

Soil Health and Carbon Sequestration in US Croplands: A Policy Analysis

Prepared for: Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) and the Berkeley Food Institute (BFI)

By: Léopold Biardeau, Rebecca Crebbin-Coates, Ritt Keerati, Sara Litke, and Hortencia Rodríguez

Goldman School of Public Policy, University of California Berkeley

May 2016

Table of Contents

Executive Summary	3
1. Introduction: The Benefits of Soil Health	5
2. Carbon Capture as a Co-Benefit of Soil Health Practices	8
2.a. Potential Soil Carbon Sequestration in US Croplands	11
2.b. Cost to Farmers of Implementing Soil Health Practices that Sequester Carbon.....	12
3. NRCS Conservation Program Overview	15
3.a. Environmental Quality Incentives Program (EQIP)	15
3.b. Conservation Technical Assistance Program (CTA).....	16
3.c. Regional Conservation Partnership Program (RCPP)	16
3.d. NRCS External Partnerships	17
4. Challenges with Cropland Soil Health and Carbon Sequestration in California and Iowa	19
4.a. Positive Externality Problem.....	19
4.b. Prohibitive Transaction Costs	20
4.c. Limitations of Soil and Carbon Sequestration Science and Quantification.....	21
4.d. Insufficient Technical Assistance for Farmers	22
4.e. Poor Targeting and Misalignment of Owner/Renter Incentives.....	23
5. Criteria for Analysis	28
5.a. Policy Effectiveness	28
5.b. Cost Effectiveness	28
5.c. Distributional Equity among Program Beneficiaries	28
5.d. Political Feasibility	28
6. Policy Alternatives.....	29
6.a. Maintain Existing NRCS Program Funding Structure and Implementation	30
6.b. Adjust NRCS Efficacy within Existing Programs and Budget	30
6.c. Support Public-Private Partnership to Promote Sustainable Farming	31
6.d. Promote End-Market Demand for Crops Grown Through Sustainable Practices	32
6.e. Create a Carbon Market for Farmers to Participate in the Cap-and-Trade Program.....	33
6.f. Create a Protocol to Allow NRCS to Participate in the Cap-and-Trade Program as a Carbon Broker ..	34
7. Policy Recommendations.....	36
8. Conclusion	37
Appendix 1: California Case Study.....	38
Appendix 2: Iowa Case Study	42
Appendix 3: GHG flux in US Agriculture, Land Use, and Forestry.....	46
Appendix 4: NRCS Cropland Soil Health Practices - Carbon Sequestration Potential	47
Appendix 5: NRCS Program Financial Information	49
Bibliography	52

Executive Summary

Soil health is a key driver of agricultural productivity, environmental resilience, and human security worldwide. In the United States, soils are one of the most valuable commodities, producing \$835 billion in agriculture and related industries annually, and providing 17.3 million jobs at 9.4% of total employment (USDA ERS 2015). Healthy soils also provide numerous environmental co-benefits to society, including carbon sequestration and reduced risk of flooding, erosion, pest and plant disease outbreak. Yet our most productive soils have already been exploited (Amundson et al. 2015), and many conventional agricultural practices such as intensive tilling threaten long-term soil health.

Despite the numerous agronomic and ecological benefits, there is not enough sustained adoption of soil health practices by farmers in the US. This constitutes a type of market failure known as a positive production externality. With rapid urbanization, increasing demand for food, and shifting climate conditions, a critical public policy question is how to improve and maintain cropland soil health.

We examine current policy challenges and opportunities for the Natural Resources Conservation Service (NRCS) of the US Department of Agriculture (USDA) in increasing the adoption of soil health practices. **We are particularly interested in how the co-benefit of capturing carbon in soils can help motivate the adoption of soil health practices.** Our research methodology includes seventeen stakeholder interviews with farmers, NRCS staff and partners, and private-sector firms; a literature review; and data analysis. Case studies of Iowa and California are presented with state-specific challenges and opportunities to represent the diversity of agriculture, climate, and political landscape in the US.

We find multiple challenges – both systemic and operational – to the adoption of soil health practices. These include prohibitive transaction costs for farmers; limitations of soil and carbon sequestration science; insufficient technical assistance for farmers; a lack of NRCS staff capacity and underutilization of partnerships; and poor targeting and misalignment of owner/renter incentives.

Our goal is to provide a set of recommendations that NRCS can pursue to overcome both systemic and operational challenges facing farmers and NRCS in increasing the adoption of soil health practices. Our policy options are summarized below:

	Policy Effectiveness	Cost Effectiveness	Equity	Political Feasibility	Overall
6.a. Status Quo	Low	Low	Low	High	Low
6.b. Adjust Program Implementation	Medium	High	High	Medium	High
6.c. Increase Public-Private Partnerships	Medium	Medium	Medium	Medium	Medium
6.d. Promote End-market Demand	Medium	High	High	Medium	High
6.e. Cap-and-Trade for Farmers	Low	Low	Low	Low	Low
6.f. NRCS as Carbon Bank/Broker	Medium	Medium	High	Low	Medium

We advise NRCS pursue a number of opportunities in the near term to modify existing programs and spending to address operational challenges. **Our primary recommendation is that NRCS pursue Alternative 6.b. Adjust Program Implementation, specifically by:**

- **Increasing technical assistance and offsetting/minimizing transaction costs for farmers,**
- **Increasing partnerships through the Regional Conservation Partnership Program (RCPP), and**
- **Better targeting of outreach to absentee and female landowners, given recent and expected shifts in land ownership and historic gendered challenges.**

These actions can increase uptake of soil health and carbon sequestration practices without requiring significant resources beyond NRCS' existing budget.

In the long run, NRCS may also explore the options of promoting end-market demand for crops grown through sustainable practices (6.d), and enhancing mechanisms to promote public-private partnerships beyond RCPP (6.c). Both of these represent cost efficient and scalable alternatives for NRCS, as they leverage participation by the private sector and create long-term incentives for farmers to adopt soil health practices.

In contrast, other alternatives that specifically leverage the benefits of carbon sequestration involve significant administrative and legislative complexities and provide minimal incentives for farmers to adopt soil health practices (Options 6.e Creating Cap-and-Trade Market for Farmers, and 6.f. Creating a Protocol to Allow NRCS to serve as a carbon bank/broker). For instance, creating a cap-and-trade market for farmers will increase farmers' income by less than three percent, while the implementation entails significant transaction costs to measure, monitor, and verify the carbon offsets that farmers generate, particularly given the heterogeneous nature of farms in the United States.

1. Introduction: The Benefits of Soil Health

Soil health has become a policy priority due to its ability to simultaneously address some of the most pressing issues of our time, such as food insecurity and rising temperatures. The concept of soil health encompasses the ability of soils to sustain life (plants, microbes, insects), withstand environmental stresses (flood, drought, erosion), and function as a key part of the ecosystem (through biogeochemical cycles and processes). While soil health is measured in a variety of ways, it can be categorized generally in terms of 1) physical, 2) chemical, and 3) biological health. Agricultural conservation programs can improve the quality of soils through land management practices that enhance and support these three health categories.

When soil health practices are applied to croplands, ecological, environmental and financial benefits are accrued, enabling farmers to use inputs more efficiently and sustainably. Healthy soils benefit farmers financially by increasing yields, decreasing irrigation needs, and minimizing fertilizer use. Healthy soils are also a way to mitigate climate-related risks such as erosion, floods, and pest and disease outbreak. These co-benefits accrue not only to farmers, but also to society at large. One ancillary benefit of healthy soils that has been underexplored in US policy (and which this report analyzes) is the ability to capture atmospheric carbon, which presents a unique opportunity to offset net greenhouse gas emissions (GHGs) (Paustian et al. 2016). The benefits of soil health can loosely be categorized into ecological and agronomic benefits; and private *versus* societal benefits:

Table 1: Soil Health Practice Benefits

	<i>Ecological/Environmental</i>	<i>Agronomic</i>
<i>Private</i>	<ul style="list-style-type: none">● <i>Erosion control</i>● <i>Local biodiversity</i>● <i>Flood control</i>● <i>Improved soil water retention</i>	<ul style="list-style-type: none">● <i>Increased yields</i>● <i>Reduced expenditures on fertilizer and weed suppression</i>● <i>Reduced need for irrigation</i>● <i>Pest control</i>● <i>Plant disease control</i>● <i>Avoided litigation risk</i>
<i>Societal</i>	<ul style="list-style-type: none">● <i>Erosion control</i>● <i>Cleaner water (fewer nitrates, etc)</i>● <i>Flood control</i>● <i>Soil carbon sequestration</i>	<ul style="list-style-type: none">● <i>Lower risk for pest outbreaks</i>● <i>Lower risk for plant disease outbreaks</i>● <i>Fewer unwanted nitrates from runoff</i>

Source: adapted from Stevens (2015)

Despite these numerous benefits, there is not enough sustained adoption of soil health practices by farmers in the US. Such a low adoption rate arises as a result of the systemic and operational challenges facing both farmers and NRCS— farmers either do not internalize all the benefits of soil health practices or cannot overcome the challenges in adopting the practices, and NRCS has insufficient resources to help farmers overcome these challenges.

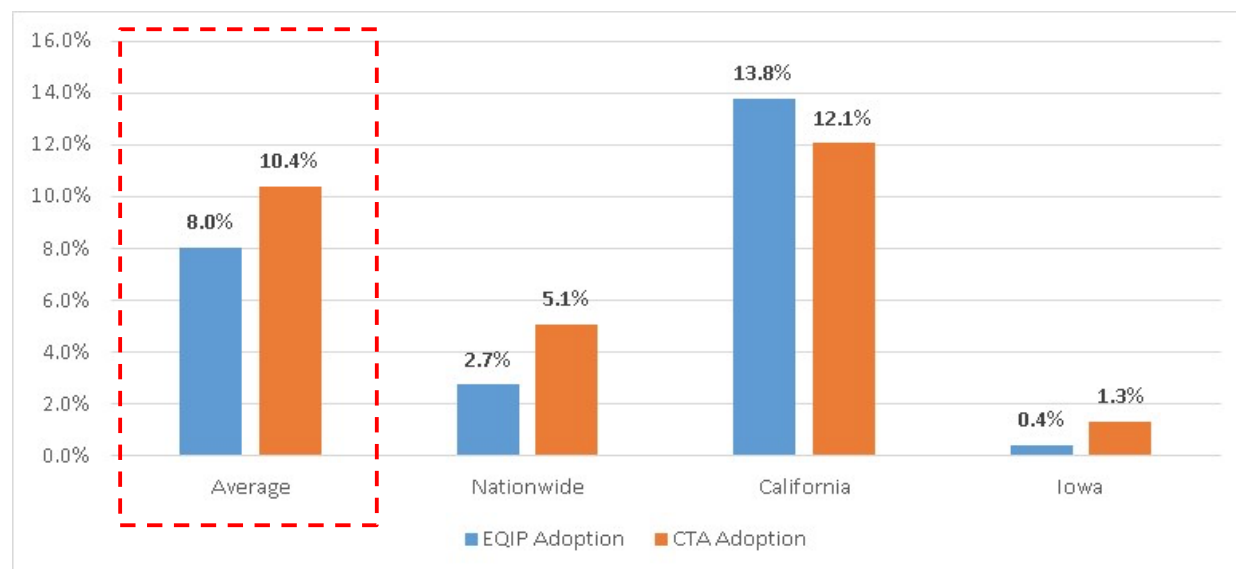
This report seeks to analyze these challenges and provide recommendations for NRCS to increase the adoption of soil health practices in the United States, specifically the practices that also capture atmospheric carbon. In particular, this report analyzes three federal conservation programs that promote these practices, which are administered by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS):

- Environmental Quality Incentives Program (EQIP)
- Conservation Technical Assistance Program (CTA)
- Regional Conservation Partnership Program (RCPP)

Only 2-5% of croplands in the United States receive funds to implement soil health practices under two of NRCS' largest conservation programs – EQIP and CTA.¹ Although these figures under-estimate the total rates of adoption of soil health practices by farmers (they do not take into account farmers who receive funding from other programs not included in this analysis, or none at all)², they provide an idea of the significant potential for expansion of NRCS programs to promote soil health.

This report also considers specific issues facing two key states – California and Iowa – as representative of the diversity of US agriculture, climate, and political landscape. The rate of soil health practice adoption varies across the US, with Iowa receiving fewer funds than California, partly because of eligibility, and partly because of farmers' attitude toward soil health practices.

Figure 1: Acreage Proportion of Farms Receiving Funding under EQIP and CTA from NRCS



Source: USDA

¹ Note that the Regional Conservation Partnership Program (RCPP) is not included in this estimation due to (1) the relatively nascent stage of the program and limited data availability (the program began in 2014); and (2) the fundamentally different nature of the program -- rather than providing a direct subsidy or technical assistance to farm operators, RCPP delivers conservation assistance to producers and landowners through partnership agreements and through program contracts or easement agreements.

² This bias is most relevant for farms generating more than \$900,000 in revenue, which are not eligible to receive NRCS subsidies.

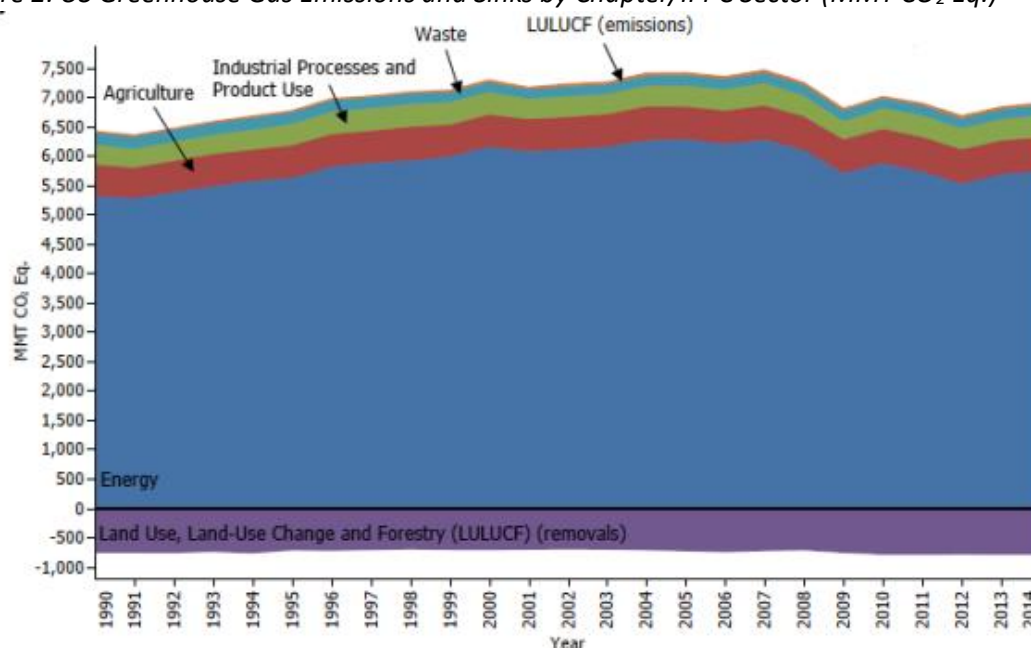
Given that soil health is a priority for farmers, the NRCS and USDA at large, we explore how to increase adoption of soil health practices on croplands. We also evaluate how the co-benefit of soil carbon sequestration fits into this larger framework. Under what circumstance is soil carbon sequestration both practical and a compelling incentive for farmers and/or the private industry? What role can the NRCS play to increase adoption?

2. Carbon Capture as a Co-Benefit of Soil Health Practices

Practices that build soil health are also some of the most cost-effective greenhouse gas (GHG)³ mitigation options in agriculture (IPPC AR5 2014). These include cropland management, grazing land management and restoration of organic soils, and the costs and benefits vary by ecosystem. This report focuses on the potential for soil carbon sequestration via cropland management, although further research on potential in other ecosystems (such as rangelands) is warranted.

Agriculture is both a carbon source and a sink in the US: in 2014, 787 million metric tons of CO₂ Eq. were sequestered through Land Use, Land Use Change, and Forestry (LULUCF), including agriculture (shown in purple in Figure 2 below); while agricultural emissions in 2014 leached 625 million metric tons of CO₂ Eq. back into the atmosphere (shown in red below).

