

## **CONTENTS**

EXECUTIVE SUMMARY	3
INTRODUCTION	4
OPPORTUNITIES TO REDUCE EMISSIONS FROM AGRICULTURAL SOURCES	6
■ CROPS & SOILS	7
■ LIVESTOCK PRACTICES	9
ANIMAL WASTE	9
■ CROP WASTE	10
■ FARM OPERATIONS	10
■ RENEWABLE ENERGY PRODUCTION	10
BIOMASS PRODUCTION	10
CURRENT INCENTIVES AND PROGRAMS	11
■ BROAD-BASED CONSERVATION	12
■ FEDERAL PROGRAMS TARGETING SPECIFIC TYPES OF CONSERVATION ACTIVITIES	13
EXISTING FUNDING MECHANISMS FOR CLIMATE RESEARCH	14
CONCLUSION	15
POLICY RECOMMENDATIONS	16
ANNEX	17
REFERENCES	17

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# **EXECUTIVE SUMMARY**

In many ways, farmers are uniquely vulnerable to the effects of climate change, but they are also strategically positioned to be part of the solution. According to the Environmental Protection Agency, U.S. agriculture directly contributes about 10% of the total greenhouse gas (GHG) emissions of the entire national economy. However, with the right incentives, farmers can significantly reduce their emissions and sequester carbon on their land – thus turning the agricultural sector into a net carbon sink and taking large steps toward mitigating climate change.

It is increasingly important that farmers should take climate change seriously and work to turn from the current course – both for the future viability of the farming sector, as well as the security of global food supplies. Extreme weather is already intensifying: in 2019, for example, areas of the Midwest went from flooding to drought within the space of three months. Over the next several decades, the situation will only get worse: higher average temperatures and more variability in precipitation (resulting in more intense droughts and more extensive floods) are projected to lead to significant reductions in crop yields and livestock performance.

In addition, changes in climatic patterns are expected to make crops and animals more susceptible to pests and diseases, as well as expand the geographic ranges in which pests, diseases, and invasive weeds might flourish. There are countless examples of how this could be devastating. For the corn industry, hotter and drier summers in the U.S. Midwest could lead to more frequent problems with aflatoxin — a dangerous mold that would render harvests worthless. Some estimates find that increased aflatoxin contamination could cause losses to corn farmers valued at up to \$1.68 billion annually.

Fortunately, the U.S. agricultural industry already has strong solutions to help farmers reduce their emissions, sequester carbon, and mitigate climate change. These solutions vary by sector, but include implementing reduced tillage, cover cropping, rotational grazing, improved feeding practices for livestock, methane capture from livestock manure and crop waste, and improved energy efficiency for on-farm activities such as irrigation and crop drying, as well as the increased generation and use of renewable energy. If these practices were put into more widespread use, it could help the industry become a consistent net sink for GHG emissions.

The U.S. government already has a significant array of voluntary programs in place to encourage farmers to adopt these types of practices, primarily coming in the form of technical assistance, cost share assistance, and tax incentives. Some examples of current impactful government programs include the U.S. Department of Agriculture's (USDA) Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP), which combined will provide about \$2.55 billion in financial assistance for fiscal year 2021, under the provisions of the 2018 farm bill. There are also a number of federal incentives for production of energy from methane digesters, wind turbines, and solar panels. These include grants and guaranteed

loans under USDA's Renewable Energy for America Program (REAP), assistance for planning from AgStar, and loans under the Energy Efficiency and Conservation Loan program, both of which are operated jointly by USDA and the U.S. Department of Energy (USDOE).

And yet, in spite of these programs, government efforts remain inadequate and unfocused, as U.S. agriculture continues to generate significant GHG emissions. In order to change course, and ultimately encourage a critical mass of farmers to adopt sustainable practices, more resources are needed under all the federal programs described above. In addition, more funding is needed for agricultural research and development (R&D) to help farmers improve the efficiency of key inputs such as energy, fertilizer, and irrigation water. Advances in animal and plant genetics, for example, also offer opportunities to improve agriculture's GHG profile.

With the right encouragement and incentives, U.S. agriculture could be a climate change mitigation success story – moving from a significant contributor of GHG emissions to becoming a net carbon sink. This paper will outline a number of opportunities for reducing emissions from agricultural sources, and discuss how current incentives and government programs could be structured to maximize farmer participation. While climate change is a significant threat to the agricultural industry and global food supplies, it is not too late to turn course. Farmers can leap to the forefront of the broader U.S. campaign to mitigate climate change before it is too late.

# INTRODUCTION

Over the next several decades, climate change is expected to manifest in many ways: higher average temperatures and more variability in precipitation — resulting in more intense droughts and more extensive flooding, both of which are projected to lead to a significant reduction in crop yields and livestock performance. A recent study in the journal *Climate* found that under a high GHG emission scenario, corn, soybeans, and rice — three major crops produced in the U.S. — are predicted to see reductions in average yield of 23%, 15%, and 4%, respectively, by 2100 (Peterson, 2019).

Figure 1 below shows the projected decline in corn yield by the year 2100, assuming continued genetic improvement in corn seed available to U.S. farmers, under both high (yellow line) and low (pink line) greenhouse gas emission scenarios. These projections assume that the corn crop benefits modestly from so-called  $\mathrm{CO}_2$  fertilization, which posits increased photosynthesis and plant growth from higher rates of carbon dioxide in the atmosphere, but the analysis finds that effect to be overwhelmed by other negative factors caused by climate change.

# Continuous Tech Improvement, With CO<sub>2</sub> Fertilization U.S. Corn yield Past vs Future

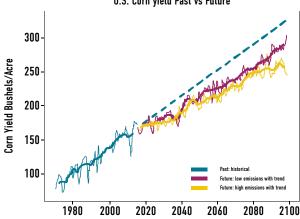


Figure 1. Projected U.S. Corn Yield Through 2100 with Impact from Greenhouse Gas Emissions.

