performance program (or a hybrid of the two). Cost-share would entail USDA issuing payments to landowners who restore trees on their land according to standardized rates and over a fixed contract period. Relative to EQIP, which already provides cost-share for conservation practices by agricultural and non-industrial forest landowners, this program could also be available to an expanded set of landowner types—including urban, residential, commercial, state and municipal—where there is opportunity for tree restoration.

Safeguards for environmental integrity

Adhering to high standards of environmental integrity is critical to ensure that federal subsidies for tree restoration achieve real, lasting carbon removal benefits. An effective tree restoration policy must therefore include safeguards that address these key dimensions of environmental integrity:

- Additionality: Each year, two million acres are replanted following timber harvest, and several million more acres regenerate naturally (Oswalt and Smith 2014). Subsidizing these business-as-usual activities could significantly increase the cost of the program without delivering clear carbon removal benefits.
- Minimal leakage: Permitting reforestation of agricultural lands may cause other lands to shift from forest to agriculture in order to meet demand for agricultural commodities, thereby producing offsetting emissions from land use change.
- Ecological alignment: Planting trees may have negative impacts on ecosystem functions in areas that are maladapted for more trees—for example, "restocking" forests that are naturally sparse,

like fire-adapted western forests, or afforesting native grassland areas like the Great Plains. The suitability of certain tree species on a landscape may also change over the trees' expected lifespan as the climate changes.

- Tree survival: Tree mortality can reverse carbon removal gains achieved by a tree restoration program, especially if the dead trees burn or decompose rather than being turned into long-lived wood products.

These facets of environmental integrity could be embedded in a subsidy program through eligibility requirements or project reviews by independent verifiers, NRCS conservationists, or relevant state agencies to screen out projects that do not meet specific criteria in statute or rulemaking. For instance, land that is not ecologically appropriate for forest growth could be excluded with eligibility requirements. Native tree species could be required of projects in key areas for biodiversity. Review by a third party or approval body might be employed to verify that areas in active timber rotations or ongoing natural regeneration are only subsidized in cases where additional management is necessary to increase tree density from understocking to full stocking. Land that has been used for agricultural production within a certain number of years might be eligible only if the farmer makes good-faith efforts to maintain production at similar levels after tree cover is established—effectively allowing silvopasture and other forms of agroforestry but ruling out full reforestation and the indirect carbon losses it may trigger through leakage.

Project review processes would allow for a more customized assessment of a project's environmental risks but would also add to the administrative complexity and transaction cost associated with the program. In all cases, safeguards must balance environmental integrity with the barriers to entry associated with inflexible rules and administrative complexity.

Use of third-party intermediaries

Lack of knowledge and technical capacity among landowners, absentee landownership, transaction costs for landowners and challenging economics of tree planting on small parcels can limit the effectiveness of a traditional subsidy paid directly to landowners. Third-party intermediaries—such as land trusts and other nonprofit organizations, private companies, or local or state governments—can serve multiple valuable functions:

- Landowner engagement and burden shifting. Aggregators can proactively solicit landowner participation—and facilitate that participation as needed by handling administrative aspects of program participation and even project implementation and reporting. This engagement would reduce the transaction cost for landowners of completing the necessary paperwork to apply for cost-share, a significant barrier to entry in existing programs that has limited enrollment from small landowners disproportionately (Bennett et al. 2014; Ma et al. 2012).
- Project aggregation. Intermediaries can package together and directly implement tree planting projects across many landowners, achieving economies of scale and making tree restoration more practicable on small parcels. Examples of economies of scale in this context include better access to private finance for larger projects; opportunities for optimizing seedling supply and use of machinery; and the possibility of using advanced technology like drone planters or organizing volunteer planting crews.
- Expert implementation. Intermediaries can place responsibility for tree planting and maintenance activities in the hands of qualified project operators, addressing the barrier posed by lack of knowledge and technical capacity among private landowners (Ma et al. 2012; Creamer et al. 2012). Intermediaries can even begin to address knowledge gaps in the communities where they operate.

- Co-funding solicitation. Intermediaries can solicit other sources of funding for large tree planting projects more easily than individual landowners.

Third-party intermediaries can be effective agents to reduce transaction costs and other barriers to entry for landowners, provided they maintain low overhead costs in recruiting landowners and processing subsidy payments (Boakye-Danquah and Reed 2019). To make a federal program attractive to intermediaries, the program must provide certainty through a clear payment timeline (i.e. one not influenced by changes in annual appropriations or legislative extension of the program) and transparently-set subsidy rates. Third parties must be eligible to receive the subsidy for tree restoration activities conducted on behalf of landowners. Payment to the landowners and other arrangements would then be negotiated between the intermediary and the landowner. A minimum project size requirement would further shift implementation toward third-party intermediaries and facilitate any project review process.

The use of intermediaries would be a departure from existing Farm Bill incentive programs like EQIP and CRP, which require direct contracts between landowners and NRCS. However, intermediaries could be used in either a direct subsidy program or a tax credit program. Because many landowners may not have a sufficiently large tax liability to fully take advantage of tax credits, it would be important to structure a tree restoration tax credit like the Investment Tax Credit (ITC) for solar energy development, under which the tax credit is transferable to financiers with greater tax liability than the landowners or project developers themselves. This transfer of tax equity comes with a cost, however, which has been estimated at 36 percent or more of the value of the wind power Production Tax Credit (PTC) (Bolinger 2014). Therefore, a tax credit approach may inherently favor larger landowners or project developers with sufficient tax liability to take full advantage of the tax credit themselves.

Role of State and Local Governments

State and local governments have a strong role to play in a tree restoration campaign. State and local land use planning is necessary to restore trees on state and locally-owned lands, which account for nearly 15 percent of the reforestation potential and over 10 percent of the forest restocking potential (Cook-Patton Forthcoming; Oswalt et al. 2014; Hoover and Heath 2011). Tree restoration also returns myriad co-benefits to states and municipalities

Delegating or sharing review and approval authority with state governments would allow states to integrate federal funding for tree restoration into state-level land use planning and ensure funded projects are consistent with state natural resource objectives. In many cases, these funds could be integrated through existing channels for federal support to states—the Forest Service, for instance, runs programs that provide funding to states for forest planning, forest health treatments, and urban and community forestry.

States and local governments also have a different set of policy tools—such as green growth policies, property tax incentives, zoning regulations, and even hunting licenses—that could play a significant role in a tree restoration campaign. Involving state and local governments in project review processes would enable these jurisdictions to identify complementary policy measures. A portion of a national program for tree restoration could also be operationalized by awarding federal grant dollars to states that meet targets for tree restoration, using whatever set of policies they choose.

Technical assistance for landowners

Several forms of tree restoration require technical expertise that many private landowners lack. Restocking forests, for example, necessitates a location-specific understanding of appropriate forest stocking levels, accounting for risks like wildfire and overcrowding. Agroforestry requires production know-how for both annual crops and trees and knowledge of specific practices has been linked directly to landowners' likelihood to adopt the practice (Valdivia and Poulos 2009). Access to information may even address some of the financial barriers to adoption such as finding markets for forest products (Strong and Jacobson 2005).

Third-party implementers are well-positioned to act as technical assistance and education providers. Where landowners serve as direct implementers, federally directed technical assistance and educational programs for landowners will likely be required above and beyond the technical assistance that is already provided to forest owners and agroforestry practitioners. These programs could build on programs run by NRCS conservationists, state forestry agencies supported by the Forest Service's State and Private Forestry Division, or the extension offices of local land-grant universities funded by the National Institute of Food and Agriculture (NIFA).

BUILDING SOIL HEALTH

In Brief

Achievable Scale: 200 $MtCO_2$ per year	**Suitable Area:** 1 billion acres (all agricultural land)
Land Types Benefitting: Cropland, ranchland	**Major Policy Options:** Extend on-farm innovation trials program to 10 million acres
Cost per Ton: ~$40/$tCO_2$[3]	**Initial Federal Investment:** $500 million per year

A variety of agricultural soil management practices can promote soil health and provide incremental carbon sequestration. Building soil health is a no regrets climate mitigation strategy in that practices that enhance soil carbon can also yield other benefits—including reduced water runoff and erosion, enhanced soil nutrients, and in many cases improved farm profitability. Key soil management practices include cover cropping, conservation tillage, crop rotations, compost amendments, grassland restoration, adding legumes to pasture, grazing optimization, biochar, and deep soil inversion. Some of these practices—like cover cropping—have well-established carbon benefits and could reasonably be implemented on agricultural lands throughout much of the United States. Other practices are less ready for scaled deployment due to scientific uncertainty or infrastructure requirements but could provide significant carbon removal following initial investments in research and demonstration.

Combining federal cost-share and technical assistance with on-farm research and monitoring will accelerate adoption of agricultural soil management practices while advancing understanding of their potential benefits and limitations. This policy would be a natural extension of existing Farm Bill Conservation Title programs. It would require up to $500 million per year to reach and maintain a 10-million-acre enrollment threshold, which would enable statistically robust inferences from monitored results and proof points to underpin further scaling. The program would likely need to run for 10 years and then transition to a broader set of financial and technical assistance efforts to scale up adoption of soil management practices.

Key Barriers to Building Soil Health

Economic, technical, and cultural barriers all challenge wide-scale adoption of agricultural soil management practices. Despite long-term net benefits, upfront costs can present a hurdle to commodity-crop producers who already operate on razor-thin margins and hold record levels of debt (Carlisle 2016; CTIC 2017; Long et al. 2014; Farm Bureau 2019). Farmers who rent rather than own their land—who now manage over half of U.S. cropland—may also have less incentive to make short-term investments in soil management practices for long-term gains (Bigelow et al. 2016; Carlisle 2016). Transaction costs, including the cost of obtaining information on new management practices and the opportunity cost of interfering with traditional crop production processes, are more difficult to quantify than other sources of upfront cost but may add substantially to the economic cost of adopting new practices (Biardeau et al. 2016).

---

[3] Cost per ton reflects a federal cost-share investment of $40 per acre where soil health practices are implemented, and a 1-for-1 match with legacy acres (continued implementation after cost-share contracts expire) and additional acres activated without federal cost-share through social influences or cultural shifts. Soil health practices are assumed to sequester 0.5 tCO_2 per acre per year on average.

Lack of technical expertise and access to markets represent additional challenges for adoption. Timing the planting and termination of a cover crop within the confines of corn or soy production schedule is a key barrier to would-be adopters of that practice, for example, as is the disappearance of regional markets for alternative crops that could make up a diversified crop rotation (Arbuckle and Ferrell 2012; Roesch-McNally et al. 2018). Carlisle (2016) found that farmers who were more knowledgeable about a new management practice and were more confident in their ability to properly implement it, were more likely to adopt the practice.

Federal Policy Design for Soil Health

Federal policy targeting the restoration of carbon to agricultural soils at scale must equally prioritize investments in financial assistance for producers, accompanying technical assistance, and monitoring and research efforts. This hybrid policy approach is necessary because of the twin needs for accelerated adoption and scientific learning in this field—and the two are mutually reinforcing: increased adoption rates across different soil types and regions offers the opportunity for data collection and scientific study, which in turn will inform further investment by producers and policymakers alike in scaling adoption in ways that are most beneficial. Focusing policy solely on deployment incentives and technical assistance would not ensure that public investments translate effectively and efficiently to carbon removal outcomes because of lingering uncertainty around the impacts and regional variability of some practices. On the other hand, a singular focus on research and monitoring would miss critical near-term opportunities to remove carbon through deployment. This hybrid approach would also generate "proofs of concept" for soil management practices and spur farmer-to-farmer.

The initial implementation period of such a program would be designed to generate data across a diverse range of soil management practices, crop or forage types, and environmental conditions. Analysis of these data, along with data shared through existing subnational programs, could provide learnings essential for designing follow-on policy to cost-effectively scale adoption of soil carbon management practices. These learnings could include:

- Improved understanding of the biophysical efficacy of soil management practices for carbon removal, including the permanence of carbon sequestered in soils, as well as any positive or negative feedback loops associated with interactions between multiple soil management practices;
- Improved understanding of success factors in promoting adoption and persistence of soil management practices in the absence of continued financial assistance—including cost-share contract lengths and rates, technical assistance, and social factors;
- Identification of any additional barriers that arise as adoption rates increase—e.g. seed production for cover crops or legumes in pasture, access to markets for crops and forage from crop rotations or cover cropping, or institutional resistance from trade groups, private companies, or other influential organizations in agricultural communities;
- An assessment of how technical assistance can effectively maximize on-farm benefits from practice adoption; and
- Improved calibration of soil carbon models to facilitate more precise planning and policymaking efforts going forward.

Subsidy to address financial barriers to adoption

We approximate an annual federal funding need of $400 million, assuming an average per acre per year subsidy of $40 (though rates may vary over time or by practice) for 10 million enrolled acres. This average subsidy rate is consistent with paying 100 percent of direct costs for the first year of cover crop implementation (Mulligan et al. forthcoming) and is within the range of subsidy rates that have led to significant increases in cover crop adoption at the state level (Maryland Department of Agriculture 2018; Virginia Department of Conservation & Recreation 2019)—though a wider variety of soil management practices could be eligible for the subsidy. Higher or lower rates may be more appropriate for other soil management practices, but data to quantify differential rates by practice are scarce.

Technical assistance, education, and research and monitoring programs to complement the financial subsidy, described in more detail in the sections that follow, would require additional funding. The National Academies proposed an agricultural research agenda totaling up to $30 million per year that includes some, but not all, of the research and monitoring objectives considered here (NAS 2018a). For a modest expansion of The National Academies' proposed research agenda alongside needed additional investments in technical assistance and education, we approximate a funding need of $100 million for these supplemental programs, pushing the total federal funding need for the proposed soil carbon management program to $500 million.

Financial subsidies for agricultural soil management practices are primarily aimed at covering the upfront costs of practice implementation, which may include some combination of seed or other inputs, specialized equipment, and temporary foregone production. These costs can be seen as an investment, as research suggests that producers may break even or even generate net financial gains over the long term where yield gains and avoided costs are realized (Fargione et al. 2018; Roberts et al. 1998; O'Reilly et al. 2012; Keene and Curran 2016; Lichtenberg 2004; Myers et al. 2019). Although net economic gains can be positive, however, risk-averse producers lacking on-farm experience with the economic returns of soil management practices may be reluctant to invest the upfront costs on their own.

Consequently, cost-share is likely necessary to entice first-time adoption of new soil management practices, especially those with high costs and few immediate benefits to producers' bottom lines. Cost-share has empirically proven successful in stimulating adoption of cover crops. In Maryland, for example, a state cost-share program that pays farmers a minimum of $45 per acre for planting cover crops has yielded adoption rates of 40-50 percent—an order of magnitude higher than the national average (Hellerstein et al. 2019).

Beyond existing cost-share mechanisms, however, effectively harnessing the potential of agricultural soil management as a carbon removal pathway will require:

- pairing cost-share with significant field data collection activities focused on carbon sequestration and producer needs and constraints;
- developing a mechanism at USDA for quantifying carbon benefits derived from public investments and applying new data and science to target and scale promising practices; and
- providing cost-share resources commensurate with demand.

Enrolling a sufficient number of acres to make possible statistically significant analysis across different practices will be important to begin generating robust data on a national scale in the first few years of the program. The minimum acreage target to achieve this goal would be 10 million acres over five years, an area less than half the size of the annual 2018 enrollment in CRP. Soil carbon monitoring tools can confidently detect average changes in soil carbon over a minimum of five years (R. T. Conant and Paustian 2002), so monitoring efforts would need to begin within five years to produce preliminary results by the end of a ten-year "pilot phase" for the payment program. Following successful enrollment of the first 10 million acres, the program could continue to expand to build greater statistical power in the monitoring results while sequestering more carbon in soils.

Technical Assistance and Education

Scaling adoption of soil management practices that enhance carbon removal will require significantly higher levels of customized technical assistance to farmers and ranchers than these shrinking services can presently provide. In a national survey, free technical assistance and more information on appropriate species to plant ranked among the top interventions that would convince farmers to adopt cover crops (CTIC 2017). Technical assistance may also be necessary to adjust farm operations in ways that allow producers to realize potential avoided-cost benefits of practice adoption, such as reduced need for fertilizer applications due to nitrogen fixation by legumes or avoided repairs for erosion damage due to increased vegetative cover.