Figure 2: US Greenhouse Gas Emissions and Sinks by Chapter/IPPC Sector (MMT CO₂ Eq.)



Source: EPA Greenhouse Gas Inventory, 2016⁴

Of total global emissions, 10%–14% are a result of agricultural production (see dark red on the above graph) (Paustian et al. 2016). The world's soils have already leached 50-70% of their original carbon stock from deforestation, the conversion of natural habitats to croplands, livestock management, and industrial farming (Schwartz 2016). In 2014, crop cultivation in the US leached 330 million metric tons of carbon equivalent-eq (CO₂ Eq.) into the atmosphere, primarily from methane and nitrous oxide (EPA 2016). These emissions are largely due to conventional agricultural practices such as heavy fertilization,

³ Primarily carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O)

⁴ For a more detailed breakdown of US Greenhouse Gas emissions and sequestration within the LULUCF (and agricultural) sector, see Appendix 2: GHG flux in US Agriculture, Land Use, and Forestry.

monocropping, intensive tilling, and livestock manure management (Kane 2015, Schwartz 2016). These practices are also unsustainable for agronomic reasons, as they degrade soils — increasing the risk of pest and plant disease, flood, and erosion.

However, a healthy soils effort has the capacity to reverse these trends. According to the Intergovernmental Panel on Climate Change, carbon sequestration will be a critical strategy to return atmospheric carbon to safe levels. Net agriculture, forestry and other land use is one of the only ways to do this (IPPC AR5 2014).

To keep the mean global temperature rise at less than 2°C, GHG levels must be stabilized at less than 450 parts per million CO₂ Eq. (Ciais et al. 2013). Even substantial reductions in anthropogenic carbon emissions will not be enough to meet this goal. Increasing soil organic matter and soil organic carbon can successfully sequester atmospheric carbon. In the carbon cycle, CO₂ is emitted into the atmosphere via both natural and anthropogenic sources, and then absorbed into oceans and living biomass ('sinks' like soils, plants, and forests). Soil carbon pools hold an estimated 2500 gigatons (Gt) -- the largest terrestrial carbon pool (Kane 2015). These pools can act as carbon 'sinks,' accumulating more carbon than they emit. In general, there are four methods of sequestering carbon in cropland soils (Kane, 2015):

- Enhancing the aggregate stability of soils (i.e. residue and tillage management, borders, barriers)
- Increasing plant and animal inputs to soils (i.e. manure, biochar, compost application)
- Improving soil microbial diversity/abundance (i.e. manure/compost application, reduced tillage)
- Providing continuous living plant cover on soils (i.e. cover cropping, borders)

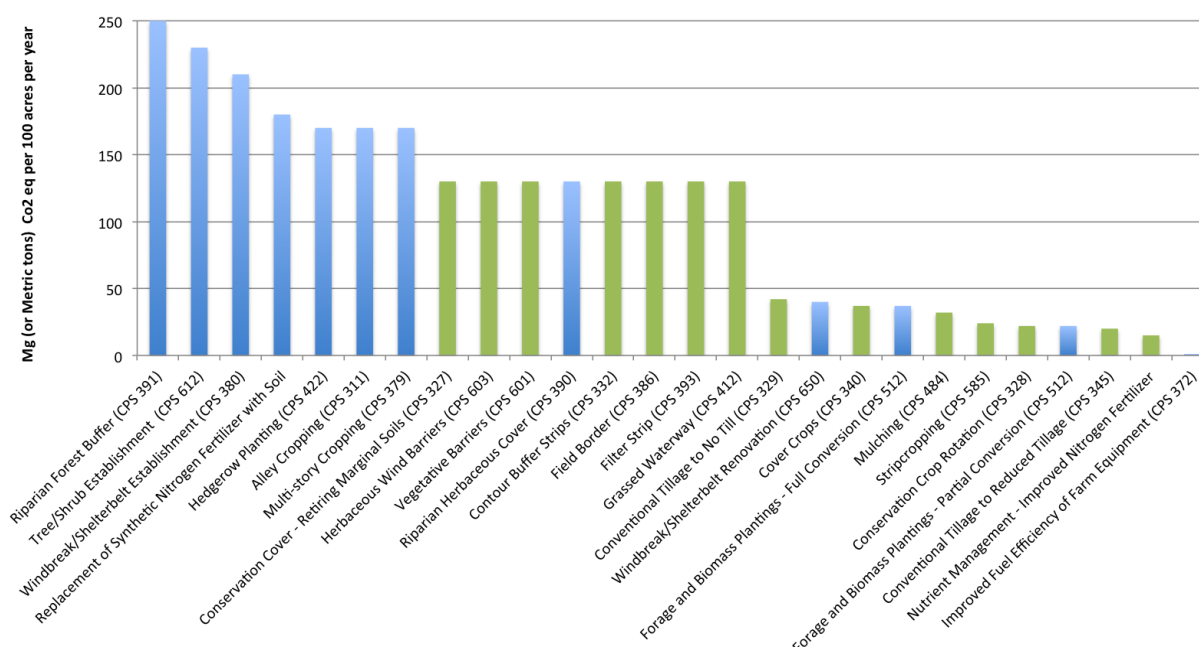
The NRCS currently classifies fifteen soil health conservation practices as "Conservation Practice Standards" (CPS) that feature the co-benefit of building soil carbon. These practices represent a segment of NRCS' "Climate Change Mitigation Building Blocks," and include conservation tillage, cover cropping, mulching, grassed waterways, and more.

Cropland management practices vary in their effectiveness to sequester carbon and/or reduce emissions, and vary additionally across climates, soil types, and geographies.

For example, conservation cover (a practice where farmers establish and maintain permanent vegetative cover on croplands) can sequester almost 0.3 metric tons CO₂ Eq. per acre in dry climates. However, in the same climate the method of reduced tillage (wherein farmers limiting the soil-disturbing activities used to grow and harvest) will sequester less than 0.05 metric tons CO₂ Eq. per acre.

In addition to practices classified by the NRCS as "Soil Health Building Blocks" (highlighted in green in the graph below), a variety of additional practices (in blue) related to nutrient management, soil cover, and agroforestry have significant potential to capture carbon and/or reduce emissions.

Figure 3: Soil Carbon Sequestration / Emissions Reduction Potential by Management Practice



Source: NRCS COMET-Planner

Agroforestry (the production of livestock or food crops on land that also grows trees) have the highest potential of carbon sequestration options on farms, but are feasible for fewer farmers. Carbon sequestration from agroforestry and afforestation practices is in the range of 1.7-2.5 metric tons CO₂ Eq. captured per acre annually. This is largely due to the high potential for carbon to be stored long-term in forests in belowground biomass and soils that remain undisturbed (Paustian et al, 2016). Many of these practices, however, involve the conversion of conventionally tilled and fertilized cropland to woody systems, such as alley cropping (CPS 311: plantings consisting of trees or shrubs in rows or corridors with alleys of agronomic crops or forage between). As such, these practices may not be feasible for cropland farmers in certain geographies or climates, or who face high opportunity costs of taking their land out of cash crop production.

A practice with high potential for reduced emissions on croplands is Nutrient Management - Improved Nitrogen Fertilizer Management (CPS 590). This includes “managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments”. Nitrous oxide emissions from nitrogen fertilizer applications are one of the main sources of greenhouse gas emissions in the U.S. Effectively managing these nutrient applications can lead to reduced emissions of roughly 1.7 metric tons CO₂ Eq. per acre.⁵

For a full description of each practice and the annual potential for carbon capture, see *Appendix 3: NRCS Cropland Soil Health Practices - Carbon Sequestration Potential*.

⁵ Note that Improved Nitrogen Fertilizer Management has much greater potential to reduce GHG emissions in Iowa (at approx. 1.8 metric ton CO₂ Eq. per acre) than in California (at approx. 1 metric ton CO₂ Eq. per acre) .

2.a. Potential Soil Carbon Sequestration in US Croplands

This analysis focuses on soil health and carbon sequestration practices that can be implemented by cropland farmers in the US. Further research is warranted on the potential in other land systems such as forests, pasture, and rangelands, and in the conversion of land out of agriculture. Similarly, further research is needed on nitrous oxide (N₂O) and methane (CH₄) reductions (through cattle production and rice paddy systems, for example).

According to the 2016 Environmental Protection Agency (EPA) “Inventory of U.S. Greenhouse Gas Emissions and Sinks”, forests, grasslands, croplands, wetlands, and even urban landscapes in the US already remove 787 million metric tons of CO₂ Eq. from the atmosphere each year through soils and aboveground biomass C stocks, offsetting approximately 11.5 percent of annual emissions (EPA 2016).

Currently, cropland soils represent a relatively small share of this total sink, at an annual removal of only 8.4 million metric tons CO₂ Eq. per year (EPA 2016).⁶ When taking into account the agricultural carbon emissions from liming and fertilization, croplands currently sequester approximately as much carbon as is emitted from these soils (making croplands carbon neutral at present).

Current carbon sequestration in US cropland soils is only 8.4 million metric tons CO₂ Eq. per year, compared to an annual potential of 100 million.

However, cropland soils have the potential to sequester up to 100 million MT CO₂ Eq. per year (McGlynn et al. 2016, Murray et al. 2005). In total, US soils (including cropland, grazing and forest land, land conversion, and other land use) have the potential to sequester an estimated 288 million MT C per year (Chambers, et al 2016 [in press]). With total annual emissions in the US of 6.87 billion metric tons CO₂ Eq. in 2014 (EPA 2016), this means that net soil carbon sequestration has the potential to offset 4.18% of *total* emissions annually.

However, when focusing on carbon flux in the agricultural sector alone, there is much greater potential to become carbon negative. For example, researchers have projected that as much as 20% of agricultural emissions could technically be offset using just one cropland conservation practice -- a full conversion to no-till methods (Del Grosso et al. 2005). **As such, it is clear that soil carbon sequestration can play an important role in climate change mitigation within the agricultural sector, but must be approached in the context of a much broader climate mitigation strategy for the US at large.**

Soil health practices have become increasingly politically, technically, and economically feasible and attractive as a method to reduce and offset GHG emissions in the agricultural sector. Many private landholders have demonstrated this potential.⁷

⁶ What this report classifies as cropland soil carbon sequestration is termed as net sequestration from ‘cropland remaining cropland’ in the EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (2016).

⁷ For examples of stakeholders who have successfully implemented soil health practices that sequester carbon, see Ruth Rabinowitz in section 4.e.ii., and Farmland LP in section 4.e.iii.

Soil carbon sequestration is more politically feasible now than ever. President Obama's Climate Action Plan requires efforts in the land sector to help meet targets in 2020 U.S. climate target and beyond. In 2015 several environmental organizations identified the need to develop a long-term, strategic policy roadmap for sustaining the U.S. carbon sink, launching the Land Carbon Policy Roadmap (LCPR) initiative. In April 2015, the United States Department of Agriculture (USDA) announced "10 Building Blocks for Climate Smart Agriculture & Forestry," with the goal of increasing land carbon and reducing emissions by 120 million metric tons of CO₂ Eq. per year by 2025, through USDA programs, partnerships, and authorities (USDA 2015f). The first building block is "Soil Health: improving soil resilience and increasing productivity."

Furthermore, politically, even if a landholder or farm operator is uncertain about anthropogenic climate change, the same practices that capture carbon are beneficial agronomically in terms of increased soil health, through benefits as outlined in Figure 1.

2.b. Cost to Farmers of Implementing Soil Health Practices that Sequester Carbon

From the federal government's perspective, the subsidy on soil health practices represents a cost competitive way to capture carbon versus other energy subsidies that aim to reduce carbon emission. By providing subsidy on soil health practices, farmers not only enjoy the benefits of improved soil health, but they also help capture carbon. Looking purely at the benefit of carbon sequestration from these subsidies, we estimate that to capture one ton of carbon through soil health practices will cost NRCS between \$32 per ton of CO₂ Eq. (for crop rotation) and \$442 per ton of CO₂ Eq. (for mulching), with an average cost of \$183 per ton of CO₂ Eq. These figures represent the approximate amount that NRCS would spend on soil health practice subsidies that would result in one ton of CO₂ Eq. being captured.⁸ This compares to the average expenditure of \$222 per ton of CO₂ Eq. on other energy subsidies that also reduce CO₂ emissions, ranging from \$84 per ton of CO₂ Eq. for the credit for energy efficient appliances to \$732 per ton of CO₂ equivalent for the production and investment tax credit and grants for renewable energy (Allaire and Brown, 2012).

However, from the farmer's perspective, carbon value alone will not be sufficient to motivate increased adoption of soil health practices; rather, the incentive for these practices is derived primarily from other agronomic and environmental benefits, as outlined in Section 2 of this report. Rather than focusing on the benefit of carbon sequestration, farmers are more interested in achieving increased revenue from improved yield, reduced input costs for pesticide and fertilizer management, and potentially higher crop prices sold as organic crops.

⁸ We calculate these figures by dividing NRCS subsidy payments for these practices per acre under EQIP (which approximately reflect the cost to implement these practices) by the amount of carbon being captured per acre in one year by these practices per COMET-Planner. Hence, these figures represent the costs based on the carbon sequestration benefits captured in the first year only. Note that some practices provide multi-year benefits in terms of carbon sequestration. These figures are in-line with the breakeven cost estimates per ICF International (2013).

Figure 4: Cost of soil health / carbon sequestration practices (per ton of CO₂ Eq.)

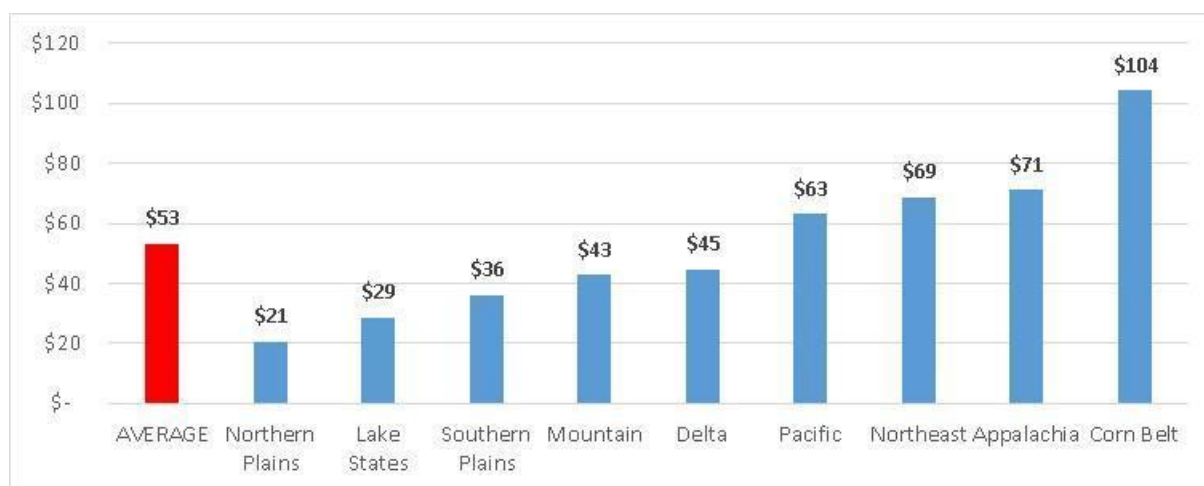


Source: Comet-Planner (downloaded 2016)

Geographically, regions offer different potential for implementation of soil carbon sequestration, given varying costs and benefits.

For instance, the average breakeven price to incentivize farmers to convert from conventional tillage to no-till varies from \$21 in Northern Plains to \$104 in the Corn Belt (ICF International, 2013). This suggests that a dollar spent in Northern Plains for this practice will yield the highest benefit in terms of CO₂ Eq. captured. Within the two states this report is studying, Iowa faces the highest breakeven cost for tilling conversion (\$104 per ton CO₂ Eq.) and California faces the lowest breakeven cost (\$63 per ton CO₂ Eq.).

Figure 5: Break-Even Prices for Changes from Conventional Tillage to No-Till (per ton of CO₂ Eq.)