In addition, changes in climatic patterns are expected to greatly affect the susceptibility of crops and animals to pests and diseases, as well as expand the geographic ranges in which pests, diseases, and invasive weeds might flourish. For example, hotter, drier summers in the U.S. Midwest could lead to more frequent problems in the region's corn crop with aflatoxin — a carcinogenic mold that would render harvests worthless. Some estimates find that aflatoxin contamination could cause annual losses to the corn industry of up to \$1.68 billion (Mitchell et al., 2016).

On the bright side, agriculture is one of the few sectors in the U.S. economy that has the potential to be a net sink for GHGs because of the ability to sequester carbon in soil. The greater the abatement of emissions and enhancement of sinks, the lower the net emissions, which would eventually enable the sector to become a net sink. There is likely an even greater possibility for agriculture to contribute to the nation's emissions reductions goals by producing biomass that is then used to produce fuels or electricity with carbon capture and geological storage of the carbon dioxide. However, for many of these abatement options to make economic sense to farmers, they would need to have access to incentives or at least observe advantageous changes in relative prices. There are also agricultural emissions that are more difficult to abate, in particular methane from ruminant livestock and paddy rice, and nitrous oxide stemming from nitrogen fertilizer application to the soil.

# Farmers should embrace the opportunity to adopt practices that help to mitigate the emissions that cause climate change for three primary reasons:

- Such adoption will collectively contribute to slowing GHG emissions and reduce the magnitude of its impacts;
- Evidence indicates that many of the practices that we will discuss in this paper can improve the agronomic performance of their crops, raise yields, and lower input costs over time;
- Through industry incentive programs and private carbon markets, many farmers will have the chance to capture additional benefits and/or income from adopting these practices. Many industry programs are driven by changing preferences of consumers, who are increasingly concerned about how their food is grown, not just how it tastes.

The structure of the U.S. agricultural industry has changed dramatically in the past few decades. It is more specialized and more complex. Farmers are facing greater demands by industry to demonstrate the sustainability of their production methods. But farmers, more than most other industries, also face very strong competitive pressure on prices. Integrating new low GHG practices require cash investment and investment of time and energy to understand these factors. And, the economics of farming is highly dependent on multiple markets, including for agricultural commodities, energy, inputs such as fertilizer, and potentially carbon markets. The focus of this brief is directed toward policies and programs administered by USDA, but it has also tried to emphasize how factors and programs outside of agriculture will affect what can be done in the sector.

In this policy brief, we briefly review the main GHG sources, sinks, and abatement options in agriculture. We then review the types and examples of current public sector incentives and programs at the federal level with an eye toward identifying gaps and an array of policy changes that might generate a more comprehensive set of policies and measures. The objective of this brief is to develop policy recommendations on how to improve the array of incentives to convince more farmers to adopt climate-smart agricultural practices.



#### WHAT IS CLIMATE-SMART AGRICULTURE?

Climate-smart agriculture (CSA) is an integrated set of practices that enable farmers to increase their productivity while adapting to, or even mitigating against, climate change.

CSA practices differ, depending on the type of farm. For instance, row-crop farmers might practice conservation tillage or cover cropping, leaving fields covered after the harvest with crop residue, grasses, or other plants for the purpose of preventing erosion and improving soil fertility. Livestock farmers, on the other hand, might use rotational grazing or feeding practices that reduce methane gas emissions. CSA can also include improving farming operations' energy efficiency, often through the use of wind, solar, or other interventions highlighted later in this report.

While CSA has a high potential for impact, encouraging widespread adoption of such practices in the U.S. remains a massive challenge. Current incentives, economics, and pricing structures need to change so that the cost of continued GHG emissions are better internalized in market prices – thus rewarding practices that reduce emissions.



#### AGRICULTURE'S SHARE OF U.S. GHG EMISSIONS

U.S. agriculture, including net CO<sub>2</sub> emissions from cropland, was responsible for approximately 10% of total U.S. GHG emissions in 2018, according to the 2020 U.S. EPA *Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018*. This share has been fairly stable for the past five years but is up slightly from about 8% in 2005. The figure below shows the main sources of agricultural emissions.

The EPA convention, following practice established by the Intergovernmental Panel on Climate Change, reports all emissions from the use of fossil fuels in the energy sector, including from fuels used in agriculture. In addition,  ${\rm CO_2}$  gains and losses from cropland are accounted under land use change in the EPA inventory and are not included in the figure. In 2018, according to the U.S. EPA inventory, cropland was a small net source of  ${\rm CO_2}$  emissions, at 38.4 MMT  ${\rm CO_2}$ , with conversions of forests and grasslands to cropland as a source of 55 MMT, and cropland gains in carbon from use of conservation practices as a sink of 16.5 MMT. Utilization of fossil fuels in farm operations are reported as energy sector emissions in the EPA inventory and are not broken out separately for agriculture.

The total food system fossil fuel  $CO_2$  emissions are alone almost 40% greater than all other emissions attributed to agriculture in the EPA inventory, but many of these emissions occur before (in the production of inputs) or beyond (in the processing and handling of agricultural products) the farm gate.

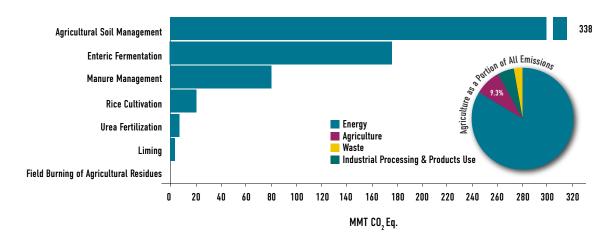


Figure 2: Greenhouse Gas Emissions Directly from Agriculture in 2018 in CO<sub>2</sub>-Equivalent. (Source: US EPA, 2020)

# OPPORTUNITIES TO REDUCE EMISSIONS FROM AGRICULTURAL SOURCES

While U.S. agriculture is currently a contributor to U.S. GHG emissions, there are many opportunities for farmers to reduce their carbon footprint. In particular, soil is one of the most powerful tools that farmers have for fighting climate change – healthy agricultural soils can be a natural sink for sequestering carbon and enable farmers to increase their productivity without clearing more land to grow crops. In the sections below, we touch on soil and many other climate-smart solutions, which span across the industry, from row crops to livestock.

#### **CROPS & SOILS**

Science of carbon sequestration. Growing plants remove CO<sub>2</sub> from the atmosphere. Carbon in plant residues that is left on the field's surface leads to increased soil organic carbon (SOC). This process is referred to as carbon sequestration. Higher levels of SOC lead to improvements in soil quality and fertility. Many of the practices which sequester carbon also enhance water retention in soils, which also helps farmers adapt to more variable precipitation patterns.

Relationship between soil organic carbon and agricultural practices. Higher levels of SOC mean less CO<sub>2</sub> in the atmosphere. Through measurements and modeling, scientists have concluded that upon

conversion of natural lands to cropland in the U.S., the carbon stocks in soils generally declined by as much as 50% through about the 1950s, and then stabilized and began to slowly increase around 1970 as shown for the Corn Belt soils in Figure 3. This pattern led to the conclusion that use of conventional tillage or other forms of disturbance increased the rate of soil carbon loss. Annual cropping may have produced less total biomass (both above and below ground) than a more diverse set of native vegetation (grasslands, shrubs, or forest), and forms of carbon that are more easily decomposed. The increase in SOC since the 1950s coincides with the widespread use of nitrogen fertilizer, resultant larger crop yields, denser crop planting, and more biomass production, leaving more residue than was generated by cropping practices used prior to the 1950s. In the 1970s, widespread adoption of conservation tillage also contributed to increased soil carbon in cropland. As indicated in the U.S. EPA inventory numbers cited above, soil carbon on existing cropland has continued to increase, although not at a rate needed to offset carbon lost from conversions to cropland. Nitrogen application (both inorganic and organic forms) increases crop yield but also increases nitrous oxide emissions, a very powerful and long-lived GHG, and considerable CO<sub>2</sub> emissions are associated with nitrogen production (Schlesinger, 1999).

Strategies to reduce other GHGs. Nitrogen application strategies that seek to more closely match the available nitrogen in forms the plant can use when it is needed (i.e. when the plant is growing rapidly) can reduce the total nitrogen applied and minimize the nitrogen that is lost either as a gas (nitrous oxide) or leached or run-off into ground or surface waters. There is often a focus on direct emissions of nitrous oxide from farm fields, but full accounting recognizes that additional nitrous oxide emissions result from nitrogen that runs off into streams and rivers (Mosier, et al., 1998). Finally, paddy rice production produces methane, another important GHG, as plant material decays under the anaerobic (without oxygen present) conditions found in the flooded rice paddy. Paddy rice is not a large crop in the U.S., accounting for less than 1% of area planted to principal crops in 2019. Draining the paddy at strategic times during the season can reduce methane production (Adhya, et al. 2014).

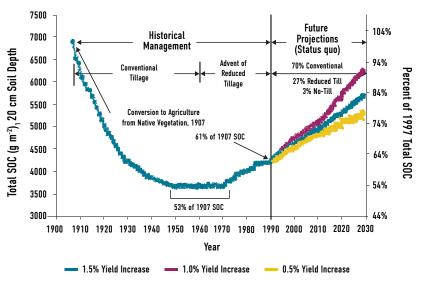


Figure 3. Soil Organic Carbon (SOC) Trends In The U.S. Corn Belt. Adapted From Donigian, A.S., Jr. et al. 1994

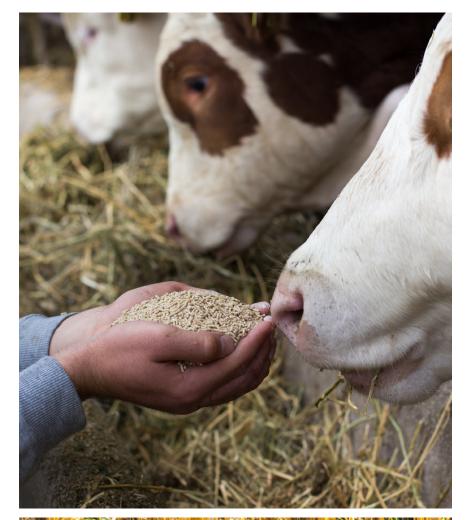
# KEY POLICY DESIGN ISSUES FOR ASSIGNING CARBON CREDITS FOR AGRICULTURAL PRACTICES

An important element of any effective policy design is how it ensures that incentives provided result in a permanent reduction in atmospheric CO<sub>2</sub>, including maintaining the carbon after accumulation has effectively ceased. If certain practices are incentivized via, for example, a cost share program, and the program is later terminated or conditions change, some or all of the carbon may return to the atmosphere as CO<sub>2</sub>. The relatively short period of time during which atmospheric CO<sub>2</sub> would be lowered in such a case would have almost no value in fighting the long-term problem of climate change.

For example, ongoing accumulation of soil organic carbon (SOC) requires continually more carbon left on the ground as residue or as roots in the topsoil than the amount being released by the soil as carbon dioxide into the atmosphere. Over long periods, production and decomposition will tend to come into balance, other things equal, leading to no more accumulation. But to maintain the climate benefit of SOC accumulation, the higher stock of SOC must either be maintained indefinitely, or offset by reductions in emissions or increases in sinks elsewhere. This requirement is often referred to as "permanence." As carbon additions begin to approach decomposition, rates of uptake decline and thus the policy process must take into account a mainly diminishing amount over time followed by a period of no net accumulation. If land use practices are reversed, the newly stored carbon can be rapidly emitted.

Various policy mechanisms for incentivizing emissions abatement in agriculture have been envisioned. One approach that has been examined extensively is the development of a carbon allowance market to control  $CO_2$  emissions from fossil energy in the general economy, with farmers allowed to sell carbon credits into the allowance market. The value of the credits would be a financial incentive for farmers to further abate emissions. Some authors have suggested that such credits should be discounted because there is a chance of some of the carbon not remaining permanently sequestered, and under some extreme conditions the value may have to be discounted 100%, making them worthless (Kim, et al., 2008). Another approach is to create a permanent liability when credits are sold. This change would make their land permanently a part of a cap and trade system (Reilly, et al. 2006; Reilly and Asadoorian, 2007). This would mean that the land would need to be permanently monitored and if carbon stocks fell, the current or any subsequent landowner would then need to acquire additional credits or allowances to cover the lost carbon, thus forcing a reduction in emissions elsewhere in the system. Such rules could complicate any subsequent sales of farmland with these types of restrictions in place.

A related policy concept is "additionality," the idea that incentive payments should increase abatement and not pay farmers for activities they would have done anyway. A recent USDA ERS report estimated additionality for a variety of conservation measures, ranging from about 50% to 80% (Claassen, et al. 2014). In a crediting system, this leads to the further concept of the baseline (Murray, et al., 2007). A baseline emissions level is one from which creditable reductions are estimated. A baseline that is above what emissions would have been anyway will mean that credit is given beyond additional abatement, but a baseline that is too low would mean that farmers and ranchers have no incentive to participate in such a voluntary credit system. If the agriculture sector were actually under a cap and trade system or an individual farm opted into such a system, then similarly their baseline emissions/sequestration level must be determined. Since such systems are capable of addressing equity concerns and efficiency implications separately, a very generous baseline could be assigned to those in the agricultural sector, making it profitable for farmers to opt-in to the system. However, to achieve the same net effect on the atmosphere, generous opt-in baselines would need to be offset with lower allowance allocations to the rest of the market participants (Reilly and Asadoorian, 2007).





#### LIVESTOCK PRACTICES

Methane emissions from livestock. Grazing animals such as cattle and sheep (known as ruminants), which primarily consume grasses, corn and wheat stubble, and other fibrous plant (cellulosic) materials, produce methane as part of the process of digesting food in their gastro-intestinal system. The methane is belched into the atmosphere. Improving feed quality and livestock management practices that create rapid weight gain or higher production of milk per animal have been the main options for reducing methane from ruminant animal production. Various additions to livestock diets have been shown to reduce methane. One recent discovery has found that under experimental conditions, particular types of seaweed added in relatively small amounts to the livestock diet can almost completely eliminate methane emissions without negatively affecting livestock digestion (Kinley and Fredeen, 2015; Kinley et al. 2016). Other research is underway to try to breed ruminant animals that utilize their feed more efficiently and thus emit less methane. Some scientists are approaching it from a conventional breeding approach with dairy cattle (Gonzalez-Recio et al., 2020), while others are exploring use of gene editing techniques such as CRISPR to improve the efficiency of bacteria that breaks down such materials in the animal's stomach (rumen) (Wallace et al., 2019).

#### **ANIMAL WASTE**

Agricultural waste presents both problems and opportunities. Large manure pits create anaerobic conditions, releasing methane as the manure decays. Vented to the atmosphere, methane is a powerful GHG. However, methane is the primary component of natural gas, and decomposition of manure and possibly other food processing wastes can be used to produce and collect methane to be used as an energy source. One estimate is that there is enough manure produced in the U.S. each year to generate methane that could supply 10% of the country's electricity needs (Zaks, et al., 2012). Other organic wastes, such as those produced in food processing, could also be incorporated into energy facilities. Because gas generation plays an important role in the power system, the ability to replace fossil-based natural gas would mean biogas could have an important role to play in a zero-emissions electricity system. While CO<sub>2</sub> is released in the combustion of the biogas, the plant growth that provided livestock feed takes up the CO<sub>2</sub>, so the entire cycle can result in net zero emissions. Residue from the methane generation process is also a useful fertilizer. Some types of animal manure can also be directly burned, replacing fossil fuels. Such technology is being used to incinerate poultry litter for energy in the U.K., but has seen limited adoption in the U.S.

The main barrier to further adoption of biogas generation is the cost. The most favorable conditions for development are large concentrated feedlots that can take advantage of economies of scale without significant transport cost. The economics of the process can be improved if it can be scaled up and serve a second purpose as a means of disposing of other organic food waste. But, with natural gas prices as low as they have been in recent years, cost competitiveness would likely depend on gas prices reflecting the full social cost of the CO<sub>2</sub> emissions.

#### **CROP WASTE**

Crop waste is also is a potential source of energy, with many studies investigating the use of corn stover, rice straw, or other plant waste as a source for ethanol production. Because this plant waste is cellulosic material like stalks, roots, and leaves, ethanol production from this feedstock depends on the development of inexpensive processes to first break down the material into starches and sugars that can be fermented into ethanol, blended into gasoline, or processed with new techniques to allow conversion to other renewable fuels that can be used to replace diesel, jet fuel, or gasoline. These latter products are known as "drop-in" fuels because they are nearly identical to petroleum-based fuels, requiring no adjustments or conversions to the engine or fuel system in which the fuel is being used. Predictions that the cost of cellulosic conversion could drop to make biofuels competitive with gasoline have not been proven. This is in part because gasoline demand and thus prices have not risen as quickly as many thought they would. Also, while plant waste is often touted as a virtuous source of biomass, it is often currently the residue that is left on the field, supporting or increasing the SOC (Wilhelm et al. 2007). And, lower soil organic matter generally reduces soil health, requiring more fertilizer, so the use of this "waste" material may not be as virtuous as often touted. Efforts to utilize this waste as a source of energy must be balanced against the need to build SOC in the farmland where the crop is grown and harvested (Obrycki et al., 2018). Dedicated perennial crops, such as switchgrass, grown on marginal land, are a more virtuous source of biomass for fuel, as they would not compete for land now in food production, and can lead to increases in carbon in these poor and degraded soils.

#### **FARM OPERATIONS**

The farm sector, like essentially all sectors of the economy, uses fossil fuels in a variety of ways. Diesel fuel and natural gas (fossilbased) are used to power farm machinery, pump water for irrigation, dry grains, and heat farmstead buildings. Any improvement in the efficiency in these systems, or in identifying ways to use them less (e.g. field sensors that turn on irrigation only when necessary) can reduce but not eliminate CO<sub>2</sub> emissions. Broader electrification, which would provide farmers the ability to power more of their farm operations directly with electricity, such as heating or cooling livestock facilities or drying grain, allowing them to greatly reduce their use of fossil fuels such as gasoline or diesel, is a potential option. While electric vehicles are seen as an attractive low-carbon option for light duty vehicles, there are now companies focused on designs that can power heavy duty trucks, possibly in combination with hydrogen fuel-cells. Greater use of bio-based drop-in fuels, sustainably produced, may be more promising, as they would not require replacement of existing machinery. Electricity-based heat pumps could supply heat where needed for crop drying or building conditioning. In general, the major barrier to these alternatives are that they require additional initial investment and are often more expensive than the currently used fossil fuels.

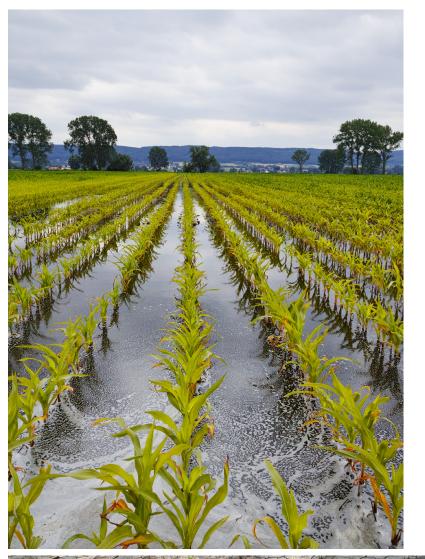
#### RENEWABLE ENERGY PRODUCTION

Quite apart from the energy used on the farm, farms and farmland are promising in terms of being able to deliver significant feedstocks for use in renewable energy production. Integration of utility-scale wind turbine installations on cropland is widespread, with minimal impact on the use of the land for crops, and provides a leasing income opportunity for the landowner. Utility-scale solar panel installation is also an opportunity, but the least costly installation takes place at ground level, replacing other uses for the land. Raising panels on to large poles or integrating installations into existing or new structures could make them compatible with other uses of the land. Farmers can also look into smaller-scale installations intended primarily to provide power needed on the farm.

#### **BIOMASS PRODUCTION**

In addition to cost, a barrier to a bio-based economy are concerns that allocating more land to biomass production will lead to the conversion of natural lands to crop production, and hence lead to a reduction of carbon in soils and vegetation, as well as the loss of other ecosystem benefits, while increasing the use of fertilizer and other inputs. The concern includes direct effects of land conversion to produce biomass, and more subtly, indirectly causes higher prices and more land use elsewhere including deforestation, perhaps on other continents. Searchinger et al. (2008) first raised this issue, estimating very high rates of deforestation in developing countries due to biofuel expansions. Other analyses take into account that not every new acre of biofuels means another acre of deforestation, estimating smaller indirect carbon losses (Taheripour, et al. 2010; Hertel, et al. 2010). In addition, some work has indicated that comprehensive incentives for increasing soil carbon would lead to intensifying production on existing crop and pasture land, making room for biomass production, and utilizing marginal and degraded lands so that the net effect would increase carbon stored in soils and vegetation (Reilly et al., 2014).





# CURRENT INCENTIVES AND PROGRAMS

In the U.S., public sector policies and programs that provide incentives to encourage farmers to adopt practices that help to mitigate climate change basically fall into two categories: 1) broad-based programs that provide assistance for adoption of a wide range of the practices described above, and 2) programs that target specific types of conserving agricultural practices.

We will provide examples of such programs at the federal level aimed at encouraging the adoption of the following types of practices:

- Crop cultivation practices that increase soil carbon and improve soil health;
- Animal husbandry and livestock feeding practices that reduce emissions of methane and nitrates;
- Practices that reduce emissions resulting from livestock or crop waste:
- Changes in farming operations that reduce usage of fossil fuels;
- Addition of on-farm activities that generate renewable energy.
- We will also briefly describe some types of publicly funded agricultural research that could help develop innovative techniques or inputs that farmers could use to further mitigate climate change.



#### AGRICULTURE'S ROLE IN CARBON CAP AND TRADE PROGRAMS

There is no federal policy in place to regulate GHG emissions on a nationwide basis. One such attempt was passed in the U.S. House of Representatives in June 2009, the so-called Waxman-Markey bill, which among other provisions would have established a carbon cap and trade system, but the legislation was never taken up by the Senate during that Congress.

However, in that same year that Waxman-Markey failed to advance, several states in the U.S. Northeast established a regional cap and trade market for GHGs, called the Regional Greenhouse Gas Initiative, or RGGI. Eleven states are now formal members of RGGI: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia. Initially, the emissions cap was set above actual emission levels, but emitters were required to purchase allowances through quarterly auctions. As of July 2019, these auctions had generated \$3.2 billion in revenue, which are used to invest in increasing renewable energy generation and expanding energy efficiency efforts (Ramseur, 2019). Currently, avoided methane emissions from livestock operations is the only approved offset activity from the agricultural sector under RGGI.

In 2013, the state of California launched a carbon cap and trade program to help reduce emissions of GHGs below 1990 levels by 2020, and 80% below 1990 levels by 2050. Under this program, large-scale industrial facilities such as power plants and fuel distributors are required to obtain emission allowances and cap their emissions, but those companies can also comply by obtaining offsets through the carbon trading market. The emissions of the state's agricultural sector are not capped under the program, but farmers and ranchers can benefit from it in two ways:

- Agricultural activities that sequester carbon are eligible to be considered as offset credits for the market, although
  only methane capture from livestock manure management and reduced methane emissions from rice cultivation
  have qualified to date (California Air Resource Board, 2020);
- Sustainable agricultural activities are eligible for investments from revenues generated by the emission allowances market. However, to achieve the same net effect on the atmosphere, generous opt-in baselines would need to be offset with lower allowance allocations to the rest of the market participants (Reilly and Asadoorian, 2007).

#### **BROAD-BASED CONSERVATION**

USDA's Natural Resources Conservation Service (NRCS) operates two major voluntary programs that provide financial and technical assistance to farmers wishing to implement conserving practices in their operations. The Environmental Quality Incentives Program (EQIP), first established in the 1996 farm bill, and the Conservation Stewardship Program (CSP), first established in the 2002 farm bill, are both known as "working lands programs" to distinguish them from other USDA programs focused on retiring environmentally sensitive farmland such as the Conservation Reserve Program, although they cover adoption of conserving practices in both crop and animal production. In general, financial and technical assistance is available to help farmers adopt practices addressing nearly all the categories listed above.

Under the 2018 farm bill, EQIP and CSP are provided \$1.8 billion and \$750 million respectively in mandatory funding for fiscal year 2021. Under EQIP, farmers may receive up to 75% cost-share for installing their practices, and up to 90% if they qualify as having limited resources or being socially disadvantaged, such as farmers beginning their farming career or military veterans. Under CSP, farmers are eligible for payments for implementing new practices under a CSP contract, which would cover some portion of the costs of doing so.

EQIP is statutorily required to allocate at least 50% of its funding on annual basis to livestock producers – reduced in 2018 from a 60% requirement set in the 2002 farm bill. These practices focused primarily on the management of animal waste (a major source of emissions of methane), brush management, and improving fencing and grazing practices. Other common practices funded under EQIP include cover cropping, improving irrigation systems, and residue management (Government Accountability Office, 2017).

Between fiscal years 2017 and 2019, cropland soil quality practices such as conservation tillage and cover cropping were implemented on 7.4 million acres due to financial assistance provided under CSP. Another 5.5 million acres had new grazing practices implemented under the program during the same period (NRCS/USDA, 2020). For purposes of comparison, there were 302 million acres planted to principal crops in 2019. Studies have found that practices such as rotational grazing can reduce GHGs by as much as 35% as compared to non-adopters when utilizing the practice for more than two years (Bogaerts et al., 2017). In 2018, NRCS estimated that cropland acres under CSP contracts retained more than 76 million pounds of soil organic carbon (NRCS, 2019).



Program history shows that there is almost always more demand for both types of assistance (financial and technical) than can be met under existing funding levels. Between 2000 and 2010, only about 40% of projects proposed under the EQIP program were actually funded on average, and farmers submitting requests for technical assistance often faced long waiting periods (Stubbs, 2011).

# FEDERAL PROGRAMS TARGETING SPECIFIC TYPES OF CONSERVATION ACTIVITIES

Conservation cover on cropland. In addition to the "working lands" programs just described, USDA also operates conservation programs designed to idle or retire farmland deemed to be environmentally sensitive and marginally productive. The largest of such programs, the Conservation Reserve Program (CRP), was established in the Food Security Act of 1985 (1985 farm bill). It allows farmers to withdraw certain farmland from production for 10 to 15 years in exchange for an annual rental payment. CRP contracts are awarded competitively, based on the anticipated environmental benefits generated from retiring the land and the rental rate the farmer is willing to accept. Farmland entered into the CRP is generally highly erodible or has other characteristics that make it environmentally vulnerable.

The land under CRP contract is generally planted in grass, legumes, forbs, or trees, and/or converted into wildlife habitat or wetlands, all of which help build carbon content in the soil. The Conservation Reserve Enhancement Program or CREP, is a part of the CRP that allows states to enter into agreements with USDA to use practices available under CRP to address state-identified conservation issues. Under CREP, states supplement federal funds to provide additional incentives for farmer participation. As of June 2020, there were

nearly 22 million acres enrolled in this program. A recent study of soil carbon content in CRP fields in Iowa found on average a nearly seven percentage point increase over a nine-year timeline, and those fields had statistically significant higher carbon concentration than neighboring corn fields (Magee, 2020). Overall, USDA has estimated that between 2012 and 2017, CRP reduced GHG emissions in CO<sub>2</sub> equivalents by 47 million metric tons annually on average (Farm Service Agency, 2018).

Conservation practices in the livestock sector. Improved grazing practices such as rotational grazing help to mitigate climate change by increasing the amount of carbon sequestered on pastureland. In addition, methane emissions from cattle produced in such a grazing system may also be lower than from cattle fed on conventional pasture systems. These practices are eligible for cost-share assistance under EQIP and CSP (Jensen et al., 2015).

Practices that reduce emissions from livestock or crop waste. Scientists discovered that methane was emitted from animal waste more than 200 years ago, and the first U.S. farm-based methane digester was installed at a Pennsylvania dairy farm in 1979. As of the 2017 Census of Agriculture, there were 686 farms that reported having methane digesters that converted cattle or hog waste into electricity for use on the farm, an increase of 28% from the previous Census in 2012. Such equipment can capture methane from any form of organic solid waste on the farm, but most such systems primarily utilize animal manure.

These systems are expensive, and even with cost-share assistance, they are out of reach for most farmers at this time. Estimates published by EPA in 2009 ranged from \$460,000 for a 160-cow operation up to \$2.7 million for a 2,800 dairy-cow operation (Lazarus, 2019).

There are several federal programs that provide such assistance. These include AgStar, which is a program run collaboratively by both EPA and USDA, to help with project planning and determining financial feasibility, the Rural Energy for America Program (REAP) operated by USDA which provides grants and/or guaranteed loans up to \$1.75 million per farmer, to help farmers install a range of renewable energy systems, and the Conservation Loan program, which provides loan guarantees for installing conservation practices and systems. Between 2008 and 2019, this loan program provided less than \$20 million in direct and guaranteed loans.

Changes in farming operations that reduce usage of fossil fuels. Some conserving cropping practices, such as reduced or no-till cultivation, cut farm usage of fossil fuels by reducing the frequency of combine or tractor operations in the field or the size of the farm equipment used, while increasing soil organic content. Improving irrigation efficiency by converting to drip irrigation or other lower-flow practices also reduces energy consumption due to less electric pump usage.

The adoption of precision agricultural technology allows for better targeting of a range of inputs, including fertilizer, pesticide, and irrigation water, to the portions of fields where it can be utilized most efficiently by the planted crops. Precision agriculture is especially beneficial when there is significant variability in soil type or slope conditions within fields. It also allows for reduced energy consumption because production of most of these inputs involve significant

energy expenditures as well. Studies have shown that variable rate application of nitrogen fertilizer (N) can reduce fertilizer use by row crops by as much as 48 pounds of N per acre for corn and up to 92 pounds of N per acre for winter wheat. These changes reduce farmers' costs of production while not adversely affecting crop yields. Such reductions would also reduce GHGs of nitrous oxide (N<sub>2</sub>O) and leaching and runoff losses from cropland (Adler et al., 2012).

Additional on-farm activities that generate renewable energy. In addition to generating energy from methane digesters, described above, many farmers are choosing to generate energy from other renewable sources within their farming operations. As reported in the 2017 Census of Agriculture, more than 90,000 farmers had installed solar panels on buildings or within fields, more than 14,000 farmers had purchased and installed wind turbines on their farms, and more than 20,000 farms had leased land to enable other parties to erect wind turbines (NASS/USDA, 2019). Over the last decade or so, some farmers have experimented with producing renewable fuels, primarily biodiesel, on their own farms, but this activity has not yet been shown to be commercially viable, although it does reduce GHGs compared to using conventional fuels (Fredriksson et al., 2006).

There are a number of federal incentives for production of wind and solar power, both on and off the farm. Grants and guaranteed loans under USDA's REAP described above, and loans under the Energy Efficiency and Conservation Loan program, operated jointly by USDA and the U.S. Department of Energy (USDOE), are available for installing these types of equipment. Farmers who install solar panels and wind turbines are also eligible for production and investment tax credits (Office of Energy Efficiency and Renewable Energy, USDOE), although these programs are typically enacted only a year at a time by Congress as part of the so-called tax extenders package, and can sometimes lapse for months at a time.

# EXISTING FUNDING MECHANISMS FOR CLIMATE RESEARCH

The Conservation Innovation Grant (CIG) Program was added to the EQIP program in the Farm Security and Rural Investment Act of 2002 (2002 farm bill), and provides for competitive grants to "stimulate innovative approaches to leveraging federal investments in environmental enhancement and protection." For fiscal year 2020, a total of \$40 million was available under this program—one of the five identified priorities in the FY20 notice was energy conservation. Grants under this program can range in size from \$150,000 to \$2 million, and must be fully matched through non-federal in-kind or cash contributions. Eligible recipients include non-federal government agencies, non-governmental organizations (NGO's), and individuals.

The 2018 farm bill established on-farm conservation trials as part of the CIG program to provide funding directly to partners, who can then offer technical assistance and payments to producers interested in implementing innovative conservation practices on their land. More resources for this program would be very helpful to expanding adoption of conservation practices, especially now that it can provide incentive payments to farmers to allow them to adopt experimental

practices under such a trial without putting their financial bottom line at risk, and share their findings with their neighbors.

In addition, projects relevant to climate change mitigation and adaptation efforts are often undertaken at USDA's research agencies, primarily the Agricultural Research Service and the Economic Research Service, or funded through formula funds or competitive grants overseen by the National Institute of Food and Agriculture.

The Foundation for Food and Agriculture Research (FFAR), a nonprofit foundation established in the Agricultural Act of 2014 (2014 farm bill) with mandatory funding that requires non-federal matching funds for projects, has awarded a number of grants in this area as well over the past several years. The Foundation is one of several funders of the so-called RIPE project headquartered at the University of Illinois, which is seeking to improve the efficiency of the photosynthetic process, which is the conversion of energy from the sun and carbon dioxide into plant matter. Their initial work has focused on cowpeas, cassava, rice, and soybeans. This research could help farmers by creating crops that thrive with increased carbon dioxide levels and hotter temperatures. Crops with enhanced photosynthetic capacity could also be produced using less nitrogen fertilizer, which is also a mitigation benefit.

While these initiatives are impactful, more resources are still needed for climate-smart agricultural research. A recent report from the Supporters of Agricultural Research (SoAR) Foundation highlighted several key focus areas where more research is needed for plant-based agriculture. These included research into improved plant genetic diversity, climate modeling, soil health, nutrient and wateruse efficiency, and tracking and treating plant pests and pathogens. As the effects of climate change are rapidly evolving, it is exceedingly important that stakeholders prioritize research that delivers solutions that keep pace.





# **CONCLUSION**

The examples reviewed above highlight the availability of various policy mechanisms used at the federal levels that have been developed to provide incentives for farm practices that are "climate smart." These include direct cost share, loans, tax credits, and broad measures that create a demand for carbon credits or renewable fuels from which farmers can benefit. Many of the federal programs are run by the USDA, but as highlighted above, DOE and EPA programs are also available to farmers, as are tax incentives for renewable energy. The cooperation between agencies in these programs should be applauded and encouraged to go further. For many of the cost share and loan programs available, funding is limited, as evidenced by the fact that only a fraction of the projects proposed under them can be funded in any given year. Furthermore, despite these various programs, GHG emissions from the agricultural sector have not declined and, if anything, have increased slightly since 2005, while emissions in the rest of the economy generally have declined.

With soil management as the largest single source of emissions, more attention is needed to address nitrogen fertilization practices that can reduce nitrous oxide emissions from soils. Methane from ruminant animals and animal waste are also major sources of GHGs. Eliminating methane from livestock waste and turning it into a source of energy is a well-established technology, but not cost-competitive. Innovative approaches for creating an industry around waste-to-energy could help, but market conditions likely need to change to make this a viable economic proposition. There is now scientific evidence that some natural feed additives can significantly reduce methane emissions from ruminant livestock. Further demonstration of the efficacy and efforts to scale up the harvest or production of additives is needed. And, the potential for a bio-based economy has largely been derailed by very low-cost fossil fuels. A big gap in making many of these practices more economical is the lack of a carbon price that reflects the full social cost of using fossil fuels, including the damage from CO<sub>2</sub> emissions.

The structure of the agricultural industry has changed dramatically in the past few decades. It is more specialized and more complex. Farmers are facing greater demands by industry to demonstrate the sustainability of their production methods. But farmers, more than most other industries, also face very strong competitive pressure on prices. Integrating new low GHG practices requires cash investment and investment of time and energy to understand these factors. And the economics of farming is highly dependent on multiple markets, including for agricultural commodities, energy, inputs such as fertilizer, and potentially carbon markets. The focus of this paper is directed toward policies and programs administered by USDA, but it has also tried to emphasize how factors and programs outside of agriculture will affect what can be done in the sector. For example, certification of carbon credits will not have much value if there is not a robust carbon market in the U.S. It's clear that to meet the grand challenge of ending global hunger by 2030 (as enunciated by UN Sustainable Development Goal #2), under the more difficult conditions caused by climate change, the U.S. government needs to double down on providing farmers with more and better incentives to adapt their practices to this changing world.

# POLICY RECOMMENDATIONS

Given the opportunities and challenges presented in this paper, we believe that policymakers should consider the following recommendations:

- Increase funding for federal programs that help farmers reduce GHG emissions, such as the Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), the Rural Energy for America Program (REAP), and the Conservation Loan Program. The current funding levels appear to meet only a fraction of the demand for these funds. Congress should also prioritize funding for practices that reduce GHG emissions and/or sequester carbon, such as the 35 practices listed under the NRCS ranking system discussed in the annex.
- Increase funding for agricultural research that helps farmers adapt to and mitigate the effects of climate change. Funding could prioritize investigating methods of reducing methane emissions by livestock, making methane digesters more affordable to small and medium-sized farming operations, and evaluating the economic benefits to farmers from adopting climate-smart practices. For plant research, key focus areas also include plant genetic diversity, climate modeling, soil health, nutrient and water-use efficiency, and addressing pests and diseases (SoAR Foundation, 2018). The federal government should also support private sector initiatives by supporting research into developing better tools such as sensors for measuring and monitoring changes in GHG emissions or SOC content in soils. In order to better leverage these dollars, policymakers should consider allocating at least some of the increased funding to be distributed through the Foundation for Food and Agriculture Research, which has demonstrated the efficacy of the public-private partnership funding model.
- Reintroduce and pass the Growing Climate Solutions Act.
  In June 2020, the Growing Climate Solutions Act (S.3894) was introduced in the U.S. Senate on a bipartisan basis by four Senators—Senators Mike Braun (R-IN), Debbie Stabenow (D-MI), Lindsey Graham (R-SC), and Sheldon Whitehouse (D-

- RI). An identical version of the bill was also introduced in the House of Representatives and has 21 sponsors or co-sponsors from both parties. The legislation would set up a program to help create a pool of accredited technical assistance providers and third party verifiers to help farmers. Once up and running, this program will enable USDA to provide transparency, legitimacy, and informal endorsement of such personnel that help private landowners generate marketable carbon credits through a variety of agricultural and forestry related practices. This bill has broad support from both the U.S. agricultural and environmental communities.
- Make it more affordable for farmers to adopt more radical and highly impactful interventions to improve their energy efficiency. In particular, the Energy Efficiency and Conservation Loan program has the potential to have a much greater impact if financial and technical support were increased to enable more farmers to participate. In addition, subsidies for farm-level renewable energy generation, such as through methane digesters and wind turbines, should be either added to existing programs or authorized through a new program.

### ANNEX

A USDA guide to less GHG-intensive agricultural production.

The Natural Resources Conservation Service of the USDA has created a GHG and Carbon Sequestration Ranking Tool <a href="https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/climatechange/?cid=stelprdb1044982">https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/climatechange/?cid=stelprdb1044982</a>, and from a list of hundreds of farm practices have identified those that reduce GHG or sequester carbon (NRCS/USDA, 2014). Qualitative rankings identify those with better performance. As is probably clear from the discussion above, the efficacy of many practices varies with climatic conditions and other factors, hence the qualitative nature of the rankings. This list is, however, a useful starting point.

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