Historically, NRCS field offices and cooperative extension offices from land-grant universities have served as the primary purveyors of technical assistance and educational resources to producers. Ninety percent of NRCS's workforce of over 10,000 are located in field offices across the United States, but the Service's shift in focus from multi-year land retirement contracts to shorter-term contracts on working lands has more recently strained the administrative capacity across these field offices, leaving insufficient staff capacity to provide individualized technical assistance. Meanwhile, driven by a decades-long decline in inflation-adjusted federal funding for the cooperative extension system alongside more recent cuts in state and local appropriations, the full-time workforce in extension offices has declined 22 percent from 1980-2010, with even greater losses in key agricultural regions (Mercer 2014; Wang 2014).

Pairing administration of cost-share funding with a federal effort to retain and grow staff focused on technical assistance at NRCS field offices, along with greater federal support for cooperative extension offices, may be critical for achieving and sustaining the adoption of soil management practices. Greater capacity among NRCS field offices and extension offices can also be leveraged by state departments of agriculture, soil and water conservation districts, and private industry—agribusiness networks, for example, maintain existing relationships with farmers and producer organizations and could provide both inputs and technical assistance for cover cropping (Carlisle 2016). Expanding innovative programs like the Regional Conservation Partnership Program (RCPP) can enhance the value of federal funding by further leveraging non-federal providers of technical assistance and landowner outreach.

Research and Monitoring

Alongside incentives for practice adoption and technical assistance programs, rigorous biophysical and socioeconomic monitoring and evaluation is critical to realizing the potential of agricultural soil management. A nationally-coordinated agricultural soil carbon monitoring program that combines plot-based direct measurement with landscape-scale modelling could build the data and evidence base around the efficacy, cost, constraints, and challenges of various soil management practices in different regions, soil types, and farming systems (P. Smith et al. 2019). The effort would provide a basis for program evaluation and adaptive management and underpin the provision of public resources for scaling adoption. It would also provide better data on soil health benefits to farmers, enabling them to make more informed decisions about inputs such as fertilizer and post-cost-share management practices.

A core element of a robust monitoring and evaluation effort is a consistent national plot network that can collect long-term data. The Forest Inventory & Analysis program services this function for forest carbon. USDA operates the National Resource Inventory (NRI)—a national network of tens of thousands of farm plots that have extensive land management data records dating back several decades. However, NRI does not collect soil carbon data. Adding this function to NRI's mandate—at an estimated cost of $5 million per year—is a National Academies recommendation. The land management history in NRI plots can greatly enhance the ability of researchers to make scientific inferences relating to the factors affecting soil carbon stocks and provide locally-applicable baseline data to compare to soil measurements associated with new adoption of management practices.

Congress recently expanded the Conservation Innovation Grant (CIG) program to include monitoring projects—and added a $25 million per year on-farm conservation innovation trial program that will allow USDA to gather new data on the benefits of agricultural soil management practices (Stubbs 2019). This approach will enable producers to experiment, and researchers to collect on-farm data from real-world implementation. However, a $25 million grant program will ultimately be limited in its contribution to the data and science behind soil carbon practices. A clear next step would be to fund monitoring and data collection activities as part and parcel of a larger-scale cost-share program.

REFERENCES

Arbuckle, J.G., and J. Ferrell. 2012. "Attitudes Toward Cover Crops in Iowa: Benefits and Barriers." Iowa State University.

Bair, L.S., and R.J. Alig. 2006. "Regional Cost Information for Private Timberland Conversion and Management." PNW-GTR-684. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. doi:10.2737/PNW-GTR-684.

Bambrick, A.D., J.K. Whalen, R.L. Bradley, A. Cogliastro, A.M. Gordon, A. Olivier, and N.V. Thevathasan. 2010. "Spatial Heterogeneity of Soil Organic Carbon in Tree-Based Intercropping Systems in Quebec and Ontario, Canada." *Agroforestry Systems* 79 (3):343–53. doi:10.1007/s10457-010-9305-z.

Bennett, D.E., M. Nielsen-Pincus, A. Ellison, A. Pomeroy, H.S.J. Burright, H. Gosnell, C. Moseley, and L. Gwin. 2014. "Barriers and Opportunities for Increasing Landowner Participation in Conservation Programs in the Interior Northwest." Working Paper. Ecosystem Workforce Program, Institute for a Sustainable Environment, University of Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/19385.

Biardeau, R.C.-C., R. Keerati, S. Litke, and H. Rodriguez. 2016. "Soil Health and Carbon Sequestration in US Croplands: A Policy Analysis." Goldman School of Public Policy, University of California Berkeley. https://food.berkeley.edu/wp-content/uploads/2016/05/GSPPCarbon_03052016_FINAL.pdf.

Bigelow, D., A. Borchers, and T. Hubbs. 2016. "U.S. Farmland Ownership, Tenure, and Transfer." EIB-161. USDA Economic Research Service.

Boakye-Danquah, J., and M.G. Reed. 2019. "The Participation of Non-Industrial Private Forest Owners in Forest Certification Programs: The Role and Effectiveness of Intermediary Organisations." *Forest Policy and Economics* 100 (March):154–63. doi:10.1016/j.forpol.2018.12.006.

Bolinger, M. 2014. "An Analysis of the Costs, Benefits, and Implications of Different Approaches to Capturing the Value of Renewable Energy Tax Incentives." LBNL-6610E, 1134230. doi:10.2172/1134230.

Cardinael, R., T. Chevallier, B.G. Barthès, N.P.A. Saby, T. Parent, C. Dupraz, M. Bernoux, and C. Chenu. 2015. "Impact of Alley Cropping Agroforestry on Stocks, Forms and Spatial Distribution of Soil Organic Carbon — A Case Study in a Mediterranean Context." *Geoderma* 259–260 (December):288–99. doi:10.1016/j.geoderma.2015.06.015.

Carlisle, L. 2016. "Factors Influencing Farmer Adoption of Soil Health Practices in the United States: A Narrative Review." *Agroecology and Sustainable Food Systems* 40 (February). doi:10.1080/21683565.2016.1156596.

Conant, R. T., and K. Paustian. 2002. "Spatial Variability of Soil Organic Carbon in Grasslands: Implications for Detecting Change at Different Scales." *Environmental Pollution (Barking, Essex: 1987)* 116 Suppl 1:S127-135.

Cook-Patton, S. Forthcoming. "Mapping US Reforestation Potential."Creamer et al. 2012
CTIC. 2017. "Annual Report 2016-2017." West Lafayette, Ind.: Joint publication of the Conservation Technology Information Center, the North Central Region Sustainable Agriculture Research and Education Program, and the American Seed Trade Association. https://www.ctic.org/files/2017CTIC_CoverCropReport-FINAL.pdf.
Fargione, J.E., S. Bassett, T. Boucher, S.D. Bridgham, R.T. Conant, S.C. Cook-Patton, P.W. Ellis, et al. 2018. "Natural Climate Solutions for the United States." *Science Advances* 4 (11):eaat1869. doi:10.1126/sciadv.aat1869.
Farm Bureau. 2019. "Who Holds Farm Debt?" January 24, 2019. https://www.fb.org/market-intel/who-holds-farm-debt.
Hellerstein, D., D. Valorio, and M. Ribauld. 2019. "Agricultural Resources and Environmental Indicators, 2019." Economic Information Bulletin No. 208. USDA Economic Research Service.
Hoover, C.M., and L.S. Heath. 2011. "Potential Gains in C Storage on Productive Forestlands in the Northeastern United States through Stocking Management." *Ecological Applications* 21 (4):1154–61.
Keene, C.L., and W.S. Curran. 2016. "Optimizing High-Residue Cultivation Timing and Frequency in Reduced-Tillage Soybean and Corn." *Agronomy Journal* 108 (5):1897–1906. doi:10.2134/agronj2015.0604.
Lee, J., C.-H. Lim, G.S. Kim, A. Markandya, S. Chowdhury, S.J. Kim, W.-K. Lee, and Y. Son. 2018. "Economic Viability of the National-Scale Forestation Program: The Case of Success in the Republic of Korea." *Ecosystem Services* 29 (February):40–46. doi:10.1016/j.ecoser.2017.11.001.
Lichtenberg, E. 2004. "Cost-Responsiveness of Conservation Practice Adoption: A Revealed Preference Approach." *Journal of Agricultural and Resource Economics* 29 (3):16.
Long, E., Q. Ketterings, and K. Czymmek. 2014. "Survey of Cover Crop Use on New York Dairy Farms." *Crop Management* 12 (1):0. doi:10.1094/CM-2013-0019-RS.
Ma, Z., B.J. Butler, D.B. Kittredge, and P. Catanzaro. 2012. "Factors Associated with Landowner Involvement in Forest Conservation Programs in the U.S.: Implications for Policy Design and Outreach." *Land Use Policy* 29 (1):53–61. doi:10.1016/j.landusepol.2011.05.004.
Maryland Department of Agriculture. 2018. "Maryland's 2018-2019 Cover Crop Sign-Up." https://mda.maryland.gov/resource_conservation/counties/2018CCSignup.pdf.
Mercer, M. 2014. "Cooperative Extension Reinvents Itself for the 21st Century." Pew Charitable Trusts. *Stateline* (blog). 2014. http://pew.org/2gMnGXS.
Mulligan, J., A. Rudee, K. Lebling, K. Levin, J. Anderson, and B. Christensen. Forthcoming. "CarbonShot: Federal Policy Options for Carbon Removal in the United States." World Resources Institute.
Myers, R., A. Weber, and S. Tellatin. 2019. "Cover Crop Economics: Opportunities to Improve Your Bottom Line in Row Crops." Technical Bulletin. Sustainable Agriculture Research & Education (SARE). https://www.sare.org/Learning-Center/Bulletins/Cover-Crop-Economics.
NAS. 2018. *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda*. doi:10.17226/25259.
O'Reilly, K.A., J.D. Lauzon, R.J. Vyn, and L.L. Van Eerd. 2012. "Nitrogen Cycling, Profit Margins and Sweet Corn Yield under Fall Cover Crop Systems." *Canadian Journal of Soil Science* 92 (2):353–65. doi:10.4141/cjss2011-065.
Oswalt, S.N., and W.B. Smith. 2014. "U.S. Forest Resource Facts and Historical Trends." FS-1035. U.S. Department of Agriculture, Forest Service. https://www.fia.fs.fed.us/library/brochures/docs/2012/ForestFacts_1952-2012_English.pdf.
Oswalt, S.N., W.B. Smith, P.D. Miles, and S.A. Pugh. 2014. "Forest Resources of the United States, 2012: A Technical Document Supporting the Forest Service 2010 Update of the RPA Assessment." WO-GTR-91. Washington, DC: U.S. Department of Agriculture, Forest Service. doi:10.2737/WO-GTR-91.

Peichl, M., N.V. Thevathasan, A.M. Gordon, J. Huss, and R.A. Abohassan. 2006. "Carbon Sequestration Potentials in Temperate Tree-Based Intercropping Systems, Southern Ontario, Canada." *Agroforestry Systems* 66 (3):243–57. doi:10.1007/s10457-005-0361-8.

Roberts, R.K., J.A. Larson, D.D. Tyler, B.N. Duck, and K.D. Dillivan. 1998. "Economic Analysis of the Effects of Winter Cover Crops on No-Tillage Corn Yield Response to Applied Nitrogen." *Journal of Soil and Water Conservation* 53 (3):280–84.

Roesch-McNally, G.E., J.G. Arbuckle, and J.C. Tyndall. 2018. "Barriers to Implementing Climate Resilient Agricultural Strategies: The Case of Crop Diversification in the U.S. Corn Belt." *Global Environmental Change* 48 (January):206–15. Smith, J.E., L.S. Heath, K.E. Skog, and R.A. Birdsey. 2006. "Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States." NE-GTR-343. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. doi:10.2737/NE-GTR-343.

Sohngen, B. 2018. "Summary_data_allsites_20.Xlsx." Unpublished.

Strong, N.A., and M.G. Jacobson. 2005. "Assessing Agroforestry Adoption Potential Utilising Market Segmentation: A Case Study in Pennsylvania." *Small-Scale Forest Economics, Management and Policy* 4 (2):215–28. doi:10.1007/s11842-005-0014-9.

Stubbs, M. 2019. "Agricultural Conservation in the 2018 Farm Bill." R45698. Congressional Research Service.

Swan, A., S.A. Williams, K. Brown, A. Chambers, J. Creque, J. Wick, and K. Paustian. 2015. "COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRCS Conservation PRactice Planning." USDA NRCS.

Valdivia, C., and C. Poulos. 2009. "Factors Affecting Farm Operators' Interest in Incorporating Riparian Buffers and Forest Farming Practices in Northeast and Southeast Missouri." *Agroforestry Systems* 75 (1):61–71. doi:10.1007/s10457-008-9129-2.

Vargas, K.E., E.G. McPherson, J.R. Simpson, P.J. Peper, S.L. Gardner, and Q. Xiao. 2007. "Interior West Community Tree Guide: Benefits, Costs, and Strategic Planting." PSW-GTR-205. U.S. Department of Agriculture, Forest Service. https://www.fs.fed.us/psw/publications/documents/psw_gtr205/psw_gtr205.pdf.

Vasievich, J.M., and R.J. Alig. 1996. "Opportunities to Increase Timber Growth and Carbon Storage on Timberlands in the Contiguous United States." In *Forest Management Opportunities for Mitigating Carbon Emissions [Sampson, R. N. and D. Hair (Eds.)]*, 2:91–104. Washington, DC: American Forests.

Virginia Department of Conservation & Recreation. 2019. "Program Year 2020 Virginia Agricultural Cost-Share (VACS) BMP Manual." http://consapps.dcr.virginia.gov/htdocs/agbmpman/csmanual.pdf.

Wang, S.L. 2014. "Cooperative Extension System: Trends and Economic Impacts on U.S. Agriculture." *Choices* Quarter 1. http://www.choicesmagazine.org/choices-magazine/submitted-articles/cooperative-extension-system-trends-and-economic-impacts-on-us-agriculture.

Overarching Issues in the Design of Climate Mitigation Policy for Agriculture and Forestry

Robert Bonnie, Nicholas Institute for Environmental Policy Solutions, Duke University

Rural America is vital to solving the climate change challenge. First, significant greenhouse gas (GHG) emission reductions and carbon sequestration in U.S. agriculture and forestry will be necessary for the United States to meet GHG reduction goals by 2050. Second, rural America matters, a lot, to climate policy—in two senses: many of its people play a central role in managing forests and agricultural lands and, as a group, rural Americans are generally more skeptical of climate-change concerns and environmental regulation generally than their urban/suburban counterparts. Thus, attention to the thoughtful design of climate policies that impact rural constituencies is essential.

This paper discusses a number of issues to be considered in designing climate policies for the agriculture and forestry sectors in the U.S. context. I begin by articulating some overarching principles that should inform future policy efforts.

<u>Climate policy should support agriculture and forest profitability, and rural development</u>. The ability of farmers, ranchers, and forest landowners to reduce GHG emissions and sequester carbon in soils, grasslands, and forests depends to a significant degree on those producers maintaining profitability. Voluntary incentives should enhance the profitability of agricultural and forestry operations. Given a growing global population, maintaining and enhancing yields of agricultural and forestry products provides additional climate benefits, since it reduces pressure to convert natural ecosystems to production. Done well, mitigating GHG emissions through improved agricultural and forestry activities can significantly enhance rural economies.

<u>What's good for agriculture and forestry is often good for the climate.</u> The good news is that, with respect to agriculture and forestry, many of the practices that benefit the climate (e.g., soil conservation, reforestation, manure management, nutrient management) also can benefit the operations of farmers, ranchers, and forest owners. Moreover, sound, incentive-based climate policy can support rural jobs and bolster farm, ranch, and forest economic viability. Of course, implementing many of these practices still requires financial resources and other assistance, but there is often strong alignment between climate-smart land management and the economic productivity of working lands.