Source: ICF International (2013)

Soil carbon sequestration in croplands may be cost-effective from the perspective of NRCS or the US government at large, relative to other options for carbon sequestration or emissions reduction. However, to enable farmers to monetize the carbon sequestration benefit requires significant efforts by NRCS in terms of monitoring the practices and validating the carbon sequestration benefits, both of which require substantial additional costs. Additionally, given the high cost from the perspective of the farmer of implementing these practices, it is evident that carbon pricing would play a relatively minor role in motivating participation in soil health programs.

As such, rather than promoting carbon pricing as a motivator for farmers to convert to climate-smart land management practices, NRCS should focus on communicating the numerous agronomic and ecological benefits of healthy soils.

With this in mind, we explore in the remainder of this report how NRCS could adapt to increase adoption of soil-health practices (while taking carbon sequestration potential into account) via: 1) providing greater motivation, incentives, and support to farmers; and 2) engaging the private sector.

3. NRCS Conservation Program Overview

NRCS has focused on enhancing soil health and increasing agricultural productivity since its inception. Founded in 1933 as the Soil Erosion Service, it was meant to respond to the agricultural crisis of the decade: The Dust Bowl. To this day the agency continues to provide comprehensive assistance to farmers through a wide variety of voluntary programs that promote management practices, of which carbon sequestration is one of many co-benefits, and the use of technology that ensure the long-term welfare of farming communities and the nation as a whole.

NRCS operates locally, through field offices in nearly every county in the United States. Through strong partnerships with other local agencies and organizations, and on-site evaluation of the land's resources, field staff develops conservation plans that help landowners achieve their conservation goals. NRCS technical expertise and financial assistance help farmers effectively implement these conservation plans.

For the purposes of this memo, we will be focusing on three programs that are of priority to current NRCS management: the Environmental Quality Incentives Program, the Conservation Technical Assistance Program, and the Regional Conservation Partnership Program. It should be noted, however, that there are additional conservation programs, such as the Conservation Stewardship Program (CSP) and Conservation Reserve Program (CRP), which have higher take-up rates in Iowa and California. These programs fall outside of the scope of this assessment, but should be closely examined in future research.

For detailed financial information on these programs over the past five years across California and Iowa, see Appendix 4: NRCS Program Financial Information.

3.a. Environmental Quality Incentives Program (EQIP)

The Environmental Quality Incentives Program (EQIP) is a voluntary program that provides financial and technical assistance to agricultural producers to plan and implement structural and management practices that improve soil, water, plant, animal, air and related natural resources on agricultural land and non-industrial private forestland. Eligible applicants must:

- Be an agricultural producer.⁹
- Control or own eligible land.¹⁰
- Comply with adjusted gross income (AGI) for less than \$900,000.¹¹
- Be in compliance with the highly erodible land and wetland conservation requirements.
- Develop an NRCS EQIP plan of operations that addresses at least one natural resource concern.

Producers apply by visiting their local NRCS field office. Applications are processed on a continuous basis and are ranked based on local resource concerns and criteria determined through a local work group led by the NRCS district conservationist. If selected, producers select the Technical Service Providers (TSPs)

⁹ Defined as a person, legal entity, or joint operation who has an interest in the agricultural operation, or who is engaged in agricultural production or forestry management.

¹⁰ Examples of eligible land are cropland, rangeland, pastureland, non-industrial private forestland and other farm or ranch lands.

¹¹ Federally recognized Native American Indian Tribes or Alaska Native corporations are exempt from the AGI payment limitations.

they would like to work with to jointly develop a Conservation Activity Plan (CAP). Upon completed practices or activities, the producers receive financial assistance payments through EQIP. Payment rates are set each fiscal year and are attached to the EQIP contract when it is approved. EQIP payments are set relative to income foregone as well as costs incurred associated with planning, design, materials equipment, installation, labor, management, maintenance, and training. Under the 2014 Farm Bill, individual EQIP payments are capped at \$450,000 in aggregate payments over the life of the five-year farm bill, regardless of the number of contracts a producer may have.

3.b. Conservation Technical Assistance Program (CTA)

The Conservation Technical Assistance Program (CTA) is a voluntary program that provides land users with proven science-based conservation technology and the delivery system needed to achieve the benefits of a healthy and productive landscape. Technical assistance is provided by NRCS, employees of other entities or agencies under the technical supervision of NRCS, to clients to address opportunities, concerns, and problems related to the use of natural resources. Most technical assistance provided by NRCS leads to the voluntary development of a conservation plan - a resource assessment of the land that allows the client to determine the opportunities for using the resources under their care and how they may achieve their goals.

The program goals are varied:

- Assist individuals or groups of decision makers, communities, conservation districts, units of State and local government, tribes, and others to voluntarily conserve, maintain, and improve natural resources; to comply with Federal, State, tribal, and local environmental regulations and related requirements; and to prepare them to become eligible to participate in other Federal, State, and local conservation programs.
- Assist agricultural producers to comply with the Highly Erodible Land (HEL) and Wetland (Swampbuster) Conservation Compliance Provisions of the 1985 Food Security Act.
- Provide soils information and interpretation to individuals or groups of decision makers, communities, States, and others to aid sound decision-making in the wise use and management of soil resources.
- Collect, analyze, interpret, display, and disseminate information about the status, condition, and trend of soil, water, and related natural resources so that people can make informed decisions for natural resource use and management.
- Assess the effects of conservation practices and systems on the condition of natural resources.

3.c. Regional Conservation Partnership Program (RCPP)

The Regional Conservation Partnership Program (RCPP) promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners through partnership agreements and through program contracts or easement agreements. It gives local organizations opportunities to design and deliver solutions that benefit natural resources where they live and work.

As a result of changes to the 2014 Farm Bill, RCPP combines the authorities of four former conservation programs and program assistance is delivered through their channels – the Agricultural Water Enhancement Program, the Chesapeake Bay Watershed Program, the Cooperative Conservation Partnership Initiative and the Great Lakes Basin Program. Assistance is delivered in accordance with the

rules of EQIP, Conservation Stewardship Program (CSP), Agricultural Conservation Easement Program (ACEP) and Healthy Forests Reserve Program (HFRP); and in certain areas the Watershed Operations and Flood Prevention Program.

Eligible partners include:

- Agricultural or silvicultural producer associations
- Farmer cooperatives or other groups of producers
- State or local governments
- American Indian tribes
- Municipal water treatment entities
- Water and irrigation districts
- Conservation-driven nongovernmental organizations
- Institutions of higher education

NRCS publicizes RCPP partnership opportunities through an Announcement of Program Funding (APF) to which potential partners submit proposals. Producers apply for RCPP assistance in two ways: 1) At the producer's request, a partner submits the application for a selected project area and 2) by visiting their local USDA Service Center in a selected project area. NRCS reviews partnership proposals and selects projects according to the priorities identified in the announcement. Upon selection of a partnership proposal, NRCS and the partner enter into a partnership agreement through which they coordinate to provide assistance to producers in the project area. Partnership agreements may be for a period of up to five years.

Funding for RCPP is allocated to projects in three different categories:

- **Critical Conservation Areas:** For projects in eight geographic areas chosen by the Secretary of Agriculture. These receive 35 percent of funding.
- **National:** For nationwide and multistate projects. These receive 40 percent of funding.
- **State:** For projects in a single state. These receive 25 percent of funding.

3.d. NRCS External Partnerships

In the three states we examined, NRCS follows a framework of cooperative conservation to achieve its objectives. It partners with conservation districts, state and federal agencies, agricultural and environmental groups, professional societies and universities. In the case of California and Iowa, some NRCS county offices are co-located with some of their partners' offices, which allow them to share information and communicate in a timely way. Additionally, partners engage in cost-sharing and often provide more targeted outreach to farmers that is beyond NRCS capacity.

In California, Regional Conservation District (RCD) partners are actively involved in setting state conservation priorities, which guide the allocation of funding towards specific practices. They engage in relationship-building with farmers and farmer associations, which provide some NRCS county offices with unique access to potential adopters of soil health practices that they with otherwise not have due to staffing constraints. Groups such as Blue Point Conservation Services and the Marin Carbon Project are able to provide continuous, high-touch outreach and mentoring to farmers, while specialized NRCS staff, such as biologists and agronomists, offer technical assistance and monitor contracts.

In Iowa, groups such as Practical Farmers of Iowa (PFI) participate in state NRCS committees, Farm Bureau meetings, and working groups to establish conservation priorities and identify needs. They manage a network of farmers through which they effectively disseminate soil health practices implementation strategies. PFI continuously conducts outreach to farmers and encourages them to experiment with conservation practices, such as cover cropping and crop rotation, to build a body of evidence of farmers' perspectives that is accessible to other farmers, helps widen PFI's network and ultimately increases the adoption of these practices.

4. Challenges with Cropland Soil Health and Carbon Sequestration in California and Iowa

When looking at reasons for low adoption of soil health practices, the challenges of NRCS program implementation and management fall into several categories. This list is not intended to be comprehensive, but to identify the key issues associated with increasing soil health practices through NRCS' programs in CA and IA.

SYSTEMIC CHALLENGES

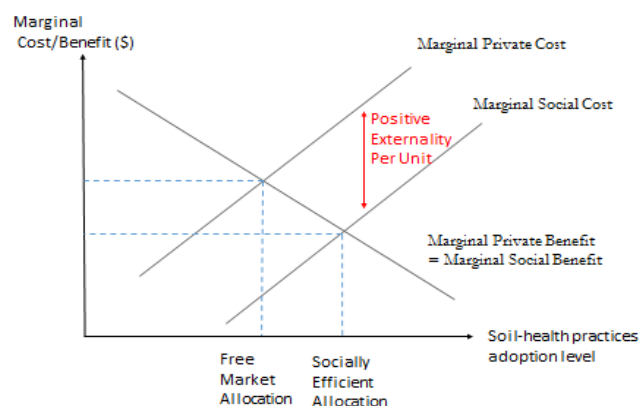
4.a. Positive Externality Problem

An economic externality is the uncompensated impact of one market agent's actions on the well-being of a third-party. Third-parties include any individual, organization, property owner, or resource that is indirectly affected.

In the case of carbon sequestration and its impact on agricultural soil health, this report makes the case for the existence of positive production externalities where the marginal cost to a farmer of capturing an additional ton of carbon is greater than the marginal cost to society as it would benefit as a whole, from several practices presented in the Figure 1 of Section 3. Individual farmers focus on the private costs and benefits associated with soil health management when considering implementing or transitioning practices. This often represents a significant upfront cost for farmers, while the private benefits often only accrue in the long run.

Furthermore, while soil health practices provide numerous benefits to society (such as increased biodiversity, reduced flood/erosion risk, etc.), the value of these benefits are not fully internalized by any single farmer. **This positive production externality constitutes a type of market failure, a situation where the market fails to allocate resources at the optimal level.** In the presence of this type of externality, individual farmers will adopt soil-health practices at a level that is below the socially optimal level because their private incentives are lacking.

Figure 6: Gap between socially-efficient adoption of soil-health practices and free market adoption level in the presence of a positive production externality



Positive externalities can be internalized via one of the following two methods:

1. Pigouvian subsidies

Pigouvian subsidies are named after British economist Arthur Pigou who revolutionized the way economists thought about market externalities. In substance, a Pigouvian subsidy compensates a private agent for public benefits provided by some behavior the agent engages in.

In the case of carbon capture & soil health, a Pigouvian subsidy would entail the government paying farmers to engage in carbon capture management practices. Theoretically, the size of the subsidy should not exceed the benefits not captured by the private user. Unfortunately, this report shows in Section 5.c. that the benefits are currently impossible to quantify. Setting an inappropriate subsidy could have the following consequences:

- On the one hand, a Pigouvian subsidy that is too large will cost society more money than is needed to achieve the desired level of carbon sequestration. In other words, public funds can crowd-out privately optimal behavior.
- On the other hand, a Pigouvian subsidy that is too small would fail to incentivize farmers to capture the socially desirable amount of carbon in agricultural soils.

2. Coase theorem inspired bargaining

The Coase theorem states that if trade in an externality is possible and there are sufficiently low transaction costs, bargaining will lead to an efficient outcome regardless of the initial allocation of property. However, there are a number of settings in which the theorem will not solve externality problems. These settings include the presence of high transaction costs, difficulties in defining and allocating rights, imperfect information, search costs. Section 5 highlights some of the difficulties we have identified when it comes to helping farmers internalize the externalities linked to carbon sequestration in agricultural soils.

4.b. Prohibitive Transaction Costs

One of the features of agriculture in the US that contributes to multiple challenges has to do with producer heterogeneity. Indeed, the U.S. agricultural landscape is characterized by a great deal of diversity in soil type, weather, climate, and crop production across farms. This great diversity of US agriculture makes it challenging for any particular farmer to access information about the costs and benefits of soil health or carbon capture practices.

The real and perceived transaction costs of soil health (and soil carbon sequestration) practices are often a deterrent to many farmers who might otherwise be interested in implementation.

Farmers may not know how to overcome the various transaction costs and risks associated with implementing these practices. Such transaction costs include:

1. Search costs: obtaining information on expected benefits is costly either financially or behaviorally. When farmers are interested in developing a conservation management plan, or learning about how they can improve soil health or capture carbon, it is often costly to gather this information.

2. Switch and opportunity costs: the opportunity costs associated with cash crop interference, as well as the switch costs associated with the initial investment in equipment or infrastructure, and ongoing investment in seed, labor, and management often outweigh the perceived benefits of soil health practices.

However, climate change and technological development are both contributing to a shift in farmer perceptions of switch and opportunity costs of soil health practices.

For an example, see Appendix 4: Iowa Case Study - Shifting transaction costs for farmers due to technological innovation and climate change.

4.c. Limitations of soil and carbon sequestration science and quantification

“Implementing effective soil-based GHG mitigation strategies on a large scale will require the capacity to measure and monitor GHG reductions with acceptable accuracy, quantifiable uncertainty and at relatively low cost.” Paustian et al (2016)

While NRCS programs promote a range of soil health practices –many of which also have the benefit of carbon sequestration– the benefits of these practices are by essence difficult to quantify. While the benefits of soil health can be seen by the farmer after a practice has been adopted, it is difficult to estimate in exact benefits in advance.

The benefits of various soil health practices vary widely by soil type, crop, and climate. This creates technical challenges for choosing which practices to implement on any given farm. This is particularly a concern in California, which has greater variability in soil types than Iowa. For example, if a leafy greens farmer in California is interested in converting to conservation tillage, it is difficult to approximate exactly how this will impact yields, water retention and soil stability, as well as the precise amount of carbon that will be captured. As a result, farmers are not always able to appreciate the benefits of soil health practices since they are faced with uncertainties around the actual amount of benefits they will receive from implementing these practices.

Additionally, the science on quantification of carbon capture benefits is currently limited, and it is often difficult for farmers to meet State standards on carbon sequestration for cap-and-trade or other programs. In an effort to improve access to information for farmers interested in soil carbon sequestration, NRCS has developed a series of quantification tools known as the COMET-Planner and COMET-Farm. These tools allow farmers to estimate the carbon sequestration potential on their land using various soil health practices, and to develop land management plans accordingly.

OPERATIONAL CHALLENGES

4.d. Insufficient technical assistance for farmers

4.d.i. Lack of staff capacity within NRCS

NRCS simply does not have enough “boots on the ground” to deeply engage farmers to ensure long-term adoption of soil health practices. Farmers face both financial and technical challenges in implementing soil health practices, and support from NRCS staff is critical to overcoming these barriers.

Through numerous interviews with NRCS staff, we heard that NRCS budget for conservation programs has substantially increased over the past decade, while staffing capacity has shrunk.¹²

Given staffing constraints, NRCS currently cannot adequately assist all farmers who would like to participate in programs to increase soil health. NRCS has limited capacity to provide adequate technical assistance to all interested farmers, who face a multitude of choices in terms of which practice(s) to pursue for their individual farm and a lack of information on the specific benefits of these practices.

This challenge with staff capacity is partially driven by producer heterogeneity in farming. In California in particular, soil type and crop production vary widely from district to district, there is an unmet need for hyper-local technical expertise.

Farmers who have differing priorities than the conservation priorities agreed upon by the state working group, may not have adequate information to choose or implement practices appropriate for their farm and are unlikely to implement new practices on their own. Due to the limited NRCS staff capacity interested farmers receive insufficient support for planning and monitoring soil health projects. Farmer requests for support are often time-sensitive, due to planting cycles, and insufficient staffing levels at NRCS mean that these requests are occasionally not handled in a timely manner. NRCS staff also needs to have the expertise and training to help farmers navigate the soil science limitations discussed above.