<u>Many climate mitigation measures also align well with improving climate resilience.</u> Farmers, ranchers, and forest owners are already seeing the impacts of a changing climate in the form of lengthened growing seasons, more extreme weather events, and longer and more deadly wildfire seasons. Fortunately, there is also a high degree of alignment between practices that promote climate mitigation and those that improve the resilience of agricultural systems and forests to the impacts of climate change.

Directly regulating farms, ranches and forests won't work. Besides being politically unpopular in rural America, a regulatory approach to climate change on farms, ranches and forests would be extremely challenging. First, US farming, ranching and forestry operations are highly diverse – designing regulations to fit the broad array of agricultural and forestry practices will be incredibly difficult. In addition, regulatory approaches would require information on private lands that will be difficult to collect. Confidentiality of private landowners is an important issue in rural America. Lastly, regulations are mostly designed to keep people from doing damaging things. But we need producers and landowners to agree to take positive steps to protect the climate and regulations.

Carbon offsets can work, but present challenges. The last two-plus decades of U.S. climate policy have largely assumed that agriculture and forestry would be integrated into national and/or state cap-and-trade programs through programs that allow regulated companies to purchase emission offsets from non-regulated sectors, including agriculture and forestry. Yet, offset programs have met resistance, both from environmentalists who are concerned about these programs' environmental integrity and from agricultural and forestry stakeholders who are skeptical that carbon markets will materialize and be beneficial to them. Policymakers should recognize that offsets are likely to need considerable "help" in the form of government funding or other assistance to work at the scale needed (more on this issue below).

Large public investments are needed with or without offsets. Carbon offsets have been attractive to policymakers, in part because they were presumed to be free – that is, private industry, not the government, would fund conservation practices. Given the growing recognition that offsets alone are unlikely to provide capital in the amount and in the timeframe necessary to dramatically increase the uptake of climate-smart agricultural and forestry practices, the federal government will need to make substantial investments to support farmers, ranchers, and forest owners.

Private investment is also critical. One of the benefits of carbon offsets is that they attract private investment. Given the scale of GHG reductions needed from agriculture and forestry, private investment could be very important in funding conservation practices on farms, ranches and forests. Incentive programs that require cost-sharing from non-governmental sources (as Farm Bill programs do) or carbon offsets that have some sort of government support (e.g., either direct support or some insurance mechanism backing the offsets) can encourage private investment.

Policymakers will have to decide whether to pay for performance or practice. Ideally, if taxpayers or private actors are going to invest in practices that reduce GHGs, they need a guarantee that those investments will yield meaningful reductions. Offsets programs or other performance-based systems reward farmers, ranchers and forest owners based on the amount of GHG reductions they produce. But, farmers, ranchers and forest owners have no guarantee that the investments they make will yield substantial GHG reductions and, therefore, financial returns. This, of course, is true for everything farmers, ranchers and forest owners produce from their land. But, GHG reductions are not likely to be a primary product for many producers or landowners and they will be unfamiliar with the market, at least initially. Thus, many will be skeptical about making significant changes to their operations without some revenue guarantee. Practice-based programs reward participants for simply implementing GHG reduction activities. (Most Farm Bill programs follow this model.)

Thus, while performance-based approaches are most attractive from an environmental and investor standpoint, practice-based payments may be preferable to many farmers, ranchers and forest owners. On the other hand, if farmers, ranchers, and forest owners had some sort of price guarantee or insurance mechanism, they would likely be more willing to enter into a performance-based GHG program or market.

<u>Conservation programs don't implement themselves.</u> Conservation programs – whether for GHG reductions, wildlife conservation, watershed protection, or other purposes – require people backed by science to implement them. In the case of climate practices, farmers, ranchers and forest landowners will often need technical assistance to implement such activities. Thus, Congress should fund this type of support. That said, technical assistance doesn't need to be purely, or even primarily, government-provided. While the U.S. Department of Agriculture's NRCS is a logical agency to provide this type of assistance, there is a significant network of other federal agencies; state natural resource, forestry, and agricultural agencies; land grant universities; conservation groups; farm and forest commodity organizations: business and crop consultants; and many others that could and should play a vital role in implementing GHG conservation practices on the ground. Indeed, the most successful conservation efforts today on working lands are collaborative – typically involving stakeholders with diverse interests and perspectives. Programs such as the Regional Conservation Partnership Program, Collaborative Forest Landscape Restoration Program, Conservation Reserve Program, Land and Water Conservation Fund, and others, all demonstrate the value of leveraging non-governmental partners to implement conservation programs. Climate change programs will benefit from policies that foster and reward these locally and regionally led partnerships.

<u>The U.S. Department of Agriculture (USDA) should take a leading role.</u> Where policy does empower federal agencies to work with agriculture and forestry stakeholders and landowners, USDA has the best network of staff and local partnerships. Importantly, among federal agencies, USDA also has the highest level of trust with farmers, ranchers, and forest landowners. The agency already has significant technical and scientific expertise but it can also partner with experts at the Departments of Interior and Commerce and at the U.S. Environmental Protection Agency (EPA) to support climate-related activities. If federal policy ultimately allows some type of offset program for agriculture and forestry measures, then EPA can assist USDA in ensuring that such offsets provide real GHG reductions. But for these programs, EPA should not deal directly with landowners or carbon project organizers.

<u>Climate-smart agricultural and forestry practices can deliver significant co-benefits.</u> Climate-smart agricultural and forestry activities produce ample co-benefits, including clean water, wildlife habitat, open space conservation, and rural economic opportunities. These co-benefits

can help justify a significant federal investment in farms, ranches, and forests. Moreover, many conservation groups and others are working on ways to allow farmers, ranchers, and forest owners to create new income streams around some of these co-benefits, including not just carbon reductions, but water, wildlife habitat, and other ecosystem services.

Policy Mechanisms

This section reviews several broad policy mechanisms that are often discussed as options for promoting improved, climate-friendly agricultural and forestry practices on private working lands.

A. Offsets

Although carbon offsets have long been considered the policy mechanism of choice for agricultural and forestry activities, there is growing acknowledgment that offsets are likely at best one piece of a much larger puzzle. The advantages of offsets include a built-in accountability mechanism for ensuring real GHG reductions and the ability to encourage private investment into agricultural and forestry conservation practices. However, offsets also have several disadvantages:

1. **Offsets programs may struggle to reach scale quickly given a limited financial proposition and onerous monitoring and verification requirements.** Even at high carbon prices, the average farm would likely generate only a relatively small percentage of annual revenues from carbon offsets. The financial returns may not be enough to justify long-term investments in climate-friendly practices. This is even more the case if the transaction costs associated with monitoring and verification are significant.
2. **Implementing an offsets program sets up a challenging political dynamic in the development of carbon accounting protocols.** The implementation of offsets policies to date, whether as part of state or voluntary programs, has been dominated by arcane arguments around carbon accounting, including to address concerns about additionality, leakage, permanence, and other issues. Environmental advocates tend to want to over-engineer offset protocols to provide higher certainty with respect to GHG gains. But this also results in higher transaction costs. Landowner and producer groups, on the other hand, want more streamlined rules to allow for broader participation and lower transaction costs. This creates a political dynamic that pits environmental groups against agriculture and forestry stakeholders, instead of engendering shared objectives and collaboration. A contentious or even adversarial dynamic could even persist after policy adoption, as litigious environmental groups seek to ensure that transacted offsets fully represent additional and permanent GHG reductions.
3. **Uncertainty about whether future climate policy at the federal level will be driven by a cap-and-trade program, a carbon tax, or other policy approaches has enormous**

implications for the efficacy of offsets. Offsets have generally been designed as a mechanism for providing additional compliance flexibility under a cap-and-trade program. While it possible to design carbon offsets to play a role in other types of policy frameworks (such as a carbon tax), the lack of clear direction in federal climate policy creates uncertainty as to whether a market for carbon offsets will materialize.

B. USDA Carbon Bank

A carbon bank has the potential to address the challenges associated with offsets while creating incentives for private investment in agriculture and forestry activities. One way to establish such a bank would be for the USDA to enter the carbon market as a buyer and operate a reverse auction – that is, USDA would offer to buy carbon reductions through agricultural and forestry activities and allow farmers, ranchers, and forest owners to bid the price at which they would sell.

To implement this idea, Congress could simply authorize the Commodity Credit Corporation (CCC) to purchase carbon reductions. The CCC was established for the purpose of stabilizing, supporting, and protecting farm incomes and prices. Thus, helping develop a robust carbon market is consistent with the CCC's mission. USDA could ask bidders to use existing third-party, carbon measurement protocols when submitting bids, thereby assuring that the carbon or GHG reductions meet rigorous standards.

A competitive bidding process would lower the cost to the taxpayer while allowing farmers, ranchers, and forest owners to set a price at which they could be profitable. Bids could come from farmers, ranchers, or forest landowners or, more likely, from producer groups, conservation organizations, businesses, and others who could aggregate multiple landowners or producers into a single project bid – this would lower transaction costs. Measurement, accounting, and other costs would be capitalized into the cost of the bid. The bank could also serve as a buyer of last resort by guaranteeing a floor price.

Alternatively, the bank could be used to insure carbon credits produced through certain activities. For example, let's say a southern forest landowner wanted to convert lands from loblolly pine to longleaf pine and manage those new trees over longer rotations. While the landowner may have initial GHG emissions from harvest, over time the lands would sequester carbon. USDA could insure the long-term performance of the project, thereby allowing those carbon tons to sell in a voluntary offsets market or, if applicable, a compliance market.

If future federal legislation allowed for the use of carbon offsets from the land sector to offset emissions from electric utilities, manufacturing facilities, or other emitters (known as "offset utilization in a compliance market"), then the USDA carbon bank could sell GHG reduction credits into the market. USDA would guarantee the environmental integrity of the credits by holding back some carbon tons to self-insure the credit sales. Thus, environmental advocates would not have to worry about the integrity of the offsets. While the bank might lose money, it could use sale proceeds to replenish its funds and reinvest those dollars in other projects.

Another benefit of a carbon bank is that it would dramatically increase the speed at which farmers, ranchers and forest owners could enter into GHG-reduction agreements. A bank would not have to wait for the development of offset protocols, nor would it be subject to the same funding cycles and application requirements as existing programs, thereby reducing delays and paperwork.

B. Use of Existing Incentive Programs in the Farm Bill

Farm Bill programs already provide cost-share funding for GHG reduction activities on working farms, ranches, and forests. Typically, these activities are called something else, such as conservation tillage, reforestation, manure management, nutrient-use efficiency, etc. One step Congress could take is simply to dramatically increase funding for Farm Bill programs such as the Conservation Reserve Program (CRP), the Environmental Quality Incentive Program (EQIP), the Agricultural Conservation Easement Program (ACEP), and the Conservation Stewardship Program (CSP).

Two benefits of this approach are the fact that agriculture and forest landowners are already familiar with these programs and an infrastructure for implementation already exists. Programs, such as the Regional Conservation Partnership Program (RCPP), that fund locally developed and led projects, are particularly interesting as a vehicle because they enable the aggregation of many landowners into single projects thereby reducing transactions costs. But leveraging existing programs also presents challenges: a focus on carbon reductions may compete with other demands, existing programs may emphasize practices and not performance, existing program structures may not be compatible with a focus on carbon, and concerns may emerge about paperwork and delay.

Several questions would need to be addressed to utilize existing Farm Bill programs so that they work for participants while also effectively incentivizing GHG reductions.

1. <u>Has Congress made climate mitigation a program priority</u>? Farm Bill conservation programs support a wide range of activities, many of them critical (e.g., Great Lakes conservation, erosion control, water-use efficiency). If Congress simply adds dollars to these programs as a way to address climate change, climate practices could compete with other important resource priorities. Given the importance of quick action, policymakers might carve out specific dollars to devote to climate practices.
2. <u>Should programs be changed to reward performance over practice</u>? Generally speaking, Farm Bill programs provide cost-share payments for conservation practices, not performance. Practices are central. Changing programs to reward GHG performance would likely be a substantial undertaking. On the other hand, policymakers could focus programs on particular practices with the expectation that doing so would produce substantial GHG benefits.

3. Which programs are a good fit for encouraging climate-friendly practices?
    a. **CRP** has been enormously important in increasing carbon sequestration on working lands by restoring lands to grassland and forests. This program could be improved in four ways to increase the carbon benefits, including increasing the acreage cap, opening the program to allow tree planting on marginal pastureland, expanding the CRP grasslands program to allow for grazing while maintaining important grasslands, and increasing incentives to target flood-prone lands, peatlands, or other areas where carbon gains could be substantial.
    b. **RCPP** could be an important climate change program because of its flexibility and adaptability to local conditions, as noted above. Further, this program would allow aggregators or other intermediaries to reduce the transaction costs of delivering programs. Like other Farm Bill programs, RCPP funds practices. But policymakers could consider focusing the program on carbon projects or amending it to allow for a performance-based approach.
    c. **EQIP** is very flexible and can fund virtually any conservation practice, with the exception of conservation easements and some capital expenses such as the installation of methane digesters. Policymakers could consider devoting a portion of EQIP to climate change practices. This approach would face two challenges. First, EQIP is practice-based; second, the program doesn't easily allow for the aggregation of multiple landowners into a single project.
    d. **CSP** rewards existing stewardship practices and creates incentives for producers to adopt additional conservation measures. The program is designed to encourage landowners to address multiple land-use concerns in designing conservation plans and developing CSP contracts. This may make it challenging to use CSP as a vehicle focused on GHG reductions.
    e. **ACEP and the Forest Legacy Program** could be used to encourage voluntary conservation easements. Such easements, for grasslands and especially for forests, could be very important in maintaining existing U.S. carbon sinks (by reducing losses to development) while keeping land in agriculture and forest production. Policymakers should consider dramatically increasing the Forest Legacy Program, which is implemented in partnership with state forestry agencies.
4. Are there conservation practices that aren't addressed through existing Farm Bill programs? Farm Bill programs are flexible but they generally haven't been used to fund significant capital investments such as methane digesters that could yield enormous GHG benefits. The Obama Administration sought to finance digesters through Rural Development loans. Policymakers should consider ways to reduce the financial risks of investing in methane digesters where they make sense.

C. Tax Incentives

Tax incentives may be an option for encouraging GHG mitigation in the land sector. Section 45Q of the tax code creates a powerful incentive for the geologic storage and beneficial use of carbon captured from industrial facilities, power plants, and ambient air. Likewise, policymakers could consider creating a new tax credit to provide incentives for agriculture and forestry sequestration activities. A benefit of this approach would be that it would reduce transaction costs while also reducing the potential for delay and paperwork requirements. The challenge with using the tax code in this way is how to devise a monitoring/accounting system that ensures that taxpayers are receiving GHG values for their investment. The IRS isn't in the carbon business. Thus, policy would have to develop some mechanism – for example, through USDA agencies and partners or by requiring third-party certification/auditing – to provide some guarantee as to GHG benefits.

The existing reforestation tax credit already provides favorable tax treatment for reforestation expenses. It could be significantly expanded to increase reforestation investments—including by opening eligibility to aggregators who could work with landowners to implement reforestation and restocking projects. Tax policy could also help producers invest in capital-intensive activities such as installing methane digesters. Lastly, it's worth noting that tax policy has provided a central motivation for many landowners to place land into conservation easements, thereby reducing the loss of forest and grassland and associated carbon losses.

D. Research and Development

Advances in technology are already improving the productivity of agriculture and forestry operations while increasing efficiency. In agriculture, precision farming techniques, nitrogen inhibitors, changes in livestock feed mixes, and many other new technologies can produce significant climate benefits. Likewise, genetic tree improvement, more efficient wood utilization, and improved silvicultural techniques can increase carbon storage in forests. Investing in technology will be a key component in long-term efforts to reduce the climate footprint of agriculture and forestry.

A related area for public investment would be to bolster programs at USDA, specifically the Forest Service's Forest Inventory and Analysis and NRCS's Natural Resources Inventory, that provide critical baseline data on land-based carbon sequestration and emissions in the US. For example, investments could allow for more frequent measurement at thousands of inventory plots across the country and increase the integration of new technologies into measurement. Doing so would provide benefits to farmers, ranchers, and forest owners who undertake carbon projects by providing more robust data for projecting carbon gains from conservation practices.

E. Investments in Climate-Related Rural Jobs and Infrastructure

In many cases, the implementation of climate-smart practices in agriculture and forestry relies on jobs, products, or services that are in short supply. This creates significant opportunities to boost rural jobs while supporting natural climate solutions. Thus, another role federal policy could play is in providing direct grants, low-interest loans, and other assistance to kickstart new and expanded markets for agriculture and forestry products that deliver real climate benefits. Several areas of opportunity should be considered:

Wood product markets—Cross-laminated timber and other engineered wood products store significant amounts of carbon in long-lived products. There is growing interest in using these products to construct commercial construction, including tall buildings. Markets for wood products provide incentives for landowners to retain forests and protect them from development. On public lands, markets support forest restoration. But manufacturing capacity for wood products in the United States is limited. Investments to bolster wood product markets could have significant gains for the climate.

Forestry jobs—Restoring public and private forests so that they are more resilient to fire and other threats, such as pests, will require large-scale forest restoration. In many regions, the supply of workers available for logging and other forestry jobs is limiting. Thus, investments in a forestry workforce could be important.

Seeds, nurseries, and other agricultural products—Nurseries, seed banks for cover crops, equipment cooperatives, and other infrastructure and operations may be needed to support expanded carbon-beneficial practices like reforestation, cover cropping, and conservation tillage.

Methane digesters—Investments in the construction and maintenance of methane digesters could yield substantial GHG benefits and job opportunities.

New products and technologies—Investments in compost collection, processing, and distribution infrastructure could enable expanded use of organic municipal waste and agriculture and forestry byproducts as a low-carbon alternative to synthetic fertilizer. Likewise, production of biochar, a soil amendment derived from wood and other organic material, could create new rural jobs and could benefit from federal assistance.

Broadband and precision agriculture— Precision agriculture, which involves using GPS and other technology to improve the efficiency and productivity of cropland management, offers significant potential climate benefits because it can improve nitrogen-use efficiency, soil heath, and crop yields. Likewise, these technologies could improve forest management by providing better information on forest conditions and inventories, for example. Thus, efforts to expand broadband in rural America could have substantial climate benefits as well.

F. Bioenergy

While bioenergy remains controversial with some stakeholder groups, there is a significant opportunity to boost carbon sequestration and reduce GHGs through bioenergy from agricultural and forestry sources. In agriculture, low-carbon fuel standards or other mechanisms can be used to create incentives for biofuels that have a significantly smaller carbon footprint than fossil fuels.

With respect to wood energy, markets for low-value wood could be important in maintaining economic incentives for landowners to retain land and invest in reforestation. On public lands, markets for low-value wood are vital to help underwrite the large-scale forest restoration efforts needed to reduce the threat of catastrophic fire and bark beetle and other pest epidemics.

G. Public Lands Management

Catastrophic wildfires, caused by decades of management practices that suppressed natural fires, and exacerbated by climate change, are an enormous source of GHG emissions. These unnaturally destructive fires will continue to worsen unless steps are taken to restore more natural forest conditions on all forestlands, but particularly in the National Forests of the western states. Both selective thinning of forests to restore more natural conditions (while also providing timber to local mills) and the use of prescribed fire are paramount. Likewise, control of invasive species, such as cheat-grass, can substantially reduce the intensity of fires in rangeland. Landscape-scale forest restoration efforts, using collaborative approaches that bring industry, environmental advocates, agencies, and rural communities together, have demonstrated that well-conceived forest management practices can increase the resilience of forests to wildfire. But these efforts also cost money to support forest planning and, in many cases, to subsidize forestry treatments. In addition, substantial opportunities for reforestation exist on public lands, particularly in areas that have be subject to catastrophic fire.

However, the Forest Service spends well over half of its budget today on firefighting to the detriment funding for forest management and restoration. While Congress has passed legislation to allow the agency to draw on emergency funding for firefighting, this does little to replenish the funding that has been redirected over two decades from forest management to firefighting. In other words, Congress has stopped the bleeding, but the patient remains in critical condition. Substantial investments will be required to reduce the threat of catastrophic fire and related forest health challenges on public lands.

Perennializing Grain Crop Agriculture: A Pathway for Climate Change Mitigation & Adaption

The Land Institute, Salina, KS

Perennial grain crops deliver dramatic amounts of carbon to the soil, as illustrated by the extensive root system of intermediate wheatgrass (left) compared to annual wheat (right). Intermediate wheatgrass produces Kernza® perennial grain. Photo: Jim Richardson

Fred Iutzi, MS
President, The Land Institute
iutzi@landinstitute.org
785-823-5376

Timothy Crews, PhD
Director of Research, The Land Institute
crews@landinstitute.org
785-823-5376

The Land Institute, 2440 E. Water Well Rd., Salina, KS 67401 www.landinstitute.org

CONTENTS

Contents 51

Executive Summary 52

Summary of innovations, strategies, and policies proposed 52

Summary of RFI priority areas addressed 53

Climate change mitigation & adaptation through perennial grain crops – non-technical narrative 53

Perennializing grain crops is a major untapped carbon sequestration opportunity 53

How perennial grains can sequester large amounts of carbon in the soil 54

Transformational benefits for more than climate 55

Developing the world's first perennial grain crops 55

Pathways to full development and deployment of perennial grain crops 56

A federal policy agenda for perennialization of U.S. agriculture 58

Detailed technical narrative 60

Discussion of RFI priority areas addressed 65

Appendix: References for technical narrative 67

EXECUTIVE SUMMARY

Summary of innovations, strategies, and policies proposed

- Soil carbon sequestration is the most beneficial source of negative emissions for the U.S. climate change mitigation portfolio, and current grain crop production acreage is the prime candidate for major sequestration opportunities.
- U.S. grain crop agriculture is based on crops that are shallow-rooted annual plants grown in low-diversity monocultures that have lost the majority of the soil carbon that existed pre-settlement. The native grasslands that sequestered that carbon to start with were composed of deep-rooted perennial plants growing in high-diversity mixtures of multiple species.
- While discussions of soil carbon sequestration often emphasize uncertainty, it is unambiguous in the scientific literature that the highest levels of carbon sequestration achievable occur when lands previously planted to annual crops are converted to continuous perennial vegetation.
- In other words, we now have actionable knowledge that perennializing the agricultural landscape is the single most effective thing we can do for carbon sequestration.
- In addition to providing a major carbon sequestration opportunity, perennial polyculture grain cropping systems have the potential to substantially reduce emissions of the potent greenhouse gas (GHG) nitrous oxide from agricultural soils, and to reduce carbon dioxide emissions from farm equipment operations and the synthesis of inputs, especially nitrogen fertilizers.
- In addition to their climate change mitigation benefits, perennial grain crops can also make major contributions to increasing agriculture's adaptation to climate change, as well as reducing soil degradation, reducing negative water quality impacts, and reducing agricultural pesticide use.
- The Land Institute and its network of global research collaborators have recently achieved proof of concept with their perennial grain crops research efforts. The world's first two perennial grain crops are now in pilot scale commercial production: Kernza® perennial grain and perennial rice. Other perennial grain crops are under development.
- Results achieved to date demonstrate that a suite of perennial grain crops can be developed to replace the bulk of current U.S. and global grain crop production, resulting in transformational increases in carbon sequestration – but at current levels of investment, full deployment is decades away.
- Decisive action by the federal government is now warranted to accelerate perennial grain crop research and development by increasing public funding and stimulating private investment.

Summary of RFI priority areas addressed

This submission primarily addresses the following priorities identified in the 2019 Request For Information from the U.S. House Select Committee on the Climate Crisis:

- Agriculture (Priorities 6 & 7)
- Non-CO_2 Greenhouse Gases (Priority 9)

It also has significant implications for:

- Innovation (Priority 5)
- Carbon Removal (Priority 10)
- Resilience and Adaptation (Priority 11)
- International (Priority 13)

CLIMATE CHANGE MITIGATION & ADAPTATION THROUGH PERENNIAL GRAIN CROPS – NON-TECHNICAL NARRATIVE

Any credible portfolio of measures for mitigating climate change requires a negative emissions component, and soil carbon sequestration is arguably the most effective and beneficial source of negative emissions. Current U.S. grain crop production acreage should be a priority setting, because it has the most soil carbon to regain and because the most effective soil carbon sequestration method likely also will serve to reduce GHG emissions from agriculture. We argue that fully developing perennial grain crops and deploying them to replace current annual grain crop production is the path forward.

Perennializing grain crops is a major untapped carbon sequestration opportunity

U.S. and global grain crop agriculture is overwhelmingly based on crops that are annuals (plants that need to be reseeded every year) grown in single-species monoculture plantings. In contrast, the native ecosystems that preceded grain crop agriculture, such as native grasslands and forests, consisted of perennials (plants that regrow from year to year) growing in multi-species polycultures. It is well known that major losses in soil carbon were in all cases an immediate consequence of conversion of native ecosystems to grain crop fields early in history, and that in many farming systems these losses have continued over time. We now know that native grasslands were able to accumulate high levels of soil carbon precisely because of their perenniality and biodiversity – functions that current annual grain crops are unable to replicate. Developing perennial grain crops suitable to be grown in high biodiversity would be a decisive intervention to substantially increase soil carbon sequestration under grain crop farming, bringing it closer to pre-settlement carbon levels as close to pre-settlement levels as is possible.

The science of soil carbon sequestration is notoriously complex, and emphasis is often placed on the difficulty of precisely estimating sequestration rates under different agricultural practices. But the reality that carbon accumulation under continuous perennial cover, like native grasslands or permanent pasture, greatly exceeds carbon accumulation under current annual grain crop production has been well characterized for many decades. And soil and plant science research in recent decades has given us a greatly improved understanding of the linkages between carbon sequestration and specific functional characteristics of perennial vegetation (e.g. large root systems). We can therefore predict with high confidence that crops and cropping systems that closely mimic the functional characteristic of native grasslands will be able to come closer to pre-settlement carbon sequestration levels than crops and cropping systems that do not. This prediction is strongly supported by empirical work on perennial pasture crops and the first emerging perennial grain crops. In other words, **we now have actionable knowledge that perennializing our agriculture landscape is the single most effective route to increased soil carbon sequestration.** Perennial grain crops are the centerpiece of a strategy for getting there.

<u>How perennial grains can sequester large amounts of carbon in the soil</u>

The carbon sequestration benefits of a grain crop agriculture based on perennial polycultures is delivered through several mechanisms. Key among them is the deep, massive root system produced by perennial crops. As roots release organic exudates and as individual root strands die and are constantly replaced, these large root systems allow perennial plants to act as highly efficient carbon pumps, taking carbon pulled out of the air during photosynthesis and placing it deep underground in chemical forms likely to persist in the soil. Compared to perennial species, annual plants typically produce less total biomass every year and allocate far less of it to underground roots. Total biomass productivity of the species chosen for domestication into perennial grain crops is high enough that grain yields can be increased by reallocating excess aboveground vegetative biomass (leaves and stems) into grain biomass.

Another critical mechanism by which perennial grain crops increase carbon sequestration is eliminating the frequent soil-disturbing tillage associated with annual grain crop production, resulting in less oxidation of soil organic matter and consequent loss from the soil. Low soil disturbance and permanent vegetative cover also overwhelmingly reduces soil erosion compared to annual cropping systems, and the associated losses of organic compounds attached to soil particles. Several of the factors mentioned so far – large root structures, elimination of tillage, and presence of a diversity of crop species in a polyculture – combine to create a healthier, higher functioning soil microbiota. This increased soil health contributes to carbon sequestration both directly through the microbial biomass produced and indirectly through improved plant health and productivity, as well as through more efficient conversation of root biomass inputs into stable forms of soil carbon. Finally, combining nitrogen-fixing legumes in the same polyculture with non-legume perennial grain crops will serve to reduce the need for synthetic nitrogen fertilizer, in some cases drastically.

Drastic reductions in nitrogen fertilizer requirements could lead in turn to drastic reduction in nitrous oxide emissions compared to fertilized annual monocultures – an effect that is supported by a growing body of research.

Transformational benefits for more than climate

While the focus of this white paper is on the high level of benefits perennial grain crops provide for soil carbon sequestration and GHG emissions reduction, perennials also provide transformational benefits for a host of other ecosystem services. The same nitrogen fertilizer uptake advantage that sharply reduces GHG emissions also sharply reduces nitrate contamination of ground and surface water. The same deep root systems that sequester soil carbon also sharply reduce soil erosion, and in the process reduce phosphorus contamination of surface waters – and they may also result in increased yield stability in the face of drought. The physiology and production ecology of a perennial serves to reduce weed competition and the need for herbicides, while future polyculture systems are likely to reduce the need for insecticides and fungicides – all serving to reduce off-target impacts of pesticides.

Developing the world's first perennial grain crops

Replacing annual grain crops with perennial vegetation is the best opportunity for increasing soil carbon sequestration in the U.S. because of the large share of cropland acreage occupied by these crops and because they have the most soil carbon to regain. But because we rely on this grain crop production acreage directly or indirectly for more than 70% of the calories we consume, there are distinct limits to the proportion of cropland that can be shifted to the perennial vegetation options that have historically existed: perennial pasture and hay crops, native grasslands, and forests. Because all current major and minor grain crops were originally domesticated as annuals, development of the world's first perennial grain crops is the keystone innovation priority for perennialization of agriculture.

The Land Institute, a nonprofit agricultural research organization based in Salina, KS, leads a long-term research initiative to develop the world's first perennial grain crops. The initial conceptual and scientific groundwork for this effort was laid in the 1980s and 1990s, and since the mid-2000s the pace of the research outputs has accelerated substantially. **We now have proof of concept that perennial grains are possible.** Over the last three years, the world's first two meaningful perennial grain crops have entered pilot-scale production: Kernza® perennial grain in the U.S. and perennial rice in southern China. The products of a Land Institute-led consortium and a Land Institute-sponsored project, respectively, these two crops are the first two meaningful perennial grain crops in the history of agriculture.

Additional perennial grain crops are in development at various stages of the R&D pipeline: perennial wheat, perennial grain sorghum, perennial oilseed sunflower, and two perennial pulse crops (perennial legumes that produce a protein-rich grain comparable to a bean). These are all edible crops that will be able to functionally replace current food ingredients, including flours, starches, vegetable oils, and vegetable proteins. They will also no doubt be utilized for livestock feed and industrial purposes.

Growing perennial grain crops in biodiversity, especially in multi-species polycultures, will have even greater benefits for GHG-reduction and for production of other ecosystem services than the considerable benefits already supplied by a single-species stand of perennial grains. Polyculture research to date has focused on simple two-species mixtures of a perennial cereal grain and a perennial legume, because of the disproportionately large ecological benefits provided by this combination. In particular, the presence of the nitrogen-fixing legume has the potential to reduce the amount of synthetic nitrogen fertilizer needed for the cereal grain, thereby reducing emissions of nitrous oxide, a potent GHG. Polycultures of Kernza perennial grain and forage alfalfa are now entering pilot commercial production, while research is underway on intercropping Kernza with prospective edible grain legumes. Future research will address more complex polycultures.

Pathways to full development and deployment of perennial grain crops

The existence of annual grain crops like corn and wheat is the product of 10,000 years of folk plant breeding, and today's high grain yields are the product of 100 years of scientific plant breeding and genetics. Full development of perennial grain crops likewise hinges on plant breeding and genetics – but with the considerable advantage of being able to access new plant breeding technologies from the ground floor. Although transgenic methods and other forms of interventional biotechnology attract disproportionate public attention, the innovation that has arguably contributed more to grain crop yield gains is the use of observational biotechnology tools such as marker-assisted selection and genomic selection to greatly accelerate conventional plant breeding. The other "innovation" behind current annual crop performance is scale: billions of dollars of public and private investment each year in plant breeding and genetics.