NRCS staffing levels are currently insufficient to help all interested farmers address these concerns. The EQIP program, in particular, requires a complicated application process, and NRCS staff is also needed to help farmers navigate the eligibility, application, and monitoring requirements. Insufficient staffing also leads to limited support for partnerships, including those with local conservation districts. Within our own research for this report, NRCS staff were often difficult to reach for interviews as a result of their busy schedules - and in some cases were unable to speak with us at all due to their demanding workloads and lack of staff capacity.

4.d.ii. Partnerships are not sufficiently developed and utilized

Conservation districts and other partners vary in the level of their relationship with NRCS. Local conservation districts are often the first point of contact with farmers, and can often reach out to and provide ongoing assistance for farmers who do not want to interact with NRCS directly. This is

¹² We were unable to verify this statement, as NRCS budgets outlining the distinction between staffing and programmatic spending were not publically available. However, NRCS should further investigate this important discrepancy between funding for conservation programs and funding for staff.

particularly important for farmers who have concerns about privacy or encroaching government regulation, as many of these farmers will not adopt soil health practices through NRCS programs. Some conservation districts rely heavily on NRCS, often due to lack of funding and staff of their own, but others operate independently. The work of NRCS and local conservation districts is often not sufficiently integrated due to NRCS staff limitation, and does not leverage available partnerships and resources, which limits adoption of soil health practices.

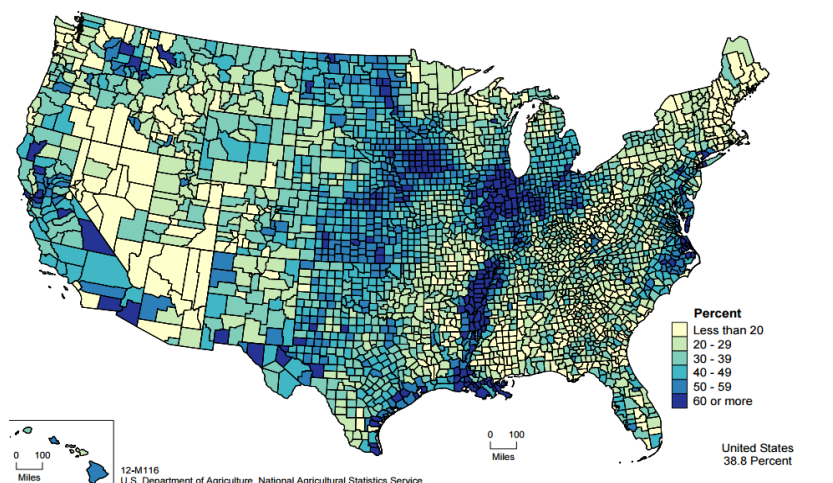
4.e. Poor Targeting and Misalignment of Owner/Renter Incentives

4.e.i. Tenant farmers

Nearly 40% of farmland in the U.S. was operated by renters in 2012. Full owners accounted for just 67.7% of farms and 36.8% of farmland nationally, part owners (who both rent and own parts of the land they farm) accounted for 25.5% of farms and 53.7% of farmland, and tenants accounted for 7% of farms and 9.5% of farmland (USDA 2014). Some regions of the country, including parts of the Midwest, have high percentages of farmland that is rented. Iowa has the 5th largest percentage of rented land in the country, at 53% (*ibid*). Some have upwards of 15 landlords for just 1,000 acres of farmland. This indicates that some states may gain greater benefit from addressing this challenge, including Iowa.

Current NRCS programs may be insufficiently structured to incentivize renters to adopt soil health practices. This is primarily due to the tradeoff between near-term costs borne by farmers and the long-term benefits of implementing these practices. Many farmers who are renters may be more focused on short-term costs and benefits, because they are not as financially invested in a given farm as the landowner, and will value long-term soil benefits less than farmers who also own their land. Additionally, there is often a generational divide between parents and children manifested as a misalignment in conservation and soil health priorities. Parents or grandparents may own the land that their children or grandchildren farm, but may not see the benefits of adopting soil health or conservation practices either informally by providing buy-in or formally by incorporating specific management practices in the stipulated lease.

Figure 7: Percent of Land in Farms Rented or Leased in 2012



Source: USDA 2012 Census of Agriculture

4.e.ii. Female farm-owners

It is estimated that by 2030, women over 60 may own about 75 percent of transferred farmland in the U.S. (Petrzelka and Sorensen 2014). Given recent and expected shifts in land ownership, a need has surfaced for more targeted and sustained NRCS outreach strategies that cater to this specific demographic. Although, there continues to exist a gap of exact national and state-level data on non-operating landowners (NOLs) and women non-operating landowners (WNOLs), meta-studies have noted that WNOLs face a number of gendered barriers to implementing soil health and conservation practices on their land (Petrzelka and Sorensen 2014). Barriers include tenants who dismiss their conservation goals and less frequent outreach from conservation agencies and professionals. In one survey, female landowners expressed reluctance to demand and even discuss the implementation of sustainable agricultural practices with their tenants because of fears that tenants would lease elsewhere (Carolan 2005).

Iowa, through the Iowa Land Ownership Survey, is one of only a few states that regularly collects information on land ownership trends. The latest survey conducted in 2012 reveals that 49 percent of farmland owners in Iowa are WNOLs, who own 47 percent of Iowa's agricultural land and lease about 52 percent of it to tenant farmers (Duffy and Johanns 2012). A study conducted in Iowa revealed that conservation outreach materials used by conservation agencies and partner organizations lacked representation (in pictures and narrative) of older, female landowners. Additionally, the language was described to be too technical and riddled with acronyms that were not familiar to WNOLs (Eells and Adcock 2012).

Case Study: Rabinowitz Family Farm

Ruth Rabinowitz is one female landowner in Iowa who is committed to ensuring that her tenants implement soil health and conservation practices with assistance from NRCS.

Ruth currently manages seven out of the eleven farms in Iowa and South Dakota that comprise the Rabinowitz Family Farm. Over a twenty-five-year period, her father, a former physician, decided to pursue a dream of his and invest in farmland. Growing up, the family



made annual trips from Arizona to Iowa to visit the land and meet with the farm managers, who leased the land to farmer-operators. As her father aged, Ruth took on the responsibility of monitoring the farms and began to travel to Iowa once a year on his behalf. Instead of visiting in August during the peak corn season as her family would often do, she traveled to Iowa in April prior to planting and discovered that the soil was heavily eroded. The management team had not taken care of the land for many years and they were promptly fired. In the family's absence, the farm manager's roles had diminished from land stewards to mere rent-collectors. Ruth took over the management of the farms and embarked on a journey to learn about sustainable agricultural practices: "It was like buying a Victorian mansion that has been neglected for thirty years."

Ruth and her sister enlisted the help of NRCS and asked for a meeting with several district conservationists. She eagerly prepared by developing a presentation that included a long list of questions about NRCS programming and support. NRCS staff answered their questions and decided that they needed to do site visits to address their needs first-hand. They soon realized that large portions of the land being farmed were low yield, had low corn suitability ratings, and high slopes. The long-standing farm managers and operators had farmed almost every corner of the land using unsustainable practices that had severely eroded the soil.

She was committed to educating herself about all the different soil health practices that could be funded through NRCS programming. She applied to the Conservation Reserve Program (CRP) and currently manages twenty-five CRP contracts. The family was able to double their enrollment contracts since 2014. Now, they lease only the best acres and maintain strong relationships with their tenants who share the same soil health and conservation goals. CRP provided Ruth with the financial stability to take land out of production and engage in soil health and conservation practices that enhance air quality, water quality, restore habitats, and strengthen the topsoil which is crucial for long-term sustainability and soil maintenance. The farm primarily produces corn and soybeans and, through technical assistance from NRCS, they have adopted crop rotation, cover cropping, no-till and forest management practices.

Although, the Rabinowitz Family Farm does not currently participate in the NRCS programs included in this report, it has several EQIP applications in the pipeline: "It's moving slowly."


"When I write those checks to pay my taxes, I know that some of that is coming back to my farm and I'm going to get some of this funding to help the land, which in turn helps the planet. We don't have another planet to go to. Eventually it pays off, you just have to stay the course. It requires endurance."

4.e.iii. Non-farmer Investor Owners

Over the past fifty years, the amount of farmland that is rented by farm operators has fluctuated over time, ranging between 34 percent and 43 percent (Nickerson et al. 2012). This distribution of rented farmland varies across regions, with the highest proportions in Illinois, Iowa, Kansas, and the Mississippi Delta. In fact, three of the top four regions in terms of land in agriculture (Northern and Southern Plains and the Corn Belt) have non-operating owners owning more than 30 percent of the land (*ibid*). Additionally, although only 1.7 percent (or 22.8 million acre) of privately owned farmland in the United States was owned by foreigners as of 2009, this ratio has been gradually increasing, which could have an implication on farming practices in the United States in the future.

The ownership arrangement can affect farmers' and landowners' decision making and behaviors, including production decisions, adoption of technologies, and conservation practices. For instance, operators who are full tenants and do not own land are more likely to specialize in crops (versus livestock) than operators who own the land they operate (Nickerson et al, 2012). In particular with respect to soil health practices adoption, the mismatch in the timing between the significant upfront cost to adopt these practices and the long-term benefits that these practices will generate disincentivize some renters, particularly those with short-term tenure, from adopting these practices. Some farm owners also fail to internalize the long-term detriments from poor farming practices undertaken by their renters which could affect the yields on their land in the long-run. Additionally, absentee landowners, who reside in a different county or outside of the state, are less likely to be engaged in the active management of their farmland (Petrzelka, Ma and Malin 2013).

With that said, there is an emerging trend whereby farm owners engages in promoting sustainable farming practices, which also allow them to charge higher rent from tenants. Meanwhile, tenants can also sell their agricultural products as organic crops at higher prices, allowing them to earn more profit, despite higher rent, as well. This represents a potential opportunity for NRCS to consider promoting whereby institutional ownership of farmland can help promote soil health practices adoption.

**FARMLAND LP**
Investing in Sustainability™

Case Study: Farmland LP

Farmland LP represents an example of how institutional ownership of farmland can help promote sustainable farming practices.

Founded in 2009, Farmland LP operates as an investment partnership, investing in sustainable farming practices by acquiring, operating, and managing farmland. The partnership acquires conventional farmland and then converts it to sustainable farmland, pursuing land management practices that aligns the interests of the investors, the environment, farm managers, consumers, and the communities. The partnership bought its first farm in 2010 in Corvallis, Oregon, and today, it owns and manages over 13,500 acres of farmland — over 5,700 acres 55 miles east of San Francisco Bay and over 4,000 acres in Oregon's Willamette Valley.

The partnership makes money in two ways: (a) real estate value appreciation, and (b) operating and rental income from the farmland. By engaging in sustainable farming practices, the partnership, and

their land renters, can sell their crops at higher prices as organic crops. As an example, the partnership acquired conventional farmland which originally yielded approximately \$125-\$150 per acre in rent from farmers growing commodity crops. After converting it to sustainable farmland, the partnership can rent the land for \$830-880 per acre to farmers growing organic crops. This significant pricing premium provides sufficient return for Farmland LP to engage in the initial conversion of the farmland from conventional to sustainable ones. In the long-run, sustainable farmland should also enjoy more value appreciation given its high quality and productive yield.

Farmland LP represents an example whereby private investors can earn profits by engaging in sustainable farming practices. The practice is replicable and scalable, particularly in states where demand for organic crops is strong. This represents a potential opportunity for NRCS to leverage private capital to promote sustainable farming practices.

5. Criteria for Analysis

In order to evaluate policy alternatives for NRCS, we analyze each policy option using four criteria: (a) policy effectiveness, (b) cost effectiveness, (c) distributional equity, and (d) political feasibility. For each of these criteria, each policy alternative will be ranked High, Medium, or Low.

5.a. Policy Effectiveness

Policy alternatives will be assessed on the extent to which they increase adoption of soil health practices that have co-benefits of carbon sequestration. Policy alternatives that will lead to a significant increase in the adoption of soil health practices will receive higher scoring. We will also examine how well the alternatives address identified needs with respect to EQIP, CTA, and RCPP.

5.b. Cost Effectiveness

Policy alternatives will be evaluated on the benefits relative to the costs of each policy. Alternatives that can increase the adoption of soil health practices with the least cost will receive high scoring. We will also take into account the scalability of the alternatives.

5.c. Distributional Equity among Program Beneficiaries

Policy alternatives will be assessed on whether the costs and benefits of each policy would be distributed fairly within the target beneficiaries. This includes equity with respect to demographics (age and gender), operator status (owner versus renter), physical farm attributes (soil types and crop types), geographic distribution (whether the policy favors farmers in one state over the other), and current participation in NRCS programs (whether the policy favors existing program participants vs. non-participants). Policies that offer equal distributional outcomes will receive high scoring.

5.d. Political Feasibility

Policy alternatives will also be evaluated on the likelihood of each policy to survive political processes, including the process associated with changes internal to NRCS and processes requiring legislative changes. Policies that have a high likelihood to pass administrative and legislative approval will receive high ranking.

6. Policy Alternatives

The policy alternatives of this study aim to increase the adoption of soil health practices in the United States, whether by promoting the benefits of these practices on soil health directly or by leveraging the benefits of carbon sequestration from these practices.

To arrive at these alternatives, we conducted expert interviews with 17 stakeholders in the agricultural industry in California and Iowa, conducted a thorough literature review (see Bibliography), and analyzed NRCS financial and program data. The table below summarizes the most salient policy options for NRCS to increase the adoption of soil health practices that feature the co-benefit of carbon sequestration, followed by a detailed analysis of each option.

Table 2: NRCS's policy options to increase the adoption of soil health practices that feature the co-benefit of carbon sequestration.

	Description	Adherence to Criteria/Recommendation
6.a. Status Quo	Maintain existing programs	Ineffective
6.b. Adjust Program Implementation	Promote RCPP & Strengthen Technical Assistance	Maximize utilization of NRCS's resources
6.e. Public-Private Partnership	Encourage investments from the private sector	Highly scalable, but more effective in certain states; may face political resistance
6.f. Promote End-market Demand	Increase demand for crops grown through sustainable farming practices	Create long-term incentives for farmers with minimal cost; more effective in certain states
6.c. Cap-and-Trade for Farmers	Create a mechanism to allow farmers to trade carbon offsets	Limited farmers' engagement with high transaction costs
6.d. NRCS as Carbon Bank/Broker	Allow NRCS to benefit from carbon offsets from soil-health practices	Increase proceeds for NRCS, but involve implementation complexity

6.a. Maintain Existing NRCS Program Funding Structure and Implementation

This scenario consists in continuing the NRCS programs aimed at improving soil health with the co-benefit of carbon sequestration in their current forms.

This alternative will likely prove ineffective at increasing the adoption of soil health practices. Maintaining the status quo implies that the rate at which farmers adopt NRCS guidelines to improve soil health will likely continue at the current rate. More farmers could adopt soil health practices if they recognize the benefits of soil health practices, but such an increase in the adoption rate will likely be less than if NRCS were to engage actively in promoting the practices.

6.b. Adjust NRCS efficacy within existing programs and budget

NRCS should enhance its existing program implementation to improve program efficacy and effectiveness. Our interviews with NRCS partners confirm the strength of NRCS's capability and program offerings, but there are areas for potential improvement. Partners shared their perspectives that NRCS field staff offer distinct, specialized technical assistance and have unique expertise on management practices that are not shared by all partners. One partner in California reported that NRCS is best positioned to share up-to-date scientific findings related to soil health practices. This is in part due to the academic partnerships that NRCS maintains with research institutions and universities in multiple states. However, NRCS field staff spend a disproportionate amount of time processing contracts and related paperwork instead of offering continuous field guidance to potential and new adopters of soil health practices.

To strengthen its programs, NRCS may consider pursuing the following alternatives:

6.b.i. Increase emphasis on RCPP

Given budgetary constraints, one option that would strengthen current programming without increasing operational costs is to more actively promote RCPP. NRCS management should ensure that NRCS field staff have complete and adequate information to inform current and potential county-level partners about program eligibility and structure. Our interviews suggest that some partners were not aware of RCPP or were not sufficiently informed about RCPP eligibility and the application process to encourage uptake. NRCS could focus on adopting a convening role leading greater coordination with existing partners to disseminate information about RCPP and helping to incorporate critical conservation areas into regional boundaries. This would increase the potential to forge and strengthen long-term cost-sharing partnerships with organizations and agencies that share the same conservation and soil health goals.

6.b.ii. Increase emphasis on technical assistance

The 2014 Farm Bill authorizes the transfer of decision-making authority over technical assistance funding from the Office of Management and Budget (OMB) to the USDA Secretary. This is a helpful reform that enables the USDA to make more effective decisions over funding allocations given the agency's greater knowledge of state priorities and field staff needs. NRCS should capitalize on this change in the stream of decision-making to effectively communicate the demand for additional technical assistance staff at the county level. In California, NRCS staff reported spending more time

developing EQIP contracts and other paperwork and less time developing resources for farmers or visiting farms to offer field-specific technical assistance. This would require that the state conservationist stay abreast of county-level needs and challenges and indicate when state priorities might require additional resources for technical assistance. Partners reported that there are both not enough NRCS staff members to fill the technical assistance demand and not enough NRCS staff that focus on soil biology and vegetation management as opposed to engineering. NRCS should ensure that state-level committees and working groups serve as feedback spaces where staffing and funding concerns can be effectively addressed.

6.b.iii. Expand program engagement to absentee and female landowners

Both California and Iowa reported an increase in tenant farmers and private, absentee landowners. They reported that this is a growing issue that affects long-term buy-in of soil health and conservation practices. NRCS should shift marketing and outreach strategies to specifically target private absentee landowners to develop bridges between tenant farmers and their landlords. Private landowners are not a homogenous group and NRCS will have to develop an array of strategies related to marketing and messaging to appropriately target all landowners. For example, there has been a slight increase in out-of-state investors purchasing farmland after the housing collapse, given the rise in farmland values. They are less knowledgeable about soil health and agriculture and primarily motivated to invest in their land to ensure asset appreciation. Educating them on the long-term economic benefits of soil health practices might secure more buy-in for landowners to include conservation-specific clauses in their leases. The messaging required to engage all landowners needs to be tailored to their interests.

Given the trends and opportunities discussed in section 4.e.ii., female landowners have the potential to become key stakeholders in the fields of conservation and sustainable agriculture. It will be imperative that NRCS tap into female farmer associations, such as the Women, Food and Agriculture Network (WFAN), and commit to long-term engagement with members to disseminate knowledge of soil health practices and offer support. NRCS may have to serve as a liaison between female landowners and tenants, who are resistant to implementing long-term soil health practices. Additionally, NRCS should be more inclusive and develop marketing campaigns and materials that cater to this population.

This alternative represents an effective way to increase the adoption of soil health practices without requiring significant additional resources. It encourages NRCS to rebalance its resources to emphasize the areas in which we see significant potentials to promote adoption of soil health practices. It will also promote equal distributional outcomes by increasing access to NRCS's programs among farmers with different farming practices and needs. Some of the aforementioned options may require legislative changes, in which case NRCS will need to evaluate the political landscape to assess the right timing to pursue the option.

6.c. Support Public-Private Partnership to Promote Sustainable Farming

Although NRCS has continually been engaging with partners, such as local communities, conservation districts, universities, and agribusinesses, opportunities exist for NRCS to engage with businesses and investors. This approach aims to increase engagement in sustainable farming by the private sector and attract both capital and expertise.

The efforts could be in the form of subsidy to large-scale privately-owned farms and knowledge sharing and technical collaboration. For instance, NRCS may expand program eligibility for EQIP to allow larger farms to participate. It may also provide technical assistance to such farms or to large investors who seek to convert conventional farmland to one that employs sustainable farming practices. This alternative creates opportunities for private investors to participate in sustainable farming by acquiring conventional farmland and converting it into farms that employ sustainable farming practices. Such an investment will allow private investors to generate investment returns on both land appreciation and the increase in annual cash flow as farmers on that land can sell organic crops at higher prices than traditional crops.¹³ This alternative will help attract private capital to engage in sustainable farming, which will expand the adoption of soil-health practice, while also generating more carbon sequestration benefits.

Depending on the types of engagement and implementation, this alternative will prove both efficient and cost-effective. It will leverage participation by the private sector and expand NRCS's involvement in promoting soil-health practices. Nevertheless, this approach will likely prove more effective in selected regions, particularly those where the demand for sustainable crops allow for price premium. Such price premium for organic crops above conventional crops is crucial to generate investment return to offset the upfront investment required for land conversion. Hence, this approach may prove more effective in states such as California or Oregon than others. More importantly, this approach may face political resistance, as it redistributes NRCS's fund from small-scale farmers toward larger-scale farm owners.

Despite some potential hurdles, this approach is worth further attention, as it has the ability to scale effectively. Over time, the geographic hurdle may become less of an issue as demand for organic crops expand to more states. Existing NRCS's programs that assist small-scale farmers also serve to balance the distribution of assistance between small-scale and large-scale farmers.

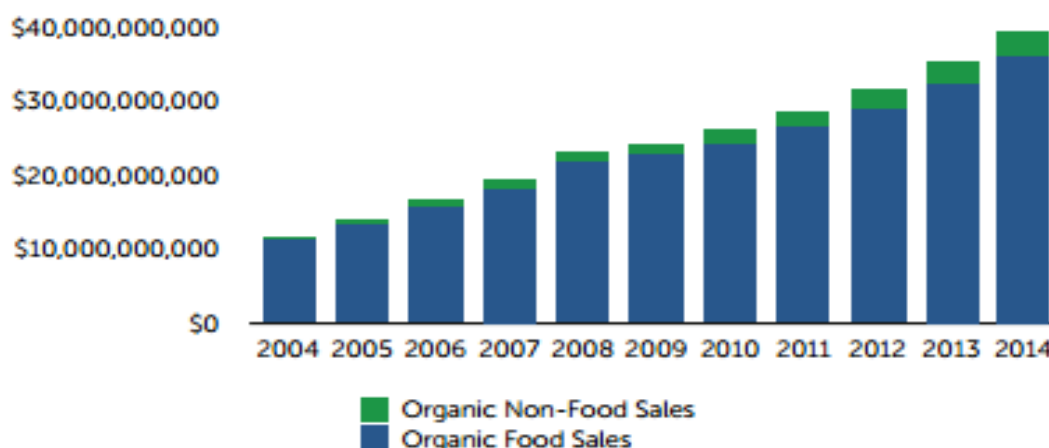
6.d. Promote End-Market Demand for Crops Grown Through Sustainable Practices

This approach aims to emulate the success of the organic food industry, which has grown tenfold in less than 20 years, from a \$3.6 billion industry in 1997 to a \$39 billion industry in 2014. By promoting awareness among consumers for the importance of sustainable farming, including soil-health practices and their carbon sequestration benefits, this approach will create end-market demand for crops grown through sustainable farming practices, which will increase adoption of these practices by farmers.

To achieve this goal, NRCS may advertise to general consumers to promote the importance of sustainable farming practices, the direct benefits of soil-health practices, and the co-benefit of carbon sequestration. NRCS may also partner with supermarket chains and grocery retailers, such as Walmart and Whole Foods, to create help instill awareness among consumers for the importance of soil-health practices and create demand for crops grown with such practices.

¹³ Currently, private investors have the opportunity to acquire conventional farmland and convert it into one that employ sustainable farming practices. Such an investment will generate investment returns on both land appreciation and the increase in annual cash flow as farmers on that land can sell organic crops at higher prices than traditional crops. This amounts to an investment return of approximately 5-15% per annum, based on recent experience of private investor pursuing this strategy.

Figure 8: Total U.S. Organic Food Sales, 2004-2014



Source: Organic Trade Association, "State of the Industry," 2014

Finally, NRCS may consider supporting product labelling that describes certain agricultural crops as grown using "sustainable agricultural practices," by working with existing third-party environmental and sustainability certification companies. For example, SCS Global Services (a California-based company providing third-party environmental, sustainability and food quality certification, auditing, testing and standards development) provides a variety of certifications and verifications in the categories of sustainable agriculture and carbon offset verification/neutrality, such as: Verified Carbon Standard; Climate Action Reserve; American Carbon Registry; Climate, Community, and biodiversity Standards; and the Pacific Carbon Trust.

If successful, this approach will increase adoption of soil-health practices with minimal burden on NRCS's resources. Creating end-market demand for crops grown through these practices will change farmers' perspective on soil-health practices: these practices will no longer represent a significant cost burden but will instead be potential profit opportunities. This will overcome the current difficulty facing by NRCS of changing farmers' attitude toward soil-health practices. It will require minimal financial outlays and little ongoing engagement by NRCS's staff. More importantly, it will create equal benefits for all farmers, large or small, and shall face minimal political resistance as there is no losers resulting from this effort.

6.e. Create a Carbon Market for Farmers to Participate in the Cap-and-Trade Program

Currently, no market exists for farmers, particularly small-scale farmers, to participate in the carbon cap-and-trade market. This is despite the fact that the agricultural sector has the ability to be a provider of carbon offsets under the American Clean Energy and Security Act (HR 2454).¹⁴ Creating such access will allow farmers to capture the positive externality of carbon sequestration from soil health practices, which will increase income for farmers, and provide additional incentives for farmers to engage in soil-health practices to generate these carbon offsets.

¹⁴ Offsets refer to greenhouse gas reductions from mitigation activities in uncapped sectors, such as agriculture, that can be purchased by capped entities to meet their compliance obligations.

Although this alternative is theoretically plausible, its implementation may prove ineffective and costly. The program will also favor large-scale farms and may face resistance from existing participants in the cap-and-trade program who disfavor additional supply of carbon offsets. Three key implementation issues lead to the aforementioned outcome:

1. Limited effect on farmers' engagement,
2. High cost of measuring and monitoring, and
3. Insufficient data to create such a market.

First, the carbon sequestration benefit from soil health practices is small relative to the value of agricultural output. For instance, no-till will generate approximately \$4.8 worth of carbon offset (based on \$12 per metric ton of CO₂ Eq.), compared to \$175 worth of corn output (based on 50 bushels per acre of output at \$3.50 per bushel), or less than three percent. As a result, this approach will only provide marginal impact on farmers' engagement in soil health practices.

Second, the cost of measuring, monitoring, and verification will prove too costly. Farmers have a short list of activities that will generate carbon offsets, and each of these activities generate small carbon sequestration benefits. These factors prevent farmers, especially small farmers, from reaping the benefits of scale, which is crucial in the cap-and-trade program.

Finally, although the availability of data on carbon sequestration benefits from soil-health practices has increased dramatically over the last few years, such data is only suitable for broad-based utilization. To facilitate effective participation in the cap-and-trade program, farmers must be able to quantify more accurately the amount of offsets based on their soil-health activities, crop types, soil conditions, and other factors. This goal requires better data collection and enhanced measurement techniques.

Enhancing farmers' ability to participate in the cap-and-trade program, therefore, may prove a less viable option for NRCS, given the significant administrative complexity and costs involved. This approach may prove suitable for promoting afforestation, which will provide the most carbon sequestration benefits and require scale operations, but such activity is less pertinent to the goal of promoting soil-health practices.

6.f. Create a Protocol to Allow NRCS to Participate in the Cap-and-Trade Program as a Carbon Broker

This alternative seeks to promote the agricultural sector's participation in the carbon cap-and-trade program, while circumventing the challenges that will arise in 6.d (direct participation in the carbon cap-and-trade program by farmers), namely the fragmentation of the agricultural market and high transaction costs. Rather than letting farmers sell their carbon offsets directly, this approach makes NRCS a carbon bank and broker, aggregating the carbon benefits from multiple farmers.

Effectively, this approach will allow farmers that receive financial assistance from NRCS to attribute their carbon offsets to NRCS, allowing NRCS to serve as an offset aggregator. Additionally, farmers who adopt soil health practices with their private funds will also be allowed to sell their carbon offsets to NRCS. NRCS can then sell these carbon offsets to carbon emitters and use the proceeds to offset some

of the cost of its subsidy program. This will allow NRCS to take advantage of the carbon cap-and-trade program, increase the spending capacity of its existing soil health program, and increase the awareness of soil health practices, including the carbon benefits, among farmers.

Although this approach does not directly alter farmers' incentives to implement soil health practices, it may prove an efficient and cost effective way to increase the adoption of soil health practices by expanding the size of existing NRCS programs with the proceeds from carbon offsets. Based on the current annual outlays by NRCS on various soil health practices programs of approximately \$3.5 billion, this translates into a soil carbon sequestration benefit of approximately 19 million tons of CO₂ equivalent per year. Based the price of carbon of \$12 per ton of CO₂ Eq., this translates into approximately \$232 million of potential proceeds of carbon offsets, which needs to be reduced by any purchase of carbon offsets from farmers who implement soil health practices with their own funds. Effectively, this approach has the potential to increase the coverage of NRCS program by 7%.

This approach may also have even further potentials with larger cropland coverage and with an inclusion of NRCS's efforts on rangeland and afforestation. Given that the carbon sequestration rates on land maintained in agricultural use vary around 0.04-0.40 ton of CO₂ equivalent per acre per year, this amounts to between \$200 million and \$2 billion of potential proceeds from carbon offsets for NRCS (based on approximately 165 million hectares of cropland in the United States and the price of carbon of \$12 per ton of CO₂ equivalent; source: Paustian et al. 2016). Finally, since this approach will allow farmers to benefit from the cap-and-trade program whether they receive funding from NRCS or not, it will benefit all farmers equally, whether they are small- or large-scale, and owned-and-operated or rental farms.

Despite these advantages, this approach involves significant administrative complexity and potential political hurdles. Implementation of this approach likely requires Congressional approval and NRCS to devise an effective mechanism to calculate the carbon benefits from various soil health practices that it helps fund. As with 6.d., monitoring, reporting, and verification systems are a key element in a climate-smart agricultural program. Nevertheless, by allowing NRCS to serve as the coordinating agent, this approach may help reduce some of the transaction costs faced by farmers in their efforts to directly participate in the carbon cap-and-trade program. Finally, this approach has the potential to increase the supply of carbon offsets by approximately 20 million tons per year, based on the current NRCS's program outlays. This may lead to resistance from other participants in the carbon market. It also entails significant legal and legislative complexity in structuring this program.

Given the tradeoffs between the potential benefits and hurdles, this approach is worth additional consideration by NRCS. It has the potential to increase the adoption of soil health practices with minimal cost to NRCS. It also promotes awareness among farmers on the carbon sequestration benefit of soil health practices. Implementation strategies and details are crucial in the viability and effectiveness of this approach.

7. Policy Recommendations

To derive the final recommendation, we score each alternative based on the four criteria discussed in Section 6, namely policy effectiveness, cost effectiveness, equity and political feasibility:

	Evaluation Criteria and Recommendations				
	Policy Effectiveness	Cost Effectiveness	Equity	Political Feasibility	Overall
6.a. Status Quo	Low	Low	Low	High	Low
6.b. Adjust Program Implementation	Medium	High	High	Medium	High
6.c. Increase Public-Private Partnerships	Medium	Medium	Medium	Medium	Medium
6.d. Promote End-market Demand	Medium	High	High	Medium	High
6.e. Cap-and-Trade for Farmers	Low	Low	Low	Low	Low
6.f. NRCS as Carbon Bank/Broker	Medium	Medium	High	Low	Medium

Based on the above analysis, we recommend that NRCS pursue Alternative 7.b., which would adjust NRCS efficacy within existing programs and budget by: strengthening partnerships at the state and district level (primarily through RCPP); increasing funding for technical assistance and decreasing transaction costs for farmers; and/or shifting marketing to target private landowners. These options are not mutually exclusive, and priorities among them should be evaluated through future research. This alternative allows farmers to leverage NRCS's expertise, expands the reach of the existing programs, and encourages NRCS to utilize its resources in the most productive manner.

We recommend that when promoting increased uptake of soil health practices on behalf of farmers, NRCS should focus on communicating the numerous agronomic and ecological benefits of healthy soils, rather than promoting carbon pricing as a primary motivator. Furthermore, we recommend prioritizing soil health practices that present relatively low opportunity and transaction costs for farmers (such as conservation tillage), as they are more politically feasible, while also increasing incentives for, and information about, certain practices that have greater carbon sequestration potential and can be incorporated into croplands (such as alley cropping).

Over a longer time horizon, NRCS may also consider Alternative 7.d. Promote End-Market Demand for Crops grown through Sustainable Practices, and Alternative 7.c. Increase Public-Private Partnerships. Both of these represent cost efficient and scalable alternatives for NRCS, as they leverage participation by the private sector and create long-term incentives for farmers to adopt soil health practices. Note that both alternatives may be more feasible in the context of California, where sustainability marketing is already a strong market driver. Pursuit of these alternatives will require NRCS to develop a detailed implementation mechanism and evaluate potential political hurdles in pursuing these alternatives.

8. Conclusion

There are many barriers to increasing adoption of soil health and carbon sequestration practices, including both systemic and operational challenges. Operational challenges include insufficient technical assistance for farmers, due to lack of NRCS staff capacity and underutilization of partnerships, as well as poor targeting and misalignment of owner/renter incentives. In the near term, there are a number of opportunities for NRCS to modify existing programs and spending to address these operational challenges. **Our primary recommendation is that NRCS pursue Alternative 7.b., which would increase emphasis on RCPP, improve funding for technical assistance, and expand program engagement to absentee and female landowners.** These actions can increase uptake of soil health and carbon sequestration practices without requiring significant resources beyond NRCS' existing budget.

Addressing systemic challenges -- including the positive externalities associated with soil health, prohibitive transaction costs for farmers in implementing soil health practices, and the current limitations of soil and carbon sequestration science -- will require long-term, broad-based solutions. Based on our analysis, NRCS can begin to address these systemic challenges through increasing public-private partnerships (Alternative 7.c) and promoting end-market demand for crops grown through sustainable practices (Alternative 7.d). Implementation of these policy options will require a long time horizon and additional analysis on the most suitable partnerships, regions, and methods.

This analysis focused primarily on land management practices that can be implemented by cropland farmers in the US. Further research is warranted on the potential to implement policies that promote soil carbon sequestration through the conversion of land out of agriculture (for example, converting croplands to grasslands or wetlands). Similarly, other land systems such as forests and rangelands represent significant potential to capture carbon. For example, recent research shows there may be significant potential to increase soil organic carbon through rotational grazing and/or compost application on rangelands (Kane 2015). Similarly, we have focused on offsetting carbon emissions through sequestration, but further research should be done on the potential to reduce GHG emissions on farms - particularly methane (CH₄) (through cattle production and rice paddy systems), and nitrous oxide (N₂O).

Appendix 1: California Case Study

Overview

California is a major agricultural state, with the highest value of agricultural products sold in the nation. In 2012, the value of all crops totaled \$30.4 billion (USDA 2015). The top 5 crops grown in California are forage-land used for all hay and haylage, grass silage, and greenchop (1,670,027 acres); vegetables (1,175,249 acres); grapes (940,177 acres); almonds (935,804 acres); and rice (561,968 acres). California is the top producer in the U.S. for vegetables, grapes, and almonds, as well as many other specialty crops. Agricultural production is concentrated more heavily in certain counties within the state, with Tulare, Kern, and Fresno Counties at the top three counties in terms of value of production in 2013 and 2014 (CDFA 2015).

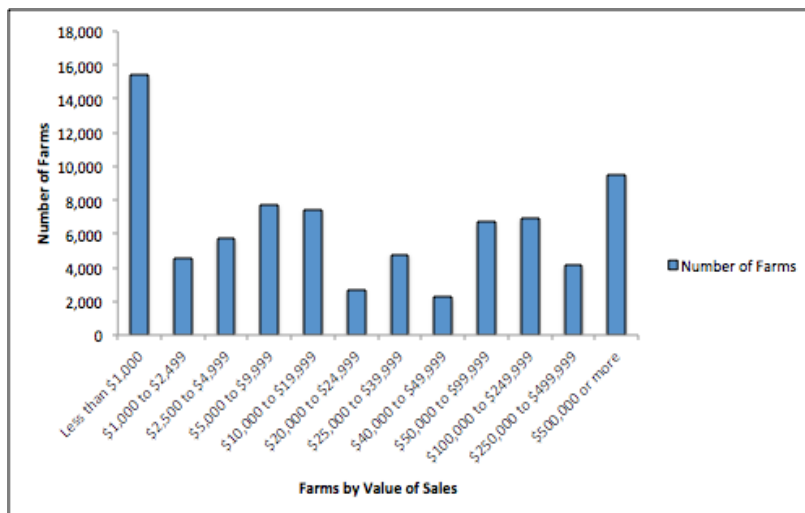


Within California, there are 77,500 farm operations, and 25.5 million acres operated (USDA 2015). The average size of farm operation is 329 acres. Most farms are relatively small in terms of revenue generated. Half of all farms in California make less than \$10,000 in terms of value of sales (See Figures 19 and 20), and 88% of farms make less than \$500,000. This indicates that nearly all farms in California are potentially eligible for EQIP based on income requirements.

Farmer Demographics

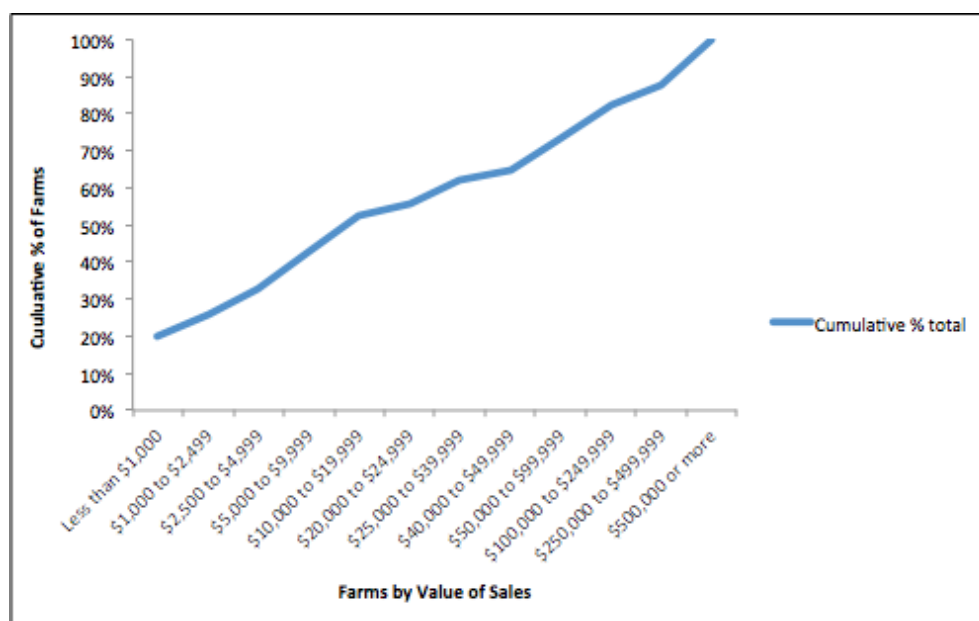
California had 77,857 principal farm operators in 2012 (USDA 2015). Of these, 54.6% have farming as their primary occupation, while 45.5% have another primary occupation. Most principal operators are male (82%), while 18% are female. The farmer population in California is aging, with an average age of principal operators of 60.1 years. The large majority of farm operators are white (80.8%), with Hispanic/Latino farmers (11%) and Asian farmers (5.4%) as the next largest groups.

Figure 9: California Farms by Value of Sales



Source: USDA 2015

Figure 10: California Farms by Value of Sales (Cumulative Distribution)



Source: USDA 2015

Level of Participation in EQIP, CTA, & RCPP

Program adoption in California is higher than the nationwide average, and much higher than in Iowa. In 2014, EQIP adoption in California was approximately 13.8% by acreage - that is, 13.8% of California farmland implemented conservation practices under the EQIP program (USDA 2014). Similarly, CTA adoption in California was 12.1% by acreage in 2014. In 2016, there are 6 RCPP projects specific to California, for a total of \$32.8 million (NRCS 2016). One of those projects, on wet meadow habitats, also encompasses Oregon. These projects combined are approximately 14.9% of the total \$220 million spent through RCPP nationwide in 2016, on 84 projects. While adoption of EQIP, CTA, and RCPP in California is relatively high in comparison to other states, there are a number of opportunities to increase uptake even further.

Specific Soil Health Adoption Challenges and Opportunities in California

There are several challenges to increasing farmer adoption of soil health practices that are specific to California, in comparison to Iowa. **One major challenge is the wide range of soil types found throughout California, often varying within regions and across nearby farms.** This creates a substantial need for technical assistance for farmers in relation to soil health, as it is often difficult for farmers to identify soil health practices and methods appropriate for their specific soil conditions. The need for individualized recommendations and support from soil health experts is not currently met by NRCS staff, due to lack of capacity - there are not enough “boots on the ground” to assist farmers with their unique soil challenges

California also presents unique opportunities for increasing adoption of soil health practices. One opportunity is the current trend towards increasing end-market demand for soil health practices. Branding of sustainable soil health practices can be a major product marketing point in some industries,

particularly viticulture, and this is already a primary motivator for adoption of soil health practices for many farmers. As consumer demand for more sustainable products increases, farmers in other industries may also be incentivized to adopt practices that make their crops more marketable.

Soil Health Programs and Initiatives in California

California has been a leader in promoting soil health practices. The Brown Administration announced a Healthy Soils Initiative in California's 2015-2016 budget, which states that:

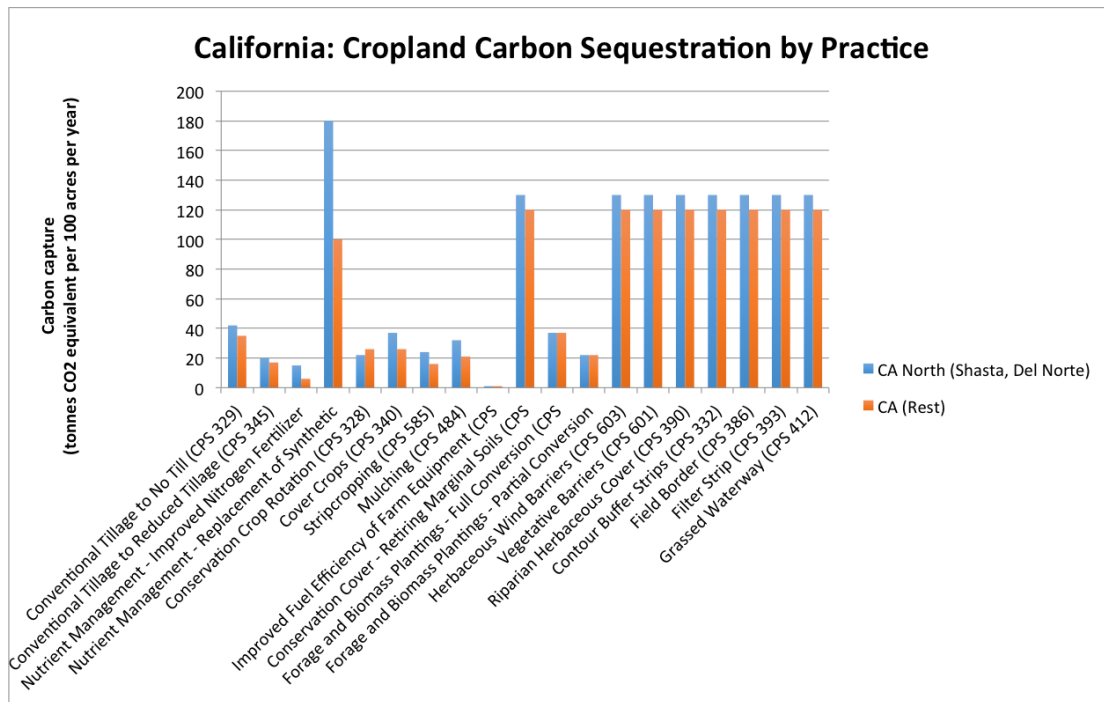
As the leading agricultural state in the nation, it is important for California's soils to be sustainable and resilient to climate change. Increased carbon in soils is responsible for numerous benefits including increased water holding capacity, increased crop yields and decreased sediment erosion. In the upcoming year, the Administration will work on several new initiatives to increase carbon in soil and establish long term goals for carbon levels in all California's agricultural soils. CDFA will coordinate this initiative under its existing authority provided by the Environmental Farming Act (CDFA 2015b).

The California Department of Food and Agriculture (CDFA) is working to implement a suite of actions to increase soil health, in coordination with the Department of Water Resources (DWR) and other agencies. Short-term actions include establishing goals, identifying research needs and demonstration projects, and exploring opportunities for implementing healthy soils practices on public lands (CDFA 2015c). Longer-term actions will work to:

1. Identify sustainable and integrated financing opportunities, including market development, to facilitate increased soil organic matter;
2. Provide for research, education and technical support to facilitate healthy soils;
3. Increase governmental efficiencies to enhance soil health on public and private lands; and
4. Ensure interagency coordination and collaboration.

There are a number of other efforts in California that are focused on soil health and carbon sequestration. In particular, the Marin Carbon Project is helping to create Carbon Farm Plans for farms in Marin County, which use COMET-Farm and COMET-Planner data to evaluate carbon sequestration potential and conservation practices for individual farms (Marin Carbon Project 2013).

Figure 11: California Cropland Carbon Sequestration by Practice

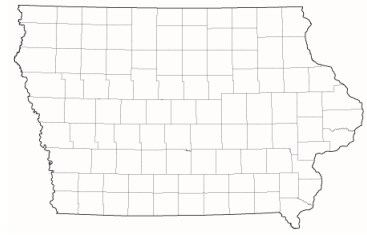


Source: USDA 2015

Appendix 2: Iowa Case Study

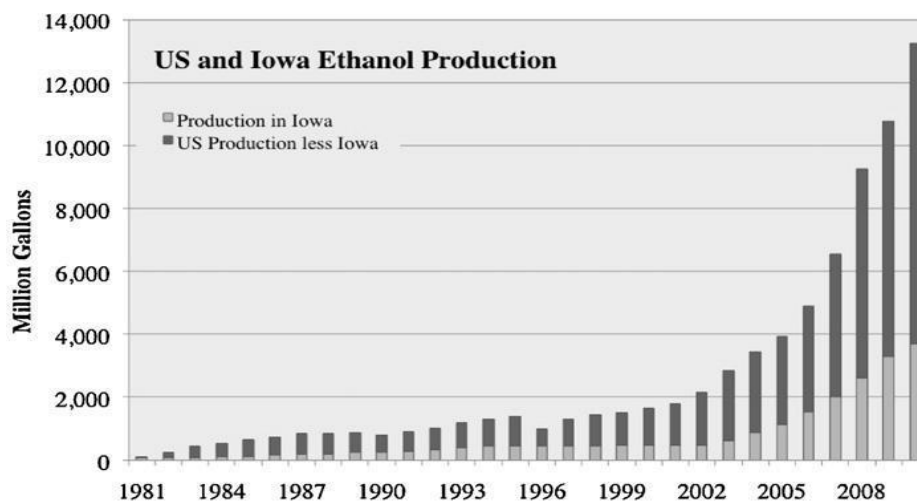
Overview

Iowa leads the U.S. in corn and corn ethanol production and is the second largest producer of soy. The state has 11,000 different soils across 99 counties and a varied geography that includes rolling plains with gentle slopes and steeply sloping bluffs near the banks of the Mississippi river and its tributaries. Agriculture is a critical component of the state's economy and its primary land use: Over 90 percent (32.9 million acres) of the state's 36 million acres is farmland, with approximately 26.8 million of these agricultural acres (81%) dedicated to crop production. It ranks third in total agricultural sales after California and Texas. Iowa also leads in hog production, raising 32 percent of the nation's hogs. There are 87,500 farm operations in the state and the average farm size has 349 acres.



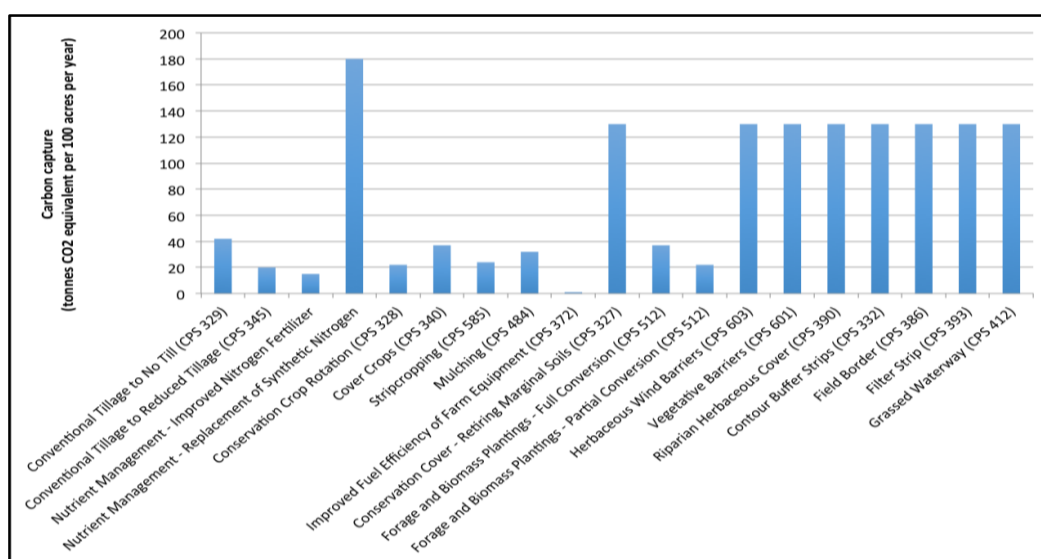
Due to prolonged agricultural interventions on the land, Iowa suffers from heavy soil erosion and highly polluted ground and surface water. During the mid 1800s, Iowa prairies were intensely plowed, resulting in the erosion of over half of the state's 14-16 inches of topsoil. It currently ranks last among all US states in term of natural vegetation remaining and last for native habitat availability with only .01 percent of native prairie remaining. Soil erosion is directly related to a farmer's preferred tillage practice, degree of slope where the land is located, placement and timing of fertilizers like nitrogen and phosphorus, and the duration and intensity of rainfall. Taking these various factors into account, studies have shown that corn yields improve as topsoil thickness increases and thicker soils absorb water more efficiently reducing runoff and nutrient loss.

Figure 12: US and Iowa ethanol production, 1981–2008.



Source: Renewable Fuels Association (2011) and EIA Annual Energy Review (2010)

Figure 13: Iowa: Cropland Carbon Sequestration by Practice



Farmer and Landowner Demographics

In the 2012 Census of Agriculture, it was reported that Iowa had 88,637 principal operators of which 47,949 (54%) listed farming as their principal occupation. The average age of the principal operator is 57 and the vast majority them are male (91%). The 2012 Iowa Landownership Survey reported that over half (56 percent) of the farmland in Iowa was owned by people over the age of 65. Farmers over the age of 75 own 30 percent of the land, yet they represent only 23 percent of the land in government conservation programs. 80 percent of landowners are full-time Iowa residents, down from 94 percent in 1982. The remaining 20 percent are either part-time or non-residents of Iowa, up from 6 percent in 1982. In 2012, women were 49 percent of the owners and owned 47 percent of the land. Additionally joint tenants own 32 percent of all farmland in Iowa, but own 43 percent of conservation acres. Land held in trusts had a lower percent of engagement with voluntary conservation programs.

NRCS Program Participation Rates

Approximately 5 percent of all Iowa farmland was in some form of conservation program. Iowa's most popular conservation programs include EQIP, CRP and CSP. Currently, .04 percent of eligible land is under EQIP contracts and 1.3 percent is under CTA. However, it should be noted that more farmers in Iowa have conservation contracts through CRP than any other state; A trend that should be examined in future research. There are five active RCPP projects that include Iowa. They range from improving habitat conditions for honey bees to improving financial impact analysis of conservation practices.

Trends Influencing the Adoption of Soil Health Practices in Iowa

Change in Landowner Demographics

Several interviewees reported that the increase in tenant-farmers and absentee landowners was a barrier to the effective dissemination of information and the long-term buy-in of soil health practices. More than half of the farmland in Iowa is rented and anecdotal evidence suggests that landowners are

less informed about the benefits of soil health practices. Only 22 percent of farmers who responded to the Iowa Farm and Rural Life Poll of 2015 agreed that landlords have a good understanding of soil health. Short-term leases are common, which further disincentivize the implementation of soil health practices by tenant-farmers. Additionally, land ownership through trusts has increased significantly in Iowa from 1 percent in 1982 to 17 percent in 2012. Additionally, the expected landownership transfer to female landowners (discussed in section 5.e.ii) may influence the adoption of soil health practices.

Past Policies and Commodity Price Fluctuations

The Renewable Fuels Standards passed in 2005 and 2007 mandated increased biofuel production until 2022. Iowa produces about 30% of the nation's corn ethanol and this incentivized greater production of corn. The rise in corn prices have now made yields more profitable and the government conservation contracts less competitive. Some believe this has disincentivized crop rotation, given that farmers want to plant corn continuously and incentivizes the conversion of fallow land and pasture into farmland. Some think that this undermines the ability of biofuels to reduce GGE since the conversion releases carbon.

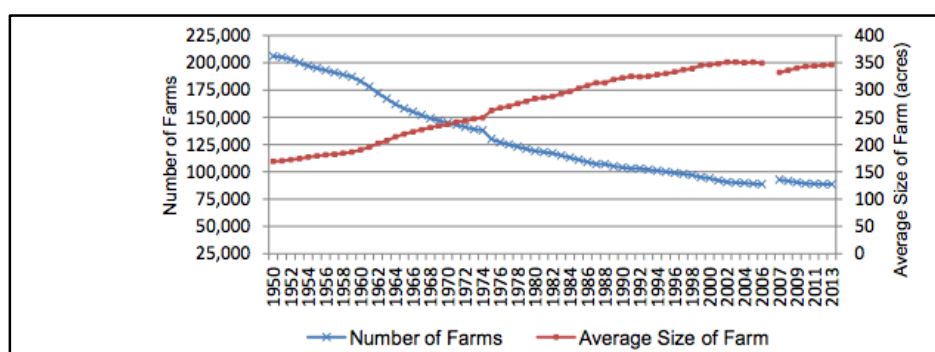
Water Pollution

The Des Moines Water Works, the largest water utility company in the state, filed a lawsuit against three northwest Iowa counties over water quality in 2015. The Des Moines utility is claiming that nitrates from the fertilizers are seeping into the waterways and ultimately the drinking water in the Des Moines metro area. The case is scheduled to be heard on August 8, 2016, and is surfacing the long-standing issues of water pollution in the state and the high cost of filtration and purification that cities like Des Moines have to incur. Conservation practices are increasingly seen as an appropriate mitigation strategy to reduce pollution at its source.

Shifting transaction costs for farmers due to technological innovation and climate change:

In Iowa in the 1980s, corn farmers made significant technological investments in wide-swath planters, in order to plant large areas at once. This type of machinery is particularly attractive in a context of rapid consolidation of smaller farms over the past sixty years (see Figure 24 below). As a result, for a farmer to transition to low-till or no-till practices, this capital investment was historically perceived as a relatively large sunk cost, in addition to the opportunity cost of not being able to plant so quickly. As a result, for decades the switch and opportunity costs of soil health practices appeared to outweigh the potential benefits.

Figure 14: Number of Iowa Farms and Average Farm Size 1950-2013



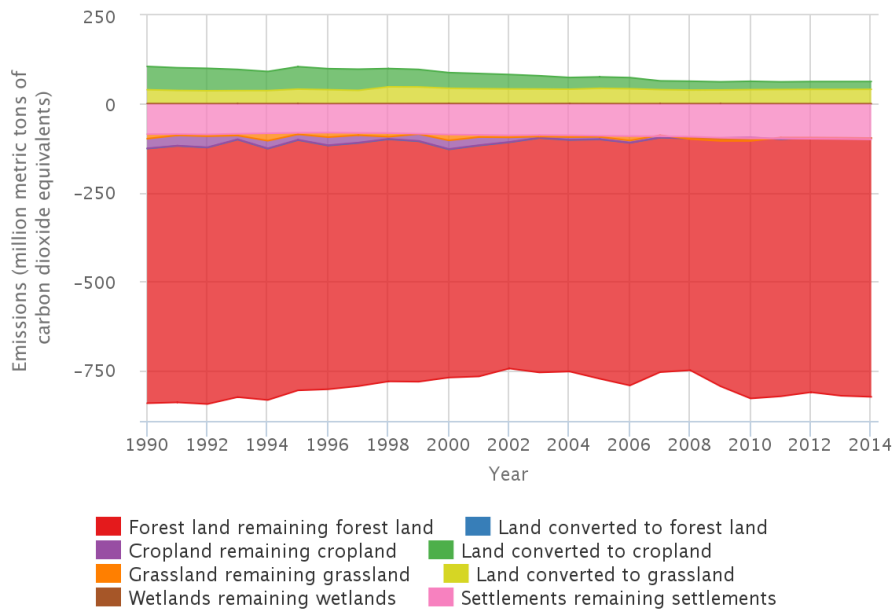
Source: Iowa Agricultural Statistics Bulletin USDA, National Agricultural Statistics Service

However, climate change and other technological developments have created additional incentives for Iowa farmers to transition to low-till and conservation tillage methods in recent years. The Midwest has experienced irregular massive rainfalls, which create rills on the surface of the soil, and cause increasingly severe erosion. This has made it difficult for wide-swath planter machines to function, because they need homogenous, smooth surfaces to plant. Wide-swath planters also cause soil compaction from driving over the fields. Additionally, the introduction of GMOs in the 1980s made it possible to control weeds without tilling, at much lower costs. This combination of climate-driven soil health challenges and technological shifts has increased the perceived benefits of low-till and conservation tillage methods, outweighing the switch costs.

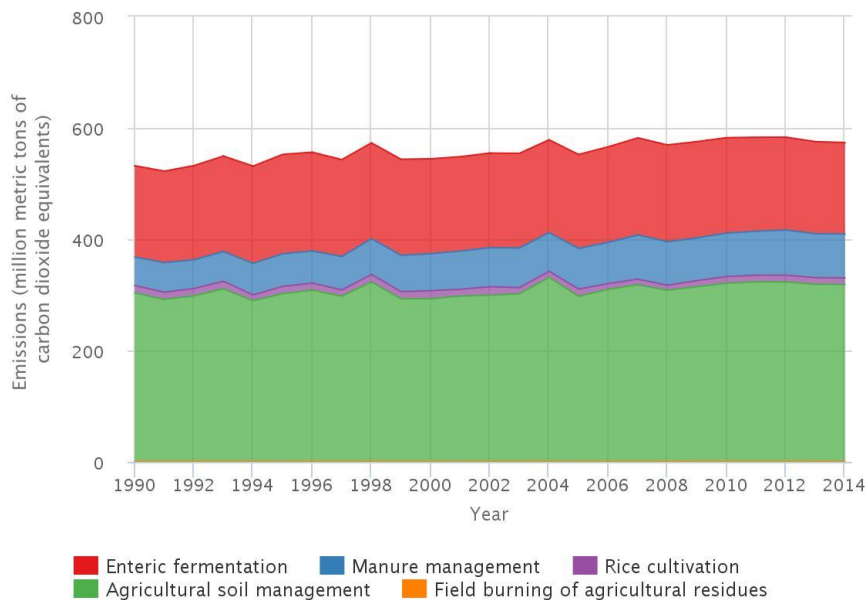
Today there is potential for a similar transition with the practice of cover cropping, which presents significant potential to alleviate widespread erosion and soil compaction in Iowa. However, corn is an annual crop that leaves a relatively small window to plant cover crops, and for many farmers this cash crop interference outweighs the potential benefits. Nonetheless, according to the Practical Farmers of Iowa, the number of farm acres using cover cropping has increased dramatically in recent years — from fewer than 10,000 acres in 2009 to about 300,000 acres in 2013.

Appendix 3: GHG flux in US Agriculture, Land Use, and Forestry

U.S. Greenhouse Gas Emissions from Land Use, Land-Use Change, and Forestry, 1990–2014



U.S. Greenhouse Gas Emissions from Agricultural Activities, 1990–2014



Appendix 4: NRCS Cropland Soil Health Practices - Carbon Sequestration Potential

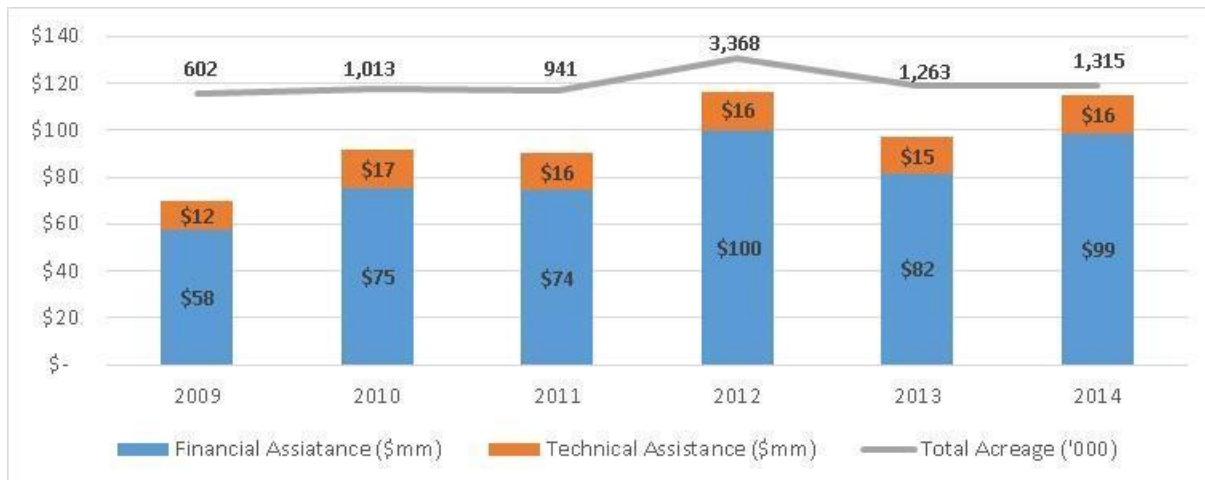
CARBON CAPTURE POTENTIAL PER 100 ACRES PER YEAR (metric tons)		Carbon Dioxide (MT CO ₂)	Nitrous Oxide (MT N ₂ O)	Total CO ₂ Equivalent (MT CO ₂ -eq)	Description of practice
CROPLAND TO HERBACEOUS COVER	Conservation Cover - Retiring Marginal Soils (CPS 327)	98	28	130	Establishing and maintaining permanent vegetative cover
	Herbaceous Wind Barriers (CPS 603)	98	28	130	Herbaceous vegetation established in rows or narrow strips in the field across the prevailing wind direction.
	Vegetative Barriers (CPS 601)	98	28	130	Permanent strips of stiff, dense vegetation established along the general contour of slopes or across concentrated flow
	Contour Buffer Strips (CPS 332)	98	28	130	Strips of perennial vegetation alternated down the slope with wider cultivated strips that are farmed on the contour.
	Field Border (CPS 386)	98	28	130	A strip of permanent vegetation established at the edge or around the perimeter of a field.
	Filter Strip (CPS 393)	98	28	130	A strip or area of herbaceous vegetation that removes contaminants from overland flow.
	Grassed Waterway (CPS 412)	98	28	130	A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross section to a stable outlet.
CROPLAND MANAGEMENT	Conventional Tillage to No Till (CPS 329)	42	0	42	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year round while limiting soil-disturbing activities to only those necessary to place nutrients, condition residue, and plant crops.
	Cover Crops (CPS 340)	32	5	37	Cover crops including grasses, legumes, and forbs for seasonal cover and other conservation purposes.
	Mulching (CPS 484)	32	0	32	Applying plant residues or other suitable materials produced off site, to the land surface.

	Stripcropping (CPS 585)	11	13	24	Growing planned rotations of erosion-resistant and erosion susceptible crops or fallow in a systematic arrangement of strips across a field.
	Conservation Crop Rotation (CPS 328)	21	1	22	Growing various crops on the same piece of land in a planned sequence.
	Conventional Tillage to Reduced Tillage (CPS 345)	13	7	20	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year round while limiting soil-disturbing activities to only those necessary to place nutrients, condition residue, and plant crops.
	Nutrient Management - Improved Nitrogen Fertilizer Management (CPS 590)	0	15	15	Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments.
	Improved Fuel Efficiency of Farm Equipment (CPS 372)	1	0	1	Installing, replacing, or retrofitting agricultural combustion systems and/or related components or devices for air quality and energy efficiency improvement.

Appendix 5: NRCS Program Financial Information

5.a. EQIP Financial Information

EQIP Program Obligations for Financial and Technical Assistance and Total Acreage – California



EQIP Program Obligations for Financial and Technical Assistance and Total Acreage – Iowa

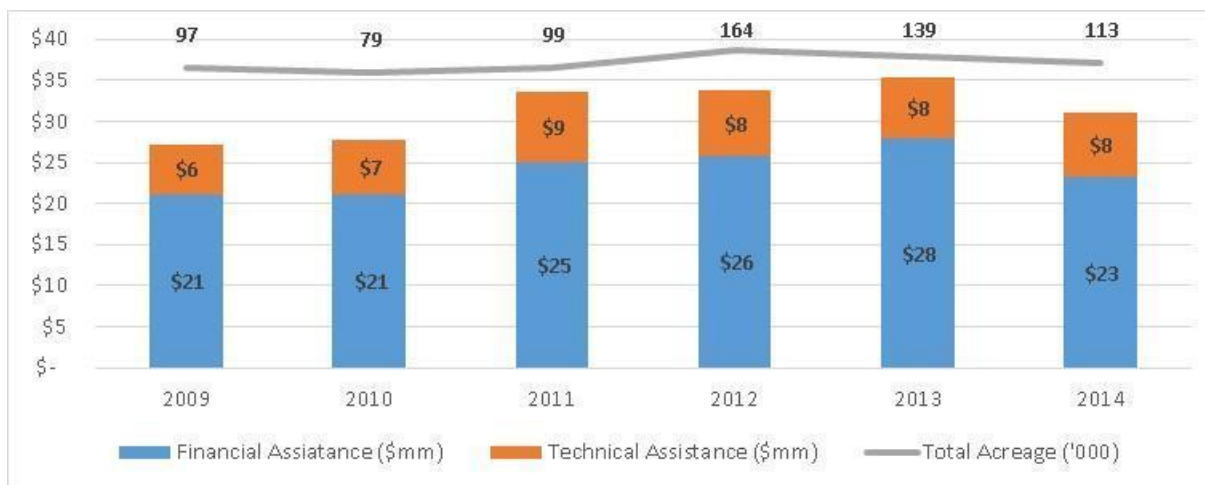
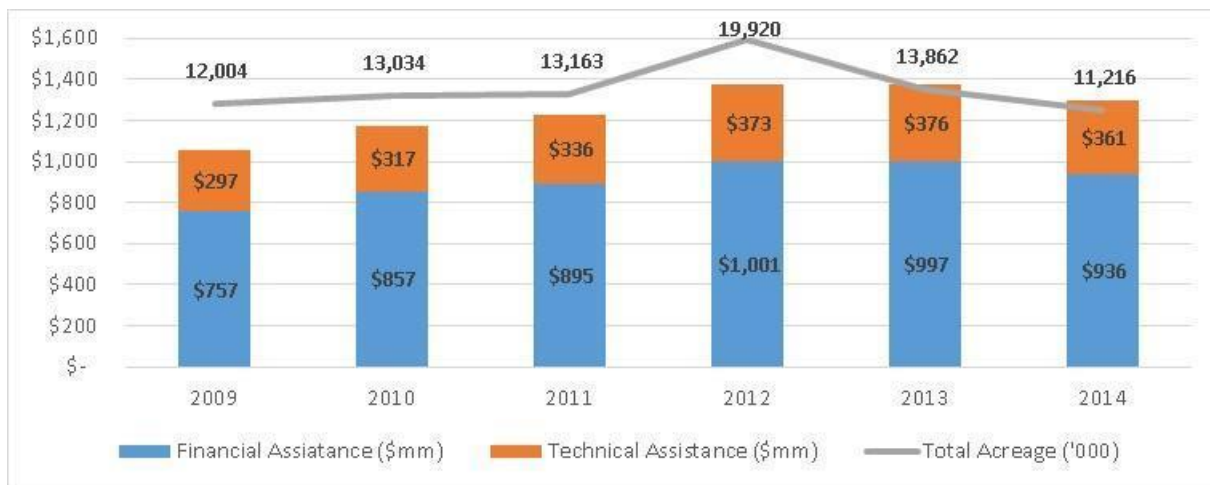


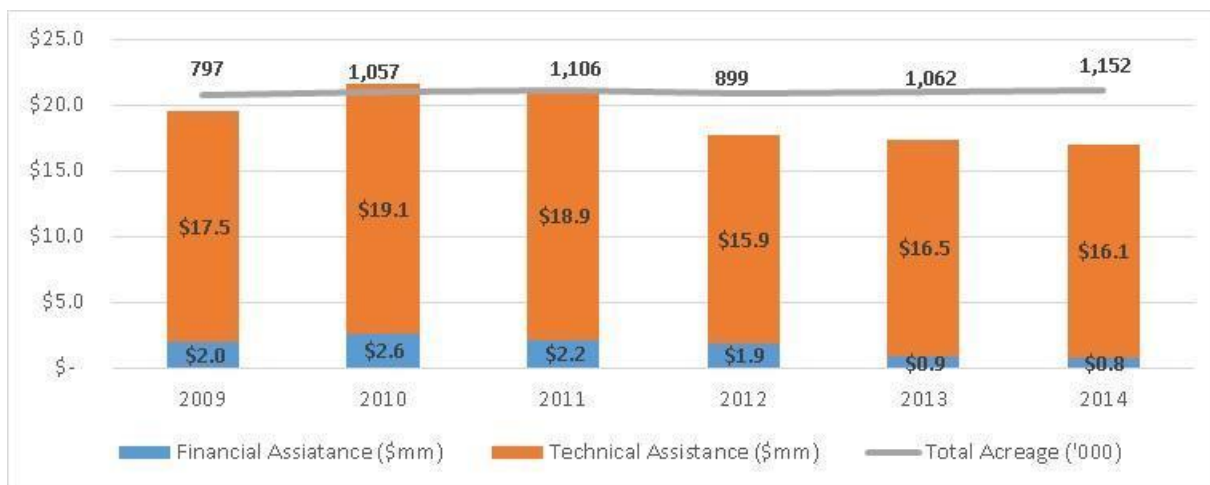
Figure: EQIP Program Obligations for Financial and Technical Assistance and Total Acreage – All States



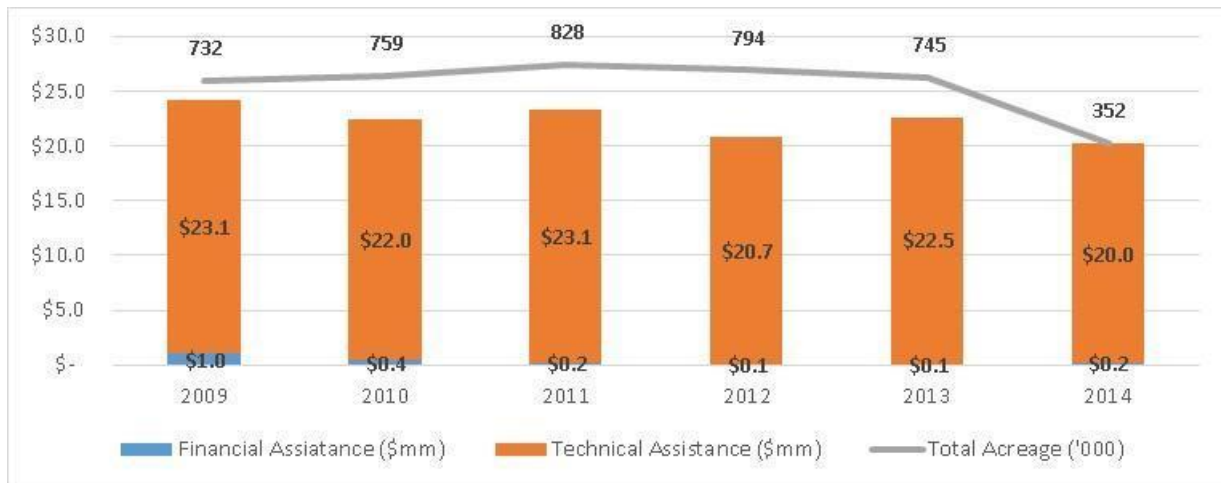
Source: Natural Resources Conservation Service- Washington- DC. 15 July 2015.

5.b. CTA Financial Information

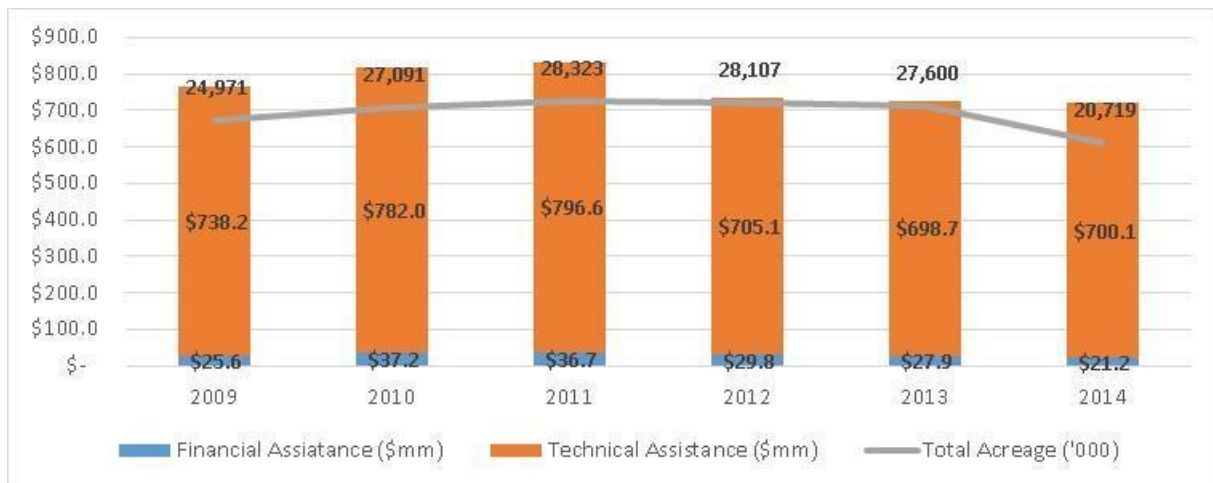
CTA Program Obligations for Financial and Technical Assistance and Total Acreage – California



CTA Program Obligations for Financial and Technical Assistance and Total Acreage – Iowa



CTA Program Obligations for Financial and Technical Assistance and Total Acreage – All States



Source: Natural Resources Conservation Service- Washington- DC. 15 July 2015.

Bibliography

- Allaire, Maura and Brown, Stephen P.A. (2012) "U.S. Energy Subsidies: Effects on Energy Markets and Carbon Dioxide Emissions, prepared for the Pew Charitable Trust." Resources for the Future.
- Carolan, Michael S. (2005) "Barriers to the Adoption of Sustainable Agriculture on Rented land: An Examination of Contesting Social Fields." *Rural Sociology* 70:387-413.
- Carlisle, Liz (2016). "Factors Influencing Farmer Adoption of Soil Health Practices in the United States: a Narrative Review." *Agroecology and Sustainable Food Systems*.
- Chambers, A., Lal, R., Paustian, K. (2016). "Soil carbon sequestration potential of US croplands and grasslands: Implementing the 4 per Thousand Initiative." *Journal of Soil and Water Conservation*. [in press]
- CDFA (2015) "California Agricultural Statistics Review 2014-2015." California Department of Food and Agriculture.
- CDFA (2015b) "Environmental Stewardship: Healthy Soils Initiative." California Department of Food and Agriculture. <https://www.cdfa.ca.gov/EnvironmentalStewardship/HealthySoils.html> Accessed 4/10/16.
- CDFA (2015c) "Healthy Soils Initiative." Administration/Department of Food and Agriculture Work Product, California Department of Food and Agriculture.
- Ciais, P. et al (2013). "Carbon and other biogeochemical cycles." In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (eds Stocker, T. F. et al.)
- Del Grosso, S.J., Mosier, A.R., Parton, W.J., Ojima, D.S. (2005). DAYCENT model analysis of past and contemporary soil N₂O and net greenhouse gas flux for major crops in the USA. *Soil and Tillage Research*
- Duffy, Michael and Ann Johanns. (2012) "Farmland Ownership and Tenure in Iowa 2012." Ames: Iowa State University Extension PM 1983 Revised.
- Eells, Jean and Leigh Adcock. (2012). "Women Caring for the LandSM: Improving Conservation Outreach to Female Non-Operator Farmland Owners." Ames, IA: Women, Food and Agriculture Network. http://www.wfan.org/Women_Caring_files/WCLManualForWeb3-12.pdf
- EPA (2016). "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2014." U.S. Environmental Protection Agency. <https://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2016-Main-Text.pdf>
- ICF International. (2013) "Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States, prepared for U.S. Department of Agriculture Climate Change Program Office."
- IPCC (2014) "Climate Change 2014: Synthesis Report." Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Kane, Daniel. (2015) "Carbon Sequestration Potential on Agricultural Lands: A Review of Current Science and Available Practices." In association with: National Sustainable Agriculture Coalition, Breakthrough Strategies and Solutions, LLC.

Marin Carbon Project (2013) "Carbon Farm Plans." Marin Carbon Project.
<http://www.marincarbonproject.org/carbon-farming/carbon-farm-plans> [Accessed 4/10/16].

McGlynn, Emily et al. (2016) "Building Carbon in America's Farms, Forests, and Grasslands: Foundations for a Policy Roadmap" Forest Trends.

Murray, Brian C. et al. (2005) "Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture." United States Environmental Protection Agency.

NRCS (2016) "2016 RCPP Projects by State." <http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/farmbill/rcpp/?cid=nrcseprd598407> [Accessed 4/18/16]

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G., and Smith, P. (2016). "Climate-smart soils." *Nature*. 7 April 2016: 49-57.

Petrzelka, Peggy and Ann Sorensen. (2014) "Women Non-Operating Landowners: Overcoming Barriers to increasing conservation on Leased Farmland Preliminary Report." Dekalb, IL: American Farmland Trust.

Petrzelka, Peggy, Zhao Ma and Stephanie Malin. (2013). "The elephant in the room: Absentee landowner issues in conservation and land management." *Land Use Policy* 30: 157-166.

Schwartz, Judith D. "Soil as Carbon Storehouse: New Weapon in Climate Fight?" *By Judith D. Schwartz: Yale Environment 360*. Yale Environment 360, 4 Mar. 2014. Web. 10 Apr. 2016.

Smith, Pete et al. (2007) "Greenhouse gas mitigation in agriculture." *Philosophical Transactions of the Royal Society B*, Issue: 'Sustainable agriculture II'.

Stevens, Andrew (2015) "The Economics of Soil Health: Current Knowledge, Open Questions, and Policy Implications."

Swan et al., "COMET-Planner: Carbon and greenhouse gas evaluation for NRCS conservation practice planning" http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf [Accessed 4/2/16]

USDA ERS (2015). "Ag and Food Sectors and the Economy." United States Department of Agriculture Economic Research Service. <http://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy.aspx> [Accessed 4/28/16]

USDA NASS (2015) a. "2015 State Agricultural Overview: California." National Agricultural Statistics Service, United States Department of Agriculture. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=CALIFORNIA [Accessed 4/28/16]

USDA NASS (2015) b. "2015 State Agricultural Overview: Iowa." National Agricultural Statistics Service, United States Department of Agriculture. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=IOWA [Accessed 4/28/16]

USDA (2014) "Farms and Farmland: Numbers, Acreage, Ownership, and Use." 2012 Census of Agriculture, United States Department of Agriculture.

World Bank (2013) "Agriculture & Rural Development." <http://data.worldbank.org/topic/agriculture-and-rural-development> [Accessed 3/12/2016]