The proof of concept recently achieved with Kernza perennial grain in the U.S. and perennial rice in China is a potentially game-changing milestone for perennialization of agriculture. But while perennial rice yields are already achieving comparable yields to annual rice, in most cases even after a new perennial grain is developed and enters its initial small-scale markets, considerable additional years of plant breeding effort will be required to achieve full yield potential and enter truly large-scale production. **Just as it took extensive plant breeding to bring annuals like corn and wheat to current yields, it will also take extensive plant breeding for perennial grains to reach their yield potential.** Substantial research agronomy and agroecology is required to develop the methods for successfully managing each new perennial grain crop and for managing perennial crops in polyculture.

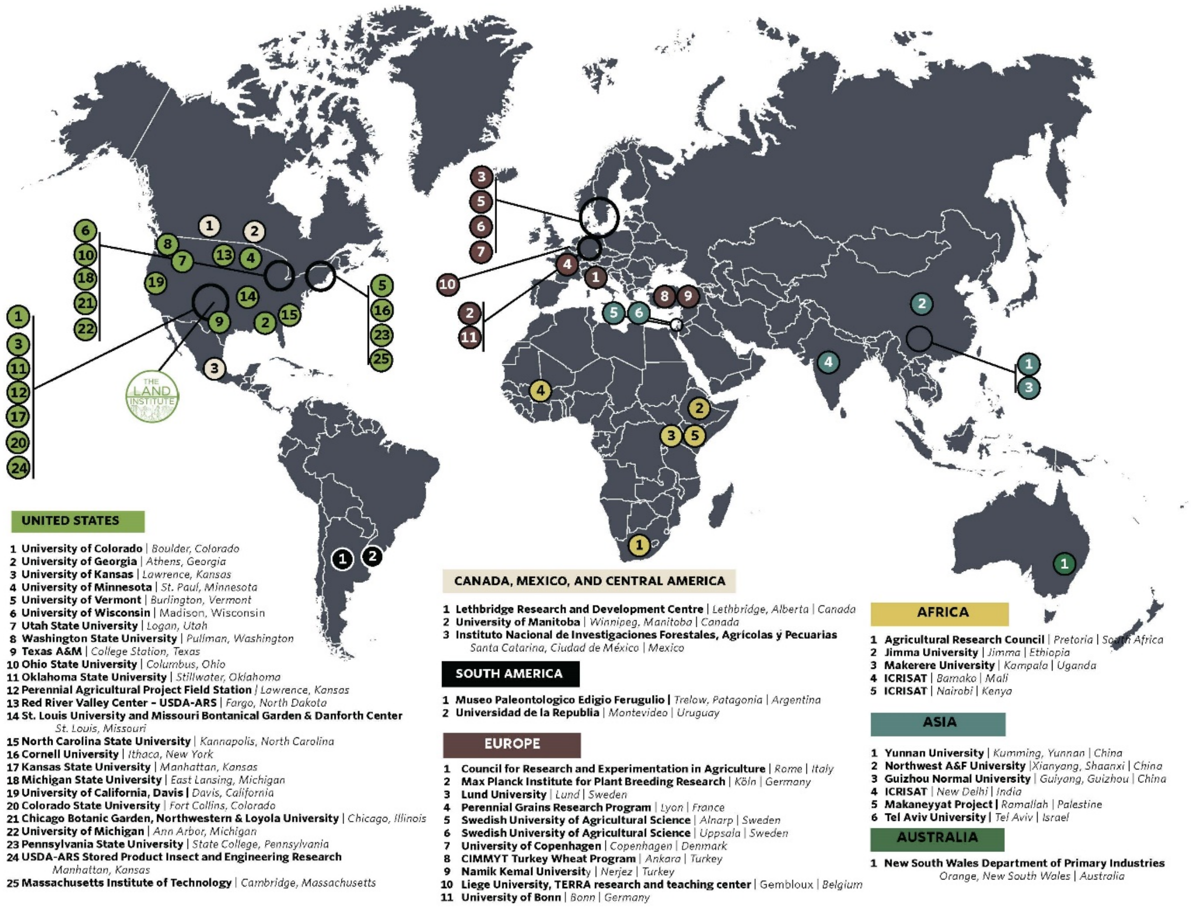


Figure 1. The Land Institute's global perennial grain crops research network as of September 2019.

The Land Institute employs an in-house research staff of 12 PhD scientists and a similar number of non-PhD research personnel, and as of December 2019 coordinates the work of 55 other public and private research institutions (Figure 1), approximately half of which are in the U.S. This growing base of capacity demonstrates the potential to rapidly scale the perennial grains R&D effort. And the important research milestones reached to date are even more impressive in light of the very limited resources available for this work to date: total resources at the direct disposal of The Land Institute are less than $8 million per year and the total global investment in perennial grain crop research has not yet reached $20 million per year. (For comparison, the total global public and private investment in annual grain crops research likely exceeds $10 billion each year.)

We argue that society is not yet investing in perennial grain crop research and development in proportion to its transformational benefits. At current funding levels, full development and deployment of perennial grain crops is still decades away. While no level of funding can bring transformational change to a biological system overnight, a major investment in perennial grain crop research could potentially cut decades from the timeline. This is especially true if an aggressive public investment sets off a virtuous circle of even more aggressive private sector investment.

A federal policy agenda for perennialization of U.S. agriculture

We propose immediate and decisive action by the U.S. government to accelerate perennial grain crops research and development through creation of a major federal research and development funding initiative. We believe this is the single most effective measure possible for soil carbon sequestration and reduction of GHG emissions from agriculture – and arguably the single most effective and appropriate negative emissions strategy in any sector.

Specifically, we propose that Congress and federal agencies:

- Recognize perennialization of the agricultural landscape as their lead strategy for soil carbon sequestration and reduction of GHG emissions from agriculture and **set a goal to bring total U.S. public and private investment in perennial grain crop research to at least $100 million per year within five years.** (For comparison, research investment for annual grain crops U.S. each year is measured in billions.)
- Establish major dedicated public funding for perennial grain crop research:
    - Allocate substantial amount of funding for dedicated perennial grain crop research within major competitive grant programs that target agriculture and applied biology, including those administered by the USDA National Institute of Food and Agriculture and the National Science Foundation.
    - Establish dedicated research programs for perennial grain programs within federal agencies conducting research relevant to agriculture, including the USDA Agricultural Research Service and the USDOE ARPA-E initiative.
    - Encourage Hatch Act and Smith-Lever Act institutions in the states to establish dedicated research in perennial grain crops.
- Encourage major investments in perennial grain crop research through dedicated funding within the multi-agency Small Business Innovation Research program, the Foundation for Food & Agriculture Research, and any other relevant programs.

Although they are outside the scope of this white paper, we also advocate the following additional policy actions and anticipate addressing them in one or more future white papers outside of this RFI:

- Launch a major federal initiative to incentivize conversion of a substantial fraction of current U.S. grain crop production acreage to permanent perennial pasture or rangeland. These perennial crops have similar ecosystem services benefits to future perennial grain crops and are available now. Acreage goals should be set with reference factors such as grain crop acreage most susceptible to soil degradation, grain crop acreage providing the least profitability for farmers, and total demands for food and feed grains in the economy.
- Incorporate into any perennial grain crop research initiative a substantial component funding expanded research in current and novel agroforestry crops,

which are also perennials that could produce substantial food while delivering high levels of ecosystem services.

- Implement changes to U.S. farm subsidy programs such that they incentivize a multifunctional agriculture that produces both abundant food and a high level of ecosystem services. This could include but is not limited to payments for carbon sequestration and other ecosystem services.

Critics of decisive action on climate change sometimes contend that because approaches based on innovation cannot be deployed instantly, only incremental changes to existing practices should be considered. We argue that to disregard the need for serious R&D into transformational change because it cannot be deployed instantly ignores the hard lessons of the last 30 years on climate change. The best time to fund research into transformational technologies like perennial grain crops was decades ago – the second-best time is now. The U.S. climate change mitigation portfolio must include a mix of decisive actions that can be performed now and decisive investments into transformational change – such as developing perennial grain crops.

DETAILED TECHNICAL NARRATIVE

As society confronts the challenge of not only stabilizing greenhouse gas concentrations in the atmosphere, but also reducing them to a significant degree, restoring carbon to the soil that has been released to the atmosphere due to land management practices is by many accounts perceived to be low hanging fruit (Griscom et al. 2017, Sanderman et al. 2017). However, as with many apparently straightforward solutions to difficult problems, altering land management techniques to sequester carbon is fraught with uncertainty and controversy (Schlesinger and Amundson 2019, Amundson and Biardeau 2018). Part of what makes carbon "draw down" approaches challenging from a policy perspective is the difficulty in actually measuring what are often relatively small changes to large pools of soil carbon over short periods of time (Necpálová et al. 2014). Another challenge is that different land management innovations take advantage of different mechanisms for increasing soil carbon. Broadly speaking, there are management approaches that increase the amount of carbon entering the soil in a given year, and then there are approaches that impede the loss of soil carbon back to the atmosphere. One approach to increasing soil carbon that researchers agree is robust, is the replacement of annual vegetation with perennial plants (Reicosky and Janzen 2019). Paustian (2014) illustrates why this is the case (Table 1), since no other approach addresses both mechanisms of improving carbon inputs into the soil while at the same time decreasing carbon loses.

TABLE 1 | Examples of agricultural management actions that can increase organic carbon storage and promote a net removal of CO_2 from the atmosphere and the main mode of action on the soil C balance (from Paustian, 2014).

Management practice	Increased C inputs	Reduced C losses
Improved crop rotations and increased crop residues	✓	
Cover crops	✓	
Conversion to perennial grasses and legumes	✓	✓
Manure and compost addition	✓	
No-tillage and other conservation tillage		✓
Rewetting organic (i.e., peat and muck) soils		✓
Improved grazing land management	✓	

Undegraded cropland soils can theoretically hold far more soil organic matter (SOM) (which is ~58% carbon) than they currently do (Soussana et al. 2004). We know this deficiency because, with few exceptions, comparisons between cropland soils and those of proximate mature native ecosystems commonly show a 40-75% decline in soil carbon attributable to agricultural practices. What happens when native ecosystems are converted to agriculture that induces such significant losses of SOM? Wind and water erosion commonly results in preferential removal of light organic matter fractions that can accumulate on or near the soil surface (Lal 2003). In addition to the effects of erosion, the fundamental practices of growing annual food and fiber crops alters both inputs and outputs of organic matter from most agroecosystems resulting in net reductions in soil carbon equilibria (Soussana et al. 2004; McLauchlan 2006; Crews et al.

2016). Native vegetation of almost all terrestrial ecosystems is dominated by perennial plants, and the belowground carbon allocation of these perennials is a key variable in determining formation rates of stable soil organic carbon (SOC) (Jastrow et al. 2007; Schmidt et al. 2011). When perennial vegetation is replaced by annual crops, inputs of root-associated carbon (roots, exudates, mycorrhizae) decline substantially. For example, perennial grassland species allocate around 67% of productivity belowground, whereas annual crops allocate between 13-30% (Saugier 2001; Johnson et al. 2006).

At the same time inputs of SOC are reduced in annual cropping systems, losses are increased because of tillage, compared to native perennial vegetation. Tillage breaks apart soil aggregates, which, among other functions, are thought to inhibit soil bacteria, fungi, and other microbes from consuming and decomposing soil organic matter (Grandy and Neff 2008). Aggregates reduce microbial access to organic matter by restricting physical access to mineral-stabilized organic compounds as well as reducing oxygen availability (Cotrufo et al. 2015; Lehmann and Kleber 2016). When soil aggregates are broken open with tillage in the conversion of native ecosystems to agriculture, microbial consumption of SOC and subsequent respiration of CO_2 increase dramatically, reducing soil carbon stocks (Grandy and Robertson 2006; Grandy and Neff 2008).

Many management approaches are being evaluated to recapture soil organic carbon, especially by increasing mineral-protected forms of SOC in the world's croplands (Paustian et al. 2016). The menu of approaches being investigated focuses either on increasing belowground carbon inputs, usually through increases in total crop productivity, or by decreasing microbial activity, usually through reduced soil disturbance (Crews and Rumsey 2017). However, the basic biogeochemistry of terrestrial ecosystems managed for production of annual crops presents serious challenges to achieving the standing stocks of SOC accumulated by native ecosystems that preceded agriculture. A novel new approach that is just starting to receive significant attention is the development of perennial cereal, legume, and oilseed crops (Glover et al. 2010; Baker 2017). Perennial grain crops represent the one approach that could increase carbon inputs and reduce carbon losses, thus potentially approaching the SOC standing stocks of native ecosystems (Crews and Rumsey et al. 2017).

There are two basic strategies that plant breeders and geneticists are using to develop new perennial grain crop species. The first involves making wide hybrid crosses between existing elite lines of annual crops, such as wheat, sorghum, and rice, with related wild perennial species in order to introgress perennialism into the genome of the annual (Figure 2) (Cox et al. 2018; Huang et al. 2018; Hayes et al. 2018). The other approach is *de novo* domestication of wild perennial species that have crop-like traits of interest (DeHaan et al. 2016; DeHaan and Van Tassel 2014). New perennial crop species undergoing *de novo* domestication include intermediate wheatgrass, a relative of wheat that produces grain marketed as Kernza® (Figure 3) (DeHaan et al. 2018; Cattani and Asselin 2018) and *Silphium integrifolium*, an oilseed crop in the sunflower family (Figure 4) (Van Tassel et al. 2017).

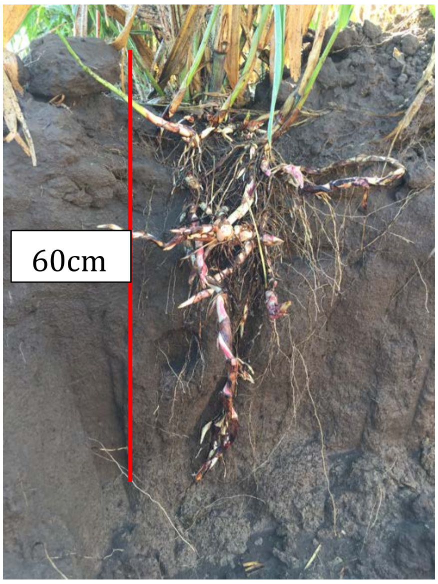


Figure 2. Perennial rhizome. A novel aspect of the newly developed perennial sorghum hybrid.

Figure 3. Comparison of root systems between the newly domesticated intermediate wheatgrass (left) and annual wheat (right). Intermediate wheatgrass produces the grain Kernza®. Photo and copyright: Jim Richardson

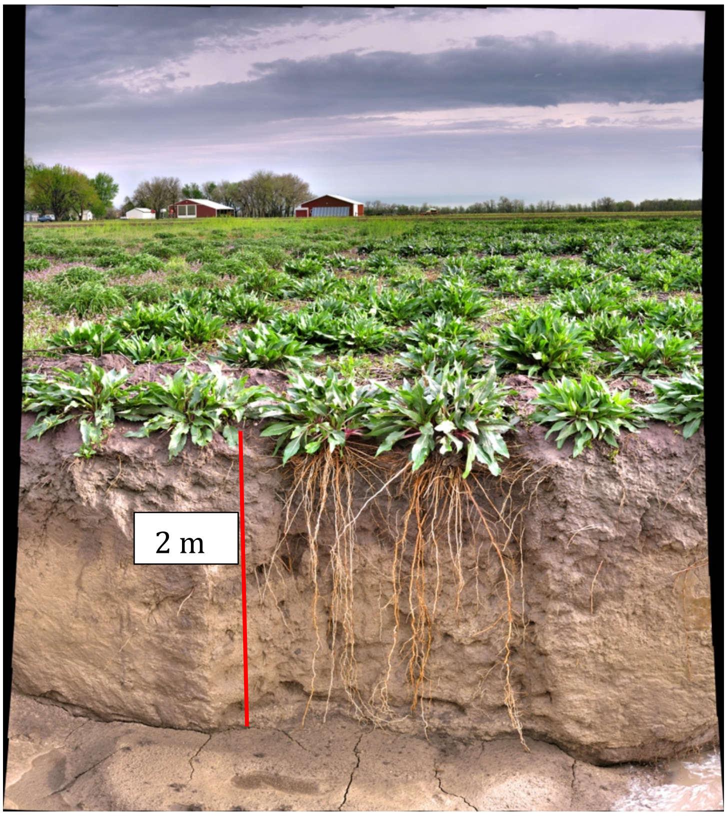


Figure 4. Deep roots of *Silphium integrifolium*. A native prairie species related to sunflower under domestication as a perennial oilseed crop.

Other perennial grain crops receiving attention include pigeon pea, barley, buckwheat, and maize (Batello et al. 2014; Chen et al. 2018) and a number of legume species (Schlautman et al. 2018). In most cases, the seed yields of perennial grain crops under development are well below those of elite modern grain varieties. In the time that it takes intensive breeding efforts to close the yield and other trait gaps between annual and perennial grains, perennial proto-crops may be used for purposes other than grain, including forage production (Ryan et al. 2018). Perennial rice stands out as a high-yielding exception, as its yields matched those of elite local varieties in the Yunnan Province for six growing seasons over three years (Huang et al. 2018).

In a perennial agroecosystem, the biogeochemical controls on SOC accumulation shift dramatically and begin to resemble the controls that govern native ecosystems (Crews et al. 2016). When erosion is reduced or halted, and crop allocation to roots increases by 100-200%, and when soil aggregates are not disturbed — thus reducing microbial respiration — SOC levels are expected to increase (Crews and Rumsey 2017). Deep roots growing year-round are also effective at increasing nitrogen retention (Culman et al. 2013; Jungers et al. 2019). Substantial increases in SOC have been measured where croplands that had historically been planted to annual grains were converted to perennial grasses, such as in the Conservation Reserve Program (CRP) of the U.S., or in plantings of second-generation perennial biofuel crops. In a recent study, researchers assessed the carbon balance of intermediate wheatgrass bred to produce the grain Kernza® in Kansas USA over 4.5 years using eddy covariance observations (de Oliveira et al. 2018). They found the net C accumulation rate of about 500 g C m^{-2} yr^{-1} in the first year of the study corresponding to the biomass of Kernza increasing, to about 120 g C m^{-2} yr^{-1}in the final year, where CO_2 respiration from the decomposition of roots and soil organic matter approached new carbon inputs from photosynthesis. Based on measurements of soil carbon accumulation in restored grasslands in the central U.S., the net carbon accumulation in stable organic matter under a perennial grain crop might be expected to fall in the range of 30-50 g C m^{-2} yr^{-1} (Post and Kwon 2000) until a new equilibrium is reached. Paustian et al. (2014) recently estimated that perennial grain crops planted on croplands previously sown to annuals could sequester 100 g C m^{-2} yr^{-1}, or 1 ton ha^{-1} yr^{-1}.

When compared to annual grains like wheat, single species stands of deep rooted perennial grains such as Kernza are expected to reduce soil erosion, increase nitrogen retention, achieve greater water uptake efficiency, and enhance carbon sequestration (Crews et al. 2018) (Figure 2). An even higher degree of ecosystem services should at least theoretically be achieved by strategically combining different functional groups of crops such as a cereal and a nitrogen-fixing legume (Soussana and Lemaire 2014). Not only is there evidence from plant diversity experiments that communities with higher species richness sustain higher concentrations of soil organic carbon (Hungate et al. 2017; Sprunger and Robertson 2018; Chen et al. 2018; Yang et al. 2019), but other valuable ecosystem services such as pest suppression, lower greenhouse gas emissions, and greater nutrient retention may be enhanced (Schnitzer et al. 2011; Culman et al. 2013).

Similar to perennial forage crops such as alfalfa, perennial grain crops are expected to have a definite productive life span, most likely in the range of 3-10 years. A key area of research on perennial grains cropping systems is to minimize losses of soil organic carbon during conversion of one stand of perennial grains to another. Recent work demonstrates that no-till conversion of a mature perennial grassland to another perennial crop will experience several years of high net CO_2 emissions as decomposition of copious crop residues exceeds ecosystem uptake of carbon by the new crop (Abraha et al. 2018). Most, if not all, of this lost carbon will be recaptured in the replacement crop. It is not known whether mineral-stabilized carbon that is protected in soil aggregates is vulnerable to loss in perennial crop succession.

The ability of perennial polycultures to sequester carbon has important potential for climate change mitigation. Perennial crops also hold significant promise for adaptation as they address multiple manifestations of soil degradation that are predicted to worsen with climate change. First, soil erosion is a very serious consequence of annual cropping, with median losses exceeding rates of formation by 1-2 orders of magnitude in conventionally plowed agroecosystems, and while erosion is reduced with conservation tillage, median losses still exceed formation by several fold (Montgomery 2007). More severe storm intensity associated with climate change is expected to cause even greater losses to wind and water erosion (Nearing et al. 2004). Secondly, the periods of time in which live roots are reduced or altogether absent from soils in annual cropping systems allow for substantial losses of nitrogen from fertilized croplands, averaging 50% globally

(Ladha et al. 2005). This low retention of nitrogen is also expected to worsen with more intense weather events (Bowles et al. 2018). A third impact of annual cropping is the degradation of soil structure caused by tillage, which can reduce infiltration of precipitation, and increase surface runoff. It is predicted that the percentage of precipitation that infiltrates into agricultural soils will decrease further under climate change scenarios (Basche and DeLonge 2017; Wuest et al. 2006).

Perennial grains hold considerable promise to reduce soil erosion and nutrient leakage while sequestering carbon. When cultivated in mixes with nitrogen-fixing species (legumes) such polycultures also reduce the need for external inputs of nitrogen — a large source of GHGs from conventional agriculture. The potential to accelerate the development of perennial grain species and eventually perennialize large percentages of U.S. and global croplands is proportionate to society's investment in moving research forward, especially in the areas of genetics, plant breeding, and ecological intensification.

DISCUSSION OF RFI PRIORITY AREAS ADDRESSED

This submission primarily addresses the following priorities identified in the Select Committee's RFI:

Agriculture, Priority 6: Reduction of greenhouse gas emissions and maximization of carbon storage. Perennial grain crops, as the centerpiece of a broader strategy that includes perennial pasture and hay crops, are the single most promising pathway to substantial increases in carbon sequestration in agricultural soils. Perennial grain crop production will require fewer field operations each year than current crop production, which will provide additional benefits in the form of reducing carbon emissions from agricultural equipment.

Agriculture, Priority 7: Helping farmers adapt to the impacts of climate change. Perennial grain crops will provide increased resilience in the face of the erratic temperature and rainfall regimes that accompany climate change. Mechanisms include improvement in soil health, reduction in soil erodibility, and increased ability to take up water and nutrients.

Non-CO_2 Greenhouse Gases, Priority 9: Reduction of emissions of non-CO_2 greenhouse gases. Grain crop agriculture currently produces large amounts of nitrous oxide, one of the single most potent GHGs, primarily as a product of breakdown of synthetic nitrogen fertilizer in the soil. Perennial grain crops are expected to require significantly less synthetic nitrogen fertilizer to be applied to a field to achieve a given crop yield goal, due to the increased efficiency of perennials' massive root systems at taking up fertilizer from the soil and due to the potential for intercropping perennial cereal crops with nitrogen-fixing perennial legumes.

This submission also has significant implications for the following priority areas:

Innovation, Priority 5a: An innovation agenda for climate change, including specific areas for federal investment. Perennialization of grain crop production is one of the boldest and most promising applied biology research agendas in history, aiming to replicate in a matter of decades a domestication process that originally took place over 10,000 years. The two most advanced perennial grain crops, Kernza and perennial rice, are nearing the point where large private sector investments will become a major factor in propelling the crops to full technological maturity. Increased federal investment in relevant research questions in the areas of plant breeding and genetics, agronomy and agroecology, soil science, and soil microbiology will help advance these two crops – and half a dozen others at earlier stages in the R&D pipeline – to this investment and deployment threshold.

Carbon Removal, Priority 10: Development and deployment of carbon removal technology to help achieve negative emissions. While the term "carbon removal" is usually associated with industrial technologies like Carbon Capture & Storage (CCS), we suggest that the single most promising mechanism for generating negative emissions is perennializing the agricultural landscape. Perennial crops are a game-changing innovation, offering the possibility of soil carbon sequestration levels significantly closer to the large amounts of carbon contained under natural ecosystems before intensive agriculture.

Resilience & Adaption, Priority 11b: Reduce climate risks for front-line communities, including low to moderate-income populations and communities that suffer from racial discrimination. Due to historical and current patterns of discrimination, African American and Native American farmers in the U.S. frequently operate on a land base that is particularly susceptible to environmental degradation and at a marginal level of profitability. The resilience benefits of perennial grain crops will likely be especially noticeable in these marginal circumstances, offering an even larger relative benefit to marginalized farmers than to U.S. farmers at large.

International, Priority 13: U.S. leadership to support international action on the climate crisis. Even the modest U.S. investments made to date in perennial grain crop research have leveraged a substantial response from counterparts overseas. Of The Land Institute's network of some 55 collaborating research institutions, slightly more than half are located outside the U.S. In the case of the single most advanced perennial grain crop developed to date, perennial rice, over approximately 15 years investments totaling only a few hundred thousand dollars from U.S. institutions have leveraged several million dollars in funding from overseas sources.

APPENDIX: REFERENCES FOR TECHNICAL NARRATIVE

Abraha, M., S. K. Hamilton, J. Chen, and G. P. Robertson. 2018. Ecosystem carbon exchange on conversion of Conservation Reserve Program grasslands to annual and perennial cropping systems. *Agric. For. Meteorol.*, 253–254, 151–160. doi:10.1016/J.AGRFORMET.2018.02.016.

Amundson, R. and L. Biardeau. 2018. Soil carbon sequestration is an elusive climate mitigation tool. *PNAS*, 115 (46) 11652-11656. doi:10.1073/pnas.1815901115.

Baker, B. 2017. Can modern agriculture be sustainable? *Bioscience*, 67, 325–331. doi:10.1093/biosci/bix018.

Basche A. and M. DeLonge. 2017. The impact of continuous living cover on soil hydrologic properties: A Meta-Analysis. *Soil Science Society of America Journal*, 81, 1179-1190.

Batello, C., L. Wade, S. Cox, N. Pogna, A. Bozzini, and J. Choptiany. 2014. Perennial crops for food security. http://agris.fao.org/agris-search/search.do?recordID=XF2017002349.

Bowles, T.M., S.S. Atallah, E.E. Campbell, A.C.M. Gaudin, W.R. Wieder and A.S. Grandy. 2018. Addressing agricultural nitrogen losses in a changing climate. *Nature Sustainability*, 1, 399-408.

Cattani, D. and S. Asselin. 2018. Has Selection for Grain Yield Altered Intermediate Wheatgrass? *Sustainability*, 10, 688. doi:10.3390/su10030688.

Chen, S., et al. 2018. Plant diversity enhances productivity and soil carbon storage. *Proc. Natl. Acad. Sci. U. S. A.*, 115, 4027–4032. doi:10.1073/pnas.1700298114.

Cotrufo, M.F., J.L. Soong, A.J. Horton, E.E. Campbell, M.L. Haddix, D.H. Wall, and W.J. Parton. 2015. Formation of soil organic matter via biochemical and physical pathways of litter mass loss. *Nature Geoscience*, 8, 776-779. doi:10.1038/NGEO2520.

Cox, S., P. Nabukalu, A. Paterson, W. Kong, and S. Nakasagga. 2018. Development of Perennial Grain Sorghum. *Sustainability*, 10, 172. doi:10.3390/su10010172.

Crews, T. E., J. Blesh, S. W. Culman, R. C. Hayes, E. Steen Jensen, M. C. Mack, M. B. Peoples, and M. E. Schipanski. 2016. Going where no grains have gone before: From early to mid-succession. *Agric. Ecosyst. Environ.*, 223, 223–238. doi:10.1016/j.agee.2016.03.012.

Crews, T.E. and B. E. Rumsey. 2017. What agriculture can learn from native ecosystems in building soil organic matter: A review. *Sustain.*, 9, 1–18. doi:10.3390/su9040578.

Crews, T.E., W. Carton, and L. Olsson. 2018. Is the future of agriculture perennial? Imperatives and opportunities to reinvent agriculture by shifting from annual monocultures to perennial polycultures. *Global Sustainability* 1, e11, 1-18.

Culman, S.W., S.S. Snapp, M. Ollenburger, B. Basso, and L.R. DeHaan. 2013. Soil and water quality rapidly responds to the perennial grain Kernza wheatgrass. *Agronomy Journal*, 105, 735-744. doi:10.2134/agronj2012.0273.

DeHaan, L. R. and D. L. Van Tassel. 2014. Useful insights from evolutionary biology for developing perennial grain crops. *American Journal of Botany*., 101, 1801–1819. doi:10.3732/ajb.1400084.

DeHaan, L. R., et al. 2016. A pipeline strategy for grain crop domestication. *Crop Sci*., 56, 917–930. doi:10.2135/cropsci2015.06.0356.

DeHaan, L., M. Christians, J. Crain, and J. Poland. 2018. Development and Evolution of an Intermediate Wheatgrass Domestication Program. *Sustainability*, 10, 1499. doi:10.3390/su10051499.

Glover, J. D., et al. 2010. Harvested perennial grasslands provide ecological benchmarks for agricultural sustainability. *Agric. Ecosyst. Environ.*, 137, 3–12. doi:10.1016/j.agee.2009.11.001.

Grandy, A. S. and J. C. Neff. 2008. Molecular C dynamics downstream: The biochemical decomposition sequence and its impact on soil organic matter structure and function. *Sci. Total Environ.*, 404, 297–307. doi:10.1016/j.scitotenv.2007.11.013.

Grandy, A. S. and G. P. Robertson. 2006. Aggregation and Organic Matter Protection Following Tillage of a Previously Uncultivated Soil. *Soil Sci. Soc. Am. J.*, 70, 1398. doi:10.2136/sssaj2005.0313.

Griscom, B.W., et al. 2017. Natural climate solutions. *PNAS*, 114 (44) 11645-11650. doi:10.1073/pnas.1710465114.

Hayes, R., et al. 2018. The Performance of Early-Generation Perennial Winter Cereals at 21 Sites across Four Continents. *Sustainability*, 10, 1124. doi:10.3390/su10041124.

Huang, G., et al. 2018. Performance, economics and potential impact of perennial rice PR23 relative to annual rice cultivars at multiple locations in Yunnan Province of China. *Sustainability*, 10, 1086-1104. doi:10.3390/su10041086.

Hungate, B. A., et al. 2017. The economic value of grassland species for carbon storage. *Sci. Adv.*, 3, e1601880. doi:10.1126/sciadv.1601880.

Jastrow, J. D., J. E. Amonette, and V. L. Bailey. 2007. Mechanisms controlling soil carbon turnover and their potential application for enhancing carbon sequestration. *Clim. Change*, 80, 5–23. doi:10.1007/s10584-006-9178-3.

Johnson, J. M.-F., R. R. Allmaras, and D. C. Reicosky. 2006. Estimating Source Carbon from Crop Residues, Roots and Rhizodeposits Using the National Grain-Yield Database. *Agron. J.*, 98, 622. doi:10.2134/agronj2005.0179.

Jungers, J.M., L.H. DeHaan, D.J. Mulla, C.C. Sheaffer, and D.L. Wyse. 2019. Reduced nitrate leaching in a perennial grain crop compared to maize in the Upper Midwest, USA. *Agric. Ecosyst. Environ.*, 272, 63-73.

Ladha, J.K., H. Pathak, T.J. Krupnik, J. Six, and C. van Kessel. 2005. Efficiency of fertilizer nitrogen in cereal production: Retrospects and Prospects. *Advances in Agronomy*, 87, 85-156.

Lal, R. 2003. Soil erosion and the global carbon budget. *Environ. Int.*, 29, 437–450. doi:10.1016/S0160-4120(02)00192-7.

Lehmann, J., and M. Kleber. 2016. The contentious nature of soil organic matter. *Nature*, 528, 60-68. doi:10.1038/nature16069.

McLauchlan, K. 2006. The Nature and Longevity of Agricultural Impacts on Soil Carbon and Nutrients: A Review. *Ecosystems*, 9, 1364–1382. doi:10.1007/s10021-005-0135-1.

Montgomery, D.R. 2007. Soil erosion and agricultural sustainability. *PNAS*, 104, 13268-13272. doi:10.1073/pnas.0611508104.

Nearing, M.A., F.F. Pruski, and M.R. O'Neal. 2004. Expected climate change impacts on soil erosion rates: A review. *Journal of Soil and Water Conservation*, 59, 43-50.

Necpálová, M., et al. 2014. What does it take to detect a change in soil carbon stock? A regional comparison of minimum detectable difference and experiment duration the North-Central United States. *Journal of Soil and Water Conservation*, 69(6), 517-531.

de Oliveira, G., N. A. Brunsell, C. E. Sutherlin, T. E. Crews, and L. R. DeHaan. 2018. Energy, water and carbon exchange over a perennial Kernza wheatgrass crop. *Agric. For. Meteorol.*, 249, 120–137. doi:10.1016/J.AGRFORMET.2017.11.022.

Paustian, K. 2014. Carbon sequestration in soil and vegetation and greenhouse gas emissions reduction. *Global Environmental Change,* 1, 399–406. doi: 10.1007/978-94-007-5784-4_10.

Paustian, K., J. Lehmann, S. Ogle, D. Reay, G.P. Robertson, and P. Smith. 2016. Climate-smart soils. *Nature*, 532, 49-57. doi:10.1038/nature17174.

Post, W. M. and K. C. Kwon. 2000. Soil carbon sequestration and land-use change: processes and potential. *Glob. Chang. Biol.*, 6, 317–327. doi:10.1046/j.1365-2486.2000.00308.x.

Reicosky, D.C. and H.H. Janzen. 2019. Conservation agriculture: maintaining land productivity and health by managing carbon flows. *Soil and Climate*, R. Lal and B.A. Stewart (Eds.). Advances in Soil Science, CRC Press, Boca Raton, FL, 131-161.

Ryan, M.R., T.E. Crews, S.W. Culman, L.R. DeHaan, R.C. Hayes, J.M. Jungers, and M.G. Bakker. 2018. Managing for multifunctionality in perennial grain crops. *Bioscience*, 68, 294-304.

Sanderman, J., T. Hengl, and G.J. Fiske. 2017. Soil carbon debt of 12,00 years of human land use. *PNAS*, 114 (36) 9575-9580. doi:10.1073/pnas.1706103114.

Saugier, B. 2001. Estimations of Global Terrestrial Productivity: Converging Toward a Single Number? *Terrestrial Global Productivity*, J. Roy, Ed., Academic Press, San Diego, CA, 543–556.

Schlautman, B., S. Barriball, C. Ciotir, S. Herron, and A. Miller. 2018. Perennial Grain Legume Domestication Phase I: Criteria for Candidate Species Selection. *Sustainability*, 10, 730. doi:10.3390/su10030730.

Schlesinger, W. H. and R. Amundson. 2019. Managing for soil carbon sequestration: Let's get realistic. *Global Change Biology*, 25:386-389. doi: 10.1111/gcb.14478.

Schmidt, M. W. I., et al. 2011. Persistence of soil organic matter as an ecosystem property. *Nature*, 478, 49–56. doi:10.1038/nature10386.

Schnitzer, S. A., et al. 2011. Soil microbes drive the classic plant diversity–productivity pattern. *Ecology*, 92, 296–303.

Sprunger, C.D. and G.P. Robertson. 2018. Early accumulation of active fraction soil carbon in newly established cellulosic biofuel systems. *Geoderma*, 318, 42-51.

Soussana, J. F., P. Loiseau, N. Vuichard, E. Ceschia, J. Balesdent, T. Chevallier, and D. Arrouays. 2004. Carbon cycling and sequestration opportunities in temperate grasslands. *Soil Use and Management*, 20(2), 219-230.

Soussana, J. F. and G. Lemaire. 2014. Coupling carbon and nitrogen cycles for environmentally sustainable intensification of grasslands and crop-livestock systems. *Agriculture, Ecosystems & Environment*, 190, 9-17.

Van Tassel, D. L., et al. 2017. Accelerating silphium domestication: An opportunity to develop new crop ideotypes and breeding strategies informed by multiple disciplines. *Crop Science*, 57, 1274–1284. doi:10.2135/cropsci2016.10.0834.

Wuest, S.B., J.D. William, and H.T. Gollany. 2006. Tillage and perennial grass effects on ponded infiltration for seven semi-arid loess soils. *Journal of Soil and Water Conservation*, 61(4): 218-223.

Yang, Y., D. Tilman, G. Furey, and C. Lehman. 2019. Soil carbon sequestration accelerated by restoration of grassland biodiversity. *Nature Communications*, 10. doi.org/10.1038/s41467-019-08636-w.

The Ecosystem Services Market Consortium (ESMC): Ecosystem Services Markets Conceived and Designed for Agriculture

Lessons learned from two decades of agriculture carbon market programs

Debbie Reed Executive Director, Ecosystem Services Market Consortium

The Ecosystem Services Market Consortium (ESMC) is launching the first ecosystem service market program dedicated exclusively to agricultural working and conservation lands. The full-scale market will launch in 2022. The ESMC is a national-scale market conceived of and designed for US farmers and ranchers. ESMC's program, which is currently in full pilot and demonstration mode with more than 40 members from across the agricultural supply chain, provides outcomes-based, quantified, salable credits representing improvements in soil carbon sequestration and retention, net greenhouse gas (GHG) mitigation, water quality impacts, and water use efficiency. ESMC's approach was designed to incorporate the successful elements of previous ecosystem service trading markets while overcoming the mistakes and pitfalls that plagued them. ESMC, however, is more than just a synthesis of lessons learned from past markets. ESMC's innovation lies not only in the incorporation of all of these parts, but also in driving technological development and research, creating new agriculture-focused market rules that accommodate the needs of buyers and sellers, developing social capital and systems to connect every corner of the market to reduce market failure risks, and demonstrating the proper role for government to spur action and mobilize change in the sector.

This paper draws heavily on work conducted by the Coalition on Agricultural Greenhouse Gases (C-AGG), including C-AGG's work over several years supporting USDA Conservation Innovation Grant (CIG) projects focused on carbon market opportunities for US agriculture. The paper identifies and summarizes the most and least successful elements of past markets. These elements are broadly categorized into policy, technological, economic, and social capital categories, and served as guideposts for the development of ESMC's market. Viewed comprehensively, ESMC's blueprint and program aims to make the agricultural sector more sustainable and resilient by addressing the environmental, economic, and social barriers to achieving and scaling improved ecosystem service impacts from working agricultural and conservation lands through a market-based approach.

Market Design

Current markets are hampered by risks associated with market design. Markets have been created without regard to matching supply and demand; without ensuring that all market participants have the requisite tools or access to participate or are prepared to participate when needed (e.g. having ample verifiers familiar with agricultural production systems who can act in a timely fashion); and without participants who can certify the programs and resulting assets. ESMC's total market planning and design overcomes these risks by creating the necessary tools, incentives, and participation agreements to create a full-service market. All the players in the agricultural supply chain and ESMC market are testing the full market design together. This approach will ensure delivery of outcomes by ensuring necessary trading volumes, participation, and ability to monetize assets at scale.

The first, and perhaps, most significant category of barriers related to market design includes the rules governing who can participate and under what conditions. Existing carbon and water asset markets markets were designed for point source pollution approaches, as were the rules of participation, and thus apply more to large point source facilities like power plants. These facilities can utilize monitors and/or indicators of GHG emissions according to known and predictable formulas. Point source market design rules make it easy for a project developer to aggregate and scale such projects, given the ease of computing changes in emissions. When applied to biological agricultural systems, however, these rules and associated requirements present a significant barrier to entry for farmers and ranchers, especially considering that more than 2 million independent agricultural producers must manage their systems according to their region, weather, precipitation, climate, and to address pests, diseases, and other issues that require flexibility of management approaches. Additionally, agricultural protocols that track and allow only one specific practice and one specific GHG or other outcome or attribute are not sustainable and not flexible enough to capture how farmers and ranchers farm and ranch, which is a systems-based approach based on their soils, regions, climate and weather and production systems. Agricultural systems require flexibility of management and thus flexibility in tracking management changes, and market rules must accommodate this flexibility to engage farmers and ranchers at scale. The result is that in existing markets, transaction costs associated with agricultural project development, data collection, monitoring, reporting, and verification and credit development are disjointed, largely unconnected, and traditionally outweigh the value of credits generated. The result is market signals that don't provide enough of an economic incentive for agricultural producers to participate. ESMC's aligned programmatic approach addresses these critical barriers in a full-service market that reduces or negates the individual and collective risk of each of these market failures.

Additionally, because most ecosystem service impacts in question are treated as market externalities, their true value is not currently reflected in monetization of these credits. While ESMC believe that valuation of ecosystem services will improve as society continues to grapple with continued degradation of natural resources and the need to enhance outcomes and improvements, that is not within our control to fix, at present. Market design is within our control, and is where we have focused our attention.

Further, the market concepts of additionality and permanence have served as the basis of voluntary and regulatory markets to date. While these tenets have helped ensure that transacted credits can be linked to improved environmental outcomes that don't shift adverse effects elsewhere, their implementation has largely prevented qualifying agroecosystems from participating, given the biological nature of these systems. Markets define "additionality" to determine which actions or interventions contribute to improved environmental outcomes and are thus eligible to earn credits. Markets strive to only award credits to actions that wouldn't have occurred without the incentive provided by the market. If an intervention is not additional, one cannot claim that a transaction is creating 'new' changes in outcomes. This rule inherently determines that any good actions already occurring cannot be rewarded, which is a known perverse impact, particularly in a sector in which adoption of beneficial practices and impacts remains relatively low. Each determination of additionality is made with reference to a baseline, or a determination that "but for this policy, this action would not have occurred", which is highly subjective. Past and current markets, which largely use project- or area-wide baselines, thus disqualify the innovations or early-adopters from market participation. Because early adopters are the teachers from whom more risk-adverse farmers and ranchers learn, the outcome has made it difficult to scale any desired impacts.

ESMC's approach adapts existing notions of baselines and additionality to account for systems-based approaches and to reward actual outcomes. We look at the baseline status at the farm scale – what systems are in place on each farm or ranch at enrollment, and what new practices or systems are adopted -- and we monitor and report the outcomes associated with the new practices and systems on an annual and an ongoing basis. This will allow us to reward system-based approaches that move the needle with regard to generating assets of interest, rather than to focus on individual practices. A market with adaptive baselines embraces the concept of "continuous improvement" and rewards each producer for gains in water use efficiency, nutrient management, and soil organic carbon content. Moreover, we believe ecosystem service markets should reward rather than penalize innovators and early adopters. ESMC has created a 3-year lookback provision to credit stored soil carbon going back 3 years when producers who enroll have average soil carbon content that is higher than the county average – a sign of past and ongoing good management.

GHG global warming potentials (GWP) are generally expressed on a 100-year time scale, and similarly, carbon sequestration projects in existing carbon markets are expected to sequester or mitigate carbon emissions for 40-100 years in order to be considered "permanent." Like additionality, the concept of permanence is not easily translated to biological systems, where carbon stocks fluctuate depending upon management and climactic factors. The carbon cycle, by its nature, is a biological cycle, and is not 'permanent' per se. The focus instead should be on increasing the amount of biological carbon and the duration of residence time of this carbon in beneficial sinks, including soil sinks. Tracking the status of these sinks, and the amount and residence time of carbon in them, in a manner that is linked to agricultural systems management is the approach taken by ESMC. We can and will track changes in soil carbon sinks at the farm and ranch scale and at larger scales, as well as the management systems that enhance these sinks and their residence time; we will reward these activities through the market, and show how the resilience associated with these outcomes benefits the farmer and rancher above and beyond the market payments, by improving bottom lines. The resulting impacts benefit society also.

In addition, ESMC has built a market with buyers and sellers at the table who are helping to refine the market design and pilot test the protocols while investing together in additional

R&D to enhance market functionality. The majority of ESMC market demand is from corporate entities operating in the agriculture, food and beverage sectors. Our market and protocol design address these buyers' needs – which currently accounts for the majority of demand -- as well as those of heavy emitters and regulated emitters, such as the oil and gas industry. ESMC's protocols generate ecosystem service assets that meet standards in supply chain sustainability initiatives as well as in voluntary and compliance grade carbon and water markets. ESMC assets meet corporate entity requirements to calculate, track and mitigate the environmental impacts in their supply chains. Buyer and seller participation as well as a commissioned demand-side analysis[1] has shown that the market is legitimate, viable, scalable, and capable of transforming the sector. Buyer 'buy-in' reduces uncertainty for sellers who traditionally have not seen value in these markets, while demonstrating that buyers are willing to work with farmers and ranchers to achieve mutual goals. Besides multi-stakeholder participation and buy-in, ESMC also differs from past markets because of the circumstances surrounding the market's development and launch. Consumer and investor demand for sustainable agriculture products, increasing levels of communication and integration throughout agriculture supply chains, and high rates of technological advancement in the sector and in the ESMC market will help to truly transform these markets.

Besides failing to design markets to meet the needs of primary stakeholders, past and current ecosystem services markets struggle to connect buyers and sellers, requiring middle-men or one-off transactions. An example is a water utility looking for upstream nutrient reductions. Farmers and ranchers in the utility's watershed may be well-suited to meet the utility's needs, but since these two groups aren't typically in contact, coordination is time- and resource-intensive. Because such transactions remain one-off deals, there has been a chicken and egg question with regards to matching supply and demand. A farmer will not incur the upfront costs of generating a credit without certainty that there is a buyer, and that the sale will offset the required monitoring, reporting, verification, and listing fees. Similarly, a buyer can't meet demand through credits that don't exist – or that don't exist when needed, or from credits for which real and opportunity costs are higher than the current costs of coming into compliance or meeting a voluntary sustainability target.

ESMC's market design addresses these risks in the market asset development and delivery chain by establishing a fully-functioning marketplace and transaction hub and by addressing the value proposition to all players and stakeholders in its design and development. Farmer and rancher engagement, technical assistance, asset quantification, verification, certification and credit generation and transactions are all included. By including all players and critical stakeholders in the market design, testing and buildout, and by fulling addressing verification and certification requirements up front, ESMC has reduced uncertainty about supply and demand as well as about verification and certification. Each transaction is mediated by standards-based protocols and rules and procedures that are being field-tested and refined during the piloting phase. The complete infrastructure design replaces the need for one-off transactions happening randomly across the asset development and market landscape. Past markets have defined and set the standard for bringing multiple producers together under a single body or project developer, but ESMC's full-service structure and programmatic

[1] https://ecosystemservicesmarket.org/wp-content/uploads/2019/09/Informa-IHS-Markit-ESM-Study-Sep-19.pdf

investments removes the need for middlemen and thus minimizes costs associated with project development, asset generation, verification, certification and sale, which currently occur in different arenas and under different groups of paid players.

The ability to cut out intermediaries and thus reduce cost and risk is made possible by a market built around the market's supply chain. ESMC's approach can also increase transparency in agricultural supply chains by connecting and harnessing previously siloed data at each stage in the supply chain – production, handling, processing, transport, and manufacturing. Agricultural technology and the use of application programming interfaces (APIs) can facilitate these connections by allowing management systems in each stage of the supply chain to share data. For example, with producer consent, nutrient application data collected by a tractor can be shared throughout the supply chain to inform a calculation of GHG and water quality impacts for a food product. The sharing of this data is predicated on data privacy and ownership agreements, established relationships, and the potential for producer value or profit from a sustainability premium or credit transaction. The proliferation of data ownership norms and the establishment of supply chain relationships is a relatively new phenomenon that ESMC seeks to further bolster through its multi-stakeholder effort. To this end, ESMC has followed the American Farm Bureau Federation and other grower and industry groups' Ag Data Transparent Core Principles and will seek certification through that initiative. Certification against this standard means that ESMC can ensure clarity around the collection, use, storage, and transfer of producer data so they can make informed decisions relative to their participation in the marketplace.[2]

As a general rule, market efficiencies increase with increased access and participation. For instance, markets operating within a single, small watershed inherently limit the number of buyers and sellers, the impacts that can be achieved, and thus the efficiencies of scale that can be achieved. Smaller markets tend to lead to incongruities between supply and demand. While certain ecosystem services have a localized impact (e.g. water quality), ESMC will nonetheless operate at a national scale in order to facilitate robust market participation and activity.

ESMC is also unique in developing a system that stacks credits that monetize different ecosystem services attributes developed on the same lands. ESMCS' protocols incorporate a single quantification approach that creates carbon / GHG, water quality, and water use impacts of agricultural management systems and generate three separate, salable assets that can be sold together in a stacked asset or disaggregated to meet the needs of different willing buyers. While the price of a carbon credit may not cover the full cost of credit generation and sale in today's markets, coupling these credits with water quality and use efficiency assets will tip the balance in favor of producers and generate greater societal returns in an outcomes-based market.

Finally, a logical but necessary change that has yet to infiltrate these markets is the use of scientific sampling for verification approaches. Risk-based, randomized sampling approaches are used in all aspects of our lives, including medicine, insurance and even security screenings. ESMC has adopted a science-based, risk-based randomized sampling approach to retain the rigor of verification approaches while drastically reducing and hopefully largely eliminating the

---

[2] https://www.agdatatransparent.com/

need for on-the-ground verifiers to visit a farm or field typically months or sometimes years after the fact to verify whether a practice or practice change occurred. Coupled with remote sensing, satellite imagery, and other forms of documented evidence, this approach will increase transparency and rigor while reducing verification costs and resource requirements that have hampered these markets from scaling.

Technology

Programmatic investments in ecosystem service markets from agriculture are imperative to scale science-based, standards-based quantification of outcomes in a verified, certified marketplace while reducing transaction costs. Technology, broadly referenced here to include improved quantification of ecosystem services assets from natural and working lands (e.g. direct sensors and microsensors as well as improved biophysical and biogeochemical models, improved soil carbon sampling and monitoring technologies), and technologies to electronically capture and store irrefutable evidence required for verification and certification (e.g., use of georeferenced apps and time and date-stamped photos and satellite imagery linked to process models), is critical in reducing transaction costs associated with ecosystem service markets and in building confidence that the assets are accurate representations of agreed upon units of ecosystem services. Also, technological advances can offer user-friendly tools and interfaces for all market players to engage without undue burden. These investments to build a scalable market focused on US agriculture have not previously been made, and are a key to scaling ESMC's market.

Inherent field-scale uncertainty surrounding the environmental impacts of, and thus quantification of impacts generated by specific management practices and systems-based approaches in agriculture is best addressed through new and developing technologies. These include the use of direct measurements (e.g. soil carbon) and sensors under development now (e.g. in-ground soil carbon and nitrous oxide sensors), coupled with robust, real-time modeling that can track and reflect impacts of new conservation and regenerative agriculture systems approaches, particularly in today's changing climate. Default values and meta-models based on past practices including limited rotations and non-regenerative systems-based approaches are not robust enough to capture real changes happening in various US regions and production systems. Nor can such practice-based meta-models possibly help to interpret and track trends in outcomes or impacts in a way that can reinforce which new systems-based approaches are moving the needle the most, by region and by production system, in order to create a positive feedback loop for producers within ESMC.

Similar to the question around baselines, market rules also decide the appropriate level of rigor for impact quantification, as well as how to achieve greatest confidence in quantification. Biogeochemical process models can track changes in ecosystem services impacts from agricultural systems at scale, and can calculate structural and data uncertainty of model outputs. The confidence in model accuracy is improved the larger the scale of operations and use. Insufficient data, or data of the wrong scale and scope, may not reflect actual conditions or outcomes on the ground. For instance, some tools and calculators use lookup tables with national, or even global averages or default values for soil carbon stocks or changes in GHG emissions associated with implementing a certain practice. Such tools and tables often do not reflect the regional, or even farm to farm variations in management decisions or soil and weather conditions, nor can they track outcomes, since they are based on past observances of past practices. Similarly, they cannot represent the myriad ways in which a producer can implement a conservation practice or suites of practices. ESMC protocols are practice neutral, allowing flexibility in producer decision making, but establish a pay for performance system based on ecosystem service impacts and outcomes. Using cover crops as an example, models cannot distinguish between cover crops that are planted to fix nitrogen, provide forage, or stabilize soil; the various seeding rates and methods; and the termination timing and methods, but do need to recognize their contribution to carbon sequestration, GHG emissions, and water quality. ESMC has developed science-based, standards-based protocols that will ensure quantification rigor keyed to market needs while providing user-friendly tools and interfaces to minimize hassle and burden for users – particularly farmers and ranchers – while tracking beneficial systems-based impacts of regenerative practices.

The choice between data-intensive models that are cumbersome for producers and simple, unreliable models is becoming less essential due to advances in precision agriculture, data governance, and rural connectivity. US agricultural producers are increasingly using software on their operations to collect, store, and manage production and financial records; to track external weather, GPS, soil, and market data; and to forecast yields and generate recommendations for management activities such as pesticide and nutrient applications. The USDA Economic Research Service's *Agricultural Resources and Environmental Indicators, 2019* report, defines precision agriculture as "tractor guidance systems that use a global positioning system (GPS), GPS yield and soil mapping, and variable-rate input technology (VRT) applications." The use of these technologies has grown steadily over the last two decades and across commodities[3]. While there are still difficulties sharing and formatting these data to allow interoperability of software and models, the mere availability of these data is helping overcome current and past trade-offs between user-friendly and scientifically robust quantification approaches. ESMC is investing in advanced analytical technologies and platforms.

The availability of more rigorous data is due in large part to technological advancements made in monitoring and computing power for predictive analysis. With respect to monitoring, satellite imagery and sensing has become ubiquitous and relatively inexpensive compared to even a decade ago. Increasingly available production data is supported by improvements in basic scientific knowledge surrounding soil health and agricultural production systems. Advancements in our understanding of soil structure, water holding capacity, the soil microbiome, organic matter, and nutrient cycling make each calculation behind a carbon, water quality, or water use credit more scientifically sound.

These data also help reduce the transaction costs associated with monitoring, reporting, and verification. They partially obviate the need for in-person site visits because conservation practices can be monitored and verified remotely. For instance, satellite imagery can track and verify tillage and cover crop practices, and link to biogeochemical process models through algorithms. Nutrient application and irrigation records, gathered from farm machinery in real time and processed by third-party farm management software, can be confidentially shared with verifiers.

[3] https://www.ers.usda.gov/webdocs/publications/93026/eib-208.pdf?v=2348.3

Social Capital

An important yet underappreciated impediment to ecosystem service market success is a lack of social capital, or networks of communication, cooperation, understanding and trust among market participants. Market rules and procedures must be known and agreed, but so must the long-term value proposition of market participants and stakeholders. To date, agricultural producers have not been mainstreamed into development of ecosystem service markets and protocol design, development, and testing. Most existing protocols were designed by well-intentioned and -qualified academics, non-profits, and corporate sustainability managers; gained universal approval among these groups; and were then published and released for use in the field. Like any product whose design doesn't consider the needs and desires of its primary user, these markets largely have not succeeded or scaled.

ESMC designed and is building a market with the participation of and to meet the needs of all stakeholders because a successful market will have the support and confidence of buyers, sellers, and critical stakeholders such as scientists and environmental NGO's. To scale the desired impacts from the agricultural sector that are clearly desired by society and corporates and others in the agricultural supply chain, ESMC's market is farmer-based and farmer-facing first and foremost. Farmers more readily trust, identify with, and learn from their fellow farmers than representatives of environmental NGOs, government agencies, or corporate sustainability departments. However, this conventional wisdom is rarely incorporated into design of ecosystem service markets or sustainability initiatives. The messenger is just as important as the message. This realization manifests itself in the establishment of peer-to-peer learning initiatives or corporate sustainability initiatives that make use of farmers' existing relationships with agricultural retailers and advisors.

Unlike traditional protocols, ESMC developed its protocols with farmers and ranchers and scientific experts and is piloting and field-testing every aspect of the protocols and the program with farmers and ranchers and other stakeholder before undergoing final scientific review, public comment and certification. Researchers and technical experts and agricultural producers have been involved since its inception. Beyond ensuring functionality and rigor in the field, producer involvement and testing helps to cultivate buy-in by getting producers to take a stake in the result. The buyers, primarily corporate entities seeking to mitigate their supply chain impacts, and sellers, agricultural producers, are all well represented in ESMC's governance, science, research, development and deployment structure, as are public agencies (USDA, DOE and EPA).

Policy

Ecosystem service markets are best established as free and open markets based on clear market rules, high quality information, and transparency of data and information. Markets will thrive with appropriate rules and transparency, and will drive price discovery to reflect societal and corporate demand for natural resource protection and enhancement in the form of ecosystem services derived from the agricultural sector, including climate mitigation and resilience, water quality, and water use. ESMC's market has been designed to not require any policy changes due to its private free-market approach.

Supportive public policies can undergird free markets, as commonly happens today. For instance, federally funded research can improve the state of monitoring, reporting, and verification of ecosystem services assets, including through the development of new and improved technologies. For instance, distributed technologies to provide rapid and accurate in-field soil carbon testing, more accurate and repeatable soil bulk density tests, or satellite and drone remote sensing technologies that are capable of feeding into quantification models and databases can improve the rigor of ecosystem services asset quantification, monitoring, reporting and verification. Examples of this include USDA investments in OpTIS (a satellite imagery technology to track conservation tillage and cover crop use); investments by DOE ARPA-e and the National Science Foundation in in-ground soil sensors to detect changes in soil carbon and in nitrous oxide and methane which can enhance the rigor of models over time. National agreement on criteria for or test methods to measure soil carbon content of soils, including certification of laboratories that do the testing, would help to ensure harmonization of testing approaches across the landscape. Updated, accurate databases such as the SSURGO database maintained by USDA, to reflect updated soils information at a more granular scale across agricultural lands, as well as more accurate reflection of soil carbon content at different depths, by region and production system, would help improve confidence in observed changes and the design of soil carbon testing and monitoring criteria in these markets. Or, continual updates to conservation practice standards to reflect new, improved or regional or production-system specific variations in conservation practices will ensure practice standards remain current over time. Additionally, increased scientific knowledge pertaining to the economics of adoption of various practices and systems approaches that improve ecosystem services outcomes at the field, farm and regional and production scale will benefit farmer adoption of these systems and help to improve the functioning and performance of these markets.

To be useful in markets, all carbon, water quality, and water use calculators, assessment tools, and biogeochemical process models must be fully and transparently documented and have associated peer-reviewed literature assessing their rigor for use as intended. The documentation for these models must be available and updated to allow certifiers to assess their applicability and rigor. If tools or tool-based interfaces are used for market approaches, documentation and peer review of the tools is also required, including specific transparency on models that may be used and how they are used, as well as whether and when any default values or emissions factors are used, when and how. Without this documentation tools cannot be independently assessed for or utilized in markets, regardless of how they were created or by whom.

Additionally, models require data in order to be parametrized, validated, and optimized for use at different scales throughout the nation, and USDA and other federal partners regularly collect data that can be used for these purposes, but which is not always made accessible. Having access to collected data, and ensuring that all data collected in the future be made available in a harmonized and compatible approach can improve market function.

Government agencies can also provide greater clarity around credit or asset ownership, credit or asset stacking, and should facilitate inter-sectoral credit trading. USDA has a long-standing policy position that producers own the environmental assets or credits they generate, regardless of whether cost-share from public conservation programs helped them achieve the credited environmental outcomes[4][5]. Other federal and state agencies should provide the same assurances, as well as clarity and certainty around the ability to stack ecosystem service credits. For an ecosystem service market to succeed in the agriculture sector, it must tackle at least the tripartite challenge of climate adaptation and mitigation, water quality degradation, and water use in farm production[6], since all are related to climate change. Federal agencies must make it clear that the same land can generate carbon, water quality, and water use credits at the same time in order to achieve outcomes-based impacts at scale. Allowing stacked credits will incentivize systems approaches to agricultural sustainability that address all three problems comprehensively and holistically while also reducing transaction costs. These assets are clearly of value to society as well as to farmers and ranchers; better recognizing their value, and reflecting the valuation in markets, will only come when we collectively resist the desire to insist on these outcomes at no cost to anyone.

Fully functioning private ecosystem service markets can also be enhanced via public-private partnerships that leverage resources. ESMC's recent award of a $10.3M grant from the Foundation for Food and Agriculture Research (FFAR), which ESMC is matching with private and philanthropic contributions and in-kind support of members and stakeholders, is an excellent example of such a partnership in support of private markets to benefit farmers and ranchers as well as society.

It is essential that any investments and advances in technologies or policies by government are coupled with strong commitments to voluntary, non-regulatory approaches. In order for voluntary conservation approaches to be adopted at scale, market participants must have faith that the rules of the game will remain constant, and that their investments in building out ecosystem service markets and attendant technologies will not be used for regulation. This could be facilitated with the use of "certainty" assurances linked to the ecosystem services contract period.

Overly restrictive or ill-conceived market rules have hindered the expansion and proliferation of ecosystem service markets for agriculture, as previously discussed. Whether these requirements are imposed voluntarily or through government intervention, the result is the same. The Environmental Protection Agency, for instance, promulgated a 2003 policy to promote water quality trading that offered "non-binding and non-mandatory recommendations and guidance for permitting authorities to consider when establishing and implementing water quality trading programs for NPDES permit compliance.[7]" The policy, though non-binding, came from the NPDES regulating agency and functioned as a de-facto rule on water quality trading.

The 2003 policy recommended that individual nonpoint sources not generate water quality credits until they meet their load allocation identified in the watershed's TMDL prevented participation in the markets. Meeting a load allocation represents a relatively high level of environmental performance, and leaves little performance left to trade. Earlier this year, EPA

---

[4] https://www.govinfo.gov/content/pkg/FR-2019-11-12/pdf/2019-24367.pdf

[5] https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045650.pdf

[6] Biodiversity credits and habitat conservation credits and other ecosystem service attributes will be added to the ESMC asset generation protocols in future.

[7] https://www.regulations.gov/document?D=EPA-HQ-OW-2019-0415-0001

began revisited this policy and (1) released a memorandum that established six principles for encouraging market-based approaches: watershed-scale implementation, adaptive management, banking credits for future use, flexibility in baselines, credit stacking, and financing for nonpoint practices[8]; and (2) requested public comment on policy approaches to implement components of a new, more flexible strategy. After 16 years, EPA recognized that nonpoint pollution reduction strategies, research on BMP performance, monitoring technologies, and mapping and modeling capabilities have all made significant strides that would allow for a more modern, flexible, and hands-off approach to water quality trading[9]. EPA's recent moves to promote water quality trading should be met by similar policies from USDA, DOI, and all other federal agencies interfacing with private landowners.

A market that incentivizes systems approaches to agricultural sustainability is well positioned to help offset the impacts of other industries, too. Agricultural production is unique in its diversity; 2 million farms operate at different sizes and scales in different regions facing different resource pressures[10]. Each has the ability and flexibility to address resource needs beyond the farm gate in its area and should be allowed and encouraged to do so. Regulatory agencies must recognize that agricultural producers can provide relatively cost-effective carbon sequestration, water quality improvements, and water use efficiency gains to regulated entities such as utilities and point source polluters. Their ability to do so will drive demand and spur market participation among farmers and ranchers. To date, government agencies have tended toward regulation as a way to spur environmental action. While compliance requirements have served as regulatory drivers for market participation in some areas, they have also made voluntary credit generation cumbersome. Past markets and current scientific research needs point to government's proper role as an enabler of markets. Federal agencies can advance our understanding of ecosystem dynamics and spur technological innovations and conservation standards that would make free market-based approaches more transparent and reliable. Federal government support as described can help facilitate markets and can obviate the need for expanded regulatory approaches.

[8] https://www.epa.gov/sites/production/files/2019-02/documents/trading-policy-memo-2019.pdf

[9] https://www.regulations.gov/document?D=EPA-HQ-OW-2019-0415-0001

[10] https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf