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Legal Pathways to Carbon-Neutral Agriculture

by Peter Lehner and Nathan A. Rosenberg

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Summary

This Article, excerpted from Michael B. Gerrard & John C. Dernbach, eds., *Legal Pathways to Deep Decarbonization in the United States* (forthcoming in 2018 from ELI), examines the agricultural strategies, practices, and technologies available to increase soil carbon sequestration and reduce greenhouse gas emissions. It details pathways for amending existing federal and state legal regimes and enacting new ones, and recommends improving public agricultural research, development, and extension efforts; reforming federal subsidy and conservation programs; and revising trade policy, tax policy, regulatory strategies, financing for carbon farming, grazing practices on government land, and greenhouse gas pricing. It also describes how the private and philanthropic sectors can stimulate carbon farming; strategies for reducing emissions that stem from farm inputs and that result from food processing, distribution, consumption, and waste; and the potential to encourage consumption of climate-friendly foods through national dietary guidelines, procurement at all levels of government, and private-sector initiatives such as certification schemes and healthier menu options.

I. Introduction

Agriculture is both a source and a sink for greenhouse gases. Decisionmakers can take full advantage of agriculture's potential to slow climate change only by acknowledging the sector's dual role in decarbonizing the economy, and seeking both to minimize agricultural greenhouse gas emissions and to maximize carbon storage.

Two terms are commonly used to describe agricultural methods that reduce net agricultural emissions. The first, "climate-friendly," refers to practices or strategies that reduce greenhouse gas emissions or increase soil carbon sequestration when compared to conventional methods. While superior to standard practices, climate-friendly practices are not necessarily optimal, both in terms of their climate benefits or their overall benefit to society. In contrast, "carbon farming" describes a suite of climate-friendly practices and strategies designed to result in optimal environmental, societal, and climate outcomes.[1]

Decisionmakers should prioritize climate-friendly practices that reinforce carbon farming systems. Although many Republican leaders, as well as rural voters, tend to ignore or doubt climate science, the many benefits of climate-friendly practices provide independent reasons for their adoption. Although not the norm currently—and not widely supported by agrochemical companies and other traditional sources of information—climate-friendly practices almost always improve soil health and thus can increase farm yield, enhance resilience to climate change, and often increase profitability (especially over the longer term). Thus, decisionmakers, regardless of their position on climate change, should strongly support broader adoption of these practices to assist farmers and ranchers and rural communities, and to protect basic environmental needs such as clean air and water.

Authors' Note: We wish to thank Alexis Andiman, Andrew Bowman, Michael Castellano, Adam Chambers, Alyssa Charney, Craig Cox, Marcia DeLonge, Graham Downey, Thomas Driscoll, Mark Easter, William Eubanks, Scott Faber, Elizabeth Hanson, Claire Horan, Wendy Jacobs, Allen Olson, Keith Paustian, Margot Pollans, Susan Schneider, Tyler Smith, Edward Strohbehn, Margaret Torn, Jim Williams, and Seth Watkins for voluntarily taking the time to review the draft Article and for offering many helpful comments. We also thank the participants of the Legal Pathways to Deep Decarbonization workshop at Columbia Law School for their suggestions. We are especially grateful to John Dernbach and Michael Gerrard for their many ideas and insightful edits and comments.

1. "Carbon farming" includes grazing and animal husbandry. Eric Toensmeier, The Carbon Farming Solution 6 (2016). "Regenerative agriculture" is another term for largely overlapping agricultural practices. *See generally* Rodale Inst., Regenerative Organic Agriculture and Climate Change.

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This Article begins by examining the on-field strategies, practices, and technologies available to increase soil carbon sequestration and reduce agricultural emissions. It then details public law pathways—amending existing federal and state legal regimes and enacting new ones—for reducing net agricultural emissions. It recommends improving public agricultural research, development, and extension efforts; reforming federal subsidy and conservation programs; and revising trade policy, tax policy, regulatory strategies, financing for carbon farming, grazing practices on government land, and greenhouse gas pricing.

The Article also briefly describes non-public law approaches, focusing on how the private and philanthropic sectors can stimulate carbon farming; strategies for reducing upstream emissions—those that stem from farm inputs—and downstream emissions—those that result from food processing, distribution, consumption, and waste; and, finally, the potential to encourage the consumption of climate-friendly foods through national dietary guidelines, procurement at all levels of government, and private-sector initiatives such as certification schemes and healthier menu options.

II. Agriculture's Role in Deep Decarbonization

A. Greenhouse Gas Emissions in the Food System

The food system encompasses the full life cycle of food. In addition to agriculture, this includes activities that take place off the farm—from the pre-planting conversion of native grasslands and production of agricultural chemicals to the post-harvest distribution, consumption, and disposal of food.[2] The food system is responsible for an estimated 19-29% of both national and global greenhouse gas emissions.[3] Decisionmakers must approach the food system as a whole to craft laws and policies that address the system's full complement of social, nutritional, and environmental impacts.

Agriculture refers to the cultivation of crops and the raising of animals for the "4Fs": food, feed, fuel, and fiber. It accounts for 51% of the country's total landmass and 61% of the landmass of the contiguous 48 states, making it the single largest type of land use in the United States.[4] Of the country's total 2.3 billion acres, approximately 408 million acres are in use as cropland, 614 million acres as grassland pasture and range, and 127 million acres as grazed forestland.[5] As a result of agriculture's large footprint, relatively small changes in agricultural practices, which may have a modest impact per acre, can significantly affect this sector's contribution to climate change if they are widely implemented. Small changes can also improve farmers' and ranchers' ability to adapt to the changing climate.

A core concept of this Article is that carbon sequestration should be added to this list of the fundamental aims of agriculture, as well as to the federal programs and policies that support it. Achieving climate stability is as critical a human need as the other functions of agriculture. By reducing greenhouse gas emissions while also increasing soil carbon stores, agricultural operations can make a substantial contribution to decarbonization in the United States.

I. Greenhouse Gas Emissions From Agriculture

The U.S. Environmental Protection Agency (EPA) estimates that emissions from agriculture account for approximately 9% of total U.S. greenhouse gas emissions each year.[6] Unlike the energy and transportation sectors, which emit primarily carbon dioxide as fossil fuels are burned, crop and livestock greenhouse gas emissions consist largely of nitrous oxide and methane. Nitrous oxide is a particularly potent greenhouse gas—the average radiative forcing of nitrous oxide is 265-298 times that of carbon dioxide over 100 years.[7] Nitrous oxide emissions will also be the primary cause of stratospheric ozone destruction this century.[8] Like nitrous oxide, methane is a powerful greenhouse gas; the average radiative forcing of methane is about 28-34 times that of carbon dioxide over 100 years.

In 2015, total agricultural emissions of nitrous oxide and methane amounted to about 520 million metric tons of carbon dioxide equivalent.[9] In other words, agriculture released an amount of greenhouse gases roughly equivalent to that produced by 111 million automobiles in a typical year.[10] Agriculture is responsible for about 80% of U.S. nitrous oxide emissions and about 35% of U.S. methane emissions, only slightly less than the methane emissions of natural gas and petroleum extraction, processing, and distribution.[11]

The largest source of U.S. agricultural greenhouse gas emissions is agricultural soil management—a series of practices intended to improve crop yields, including fer-

2. Sonja Vermeulen et al., *Climate Change and Food Systems*, 37 Ann. Rev. Env't & Resources 195, 198-202 (2012).
3. *Id.* at 195.
4. Cynthia Nickerson et al., Econ. Research Serv., U.S. Dep't. of Agric., Major Uses of Land in the United States, 2007, at 4 (2011) (EIB-89).
5. *Id.*
6. U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks (last visited Aug. 1, 2017).
7. Intergovernmental Panel on Climate Change (IPCC), Climate Change 2013: The Physical Science Basis 714 (2014). Table 8-7 presents these and other "global warming potential" values.
8. Akkihebbal R. Ravishankara et al., *Nitrous Oxide (N_2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century*, 326 Science 123, 123-25 (2009).
9. U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015, at 5-1 (2017).
10. *Compare id. with* U.S. EPA, Greenhouse Gas Emissions From a Typical Passenger Vehicle (2014) (a typical passenger vehicle emits 4.7 metric tons of carbon dioxide annually).
11. *See* U.S. EPA, *Overview of Greenhouse Gases: Nitrous Oxide Emissions*, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide (last visited Aug. 1, 2017); U.S. EPA, *Overview of Greenhouse Gases: Methane Emissions*, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane (last visited Aug. 1, 2017).

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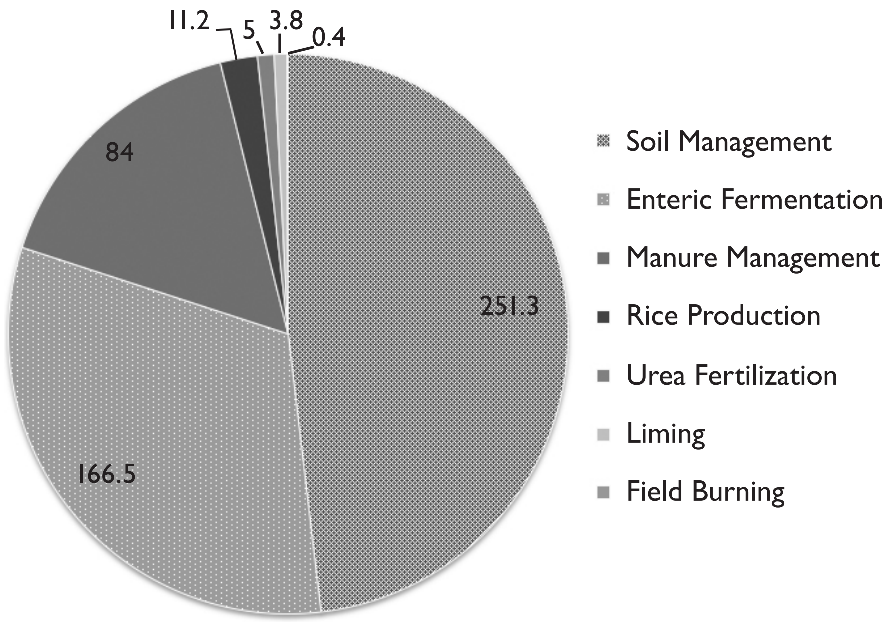
tilization, tillage, drainage, irrigation, and fallowing of land.[12] Soil management generates 48% of all U.S. agricultural emissions and 93% of all U.S. nitrous oxide emissions.[13] Seventy-four percent of nitrous oxide emissions from agricultural soil management come from cropland and 26% come from grazed grasslands.[14]

The next largest source of agricultural emissions is enteric fermentation, which results from the digestive process of ruminants (largely cows and sheep in the United States). Enteric fermentation creates methane, which animals subsequently release into the atmosphere through belching and exhalation.[15] Enteric fermentation is responsible for 32% of all agricultural emissions and 25% of methane emissions in the United States.[16]

Fig. 1. Major Sources of Agricultural Emissions in the United States



Manure management activities are the third major category of U.S. agricultural emissions, releasing nitrous oxide and methane in quantities that total 16% of total U.S. agricultural emissions.[17] Intensive livestock facilities, colloquially known as factory farms and called concentrated animal feeding operations (CAFOs) by federal law, generate the substantial majority of these emissions.

Methane emissions released from soils flooded for rice cultivation and the field burning of crop residues make up an additional 2% of total U.S. greenhouse gas emissions from agriculture.[18] In 2015, EPA included carbon dioxide emissions from urea fertilization and liming in its estimate of agricultural emissions for the first time.[19] Together, these two sources are responsible for less than 2% of agricultural emissions.[20]

The vast majority of agricultural emissions are related to animal production. This is due, in part, to the large amount of land used to grow animal feed: approximately one-half of all harvested cropland is devoted to feed crop production.[21] This cropland is often cultivated more intensely than cropland growing human food, with the result that feed crop production can emit more nitrous oxide per acre than the production of crops for human consumption.[22] Moreover, feed crop cultivation produces more calories per acre than human food crops, with the result that nonhuman animals eat two-thirds of the calories derived from crops grown in the United States. However, only a fraction of those crop calories are delivered to humans because, for example, the production of one pound of beef from feedlot cattle requires 15-20 pounds of grain.[23]

Thus, despite the greater use of resources devoted to animal production,[24] humans receive only 30% of their calories from animal products.[25] Because grazing and feed crop production contribute almost two-thirds of nitrous oxide emissions from agricultural soils,[26] and because animals are the

12. EPA, *supra* note 9, at 5-21, 5-22.
13. *See id*. at 5-2.
14. *See id*. at 5-24 tbl. 5-15.
15. Andy Thorpe, *Enteric Fermentation and Ruminant Eructation: The Role (and Control?) of Methane in the Climate Change Debate*, 93 Climate Change 407, 411 (2009).
16. *See* EPA, *supra* note 9, at ES-15, 5-2.
17. *See id*. at 5-2 tbl. 5-1.
18. *See id*.
19. *See id*.
20. *See id*.
21. There were approximately 310 million acres of harvested cropland in 2007 according to the Census of Agriculture. Nat'l Agric. Statistics Serv., U.S. Dep't of Agric., 2007 Census of Agriculture: U.S. National Level Data 16 tbl. 8 (2009). The U.S. Department of Agriculture (USDA) estimates that approximately 165 million of those acres were devoted to feed crops; however, up to 10% of the feed was diverted to biofuels. Nickerson et al., *supra* note 4, at 20. This total does not include soybeans, which USDA considers a "food crop," despite the fact that soybean meal is typically used as animal feed. Tani Lee et al., Econ. Research Serv., USDA, Major Factors Affecting Global Soybean and Products Trade Projections (2016).
22. Conventionally grown feed crops, such as corn, soybean, and hay, generally result in high nitrous oxide emissions. *See* EPA, *supra* note 9, at 5-23.
23. The feed conversion ratio expresses the number of pounds of grain necessary to increase the "live weight" of a head of cattle by one pound. At industrial feedlots, a feed conversion ratio of 6:1 is common. Dan W. Shike, Beef Cattle Feed Efficiency 3 (2013). Thirty to forty percent of the live weight of a head of cattle is sold as beef, which means that 15-20 pounds of grain is necessary to yield one pound of beef. *See* Rob Holland et al., Univ. of Tenn. Inst. of Agric., How Much Meat to Expect From a Beef Carcass 9 (PB-1822).
24. *See* Emily Cassidy et al., *Redefining Agricultural Yields: From Tonnes to People Nourished Per Hectare*, 8 Envtl. Res. Letters 1, 4 (2013). This figure is based on data from 1997-2003. Biofuel production has increased rapidly since then, likely resulting in a lower proportion of crops devoted to either feed or food.
25. USDA Econ. Research Serv., *Seventy Percent of U.S. Calories Consumed in 2010 Were From Plant-Based Foods*, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=81864 (last updated Jan. 6, 2017).
26. This includes grassland emissions, which account for 65.6 million metric tons of carbon dioxide equivalent (MMT CO_2 eq.), as well as 48% of cropland emissions—the approximate percentage of harvested cropland devoted to feed crop production in 2007—which adds an additional 89 MMT CO_2 eq. *Com-*

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major source of agricultural methane emissions, meat and dairy production account for almost 80% of agriculture's greenhouse gas emissions in the United States.[27]

2. Soil Carbon Sequestration by Agriculture

Agricultural activities not only emit greenhouse gases but can change the amount of carbon stored in soils, thus effectively releasing or absorbing carbon dioxide. Scientific studies have identified a number of agricultural practices that could help to slow climate change by capturing carbon. For example, in 2016, researchers concluded that the expansion of existing U.S. Department of Agriculture (USDA) conservation practices could lead to the sequestration of 277 million metric tons of carbon dioxide equivalent annually by 2050.[28] Capturing this volume of carbon in the soil would cut net agricultural greenhouse gas emissions in half.

Similarly, agroforestry (incorporating trees and shrubs into cropland and pastureland) and perennial agriculture (plants that live year-round and do not need annual replanting, thus disturbing the soil less) offer significant climate benefits by locking carbon in the perennial biomass of the plant roots and shoots and stimulating a more biodiverse ecosystem that stores more carbon. According to a 2012 study, the widespread adoption of agroforestry practices in the United States could sequester 530 million metric tons of carbon dioxide equivalent each year, thereby transforming agriculture into a carbon sink.[29]

Like cropland, rangeland used for livestock grazing can also sequester carbon. Overgrazing has damaged vegetation and degraded soil quality across the western United States, resulting in the release of carbon that would otherwise remain locked in organic matter.[30] However, reducing the intensity of use and adjusting the timing of grazing to facilitate plant growth can repair these landscapes[31] and restore their function as carbon sinks.[32]

As these examples demonstrate, methods to mitigate agriculture's net contribution to climate change already exist. However, policies must recognize that biological sequestration is reversible and limited. Climatic events, such as droughts or wildfires, or human actions, such as resumed tillage, increased grazing, or deforestation, can quickly destroy biomass and disrupt soils, thereby releasing stored carbon.[33] In addition, gains in soil carbon slow as soils approach a new equilibrium under improved management practices.[34] (Additional research is needed to clarify how quickly this occurs, but location, prior soil quality, and land management practices all appear to be important factors.[35])

While sequestration alone cannot offset ever-increasing greenhouse gas emissions, it remains a necessary strategy for avoiding catastrophic climate change. Current levels of atmospheric carbon are so dangerously high that we cannot choose between reducing emissions and sequestering carbon.[36] We must do both.

B. *Agricultural Practices for Reducing Greenhouse Gas Emissions*

To implement sound policy and pursue effective legal strategies, decisionmakers and advocates must become familiar with the climate-friendly agricultural practices that, together, comprise carbon farming. Accordingly, this section briefly reviews the tools and technology available to reduce agricultural greenhouse gas emissions and sequester carbon on cropland, grazing lands, and at animal feeding operations (AFOs).

1. Cropland

Responsible management of croplands should aim to reduce greenhouse gas emissions while simultaneously increasing carbon sequestration. The main sources of greenhouse gas emissions from cropland are synthetic and organic fertilizers, which release nitrous oxide, and soils, which release carbon dioxide.[37] The Article first describes farming methods to reduce nitrous oxide emissions and three methods to reduce net carbon dioxide emissions by increasing the organic matter content of soil—reducing tillage, increasing carbon inputs from crops, and adding soil amendments, respectively. Such healthier soils can also require less fertilizer, decreasing nitrous oxide emissions.

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pare EPA, *supra* note 9, at 5-2 tbl. 5-1 (showing annual emissions from agriculture by source), *with supra* note 21 (explaining how the percentage of harvested cropland devoted to feed crop production was calculated). Together, they are responsible for 154.6 MMT CO_2 eq. annually, or 62% of all emissions from agricultural soils. This total does not include the approximately 16.5 million acres devoted to the production of biofuel feedstock. *See supra* note 21.

27. This includes emissions from enteric fermentation and manure management and nitrous oxide emissions from agricultural soils devoted to feed crop production or grazing. Together, they are responsible for 405.1 MMT CO_2 eq. annually, or 78% of agricultural emissions. *Compare* EPA, *supra* note 9, at 5-2 tbl. 5-1 (showing annual emissions from agriculture by source), *with supra* note 26 (calculating emissions from agricultural soils devoted to feed crop production or grazing).

28. Adam Chambers et al., *Soil Carbon Sequestration Potential of U.S. Croplands and Grasslands: Implementing the 4 Per Thousand Initiative*, 71 J. Soil & Water Conservation 68A, 70A (2016).

29. Ranjith P. Udawatta & Shibu Jose, *Agroforestry Strategies to Sequester Carbon in Temperate North America*, 86 Agroforestry Sys. 225, 239 (2012).

30. *See* John Carter et al., *Moderating Livestock Grazing Effects on Plant Productivity, Nitrogen, and Carbon Storage*, 17 Nat. Resources & Envtl. Issues 191, 191-92 (2011).

31. Sherman Swanson et al., *Practical Grazing Management to Maintain or Restore Riparian Functions and Values on Rangelands*, 2 J. Rangeland Applications 1, 10-14 (2015).

32. David Lewis et al., Univ. of Cal. Coop. Extension, Creek Carbon: Mitigating Greenhouse Gas Emissions Through Riparian Revegetation 22 (2015).

33. Uta Stockmann et al., *The Knowns, Known Unknown, and Unknowns of Sequestration of Soil Organic Carbon*, 146 Agric., Ecosystems & Env't 80, 82 (2012).

34. Catherine Stewart et al., *Soil Carbon Saturation: Concept, Evidence, and Evaluation*, 86 Biogeochemistry 19, 25-28 (2007); Stockmann et al., *supra* note 33, at 94-95.

35. Stockmann et al., *supra* note 33, at 82.

36. *See* Marcia DeLonge, *Soil Carbon Can't Fix Climate Change by Itself—But It Needs to Be Part of the Solution*, Union Concerned Scientists, Sept. 26, 2016, http://blog.ucsusa.org/marcia-delonge/soil-carbon-cant-fix-climate-change-by-itself-but-it-needs-to-be-part-of-the-solution.

37. *See* Amy Swan et al., COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning 3, http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf.

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The Article next describes three agricultural practices that offer a range of climate benefits—organic farming, agroforestry, and perennial agriculture, respectively. It further explains the importance of prioritizing the production of crops that provide people with healthy food, instead of those that primarily become processed food, animal feed, and biofuels, and thus have a much greater climate impact. Finally, it examines practices rice producers can adopt to reduce methane emissions.

❑ *Improve management practices for synthetic fertilizers*. Because plants utilize nitrogen from the soil and crops carry it away from the field after harvest, fields must eventually be replenished. This is typically accomplished through the application of synthetic or organic nitrogen fertilizer. However, farmers routinely apply fertilizer at higher rates than crops require for a variety of reasons—as a form of insurance or risk avoidance, hope for a great year, over-focus on yield over return, habit, and misinformation.[38] On average, only 50% of the nitrogen applied as fertilizer to annual grains is removed at harvest.[39]

Similarly, a 2011 study found that farmers applied at least 40% more nitrogen than the prior harvest removed on nearly one-third of acres planted with key commodity crops.[40] Because excess fertilizer is now routinely applied, farmers can apply fertilizer less frequently—and, when necessary, apply less fertilizer per acre—without reducing yield. When they do this, they will also reduce the amount by which the supply of nitrogen in the soil exceeds the demand for nitrogen by crops, thus limiting the availability of excess nitrogen that is lost to the environment, including as nitrous oxide.[41]

In general, best practices for fertilization include reducing the rate of application so that nitrogen supply is closer to the level demanded by crops, improving the timing of application so that nitrogen is available when crops can best utilize it, and varying the placement of nitrogen within fields to account for spatial variability in utilization by crops. These practices are routinely grouped by fertilizer companies, industrial farmers, and many extension programs as the "4Rs": apply the right fertilizer product, at the right rate, using the right method, and at the right time.[42]

Even if the rate of fertilizer application matches crop needs, improper timing and placement can increase greenhouse gas emissions. One of the most important practices would be to apply fertilizer no earlier than the planting season.[43] Nonetheless, due to ease of application, soil and water conditions, the lower cost of fertilizer in the fall, availability of machinery, and other reasons, farmers now fertilize a significant portion of the nation's cropland each fall, even though those fertilized fields will not be seeded until the following spring.[44] Fertilizer left unutilized in the soil over winter is vulnerable to environmental loss, including as nitrous oxide.[45]

Some experts argue that farmers can increase efficiency by practicing "split application"—that is, applying small amounts of fertilizer early in the planting season and, again, when nitrogen demand is highest, typically after plants emerge from the ground.[46] Studies have found that split application may reduce emissions by a significant amount.[47] Slow-release fertilizer formulations can also improve efficiency.[48]

Nitrogen availability can vary within fields, as factors like prior yields (and thus nitrogen removal at harvest) affect its distribution. Precision agriculture allows farmers to optimize placement via global positioning system (GPS) and other forms of technology that use spatial and temporal data about fields.[49] Precise harvesting machines can track the yield in each small section of each row; improved satellite imagery can accurately estimate plant nitrogen and soil moisture levels in each area; and soil and plant samples can determine soil type and needs and plant needs. These data then inform how and when fields are fertilized, as well as irrigated, sprayed with pesticides, and harvested, leading to productivity gains and reduced pollution. Unfortunately, because precision agriculture requires a significant investment in technology, this management system is likely—at least for now—prohibitively expensive for most farms smaller than 500 acres.[50]

Farmers can also improve nitrogen placement by applying fertilizer in irrigation water via subsurface drip irrigation (SDI) systems, which deliver nitrogen more precisely and in proximity to plant roots, increasing plant uptake and limiting excess nitrogen in the soil.[51] SDI is also less likely to fill soil pore space with water, avoiding the anaerobic conditions that are especially conducive to the generation of nitrous oxide.[52]

38. Farmers often apply excess fertilizer "in the hopes that 'this year will be the one in ten' when extra N will pay off." G. Philip Robertson & Peter M. Vitousek, *Nitrogen in Agriculture: Balancing the Cost of an Essential Resource*, 34 Ann. Rev. Env't & Resources 97, 117 (2009).
39. G. Philip Robertson, *Nitrogen Use Efficiency in Row-Crop Agriculture: Crop Nitrogen Use and Soil Nitrogen Loss*, *in* Ecology in Agriculture 351 (Louise E. Jackson ed., Academic Press 1997).
40. Marc Ribaudo et al., Econ. Research Serv., USDA, Nitrogen in Agricultural Systems: Implications for Conservation Policy 11 (2011) (ERR-127).
41. Robertson & Vitousek, *supra* note 38, at 104.
42. *See* Terry L. Roberts, *Right Product, Right Rate, Right Time, and Right Place . . . the Foundation of Best Management Practices for Fertilizer*, *in* Fertilizer Best Management Practices 29-32 (2007).
43. Ribaudo et al., *supra* note 40, at 6.
44. According to a USDA study, farmers applied fertilizer unnecessarily early on nearly one-quarter of acres planted with key commodity crops. Ribaudo et al., *supra* note 40.
45. *Id*. at 75.
46. Bijesh Maharjan et al., *Fertilizer and Irrigation Management Effects on Nitrous Oxide Emissions and Nitrate Leaching*, 106 Agronomy J. 703, 712 (2014).
47. David L. Burton et al., *Effect of Split Application of Fertilizer Nitrogen on N_2O Emissions From Potatoes*, 88 Canadian J. Soil Sci. 229, 233 tbl. 3 (2008).
48. Maharjan et al., *supra* note 46, at 711.
49. Rattan Lal, *Preface* to Soil-Specific Farming: Precision Agriculture vii (Rattan Lal & B.A. Stewart eds., CRC Press 2015).
50. Michael McLeod et al., Cost-Effectiveness of Greenhouse Gas Mitigation Measures for Agriculture: A Literature Review 26 (OECD Food, Agric. & Fisheries Papers No. 89, 2015).
51. Diego Abalos et al., *Management of Irrigation Frequency and Nitrogen Fertilization Mitigate GHG and NO Emissions From Drip-Fertigated Crops*, 490 Sci. Total Env't 880, 880 (2014).
52. *Id*.

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Some studies have suggested that nitrification inhibitors, chemicals that delay the conversion of ammonium to nitrate, may reduce nitrous oxide emissions by allowing plants to absorb a larger share of nitrogen.[53] However, reductions may be modest compared to split application.[54] Moreover, nitrification inhibitors are antimicrobial pesticides that kill or inhibit the soil microbes involved in nitrification. The broader impact of these inhibitors on soil microbial communities, and ultimately soil health and fertility, requires further study.[55] Growers can also reduce net emissions by replacing synthetic nutrients with manure or other organic soil amendments, discussed further below.

❑ *Reduce or eliminate tillage*. To prepare for planting, farmers routinely till their land by plowing or otherwise breaking up the soil and eliminating unwanted material. This process accelerates the breakdown of organic matter in the soil, increasing emissions of carbon dioxide. Thus, farmers and others are examining ways to prepare soil for planting with no, or reduced, tillage. No-till agriculture, which completely eliminates tillage, uses herbicides or other methods to control weeds instead of tillage, and leaves the soil physically undisturbed, protecting organic matter from soil microbes that could otherwise accelerate the carbon cycle by returning soil carbon to the atmosphere as carbon dioxide.[56] Reduced tillage practices that integrate some amount of plant residue into soils may also reduce nitrous oxide emissions and further increase carbon sequestration.[57]

In 2012, farmers reported practicing no-till on 96 million acres and reduced tillage on another 77 million acres.[58] In contrast, conventional tillage was practiced on 106 million acres—only 38% of the 279 million acres suitable for tilling according to the 2012 Census of Agriculture.[59] While no-till's impact on crop yields varies according to a number of factors, including soil conditions, management techniques, weather, and crop type, a 2016 meta-analysis found that no-till generally results in similar yields to conventional tillage after a transition period of five or more years.[60] Even with yield reductions during the transition phase, however, no-till may remain more profitable for farmers than conventional tillage due to its potential to reduce expenditures on labor, fuel, and, in some cases, fertilizer.[61]

Conservation tillage, which includes no-till farming and some methods of reduced tillage, is among the most widely studied agricultural practices with respect to climate change. The evidence suggests that no-till agriculture can increase soil carbon stocks in many regions, although its effect varies considerably by soil type and location.[62] A 2013 meta-analysis also found that no-till significantly decreases nitrous oxide emissions after five years, especially in dry climates.[63]

Researchers have expressed concerns about the fact that no-till farming as practiced by commercial farmers often differs considerably from how it is implemented on research fields.[64] The available data suggest that many farmers who consider their methods "no-till" actually till their fields periodically.[65] This has important consequences, because even a single tillage event can lead to the loss of carbon built up through years of no-tillage.[66] One expert estimates that less than one-third of no-till farms in the United States are truly no-till, and that the number of these continuous no-till farms is likely decreasing.[67]

Organic no-till systems are also being investigated and could offer significantly higher levels of carbon sequestration.[68] Short-term studies of organic no-till systems indicate that they likely sequester more carbon than conventional no-till farming.[69]

❑ *Increase carbon inputs from plants through cover crops and crop rotations*. Farmers can also foster soil carbon by increasing carbon inputs from plants. Cover crops are plants grown to enhance soil conditions rather than to produce an agricultural product. They are generally grown during the late fall and winter when common commodity crops such as corn, wheat, and soy are not in season. In addition to increasing soil organic carbon by increasing

53. Maharjan et al., *supra* note 46, at 712.
54. *Id*.
55. *Nitrosomonas* bacteria are primarily responsible for the conversion of ammonium to nitrite, which is subsequently converted to nitrate. Darrell W. Nelson & Don Huber, *Nitrification Inhibitors for Corn Production*, Iowa St. U. Extension, at 1 (1992) (NCH-55). While *Nitrosomonas* are the targets of nitrification inhibitors, the impact of nitrification inhibitors on other soil microorganisms needs to be characterized as well.
56. For an overview of this process, see Daniel Kane, Carbon Sequestration Potential on Agricultural Lands: A Review of Current Science and Available Practices 5-11 (2015).
57. Cheryl Palm et al., *Conservation Agriculture and Ecosystem Services: An Overview*, 187 Agric., Ecosystems & Env't 87, 90 (2014).
58. Nat'l Agric. Statistics Serv., USDA, 2012 Census of Agriculture, Highlights: Conservation 1.
59. *Id*.
60. Unlike other crops, however, corn yields on no-till farms typically do not improve over time, resulting in lower yields than corn produced with conventional tillage. Cameron M. Pittelkow et al., *When Does No-Till Work? A Global Meta-Analysis*, 183 Field Crops Res. 156, 159 (2015).
61. Claire O'Connor, *Farmers Reap Benefits as No-Till Adoption Rises*, Nat. Resources Def. Council, Nov. 15, 2013, https://www.nrdc.org/experts/claire-oconnor/farmers-reap-benefits-no-till-adoption-rises.
62. Keith Paustian, *Carbon Sequestration in Agricultural Systems*, *in* Encyclopedia of Agriculture and Food Systems 140, 146 (Neal K. Van Alfen ed., Academic Press 2014).
63. Chris van Kessel, *Climate, Duration, and N Placement Determine N_2O Emissions in Reduced Tillage Systems: A Meta Analysis*, 19 Global Change Biology 33, 33 (2013).
64. Bram Govaerts et al., *Conservation Agriculture and Soil Carbon Sequestration: Between Myth and Farmer Reality*, 28 Critical Rev. Plant Sci. 97, 111 (2009).
65. An extensive survey conducted from 1994-1999 found that no-till farms in Illinois and Indiana tilled their fields every 2.5 years on average, while no-till farms in Minnesota were tilled every 1.4 years on average. Peter R. Hill, *Use of Continuous No-Till and Rotational Tillage Systems in the Central and Northern Corn Belt*, 56 J. Soil & Water Conservation 286, 289 (2001).
66. Richard Conant et al., *Impacts of Periodic Tillage on Soil C Stocks: A Synthesis*, 95 Soil & Tillage Res. 1, 4 (2007).
67. Brad Reagan, *Plowing Through the Confusing Data on No-Till Farming*, Wall St. J., Oct. 15, 2012, https://www.wsj.com/articles/SB10000872396390443855804577602931348705646.
68. Rodale Inst., *Our Work: Organic No-Till Overview*, http://rodaleinstitute.org/our-work/organic-no-till/ (last visited Aug. 1, 2017).
69. Patrick Carr et al., *Impacts of Organic Zero Tillage Systems on Crops, Weeds, and Soil Quality*, 5 Sustainability 3172, 3184 (2013).

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carbon inputs, cover crops have also been shown to significantly reduce nitrate loss, thereby indirectly reducing nitrous oxide emissions.[70] Cover cropping with legumes also increases biological nitrogen fixation, reducing the need for nitrogen fertilizers.[71]

Conservation crop rotations refer to planting systems designed to decrease the frequency at which fields are left uncultivated (fallow) and to rotate between a diverse set of crops, thereby increasing carbon inputs.[72] Crop rotations that include perennial plants, such as alfalfa or grass hay, can be especially effective at sequestering carbon.[73] While most crops are rotated on a seasonal basis, producers with perennial crops in their rotation may not return to annual crops for one to three years.[74]

Although neither of these methods offers large climate benefits when practiced in isolation, they both have the potential to play an important role in reducing net agricultural emissions when integrated into climate-friendly systems. Diversified crop rotations, for example, are even more effective at increasing soil carbon when combined with cover cropping,[75] although likely sequestration rates have not been established.[76] Cover cropping has also been shown to sequester carbon more quickly when used in conjunction with no-till agriculture, and it likely has a synergistic effect with other environmentally friendly practices as well.[77]

❑ *Add soil amendments*. Soil application of amendments such as manure or other organic fertilizers can lower emissions by decreasing manure waste, reducing emissions from the production of synthetic fertilizers,[78] and increasing soil carbon stocks.[79] While livestock manure remains the dominant source of organic fertilizer for agriculture, the United States has large amounts of compostable solid waste and solid residues from sewage treatment plants, called biosolids, which also can be, and now often already are, used as soil amendments.[80]

Additionally, a type of charcoal called biochar may be able to store even more carbon than traditional organic amendments.[81] Biochar is produced by pyrolysis—the thermal decomposition of organic material at high temperatures in the absence of oxygen. This process results in a carbon-rich char that is more stable than uncharred plant material, although local environmental conditions, such as climate and soil type, play an important role in determining how long it persists in soils.[82] Biochar primarily reduces emissions by stabilizing and adding to carbon stores in the soil[83]; however, it may also reduce nitrous oxide emissions and fertilizer requirements.[84]

❑ *Employ organic farming and other more climate-friendly farming systems*. There are several agricultural systems, including organic agriculture, permaculture, agroecology, and regenerative agriculture, that are built upon the fundamental premise that soil health and natural ecological systems, such as the nutrient cycle between livestock and crops, are paramount to long-term productivity. This subsection focuses on organic agriculture, since it is well-studied and there are already USDA national organic standards in place,[85] making it easier to classify. However, certified organic operations are not necessarily more climate-friendly than noncertified operations implementing these other models; all can have significant climate benefits.

Organic farming generally seeks to enhance production by supporting natural soil fertility and biological activity and prohibits the use of synthetic pesticides or fertilizers.[86] USDA, which sets standards for organic products in the United States, defines it as a form of agriculture that uses methods designed to "support the cycling of on-farm resources, promote ecological balance, and conserve biodiversity."[87] It encourages many of the practices mentioned here, such as cover cropping, crop rotation, and the incorporation of diverse elements on cropland including forestry and livestock. Its primary climate benefits are

70. Andrea Basche et al., *Do Cover Crops Increase or Decrease Nitrous Oxide Emissions? A Meta-Analysis*, 69 J. Soil & Water Conservation 471, 479-80 (2014).
71. *See* Seth M. Dabney et al., *Using Winter Cover Crops to Improve Soil and Water Quality*, 32 Comm. Soil Sci. & Plant Analysis 1221, 1224, 1228 (2001).
72. Increasing crop diversity influences soil carbon and nitrogen concentrations, microbial communities, and soil ecosystem functions, often resulting in higher soil carbon levels. Marshall D. McDaniel et al., *Does Agricultural Crop Diversity Enhance Soil Microbial Biomass and Organic Matter Dynamics? A Meta-Analysis*, 24 Ecological Applications 560, 560 (2014).
73. Alison J. Eagle et al., Nicholas Inst. for Envtl. Policy Solutions, Duke Univ., Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States: A Synthesis of the Literature 15 (2012). Perennial grasses grown for livestock may not be appropriate for water-scarce regions.
74. *Id*.
75. *See* McDaniel et al., *supra* note 72, at 560.
76. Telephone Interview with Amy Swan, Research Associate, Colorado State University, and Mark Easter, Senior Research Associate, Colorado State University (May 20, 2016).
77. *See* Humberto Blanco-Canqui, *Cover Crops and Ecosystem Services: Insights From Studies in Temperate Soils*, 107 Agronomy J. 2449, 2450 (2015).
78. See *infra* Section V.A.1., for a discussion of upstream emissions from synthetic fertilizers.
79. *See*, *e.g.*, Maysoon M. Mikha & Charles W. Rice, *Tillage and Manure Effects on Soil and Aggregate-Associated Carbon and Nitrogen*, 68 Soil Sci. Soc'y Am. J. 809, 809, 815 (2004) (discussing manure's impact on soil carbon content).
80. One-half of all biosolids produced in the United States are applied to agricultural land, although this accounts for the nutrient needs of less than 1% of the country's farmland. U.S. EPA, *Frequent Questions About Biosolids*, https://www.epa.gov/biosolids/frequent-questions-about-biosolids (last updated June 14, 2017).
81. Emissions from the production of biochar must be taken into account, however. Certain production methods negate some or all of its sequestration benefits. Dominic Woolf et al., *Sustainable Biochar to Mitigate Global Climate Change*, Nature Comm., Aug. 10, 2010, at 1, 3.
82. Samuel Abiven et al., *Biochar by Design*, 7 Nature 326, 326 (2014).
83. Woolf et al., *supra* note 81, at 2.
84. Lukas Van Zwieten et al., *The Effects on Nitrous Oxide and Methane Emissions From Soil*, *in* Biochar for Environmental Management: Science, Technology, and Implementation 490-91 (Johannes Lehmann & Stephen Joseph eds., Routledge 2d ed. 2015); Saran P. Sohi et al., *A Review of Biochar and Its Use and Function in Soil*, *in* 105 Advances in Agronomy 47, 70-72 (Donald L. Sparks ed., Academic Press 2010).
85. *See*, *e.g.*, 7 C.F.R. §205.203 (2016) (establishing the soil fertility and crop nutrient management standard).
86. Certified organic products in the United States, for example, must be "produced and handled without the use of synthetic chemicals." 7 U.S.C. §6504.
87. USDA, Introduction to Organic Practices (2015).

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reduced nitrous oxide emissions, lower energy requirements, and increased soil carbon sequestration.[88] Some studies suggest that organic farming can obtain equivalent yields to conventional farming,[89] or come close in certain contexts,[90] while others suggest that the lower per-acre yields would reduce the climate benefits of the system by requiring more cropland.[91]

❑ *Expand agroforestry*. Agroforestry is a collective name for agricultural systems that integrate management of woody perennials and agricultural crops or animals on the same piece of land.[92] By adding trees to agricultural lands, agroforestry increases both annual sequestration rates and the overall amount of carbon that a piece of land can store. As a result, agroforestry's per-acre sequestration potential is far higher than that found in annual crop systems.[93] Over time, agroforestry can also reduce indirect emissions of nitrous oxide by reducing nitrogen runoff.[94]

In the United States, agroforestry typically involves the use of trees and shrubs to act as windbreaks, buffers, and hedges on otherwise conventionally managed cropland; however, it also includes alley cropping, the side-by-side planting of annual crops with trees in adjacent rows. USDA estimated that alley cropping generally sequesters about one to two metric tons of carbon dioxide equivalent annually per acre through additional biomass.[95] This is roughly the equivalent of taking one car off the road for every three to six acres thus managed; if done on just one-quarter of U.S. cropland, it would be the equivalent of taking 26 million cars off the road.

Although not a form of agroforestry, a system of row crop production integrated with strategically placed native perennial grasses, called prairie strips, was developed by scientists at Iowa State University and modeled on agroforestry practices. The project, Science-Based Trials of Rowcrops Integrated With Prairie Strips (STRIPS), is designed to create a scalable, resilient, and environmentally responsible system of agriculture in the Midwest.[96] Further research is needed to accurately measure its impact on net emissions, but scientists estimate that prairie strips sequester approximately one metric ton of carbon dioxide equivalent per acre, about three times the sequestration rate of no-till farming.[97]

❑ *Shift from annual crops to perennial crops*. As with agroforestry, perennial crops offer a way to substantially improve upon the carbon storage potential of annual crops. They eliminate the need for tillage, generally reduce irrigation and fertilizer needs, and sequester additional carbon through their considerable biomass and deep root systems. In the United States, there are several common perennial crops grown, mostly in monocultures, including grapes, apples, blueberries, stone fruits, citrus, and almonds and other nuts.

There are also perennial crops that are able to produce ample quantities of feedstock for biofuels, such as switchgrass, that could take the place of the annual crops now grown for this purpose.[98] In part due to different fertilizer and water needs of switchgrass and corn, the life-cycle carbon intensity of switchgrass biofuel is less than that of gasoline, while that of corn ethanol is greater.[99] Other perennials can be a source of edible oils that are now largely produced by annual crops such as rape or soy. While there are now no perennial grains ready for commercial use, the Land Institute, a nonprofit research organization dedicated to developing perennial staple crops, has been making promising progress.[100] Returning to more pasture-based

88. Tiziano Gomiero et al., *Environmental Impact of Different Agricultural Management Practices: Conventional vs. Organic Agriculture*, 30 Critical Rev. Plant Sci. 95, 101-04, 109-11 (2011) (summarizing research indicating that organic farming increases soil carbon levels and reduces energy requirements); Sore Petersen et al., *Nitrous Oxide Emissions From Organic and Conventional Crops in Five European Countries*, 112 Agric., Ecosystems & Env't 200, 203 (2006) (finding that nitrous oxide emissions from conventional crop rotations were higher than those in organic crop rotations in four out of five countries).
89. Rodale Inst., The Farming Systems Trial: Celebrating 30 Years 4, 9-10 (2012).
90. Verena Seufert et al., *Comparing the Yields of Organic and Conventional Agriculture*, 485 Nature 229, 231 (2012) (demonstrating that organic agriculture nearly matches conventional yields in certain environments); Lauren Ponisio et al., *Diversification Practices Reduce Organic to Conventional Yield Gap*, 282 Proc. Royal Soc'y B 1, 4 (2014) (finding that diversified organic systems were much closer to conventional yields than organic monocultures).
91. *See* Gomiero et al., *supra* note 88, at 111.
92. Food & Agric. Org. of the U.N., *Agroforestry*, http://www.fao.org/forestry/agroforestry/80338/en/ (last updated Oct. 23, 2015).
93. The United States Mid-Century Strategy for Deep Decarbonization recognized agroforestry as a promising strategy for change mitigation and adaptation. *See* The White House, United States Mid-Century Strategy for Deep Decarbonization 78-79 (2016), *available at* http://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf.
94. EPA estimates that indirect emissions of nitrous oxide accounted for 18% of nitrous oxide emissions from agricultural soils in 2015. EPA, *supra* note 9, at 5-24 to 5-25 tbls. 5-17 & 5-18. Over time, agroforestry practices like riparian tree buffers can prevent the loss of nitrate and thereby prevent its downstream conversion to nitrous oxide. Ranjith P. Udawatta et al., *Agroforestry Practices, Runoff, and Nutrient Loss: A Paired Watershed Comparison*, 31 J. Envtl. Quality 1214, 1224-25 (2002).
95. Swan et al., *supra* note 37, at 29, using P.K. Ramachandran Nair & Vimala Nair, *Carbon Storage in North American Agroforestry Systems*, *in* The Potential of U.S. Forest Soils to Sequester Carbon and Mitigate the Greenhouse Effect (John M. Kimble et al. eds., Lewis Publishers 2003).
96. Meghann Jarchow & Matt Liebman, Iowa State Univ. Extension, Incorporating Prairies Into Multifunctional Landscapes 14-15 (2011) (PMR 1007).
97. *Id*. at 20-21.
98. Approximately 40% of the corn grown in the United States is now devoted to ethanol production. *See* Peter Riley, *Interaction Between Ethanol, Crop, and Livestock Markets*, *in* U.S. Ethanol: An Examination of Policy, Production, Use, Distribution, and Market Interactions 27 (James A. Duffield et al. eds., USDA 2015). Soybean processing can produce soy oil for biofuels and protein for animal feed at the same time, so little to no soy is grown exclusively as a biofuel; however, approximately 30% of the soybean oil produced in 2013 was used for biodiesel. Jeremy Martin, *Biodiesel Update: Now With More Soy*, Union Concerned Scientists, Jan. 2, 2014, http://blog.ucsusa.org/jeremy-martin/biodiesel-update-now-with-more-soy-360.
99. *See* Emily Cassidy, Envtl. Working Group, Better Biofuels Ahead: The Road to Low-Carbon Fuels 5 (2015); John DeCicco et al., *Carbon Balance Effects of U.S. Biofuel Production and Use*, 138 Climatic Change 667, 677 (2016).
100. *See*, *e.g.*, Pheonah Nabukalu & Thomas Cox, *Response to Selection in the Initial Stages of a Perennial Sorghum Breeding Program*, 209 Euphytica 103, 108-10 (2016); The Land Inst., Land Report No. 113 (2015).

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systems of raising livestock also effectively switches the feed from an annual to a perennial crop.

❑ *Shift to more ecologically efficient crop use*. Analyses of agricultural productivity generally focus on inputs, including labor, and crop yield. While these factors are important, they fail to provide an accurate account of whether a crop is a truly efficient use of land and energy from the perspective of fulfilling human needs. A crop with high yields and low labor requirements may be inefficient if it is integrated into an energy-intensive value chain, such as grain destined for a feedlot, or if it does not provide consumers with a nutritious end product, such as corn processed into high-fructose corn syrup.

Shifting production from crops intended to feed animals with a high conversion rate (of pounds feed to pounds meat), feedstock for biofuels with high life-cycle carbon emissions, or processed foods to crops intended for human consumption as whole foods, would therefore improve the efficiency of crop use. This efficiency could allow for the production of an adequate food supply on fewer acres than would be required otherwise. This in turn would reduce direct emissions associated with the cultivation of the excess acreage, as well as allow the restoration of grassland and forestland that can function as carbon sinks.

A 2013 study estimated that 67% of the calories and 80% of the protein in crops produced in the United States are diverted to animal feed.[101] This represents an inherently inefficient use of potential food. For example, it typically takes six pounds of grain to increase the live weight of a beef cow by one pound,[102] and only 30-40% of the animal's live weight is consumable as beef.[103] This means that 15-20 pounds of grain are required to produce one pound of beef.[104] In the United States, approximately 70 million acres of cropland are used to produce corn and soybean for animal feed.[105] The same calories and protein currently provided by animal products could be produced with a much smaller land footprint if crops were consumed directly rather than fed to animals.

The study further found that up to an additional 6% of both calories and protein of U.S. crops were diverted to biofuel production.[106] Neither the calories nor the protein were available for human consumption. Notably, this estimate predated enactment of the Renewable Fuel Standard (RFS) that spurred demand for biofuels in the United States, and the percentage of potential food lost to biofuel production is almost certainly much higher today.[107] A switch from the dominant biofuel—corn ethanol—to biofuels derived from perennial crops grown on lands that are less suitable to food crops would help to reduce competition for human food and relieve additional acreage from food production.[108]

In addition, the U.S. diet now relies heavily on processed and "ultra-processed" foods[109]; an estimated 75% of the average person's calories comes from such food.[110] Heavily processed foods largely rely on corn, wheat, and soy as well as some animal products, leading to a "commodity-based diet" in wealthy countries.[111] These diets are deficient in nutrients and other beneficial compounds found in whole or minimally processed foods.[112] The production of an adequate supply of nutritious foods without a corresponding reduction in production of commodities used in processed foods will place additional pressure on the land base. Shifting away from such high reliance on heavily processed foods could further reduce inefficiencies in the food system and result in substantial health as well as climate benefits.[113]

❑ *Optimize flood irrigation and drainage in rice cultivation*. Rice cultivation results in methane emissions due to flood irrigation of rice fields, which creates anaerobic conditions in which methane-producing bacteria thrive.[114] Rice farmers can reduce methane emissions by reducing the continuous flooding during the growing season by alternate wetting and drying. Periodic drainage temporarily restores aerobic conditions, which rapidly diminishes

101. Cassidy et al., *supra* note 24.
102. Dan Shike, Assistant Professor, University of Illinois, Presentation: Beef Cattle Feed Efficiency, Address at the Driftless Region Beef Conference (Jan. 31, 2013).
103. Holland et al., *supra* note 23, at 3.
104. A range of 15-20 pounds of grain to one pound of beef was derived by dividing the number of pounds of grain to one pound of live weight gain by the lower and upper bounds on the yield (6/0.4 = 15, 6/0.3 = 20).
105. Estimates of acres cultivated for corn and soybean used for animal feed were derived by multiplying total corn and soybean acreage in marketing year (MY) 2014/2015 (90.6 and 83.3 million acres planted, respectively) by the proportion of the corn supply used for animal feed (0.34) or the proportion of the soybean supply crushed (0.46), and multiplying this product by the proportion of the corn and soybean supply due to production in that year (0.92 and 0.97, respectively). For corn data, see USDA, Feed Grains: Yearbook Tables (last updated June 14, 2017), and for soybean, see USDA, Oil Crops Yearbook (last updated Mar. 29, 2017).
106. Cassidy et al., *supra* note 24.
107. David DeGennaro, Nat'l Wildlife Fed'n, Fueling Destruction: The Unintended Consequences of the Renewable Fuel Standard on Land, Water, and Wildlife 5-6 (2016). The Emily Cassidy et al. analysis, see *supra* notes 24, 101, and 106, was based on data from 1997-2003.
108. *See* Cassidy, *supra* note 99, at 6.
109. The term was popularized by Carlos Monteiro, who argues, "The issue is not foods, nor nutrients, so much as processing." Carlos Monteiro, Commentary, *Increasing Consumption of Ultra-Processed Foods and Likely Impact on Human Health: Evidence From Brazil*, 12 Pub. Health Nutrition 729, 729 (2009). In a subsequent study, Monteiro and his collaborators divided food products into three groups: unprocessed or minimally processed, processed, and ultra-processed. Carlos Monteiro et al., *Increasing Consumption of Ultra-Processed Foods and Likely Impact on Human Health: Evidence From Brazil*, 14 Pub. Health Nutrition 5, 7 (2010). Ultra-processed foods are produced using industrial processes "designed to create durable, accessible, convenient, attractive ready-to-eat or ready-to-heat products." *Id*.
110. Jennifer Poti et al., *Is the Degree of Food Processing and Convenience Linked With the Nutritional Quality of Foods Purchased by US Households*, 101 Am. J. Clinical Nutrition 1251, 1251 (2015).
111. David Ludwig, Commentary, *Technology, Diet, and the Burden of Chronic Disease*, 305 JAMA 1352, 1352 (2011).
112. *Id*.
113. *See* Carlos Monteiro et al., *Dietary Guidelines to Nourish Humanity and the Planet in the Twenty-First Century. A Blueprint From Brazil*, 18 Pub. Health Nutrition 2311, 2317 (2015) (describing how dietary guidelines can enhance both human health and the environment by reducing the consumption of processed foods); Dariush Mozzaffarian & David Ludwig, Commentary, *Dietary Guidelines in the 21st Century—A Time for Food*, 304 JAMA 681, 681-82 (2010) (emphasizing the importance of whole and minimally processed foods for human health).
114. EPA, *supra* note 9, at 5-16.

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the amount of methane-producing bacteria and stimulates other bacteria that metabolize methane for energy.[115] The Intergovernmental Panel on Climate Change (IPCC) estimated that, on average, draining once per season reduces emissions by 40%, while draining multiple times reduces emissions by 48%.[116] In 2016, California approved a protocol for rice farmers to quantify reductions at the farm level as the basis for generating credits under the state's cap-and-trade program, which may incentivize the adoption of mitigation practices in the rice industry.[117]

2. Grazing Land

Grazing lands cover almost one-third of the contiguous United States.[118] More than 80% of this land is rangeland, uncultivated land with minimal inputs, while the remainder is cultivated and more intensively managed grazing land, or pasture.[119] Pasture has greater potential for carbon sequestration as a result of its higher biomass unit production, but it requires irrigation or high precipitation levels, making it impractical in much of the arid West.

❑ *Improve grazing management*. A variety of management practices can increase carbon sequestration on grazing lands. Several factors influence the types of practices appropriate for any given location, including climate, precipitation, topography, local plant communities, soil type, and ranch size. However, rotation and stocking rates are important regardless of the grazing ecosystem. Management systems that rotate livestock through a series of pastures, if implemented well, may improve soil conditions and grassland productivity, thereby increasing soil organic carbon.[120] At the same time, continuous systems, which allow unrestricted grazing, are more likely to lead to poor soil quality and carbon loss.[121]

The USDA Natural Resources Conservation Service (NRCS) calls rotational systems that rotate livestock in order to foster optimal plant and animal health "prescribed grazing." There are different types of prescribed grazing systems, such as management-intensive grazing and less intensive forms of rotational and planned grazing. While not widely adopted, there are numerous such operations that appear to be successful in restoring rangelands, increasing soil carbon, and enhancing other ecological benefits while producing livestock.[122] These can be viewed as models for other farms, education programs, and government incentives.

The ability of individual systems to sequester carbon has been vigorously debated,[123] varies by region and land use history,[124] and hits an upper limit when soils become saturated.[125] Environmental factors beyond the control of ranchers, such as drought conditions, can also overshadow and overwhelm the impact of even the most effective management practices, particularly in arid rangelands.[126] Nonetheless, prescribed grazing has been shown to offer significant carbon sequestration potential in some ecosystems.

❑ *Optimize feed, breed, and herd health*. Grazing practices have been the subject of significant attention and debate; however, ranchers can also take important steps to reduce net emissions through improved feed, breed, and animal health management. By carefully managing their herds' feed and forage options, operators may be able to decrease enteric emissions.[127] Operators can also reduce emissions by maintaining herd health and choosing or developing breeds best adapted to the local environment.[128] The capacity of different breeds to thrive in local conditions, such as weather and native plant communities, affects how quickly they mature. Breeds optimized for local conditions will therefore reach slaughter weight more quickly, reducing their impact on emissions.

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115. Tapan K. Adhya et al., *Wetting and Drying: Reducing Greenhouse Gas Emissions and Saving Water From Rice Production* 6 (World Resources Institute Working Paper, Installment 8 of *Creating a Sustainable Food Future*, 2014).
116. IPCC, 4 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry, and Other Land Use 5.44-5.53 (2006).
117. *See* Cal. Envtl. Prot. Agency Air Res. Bd., *Potential New Compliance Offset Protocol Rice Cultivation Projects*, https://www.arb.ca.gov/cc/capandtrade/protocols/riceprotocol.htm (last reviewed Dec. 2, 2014). Microsoft just purchased some such offsets. USDA Natural Res. Conservation Serv., *Nature's Stewards: U.S. Rice Farmers Embrace Sustainable Agriculture and Earn First-Ever Carbon Credits for Rice Production*, http://nrcs.maps.arcgis.com/apps/Cascade/index.html?appid=c00a7710dbe04790823c4133777e49c0 (last visited Aug. 1, 2017).
118. Of the 1,937.7 million acres of nonfederal land in the contiguous United States, 130.9 million are pastureland, 417.9 are rangeland, and 56.1 are grazed forestland. Nickerson et al., *supra* note 4, at 7. USDA's data for the 48 contiguous states do not include federal lands, however, which account for a significant proportion of national grazing lands. *Id.* at 6.
119. Eagle et al., *supra* note 73, at 36.
120. Richard Conant et al., *Land Use Effects on Soil Carbon Fractions in the Southeastern United States. I. Management-Intensive Versus Extensive Grazing*, 38 Biology & Fertility Soils 386, 391 (2003); Chad Hellwinckel & Jennifer Phillips, *Land Use Carbon Implications of a Reduction in Ethanol Production and an Increase in Well-Managed Pastures*, 3 Carbon Mgmt. 27, 28 (2012). *Cf.* David D. Briske et al., *Rotational Grazing on Rangelands: Reconciliation of Perception and Experimental Evidence*, 61 Rangeland Ecology & Mgmt. 3, 11 (2008) (arguing that rotational grazing offers few, if any, benefits over other systems of grazing according to experimental evidence).
121. *See, e.g.*, Carter et al., *supra* note 30, at 202.
122. *E.g.*, Brown's Ranch, http://brownsranch.us/ (last visited Aug. 1, 2017); Pinhook Farm, http://pinhookfarm.blogspot.com/ (last visited Aug. 1, 2017). *See generally* Regeneration International, http://regenerationinternational.org/ (last visited Aug. 1, 2017); Savory International, http://www.savory.global/ (last visited Aug. 1, 2017).
123. *See, e.g.*, John Carter et al., *Holistic Management: Misinformation on the Science of Grazed Ecosystems*, 2014 Int'l J. Biodiversity 1, 5-7 (2014).
124. Megan McSherry & Mark Ritchie, *Effects of Grazing on Grassland Soil Carbon: A Global Review*, 19 Global Change Biology 1347, 1347 (2013).
125. Stewart et al., *supra* note 34, at 25-28; Stockmann et al., *supra* note 33, at 94-95.
126. Kayje Booker et al., *What Can Ecological Science Tell Us About Opportunities for Carbon Sequestration on Arid Rangelands in the United States?*, 23 Global Envtl. Change 240, 240-44 (2013).
127. Doug Gurian-Sherman, Union of Concerned Scientists, Raising the Steaks: Global Warming and Pasture-Raised Beef Production in the United States 13-19 (2011) (summarizing practices to reduce methane emissions through improved feed and forage); Karen A. Beauchemin et al., *Mitigation of Greenhouse Gas Emissions From Beef Production in Western Canada—Evaluation Using Farm-Based Life Cycle Assessment*, 166/167 Animal Feed Sci. & Tech. 663, 674-75 (2011).
128. Global Research Alliance on Agric. Greenhouse Gases et al., Reducing Greenhouse Gas Emissions From Livestock: Best Practice and Emerging Options 12-14, 20-23 (Karin Andeweg & Andy Reisinger eds., 2015).

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❑ *Add soil amendments*. New research has demonstrated that organic soil amendments like compost may be able to boost carbon sequestration on grazing land. Over the course of three years, researchers found that a single application of composted organic matter to rangeland increased net carbon storage by 25-70%,[129] while also increasing the production of grass for feed and thereby making rangelands more productive.[130]

❑ *Expand silvopasture*. Silvopasture refers to the practice of planting woody perennials on grazing lands. As with agroforestry on cropland, silvopasture offers significant greenhouse gas mitigation potential. Adding trees to pasture and rangelands adds a substantial new source of carbon storage, while also increasing livestock productivity (due to additional shade and reduced heat stress loss) and, in some cases, adding an additional source of income for producers.

Silvopasture systems have the potential to sequester more carbon than either forests or grasslands, since they can integrate perennial grasses and trees, each of which offers distinct sequestration avenues, as described above.[131] A 2012 literature review estimated that silvopasture systems would sequester an average of 2.5 metric tons of carbon dioxide equivalent per acre annually in the United States through both additional biomass and increased soil carbon storage.[132] USDA's estimated range for sequestration rates for silvopasture systems, while substantially lower, still markedly outperforms conventional grazing.[133]

3. Animal Feeding Operations

AFOs are lots or facilities in which confined animals are fed, raised, and maintained.[134] Unlike farms that allow livestock to graze or be integrated into crop production, AFOs are focused on one task: maximizing the production of meat, dairy, or eggs. EPA classifies AFOs as CAFOs if they exceed a certain size threshold or, in some circumstances, if they discharge waste into surface waters.[135]

There are roughly 450,000 AFOs[136] in the United States, including 20,000 CAFOs.[137] CAFOs alone hold the majority of the country's food-producing animals.[138] While AFOs are credited with lowering consumer costs for animal products, they have considerable externalities. They can harm animal welfare, increase antibiotic resistance due to the routine use of antibiotics,[139] emit air and water pollution,[140] depress property values,[141] hurt small-scale farms and businesses,[142] and diminish quality of life in rural communities.[143]

There are AFO systems for production of all types of meat—beef, pork, and chicken—as well as production of eggs and dairy products. While the details vary, in general, swine and dairy AFOs often rely on liquid manure systems, chicken and egg AFOs produce a dry litter, and cattle feedlots leave the animal waste on the open ground. In liquid systems, the manure is washed from the animal pens to a storage lagoon, usually uncovered, where it is eventually pumped out and spread onto fields.

AFO manure management systems also produce much more methane than manure in pasture-based livestock operations. When manure is left as a solid, as naturally happens on grazing and pasture lands, it typically decomposes aerobically and produces little to no methane. However, when it is stored or handled in a system that creates an anaerobic environment, such as a lagoon, it releases large amounts of methane.[144] Anaerobic environments can result in methane emission rates as much as 90 times higher than those in grazing systems.[145]

❑ *Reincorporate animals into croplands*. The most effective way to reduce emissions from AFOs would be to replace them with well-managed integrated crop-livestock systems. Traditionally, most farms incorporated animals into cropping systems by allowing them to forage on well-

129. Rebecca Ryals & Whendee Silver, *Effects of Organic Matter Amendments on Net Primary Productivity and Greenhouse Gas Emissions in Annual Grasslands*, 23 Ecological Applications 46, 56 (2013). This total does not include the carbon directly added to the soil from the compost. *Id*. at 46.
130. *Id*. at 51.
131. Udawatta & Jose, *supra* note 29, at 227.
132. *Id*. at 230.
133. Swan et al., *supra* note 37, at 33.
134. U.S. EPA, *National Pollutant Discharge Elimination System (NPDES)—Animal Feeding Operations (AFOs)*, https://www.epa.gov/npdes/animal-feeding-operations-afos (last updated Jan. 17, 2017).
135. 40 C.F.R. §122.23(b)-(c) (2016). "Large CAFOs" are defined as CAFOs by EPA solely due to the number of animals they hold, "Medium CAFOs" are operations that exceed a smaller size threshold, but discharge waste into surface water, and "Small CAFOs" are facilities that do not meet any size threshold, but have been designated as "significant contributor[s] of pollutants to waters" by regulatory authorities. *Id*.
136. USDA NRCS, *Animal Feeding Operations*, https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/livestock/afo/ (last visited Aug. 1, 2017).
137. U.S. EPA, National Pollutant Discharge Elimination System, 2015 CAFO Permitting Status Report (2015).
138. *See* Marc Ribaudo et al., Econ. Research Serv., USDA, Manure Management for Water Quality: Costs to Animal Feeding Operations of Applying Manure Nutrients to Land iii (2003) (noting that while CAFOs make up less than 5% of animal feeding operations, they contain 50% of all animals and produce more than 65% of all manure).
139. David Tillman et al., *Agricultural Sustainability and Intensive Production Practices*, 418 Nature 671, 674 (2002); Ellen Silbergeld et al., *Industrial Food Animal Production, Antimicrobial Resistance, and Human Health*, 29 Ann. Rev. Pub. Health 151, 162-63 (2008).
140. Tillman et al., *supra* note 139.
141. Kelley Donham et al., *Community Health and Socioeconomic Issues Surrounding Concentrated Animal Feeding Operations*, 115 Envtl. Health Persp. 317, 319 (2007).
142. *Id*. at 317.
143. *See id*.; Steve Wing & Susanne Wolf, *Intensive Livestock Operations, Health, and Quality of Life Among Eastern North Carolina Residents*, 108 Envtl. Health Persp., 233, 235-37 (2000).
144. While dry management can reduce methane emissions, switching to dry management can increase nitrous oxide emissions. Pete Smith et al., *Greenhouse Gas Mitigation in Agriculture*, 363 Phil. Transactions Royal Soc'y B 789, 794 (2008). Dry management does not always increase nitrous oxide emissions, however, and increases in nitrous oxide emissions resulting from dry management are likely to be exceeded by decreases in methane emissions. *See, e.g.*, Justine J. Owen et al., Nicholas Inst., Duke Univ., Greenhouse Gas Mitigation Opportunities in California Agriculture: Review of Emissions and Mitigation Potential of Animal Manure Management and Land Application of Manure 7 tbl. 4 (2014) (showing emission estimates of cows in California by manure management system).
145. Paul Jun et al., IPCC, CH_4 and N_2O Emissions From Livestock Manure 388 tbl. 10 (1996).

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managed grasslands or plant residues after harvest, but early agricultural scientists and extension agents discouraged this practice, perceiving it as archaic and inefficient. As scientists have begun to understand the ecology of agriculture better, however, they have started to encourage it as an environmentally friendly way to intensify agricultural production.[146] Some even argue that crop-livestock farms are economically and environmentally optimal, creating an efficient nutrient cycle between plants and animals.[147]

Mixed crop-livestock systems encourage crop and animal rotations and also help break down plant residue, all of which increases soil health and carbon sequestration. They can substantially reduce methane emissions from manure management since manure in integrated systems is typically left to decompose aerobically.[148] However, both animal growth rates and enteric emissions must be taken into account when comparing net emissions from different systems of animal agriculture.

❑ *Transition to dry manure management systems*. Dairy and swine operations accounted for 90% of methane emissions from manure management in 2015,[149] largely due to their reliance—in the United States, at least—on liquid management systems.[150] Nearly all hog producers, for example, wash waste into giant "lagoons" or hold it in large "slurry pits" below the slatted floors of production facilities until it is applied to land, ostensibly as nitrogen fertilizer.[151] In dry management systems, by contrast, aerobic conditions are maintained and methane emissions are minimized.[152] For example, manure may be drained and dried, or dry matter like straw may be added to absorb moisture and solidify it.[153] Solids can then be stacked until land application.[154]

A transition from liquid to dry management in these operations would maintain aerobic conditions, stymie the growth of methane-producing bacteria, and reduce methane emissions. A 2015 meta-analysis of field studies measuring dairy manure management emissions found that liquid manure storage systems have the highest per-head methane emission rates, while dry systems had among the lowest.[155] Dry manure can be composted and used as a soil amendment, which can increase soil carbon sequestration.[156]

❑ *Improve management of concentrated liquid manure*. Liquid manure is typically stored in lagoons and then spread or sprayed on fields. Measures can be taken to reduce emissions from both stages. Anaerobic digesters work by converting volatile solids in organic matter to biogas and capturing it. The biogas, which is predominantly methane and carbon dioxide, releases carbon dioxide when burned for energy. Anaerobic digesters also produce a solid residue, digestate, which can be composted and used as bedding or applied to fields as a fertilizer, thereby lowering net emissions by offsetting synthetic fertilizers and increasing carbon sequestration.[157]

Anaerobic digesters are relatively rare in the United States due to their high costs and the lax regulation of alternative management methods: for every digester in operation, there are about 100 CAFOs producing undigested waste.[158] Of the approximately 250 anaerobic digesters operating in the United States, almost 200 rely on dairy operations.[159]

Improvements can also be made regarding the spreading of the liquid manure. The Clean Water Act (CWA)[160] requires that the manure be spread at "agronomic rates"—that is, in quantities that the plants need and can use.[161] That provision is often ignored, however, with the result that manure can pollute nearby waters and release greenhouse gases. There is some evidence that specific practices relating to manure spreading can also affect emissions and soil carbon sequestration levels. Spreading on frozen or saturated soils, for example, tends to lead to water pollution and higher nitrous oxide emissions since the manure is more likely to enter waterways instead of being incorporated into the soil.[162]

❑ *Develop methane inhibitors and vaccines*. A number of feed additives have been demonstrated to decrease methane emissions from livestock in short-term experiments.[163]

146. *See*, *e.g.*, Michael Russelle et al., *Reconsidering Integrated Crop-Livestock Systems in North America*, 99 Agronomy J. 325, 325 (2007); Gilles Lemaire et al., *Integrated Crop-Livestock Systems: Strategies to Achieve Synergy Between Agricultural Production and Environmental Quality*, 190 Agric., Ecosystems & Env't 4, 4 (2014).
147. Patrick Veysset et al., *Mixed Crop-Livestock Farming Systems: A Sustainable Way to Produce Beef? Commercial Farms Results, Questions, and Perspectives*, 8 Animal 1218, 1218 (2014).
148. Unmanaged manure deposited on grassland by grazing animals still emits significant amounts of nitrous oxide, however. *See* EPA, *supra* note 9, at 5-24 tbl. 5-17, 5-34 to 5-35.
149. EPA, *supra* note 9, at 5-10.
150. Nigel Key et al., Econ. Research Serv., USDA, Trends and Developments in Hog Manure Management: 1998-2009, at 11 (2011).
151. *Id*.
152. Nat'l Res. Council, Air Emissions From Animal Feeding Operations 54 (2003).
153. Jeff Lorimor et al., Mich. State Univ. Extension, Manure Characteristics 4 (2004) (MWPS-18).
154. *Id*.
155. Justine J. Owen & Whendee L. Silver, *Greenhouse Gas Emissions From Dairy Manure Management: A Review of Fieldbased Studies*, 21 Global Change Biology 550, 558 fig. 3 (2014). Dry management does not always increase nitrous oxide emissions, however, and increases in nitrous oxide emissions resulting from dry management are likely to be exceeded by decreases in methane emissions. *See*, *e.g.*, Owen et al., *supra* note 144.
156. Cal. Envtl. Assocs., Greenhouse Gas Mitigation Strategies for California Dairies 52 (2015).
157. It is not clear yet whether nitrous oxide emission rates differ for synthetic or organic fertilizers; however, organic fertilizers can offset emissions from nitrogen-based fertilizer manufacturing plants, which are a significant source of carbon dioxide as discussed *infra* Section V.A.-B.
158. There are 19,245 CAFOs and 242 anaerobic digesters in the United States according to EPA. EPA, *supra* note 137; U.S. EPA, *AgSTAR Data and Trends*, https://www.epa.gov/agstar/agstar-data-and-trends (last updated Aug. 18, 2016).
159. Fourteen of the 196 digesters that use dairy manure also accept manure from other animals. *See* EPA, *AgSTAR*, *supra* note 158.
160. 33 U.S.C. §§1251-1398, ELR Stat. FWPCA §§101-607.
161. 40 C.F.R. §503.14 (2016).
162. Andrew C. VanderZaag et al., *Strategies to Mitigate Nitrous Oxide Emissions From Land Applied Manure*, 166/167 Animal Feed Sci. & Tech. 464, 469-70 (2011).
163. Mario Herrero et al., *Greenhouse Gas Mitigation Potentials in the Livestock Sector*, 6 Nature Climate Change 452, 454 (2016).

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When studied over the long term, however, these effects disappear or decrease significantly as the microflora in livestock's rumen adapt to the new diet.[164] Nonetheless, scientists are studying novel approaches that they hope will remain effective throughout a ruminant's life-span.[165]

Other researchers have focused on developing vaccines designed to reduce methane emissions.[166] Industry officials estimate that the vaccine could reduce enteric emissions by 25-30%[167]; however, as with methane inhibitors, the vaccine has yet to be proven safe, effective, or financially feasible.

Finally, eliminating routine antibiotic use may reduce emissions. Antibiotics are routinely administered to animals in confined production facilities to increase animal growth rates and to prevent disease,[168] altering the microbiota of confined animals and affecting their health and physiology,[169] and may increase the amount of methane-producing microflora.[170]

C. *Agriculture's Maximum Possible Contribution to Reducing Carbon*

This Article lays out the pathways necessary for agriculture to achieve carbon neutrality. Even greater reductions in net greenhouse gas emissions may be technologically feasible. Nonetheless, net carbon neutrality is a much more ambitious target than those set by the Deep Decarbonization Pathways Project and the United States Mid-Century Strategy for Deep Decarbonization. The former proposes an 8% cut in nitrous oxide emissions and a 6% decrease in methane emissions from the agricultural sector and does not address agricultural carbon emissions or carbon sequestration.[171] The latter is slightly more aggressive, calling for a 25% reduction in non-carbon dioxide emissions from agriculture.[172] It also highlights soil carbon sequestration on agricultural soils as a promising method for reducing net emissions, although it does not include soil carbon sequestration in its modeling results.[173]

The maximum possible contribution of agriculture to deep decarbonization is difficult to estimate. While an understanding of the chemical and biological processes that result in agricultural emissions and sinks is advancing rapidly, there is still much to learn. Additionally, greenhouse gas emissions and sequestration rates vary significantly according to a number of local variables, including climate, historical land use, the composition of microbes in the soil, and other factors.

In addition, there are often trade offs resulting from actions taken to reduce net agricultural emissions. Manure digesters capture methane but may increase incentives for concentration in livestock production; organic approaches may lower productivity, necessitating the use of more land; no-till and cover cropping usually require greater use of herbicides. These trade offs must be considered in any plan.

Not all of these practices can be used together, and among those that can, it is not always clear how their interactions will affect net emissions. Additionally, of course, not all practices can be adopted in all geographies and their impact will vary according to local climate and soil conditions, among other variables. Thus, it is not possible to simply subtract the sum of the aggregate soil carbon sequestration possibilities from total emissions. Nonetheless, the potential of climate-friendly practices to reduce the 522 million metric tons of carbon dioxide equivalent emitted by the agricultural sector in 2015, coupled with the potential of these practices to significantly increase soil carbon storage, makes carbon neutrality a realistic goal.

Table 1 below includes the average annual net emission reductions of the practices discussed in this Article for which quantitative data are available. The table offers the possible maximum acreage on which a practice could be used, a range of net emission reductions, and the total potential tonnage assuming maximum acreage and the lower end of per-acre impact. Given the diversity of geographies and uncertainties of these practices, these totals are only illustrative. As the table indicates, these practices alone could make agriculture a carbon sink if adopted widely enough.

While these practices can be cost-beneficial for farmers or ranchers, and have important additional benefits, uptake of new approaches can be slow and may require significant incentives, outreach and education, and even more robust regulatory requirements. Whether agriculture will ultimately achieve carbon neutrality will depend on whether policies with that goal are adopted—and that is ultimately a question of political will, not a scientific one. Below, the Article outlines legal pathways for reaching this objective.

164. *Id.*

165. Alexander Hristov et al., *An Inhibitor Persistently Decreased Enteric Methane Emission From Dairy Cows With No Negative Effect on Milk Production*, 112 Proc. Nat'l Acad. Sci. U.S. Am. 10663, 10663 (2015).

166. D. Neil Wedlock et al., *Progress in the Development of Vaccines Against Rumen Methanogens*, 7 Animal 244, 244 (2015).

167. Lucie Bell, *New Zealand Vaccine to Reduce Cattle Methane Emissions for Dairy and Beef Industry Reaches Testing Stage*, ABC Rural. Nov. 9, 2015, http://www.abc.net.au/news/rural/2015-11-10/mitigating-methane-emissions-from-cattle-via-vaccine/6925676.

168. In 2012, the Food and Drug Administration released a guidance calling for the voluntary phaseout of antibiotic use in animals for growth promotion. However, livestock antibiotic use has increased by nearly 5% since the start of the phaseout program. U.S. Food & Drug Admin., 2014 Summary Report on Antimicrobials Sold or Distributed for Use in Food-Producing Animals 40 (2015).

The agency is unlikely to realize lower usage rates without more active regulation and enforcement. *See* Frank Aaerestrup, Comment, *Get Pigs Off Antibiotics* 486 Nature 465, 465-66 (2012) (on the inadequacy of bans that fail to set and enforce reduction goals).

169. Nadia Gaci et al., *Archaea and the Human Gut: New Beginning of an Old Story*, 20 World J. Gastroenterology 16062, 16071 (2014).

170. Tobin Hammer et al., *Treating Cattle With Antibiotics Affects Greenhouse Gas Emissions, and Microbiota in Dung and Dung Beetles*, 283 Proc. Royal Soc'y B 1, 5 (2016).

171. James H. Williams et al., Sustainable Dev. Solutions Network & Inst. for Sustainable Dev. and Int'l Relations, Pathways to Deep Decarbonization in the United States 52 tbl. 9 (2014).

172. The White House, *supra* note 93, at 91.

173. *Id.* at 77-79.

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Table 1. Average Annual Net Emission Reductions of Select Agricultural Practices[1]

Practice	Maximum applicable area (million acres)	Average annual net emission reductions (metric ton CO_2 eq. per acre)	Possible annual sequestration potential (million metric tons CO_2 eq.)
Cropland			
Improved synthetic fertilizer management	230	0.06-0.15	14
Reduced till	178	0.17-0.20	30
No-till	232	0.31-0.33	72
Cover cropping	126-245	0.26-0.37	33
Conservation crop rotations	Unknown	0.21-0.26	Unknown
Organic amendments	Unknown	1.00-1.75[2]	Unknown
Biochar	306	0.26-7.90	80
Alley cropping	198	0.81-1.74	160
Windbreaks	11	1.09-2.09	12
Riparian buffers	2	1.08-2.47	2
Perennial biofuels and feedstock[3]	Unknown	1.74-2.43	Unknown
Grazing land			
Prescribed grazing	Unknown	0.18-0.26	Unknown
Organic amendments	Unknown	0.85-1.90	Unknown
Silvopasture	173	0.66-1.34	114

1. Data are derived from Eagle et al., *supra* note 73; Swan et al., *supra* note 37; Nair & Nair, *supra* note 95.
2. This total does not account for nitrous oxide emissions. Swan et al., *supra* note 37, at 7.
3. The perennials studied include poplar, willow, and switchgrass. Rocky Lemus & Rattan Lal, *Bioenergy Crops and Carbon Sequestration,* 24 Critical Rev. Plant Sci. 1, 15 (2005).

III. Public Law Pathways to Reducing Net Agricultural Greenhouse Gas Emissions

At first glance, reducing net agricultural greenhouse gas emissions through public law poses a considerable challenge. Agriculture operates on a "parallel regulatory framework," in which farms are provided safe harbors from regulations in a number of areas, including labor, antitrust, and the environment.[174]

While the federal government has largely declined to regulate agriculture's negative externalities, the industry relies on considerable government support. It has its own cabinet position and an agency charged with ensuring the sector's financial well-being, which it does through funding for research, training, crop insurance, loans, and numerous other programs. Nonetheless, there are a number of ways to use these existing forms of government support to reduce net agricultural greenhouse gas emissions.

Critical to the political reality of many proposals here, practices that reduce greenhouse gas emissions and increase soil carbon to mitigate climate change can also reduce costs, increase soil health and fertility, and make farms and grazing lands more resilient to climate change, and thus can all be urged and supported for those reasons. Indeed, advocacy should always emphasize the triple benefits of soil health, climate mitigation, and climate resilience.

The federal government spends almost $3 billion annually on agricultural research, development, and extension programs, much of which can be used to support climate mitigation efforts. The U.S. Congress should require USDA to do so while providing increased funding for the agency to quickly develop and disseminate climate-friendly practices and crop varieties. Agricultural operations that do not follow basic conservation practices should not be eligible to receive funds through USDA, whether through subsidies, insurance, or conservation programs.

Funding for conservation should also prioritize programs that offer the greatest climate benefits, while funding that benefits environmentally harmful operations, such as CAFOs, should be reduced or eliminated. Ultimately, however, Congress should adopt a system focused on payments for ecosystem services in place of much or

174. Susan Schneider, *A Reconsideration of Agricultural Law: A Call for the Law of Food, Farming, and Sustainability*, 34 Wm. & Mary Envtl. L. & Pol'y Rev. 935, 937 (2010).

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all of the current farm safety net. Such a system would be independent of the volatile commodity markets and the variability of weather, both of which create the perceived need for the safety net, and thus could provide farmers, rural communities, and the environment with greater and more stable benefits.

In addition to farm programs, the public sector provides significant benefits to farms through tax policy and subsidized lending programs. Tax policy should be used at all levels of government to discourage agricultural practices that increase greenhouse gas emissions and to encourage practices that decrease emissions and sequester carbon. Likewise, lending institutions operated or subsidized by the federal government should offer more favorable rates to farmers utilizing climate-friendly practices.

EPA has the authority to regulate methane and nitrous oxide emissions from agricultural operations, and state and local governments can also stop the most harmful agricultural practices. The Bureau of Land Management (BLM) and U.S. Forest Service (USFS), which oversee more than one-third of all grazing lands in the United States, have the ability to regulate grazing on those lands, but have so far failed to sufficiently regulate practices that result in increased emissions.

A. Research, Development, and Extension Programs

Congress' expressed purpose for supporting agricultural research and extension is not only to increase the productivity of agriculture in the United States, but also to "[maintain and enhance] the natural resource base on which rural America and the United States agricultural economy depend."[175] As a result, many USDA programs already focus on conservation, giving the agency significant leeway to increase funding for climate-friendly practices through already existing programs. Doing so, whether through congressional or agency action, will be crucial for decarbonizing agriculture. State governments and land-grant institutions should also provide funding for research focused on climate-friendly practices, particularly in the absence of strong federal research support.

Congress should couple increased financial support for climate-related agricultural research with generous funding to disseminate climate-friendly practices and research. By creating a nationwide network of climate extension professionals, while significantly increasing funding for climate-related outreach, education, and technical assistance, Congress can provide carbon farming with the support it needs to rapidly expand.

1. Research and Development

Congress appropriated more than $2 billion to agricultural research and development in 2014, slightly less than the amount it appropriated to research and development for energy projects.[176] The overwhelming majority of these funds go to two USDA agencies: the National Institute of Food and Agriculture (NIFA) and the Agricultural Research Service (ARS). ARS is USDA's in-house research agency, while NIFA primarily funds research at land-grant universities and administers grants to organizations outside of USDA.

About 20% of ARS' fiscal year (FY) 2017 research budget is allocated to environmental research, which includes research on climate change.[177] ARS' climate change research is focused on adaptation, however, with relatively few resources allocated toward mitigation.[178] The majority of ARS' funding should be reoriented to research projects that include mitigation components; however, this does not mean that ARS will not be able to meet other research priorities at the same time.

For example, 27% of ARS' 2017 budget is dedicated to livestock and crop production.[179] The agency could increase its support for research that advances production and mitigation simultaneously, such as projects to develop productive livestock breeds, better plant materials for cover crops, and high-yielding crops that facilitate lower emissions and sequester more carbon. This strategy would help farmers prepare for a decarbonized economy, while helping the United States meet its emissions goals.

NIFA administers dozens of programs authorized through the farm bill and other pieces of legislation. Nonetheless, little NIFA funding goes to climate.[180] Of the $375 million requested in President Barack Obama's 2017 budget for NIFA's competitive research program, for example, only $15 million was sought to support research on climate adaptation and resiliency and none was requested for mitigation.[181] On its own or with direction from Congress, NIFA, like ARS, should steadily increase the portion of funding for climate mitigation and adaptation, shifting research funding to projects designed to reduce greenhouse gas emissions or increase carbon sequestration, while improving soil health and resilience.

Both agencies should also prioritize funding for research into agroecology, which has a much greater potential to positively impact the climate than conventional systems.[182] Research into agroforestry and perennial agriculture in particular are severely underfunded.[183] Since research into these systems is unlikely to develop highly profitable products for agrochemical and seed corporations—agroforestry and perennial farmers do not need new seeds each year and require much lower rates of

175. 7 U.S.C. §3101.

176. Nat'l Sci. Found., Federal Budget Authority for R&D and R&D Plant, by Budget Function, Ordered by FY 2014 R&D and R&D Plant Total: FYs 2014-16.
177. USDA, FY 2017 Budget Summary 88.
178. *Id.*
179. *Id.* at 90.
180. Marcia DeLonge et al., *Investing in the Transition to Sustainable Agriculture*, 55 Envtl. Sci. & Pol'y 266, 269 (2016).
181. NIFA, USDA, FY 2017 President's Budget Proposal 8 (2016).
182. DeLonge et al., *supra* note 180.
183. *Id.*

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chemical inputs—privately funded agricultural research in this area is likely to remain minimal.

Increasing agricultural research will also be critical for maintaining agricultural productivity as weather patterns become more extreme and unpredictable due to climate change. Government-funded research into adaptation practices should be increased, especially for those that reinforce mitigation strategies.[184]

Several surveys of publicly funded agricultural research have concluded that research into sustainable systems is "woefully under-resourced."[185] In light of the challenge presented by climate change—and the current dearth of funding for sustainable farming systems—Congress should at a minimum restore the research budget to at least its prior level within the agency. Devoting 4% of USDA's budget to research in 2016 would have resulted in an additional $3.1 billion for agricultural research.[186] USDA should allocate these funds to develop the tools, monitoring and measurement protocols, crops, and practices necessary to achieve carbon neutrality in agriculture. While significant, this is only a fraction of the roughly $20 billion estimated to be spent annually on crop insurance and other subsidies.[187]

Congress should also increase funding for the Sustainable Agriculture Research and Education (SARE) program, which provides funding for on-farm research and efforts to increase knowledge about sustainable agricultural practices among farmers and agricultural professionals.[188] Administered by NIFA, SARE is the only USDA competitive grants program that focuses exclusively on sustainable agriculture.[189] Its annual funding ranged from $19 to $27 million between 2013 and 2016.[190] Given SARE's important role in developing and disseminating sustainable practices—many of which are climate-friendly—Congress should dramatically increase its annual budget, while also specifically appropriating funds for SARE to use to support the development of carbon farming.

While federally funded research will be critical for the development of carbon farming, states and foundations can also play an important role in stimulating research into adaptation and mitigation strategies. One mechanism is a nonprofit nongovernmental organization called the Foundation for Food and Agriculture Research (FFAR) established by the 2014 Farm Bill to support "agricultural research focused on addressing key problems of national and international significance," including, among other focus areas, "renewable resources, natural resources, and the environment."[191] Designed to spur public-private partnerships, Congress allocated FFAR $200 million to use as matching funds for nonfederal dollars.[192] Congress should expand on its initial grant, providing FFAR with annual funding to help leverage funds from foundations toward research that furthers mitigation strategies.

State governments and land-grant institutions played a critical role in the growth of sustainable and organic agriculture before the federal government began providing consistent, if relatively meager, research funding in the 1990s.[193] They are now beginning to do the same for climate-friendly practices. Both Maryland and Hawaii, for example, passed legislation in 2017 providing support for research, education, and technical assistance focused on agricultural practices that build healthy soils and sequester carbon.[194] The California Department of Food and Agriculture also appropriated $7.5 million in FY 2016/2017 for the Healthy Soils Program, an incentive and demonstration program for farmers and ranchers designed to increase soil carbon sequestration and reduce agricultural greenhouse gas emissions.[195] Other state legislatures, agencies, and land-grant institutions should expand on these efforts, giving programs designed to spread climate-friendly practices sufficient funding to develop robust research, education, and technical assistance arms.

The Leopold Center for Sustainable Agriculture at Iowa State University provides an attractive example for future state efforts. While the Iowa Legislature eliminated the center's funding in 2017, putting its future in doubt,[196] its enabling legislation provides a compelling funding model for states with more favorable political environments. Established by the 1987 Iowa Groundwater Protection Act to conduct research designed to reduce the environmental harms of agriculture and to help promulgate sustainable practices,[197] the center received approximately $1.5 million annually until 2017 from a fund consisting of revenue from a small fee on nitrogen fertilizer sales and pesticide registrations. The

184. Cynthia Rosenzweig & Francesco Nicola Tubiello, *Adaptation and Mitigation Strategies in Agriculture: An Analysis of Potential Synergies*, 12 Mitigation & Adaptation Strategies for Global Change 855, 866-67 (2007).
185. Liz Carlisle & Albie Miles, *Closing the Knowledge Gap: How the USDA Could Tap the Potential of Biologically Diversified Farming Systems*, 4 J. Agric. Food Sys. & Community Dev. 219, 221 (2013) (arguing that a lack of research has limited organic agriculture's development); *see also* Urs Niggli et al., Research Inst. of Organic Agric., A Global Vision and Strategy for Organic Farming Research 19 (2016) (arguing that a lack of research has limited organic agriculture's development).
186. Calculated by the authors. *Compare* Am. Ass'n for the Advancement of Sci., Guide to the President's Budget: Research & Development FY 2017, at 10 tbl. 1 (2016) (listing USDA's research and development budget at $2.45 billion in fiscal year 2015), *with* USDA, FY 2017 Budget Summary 2 (2016) (giving USDA's total outlays in fiscal year 2015 as $139 billion).
187. *See* USDA Econ. Research Serv., *Projected Spending Under the 2014 Farm Bill*, https://www.ers.usda.gov/topics/farm-economy/farm-commodity-policy/projected-spending-under-the-2014-farm-bill.aspx (last updated Nov. 22, 2016).
188. 7 U.S.C. §§5801-5832.
189. Nat'l Sustainable Agric. Coal., *Sustainable Agriculture Research and Education Program*, http://sustainableagriculture.net/publications/grassrootsguide/sustainable-organic-research/sustainable-agriculture-research-and-education-program/ (last updated Oct. 2016).
190. *Id*.
191. 7 U.S.C. §5939.
192. *Id*.
193. Niggli et al., *supra* note 185, at 55-56.
194. Md. Code Ann., Agric. §2-1901 (West 2017); 2017 Haw. Legis. Serv. 33 (West).
195. Cal. Dep't of Food & Agric., *Healthy Soils Programs*, https://www.cdfa.ca.gov/oefi/healthysoils/ (last visited Aug. 1, 2017).
196. Brianne Pfannenstiel & Jeff Charis-Carlson, *Branstad Defends Defunding of Leopold Center*, Des Moines Reg., May 15, 2017.
197. Iowa Code §266.39 (2017).

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fee on nitrogen fertilizer sales was set at 75 cents per ton of anhydrous ammonia—less than 0.2% of the average price paid by individual farmers.[198] While the center's $2 million annual budget represented only a tiny portion of the amount spent nationally on agricultural research, it has an impressive record in fostering sustainable practices and has developed a national reputation for its groundbreaking research.

2. Extension Service

One of the most significant challenges facing carbon farming may be the difficulty inherent in learning, adopting, and disseminating new agricultural practices. Even if food processing is dominated by a few large corporations, farming operations themselves are generally run by relatively small, family-operated firms that lack the resources to experiment with new practices.[199] Even large-scale farm operations, whether family-run or not, may be loath to try new practices since they have previously invested significant sums in infrastructure and equipment designed for conventional practices. And unlike in other industries where reducing emissions often entails the adoption of widely applicable practices or technology, each farm operation must contend with a range of unique variables, such as soil and climate conditions.

State extension services have proven remarkably effective at disseminating and perpetuating new agricultural practices.[200] No-till farming has spread more deeply and more rapidly, for example, in states where extension services have advocated for its use.[201] Research also indicates that farmers are more receptive to learning new information and practices from extension programs than they are from other government bodies.[202] While extension's importance has diminished over the past half century as agribusiness advisers and consultants have grown in number and influence,[203] extension services will be needed to foster carbon farming practices.

In 2016, NIFA received $426 million to administer the extension system and help fund state extension services.[204] This funding is more than matched by state and local support for extension services, which provide approximately 90% of public funding for the extension system.[205]

NIFA should immediately begin offering resources for carbon farming within the extension system, as it does for other issues, such as weed control and youth education. NIFA should also work with states to ensure that all extension agents are knowledgeable about climate-friendly practices and to fund specialists who focus primarily on climate mitigation practices in order to ensure an in-house constituency and expertise.

Congress should either expressly expand the mandate of existing extension services or fund a new climate extension service. This extension capacity can build on the base of the existing (as of 2017) Climate Hubs, 10 regional centers established by USDA in 2014 to provide much-needed support for climate mitigation and adaptation efforts by translating climate research into tools, materials, and methods for extension and outreach.[206] All such efforts should emphasize that climate mitigation practices also increase soil health and farm resilience.

As with federal funding for agricultural research, funding for the extension system is also historically low. The federal government spent approximately the same amount on the extension system in 2014 as it did in 1982 *without* accounting for inflation.[207] Congress should at a minimum double the extension system's budget to $900 million, designating the additional funds for climate-related education, programming, and services. Distribution of these funds should favor states providing matching funds in order to reward states that invest in carbon farming and to help win local buy-in for the new extension program.

3. Coordinating Research, Development, and Extension

In order to achieve carbon neutrality in agriculture, USDA should address emissions in a systematic fashion, organizing its research, development, and extension arms around common goals and priorities. USDA can build on the base of the existing Climate Hubs and its "Building Blocks" plan, which aims to reduce or offset greenhouse gas emissions through agriculture and forestry by 120 million metric tons of carbon dioxide equivalent per year by 2025.[208] This would have the same impact as taking 23 million pas-

198. The retail price of anhydrous ammonia was $467 per ton in July 2017. Russ Quinn, *DTN Retail Fertilizer Trends: Anhydrous Breaks 8% Lower*, DTN/Progressive Farmer, July 7, 2017, https://www.dtnpf.com/agriculture/web/ag/news/article/2017/07/12/anhydrous-breaks-8-lower.

199. In 2012, 97% of the farms in the United States were family farms, accounting for 89% of its farmland. *See* Nat'l Agric. Statistics. Serv., USDA, 2012 Census of Agriculture, Farm Typology 1 (2015).

200. *See, e.g.*, Irwin Feller, *Technology Transfer, Public Policy, and the Cooperative Extension Service—OMB Imbroglio*, 6 J. Pol'y Analysis & Mgmt. 307, 307 (1987) ("The Cooperative Extension Service has come to represent the best of both an articulated but decentralized political arrangement and of a technology transfer system."); George McDowell, *Engaged Universities: Lessons From the Land Grant Universities and Extension*, 585 Annals Am. Acad. Pol. & Soc. Sci. 31, 35-36 (2003).

201. "'We also struggle with the fact if a practice is not supported and sold by Oklahoma State University and Oklahoma State Extension, it's slow to be adopted.'" John Dobberstein, *No-Till Movement in U.S. Continues to Grow*, No-Till Farmer, Aug. 2014, at 48.

202. J. Gordon Arbuckle Jr., *Corn Belt Farmers Are Concerned, Support Adaptation Action in the Ag Community*, *in* Resilient Agriculture 22 (Lynn Laws ed., Sustainable Corn Project 2014).

203. Linda Stalker Prokopy et al., *Extension's Role in Disseminating Information About Climate Change to Agricultural Stakeholders in the United States*, 130 Climatic Change 261, 268 (2015).

204. Consolidated Appropriations Act, 2016, Pub. L. No. 114-113, 129 Stat. 2250 (2015).

205. Marsha Mercer, *Cooperative Extension Reinvents Itself for the 21st Century*, PEW Charitable Tr., Sept. 9, 2014, http://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2014/09/09/cooperative-extension-reinvents-itself-for-the-21st-century.

206. *See* USDA, Climate Hubs, USDA Regional Hubs for Risk Adaptation and Mitigation to Climate Change 1.

207. *See* Natural Research Council, Colleges of Agriculture at the Land Grant Universities: A Profile 68 (1995).

208. USDA, USDA Building Blocks for Climate Smart Agriculture and Forestry: Implementation Plan and Progress Report 2 (2016).

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senger vehicles off the road.[209] The plan has several weaknesses: its soil carbon sequestration goals are modest[210]; it favors practices preferred by agribusiness companies rather than those with demonstrated long-term climate benefits[211]; it relies on voluntary incentives, which are often impermanent and ineffective in storing soil carbon[212]; and it relies heavily on nonagricultural sectors.[213] Nonetheless, Congress should expand on these efforts by funding Climate Hubs for each state and mandating more ambitious national sequestration targets.

B. Public Subsidy and Conservation Programs

The federal government supports farms through three main avenues: crop insurance, conservation payments, and commodity programs. Collectively referred to as the "farm safety net," these three categories of programs provide farming operations with about $20 billion per year (for the period 2014-2018), making up 96% of farm bill appropriations outside of the Supplemental Nutrition Assistance Program (SNAP) (formerly "food stamps").[214] Each of these categories is examined in turn below, with an emphasis on how existing programs can be adapted to help decarbonize agriculture. Ultimately, however, new legislation should be passed to optimize government support for carbon farming.

When crafting new agricultural legislation, regulations, or programs, it is important to recognize that the ability of farming operations to integrate new practices and absorb additional transactional costs varies considerably. While many climate-friendly techniques are cost-effective regardless of a farm's scale, some requirements may nonetheless disadvantage small and mid-sized operations. The Food Safety Modernization Act attempted to account for this by exempting certain farms with gross sales below $500,000 from its requirements.[215] New regulations and requirements could also be similarly tiered so that farmers with small and mid-sized operations, or those who receive only a small portion of their household income from farming, face minimal new costs or paperwork. Additionally, USDA and the Extension Service should offer assistance and incentives to help small and mid-sized farms transition to climate-friendly practices.

1. Crop Insurance

Almost one-half of the estimated $20 billion flowing to subsidies each year through farm safety net programs now goes to crop insurance.[216] Proponents of the current crop insurance system often portray it as a safety net for farmers in the case of natural disaster.[217] But in addition to protecting farmers from crop losses—routine or not—its use of revenue guarantees also ensures that covered crops remain lucrative in the face of lower prices. Despite large increases in funding in recent years, crop insurance continues to primarily serve large-scale producers of commodity crops.

According to the Congressional Research Service, more than 70% of the acres covered by crop insurance are devoted to one of four crops—corn, cotton, soybeans, and wheat.[218] The 2014 Farm Bill opened crop insurance up to a wider range of products, and the USDA agency in charge of crop insurance programs, the Risk Management Agency (RMA), has taken important steps to open up crop insurance to diversified and organic farms.[219] Nonetheless, many farms, particularly small- and medium-scale operations, continue to find it impractical or unavailable.[220] In addition to bolstering large-scale operations, crop insurance has also motivated farmers to bring more land under cultivation, particularly wetlands and other marginal lands, leading to increased emissions.[221]

There are two key steps USDA should take to make its crop insurance programs more climate-friendly. First, RMA should ensure that its crop insurance policies do not interfere with cover cropping or other proven decarbonizing practices, or conversely encourage less beneficial practices. Farmers using innovative or sustainable methods often have difficulty receiving crop insurance, since the agency requires producers to use "good farming practices" that are "generally recognized by agricultural experts" in their immediate geographic area.[222] This effectively disallows farmers from using many innovative climate-friendly practices, such as alley cropping or integrated crop-livestock systems, with which agricultural experts in their

209. *See* U.S. EPA, *Greenhouse Gas Equivalencies Calculator*, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (last updated Jan. 24, 2017).

210. The plan calls for only 4-18 MMT CO_2 eq. of soil carbon to be sequestered each year through climate-friendly agricultural practices by 2025. USDA, *supra* note 199, at 4.

211. Building Blocks prioritizes the synthetic fertilizer industry's best management practices, conventional no-till agriculture, and manure management systems for AFOs. *See id*. The climate benefits of these practices are much lower than other feasible options available to farm managers.

212. As discussed *infra* Section III.B.3., any climate benefits derived from temporary voluntary programs such as the Conservation Reserve Program (CRP) are not permanent. Conserving sensitive lands through the CRP is one of the main elements of Building Blocks. *See id*. at 8.

213. Approximately 70% of the greenhouse gas reductions are in nonagricultural sectors. *See id*.

214. Letter from Douglas Elmendorf, Director, Congressional Budget Office, to Frank Lucas, Chairman of the House Committee on Agriculture (Jan. 28, 2014) (on file with Congressional Budget Office). Funding for these programs expires with the 2014 Farm Bill at the end of FY 2018.

215. *See*, *e.g.*, FDA Food Safety Modernization Act, Pub. L. No. 111-353, §418(l)(1)-(2), 124 Stat. 3885, 3892 (2011).

216. Ralph Chite et al., Cong. Research Serv., The 2014 Farm Bill (P.L. 113-79): Summary and Side-by-Side 4 (2014) (R43076).

217. *See*, *e.g.*, Iowa Secretary of Agriculture Bill Northey on crop insurance: "Farmers rely on crop insurance as an important safety net and protection from devastating losses from natural disasters." Memorandum from Bill Northey, Iowa Secretary of Agriculture, to Iowa Reporters and Editors (Oct. 28, 2015) (on file with authors).

218. Dennis Shields, Cong. Research Serv., Federal Crop Insurance: Background 2 (2015) (R40532).

219. *Have Access Improvements to the Federal Crop Insurance Program Gone Far Enough?*, Nat'l Sustainable Agric. Coalition, July 28, 2016, http://sustainableagriculture.net/blog/crop-insurance-access-data/.

220. *Id*.

221. Daniel Sumner & Carl Zulauf, Council on Food, Agric. & Res. Econ., Economic & Environmental Effects of Agricultural Insurance Programs 10-12 (2012).

222. *See* Chad G. Marzen & J. Grant Ballard, *Climate Change and Federal Crop Insurance*, 43 Envtl. Aff. 387, 398 (2016).

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area are unlikely to be familiar.[223] Crop insurance requirements discourage climate adaptation and mitigation, while incentivizing practices that "increase vulnerability to climate change."[224]

In 2015, RMA began allowing organic farmers to use opinions from organic agriculture experts outside of their immediate geographic area.[225] In part due to this change, the amount of organic acreage enrolled in crop insurance, while still small, increased by 34% during the first year of the new policy.[226] RMA should likewise create a new standard for carbon farming—a scientifically sound sustainable farming system—that would allow farmers to use carbon farming experts outside of their immediate area, while encouraging agricultural experts to take climate change into account when assessing "good farming practices."

Current RMA guidelines also hinder beneficiaries from using cover crops.[227] While the agency has made it easier to adopt practices promoted by NRCS, including cover cropping,[228] it needs to eliminate remaining barriers to cover cropping. RMA should also conduct outreach encouraging the practice in order to dispel the widespread fear that it interferes with crop insurance coverage.

Second, publicly funded crop insurance policies should treat carbon-intensive practices as risk-enhancing and reduce or eliminate their premium subsidies accordingly.[229] In fact, the Federal Crop Insurance Corporation (FCIC) may be compelled to consider the climate impact of practices when establishing policies and premiums. Congress requires the FCIC to adopt rates and policies "that will improve the actuarial soundness" of its insurance operations.[230] Encouraging practices that both reduce climate change and make farms more resilient to it will clearly make the program more actuarially sound. FCIC regulations also require it to seek RMA's assessment as to whether insurance policies and premiums are "consistent with USDA's policy goals" when reviewing them.[231] If the plan or premium under review is not consistent with USDA's policy goals, then the FCIC may reject it.[232]

2. Commodity Programs

The commodities title of the 2014 Farm Bill replaced direct payments to farmers with two new programs, Agricultural Risk Coverage (ARC) and Price Loss Coverage (PLC),[233] which distribute more than $4 billion each year.[234] These programs supplement crop insurance for specified commodities, such as wheat, corn, sorghum, and rice, by enhancing price or revenue protection for producers.[235] Unlike crop insurance, ARC and PLC payments are generally made according to historical plantings, or "base acres," rather than planted acres.[236] This gives producers greater flexibility in their planting decisions since they can try new crops or use crop rotations while still receiving payments based on historic crop allocations.

In order to receive ARC or PLC payments, farm owners must agree to not grow crops on highly erodible land without a conservation plan or on unconverted wetlands under any circumstances due to statutory conservation compliance requirements. Under §9018 of the agriculture title, farmers must "otherwise maintain the land in accordance with sound agricultural practices," which are determined at the discretion of the Secretary of Agriculture.[237] Congress authorized USDA to issue rules "the Secretary considers necessary to ensure producer compliance" with these requirements.[238] This appears to give USDA the authority to require farmers to implement mitigation strategies in order to receive commodity payments. USDA should require farmers receiving commodity payments to adopt cost-effective climate-friendly practices. These requirements could be instituted slowly, ensuring that farmers have time to adapt.

3. Conservation Payments

This section examines USDA's three largest conservation programs, recommending both executive and legislative

223. The most recent version of RMA's *Good Farming Practices Handbook*, released in December 2015, included some important changes. For the first time, RMA states that practices promoted by USDA's NRCS will generally be recognized by agricultural experts as "good farming practices." RMA, USDA, Good Farming Practice Determination Standards Handbook 33 (2016). This could make it much easier for farmers with crop insurance to adopt climate-friendly NRCS practices, since they are often deterred from doing so by the good farming practices requirement. However, the handbook considerably weakens the new provision by giving insurance companies the power to prohibit certain practices through the terms and conditions of their policies, and by indicating that both RMA and insurance companies may prohibit practices that do not maximize yields. *Unified Support for Conservation as Good Farming Practice Needed at USDA*, Nat'l Sustainable Agric. Coalition, Dec. 16, 2016, http://sustainableagriculture.net/blog/gfp-updated-at-rma/.

224. U.S. Gov't Accountability Office (GAO), Climate Change: Better Management of Exposure to Potential Future Losses Is Needed for Federal Flood and Crop Insurance 24 (2014) (GAO-15-28).

225. 7 C.F.R. §457.8 (2015); RMA, *supra* note 223, at 32.

226. Calculated by the authors using USDA data. *Compare* RMA, USDA, Federal Crop Insurance Summary of Business for Organic Production 2 (2015) (showing 777,966 organic acres enrolled in federal crop insurance in 2014), *with* RMA, USDA, Federal Crop Insurance Summary of Business for Organic Production 2 (2016) (showing 1,043,403 organic acres enrolled in federal crop insurance in 2015).

227. *See*, *e.g.*, Todd Neeley, *Grassley Asks Vilsack to Fix Crop Insurance, Cover Crops Glitches*, DTN/ Progressive Farmer, June 28, 2016. A 2015 survey found that the most commonly cited reason among farmers for not adopting cover cropping was the concern that doing so would interfere with crop insurance. John Dobberstein, *Crop Insurance Rules Still Hinder Cover Crop Adoption*, No-Till Farmer, Oct. 14, 2015.

228. USDA also established an interagency working group with NRCS, RMA, and the Farm Security Administration to "develop consistent, simple, and flexible policy" on cover crop practices, making it easier for operators to plant cover crops in accordance with federal rules. *See* RMA, USDA, NRCS Cover Crop Termination Guidelines 1 (2014).

229. *See* Claire O'Connor, Natural Res. Def. Council, Soil Matters: How the Federal Crop Insurance Program Should Be Reformed to Encourage Low-Risk Farming Methods With High-Reward Environmental Outcomes 10 (2013).

230. 7 U.S.C. §1508(i)(1).

231. 7 C.F.R. §400.706(b)(4) (2016).

232. *Id.* §400.706(h)(5) (2016).

233. *See generally* Agricultural Act of 2014, Pub. L. No. 113-79, 128 Stat. 649.

234. Chite et al., *supra* note 216.

235. *Id.* at 6.

236. *Id.* at 7.

237. 7 U.S.C. §9018(a)(1).

238. *Id.* §9018(a)(2). The agency has not yet used this authority.

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actions that would ensure they more effectively address climate change. The 2014 Farm Bill allocated approximately $5.8 billion annually to conservation programs, primarily the Conservation Reserve Program (CRP), the Environmental Quality Incentives Program (EQIP), and the Conservation Stewardship Program (CSP).[239]

❑ *Conservation Reserve Program*. Under the 2014 Farm Bill, 37% of conservation spending went to the CRP, which pays farmers to take environmentally sensitive land out of agricultural production for 10-15 years. Approximately 24 million acres were enrolled in the program in 2016.[240] USDA estimated that the CRP sequestered more than 43 million metric tons of carbon dioxide equivalent in 2014, about 7% of agriculture's greenhouse gas emissions.[241] If accurate, this would translate into about 1.8 metric tons of carbon dioxide sequestered per acre.[242]

The CRP's advertised climate benefits are often temporary, however. After their CRP contract has expired, many producers bring their CRP acres back into production, quickly releasing any carbon stored during the term of the contract.[243] Between 2006 and 2014, for example, an estimated 14 million acres previously protected by the CRP were returned to agricultural production.[244]

While the CRP is popular, funding for it was reduced in the 2014 Farm Bill. Congress should both restore some of the reduced funding and reform the program to provide sustained climate benefits by offering farmers 30-year agreements or permanent easements to protect environmentally sensitive land.[245] There have been proposals to expand certain productive activities on CRP land in order to increase interest in the program[246]; Congress should consider this only for activities with proven climate benefits.

Congress should also increase funding for the Conservation Reserve Enhancement Program (CREP), which gives farmers higher payments for participating in targeted conservation efforts organized by state and local officials.[247] Due to its higher annual payments, which are on average almost three times as high as general CRP payments,[248] the CREP has remained popular with farmers even when increasing commodity prices have reduced acreage reenrollment in the CRP overall.[249]

❑ *Environmental Quality Incentives Program*. Receiving about 29% of conservation spending, the EQIP provides farmers with funding and technical assistance for conservation practices. The EQIP is managed by NRCS, which was established by Congress in 1936 to reduce "the wastage of soil and moisture resources on farm, grazing, and forest lands."[250] Congress has authorized NRCS to pay producers up to 75% of the costs associated with the development and implementation of a new conservation practice and/or 100% of the income foregone by the producer as a result of a new practice.[251]

Funding decisions are made through a process that combines national, state, and local priorities. National priorities are determined by NRCS in accordance with the program's statutory guidelines, which include soil health and nutrient management. State priorities are set by the head NRCS administrator of each state in consultation with stakeholders, while local priorities are set by "local working groups," usually consisting of stakeholders such as conventional producers and industry representatives. As a result, the process can disadvantage applications for truly innovative and sustainable practices. Congress or NRCS should require greater representation of sustainable farming approaches.

Advocates have also criticized NRCS for subsidizing large-scale, environmentally harmful operations through the EQIP.[252] Since its inception in 1997, more than $1.6 billion has gone to support irrigation systems through the EQIP, making it the most well-funded set of practices financed by the program.[253] Instead of conserving water, however, support for efficient irrigation systems often leads to land conversion and increased water usage as farmers use their savings to expand irrigated crop production, switch to more water-intensive crops, or both.[254] NRCS should prioritize making existing irrigation systems more efficient.

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239. USDA Econ. Research Serv., *Conservation Programs—Background*, https://www.ers.usda.gov/topics/natural-resources-environment/conservation-programs/background.aspx (last updated Oct. 17, 2016).
240. Press Release, USDA, USDA Announces Conservation Reserve Program Results (May 5, 2016).
241. USDA, Farm Service Agency Strategic Plan: Fiscal Year 2016-2018 Update 25 & 28.
242. In contrast, a 2009 literature review of carbon sequestration rates on CRP acres estimated that they sequester slightly less than one metric ton CO_2 eq. per acre annually. Gervasio Piñeiro et al., *Set-Asides Can Be Better Climate Investment Than Corn Ethanol*, 19 Ecological Applications 277, 279 (2009).
243. Soren Rundquist & Craig Cox, Envtl. Working Group, Fooling Ourselves: Executive Summary (2016) (finding that CRP water quality benefits were counteracted by losses from farmers exiting the program); Tyler Lark et al., *Cropland Expansion Outpaces Agricultural and Biofuel Policies in the United States*, 10 Envtl. Res. Letters 9 (2015) (finding that up to 42% of all land converted to cropland came from land exiting the CRP). Wetland acreage protected by the CRP still has climate benefits, however, since the annual methane emissions while in the program are not lost if the land is converted back into production.
244. Craig Cox et al., Envtl. Working Group, Paradise Lost: Conservation Programs Falter as Agricultural Economy Booms 4 (2013).
245. *See id*. at 4-5; *USDA Freezes New Enrollments in Continuous Conservation Reserve Program*, Nat'l Sustainable Agric. Coalition, May 4, 2017, http://sustainableagriculture.net/blog/usda-freezes-ccrp-enrollment/.
246. *See*, *e.g.*, Press Release, Senator John Thune, Thune Farm Bill Proposals Would Improve Conservation Program Management (Apr. 10, 2017) (on file with authors).
247. *See Digging Deeper Into Continuous CRP Enrollments*, Nat'l Sustainable Agric. Coalition, Mar. 24, 2015, http://sustainableagriculture.net/blog/ccrp-enrollment-2015/; Cox et al., *supra* note 244.
248. States provide additional funding for the CREP, bringing the average yearly CREP payments to $140 per acre. In contrast, general sign-up payments are $51 per acre. *Digging Deeper Into Continuous CRP Enrollments*, *supra* note 247.
249. Cox et al., *supra* note 244.
250. 16 U.S.C. §590a. The agency was originally called the Soil Conservation Service, but was renamed in 1994.
251. *Id*. §3839aa-2(d)(2).
252. Andrew Martin, *In the Farm Bill, a Creature From the Black Lagoon?*, N.Y. Times, Jan. 13, 2008 (suggesting that the program's name should be changed to the "Factory Farm Incentive Program"), http://www.nytimes.com/2008/01/13/business/13feed.html.
253. Envtl. Working Group, Environmental Quality Incentives Program (EQIP) Practice Suite Payments in the United States, 1997-2015.
254. Frank Ward & Manuel Pulido-Velazquez, *Water Conservation in Irrigation Can Increase Water Use*, 105 Proc. Nat'l Acad. Sci. U.S. Am. 18215

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Similarly, waste storage facilities for concentrated animal facilities received a larger share of payments than any other single practice.[255] While some waste management systems, such as anaerobic digesters, can be highly effective at reducing feedlot emissions, sustainable agriculture and environmental justice groups have been highly critical of government efforts to finance them. Even if digesters reduce feedlot emissions, they argue, CAFOs are still bad for the environment, animal welfare, and rural communities.[256] As noted above, pasture-based systems, in contrast, lead to aerobic decomposition and much lower rates of methane production.

With capital costs often exceeding $1 million, anaerobic digesters are also beyond the price range of most dairy farmers in the United States. According to EPA, digestion systems are generally not economically viable for operations with fewer than 500 cows, even with current cost-sharing programs.[257] This significantly limits their use—more than 90% of dairy farms in the United States have fewer than 500 cows, accounting for 40% of all dairy cows in the country.[258] Of these, many do not use liquid manure systems. However, the largest 10% of dairies—which account for 60% of the dairy cow population—could more feasibly be required to install digesters. Rather than subsidize concentrated animal facilities with EQIP funds, USDA or EPA should consider imposing regulatory methane emissions limits, which could drive most large-scale operations to install digesters.

Congress and USDA should redirect EQIP funds, to the extent possible, to support farms and ranches working to significantly reduce emissions or sequester carbon. While Congress should eliminate payments to environmentally harmful operations through legislative action, the agency can—and should—eliminate or reduce these payments before Congress acts. Several rural, environmental, and family farming organizations have called for the EQIP's payment cap to be lowered or to disallow payments to large-scale AFOs.[259]

NRCS itself has significant leeway in determining which practices are prioritized and can set aside considerable funding for carbon farming practices. The agency's Organic Initiative provides an instructive example for how this might be accomplished. In the early 2000s, many organic producers were concerned that the program's reliance on local administrators and the high demand for EQIP funding from conventional producers disadvantaged applicants seeking funding for organic practices. In response, Congress in the 2008 Farm Bill required the agency to set aside EQIP funds specifically to assist organic producers or producers transitioning to organic production.[260]

Producers applying for funds from the program, the Organic Initiative, are eligible for up to $20,000 per year and $80,000 over six years. Farmers can still apply to the general funding pool for larger amounts, but the Organic Initiative ensures that a pool of money is set aside for organic practices each year. NRCS should create a similar pool to support carbon farming. Even 10% of the EQIP's total funding, $86 million, would significantly boost powerful sequestration methods, while advancing the EQIP's statutory priorities.

❑ *Conservation Stewardship Program*. NRCS also administers the CSP, which pays farmers to improve, maintain, or adopt conservation practices on their farms. Farmers are paid annually under a five-year contract with the option to renew for an additional five years if they agree to adopt additional conservation objectives.[261] The agency revised the CSP in fall 2016 by, among other things, offering farmers 67 new practices that will be eligible for funding through the program, including "planting for high carbon sequestration rate."[262]

Like the EQIP, the CSP has the statutory authority to prioritize low-carbon practices and to create a funding pool for farmers transitioning to, or practicing, carbon farming.[263] NRCS should follow up on its planned revisions by doing both as quickly as possible. Congress should also expand funding for the CSP in upcoming farm bills by raising the average payment rate per acre that is authorized for the program to ensure higher-level conservation activities can be appropriately rewarded. In particular, climate-beneficial activities like resource-conserving crop rotations should be prioritized and receive a higher, supplemental payment to reflect the high-level environmental benefits of those practices.

4. Conservation Easements

Conservation easements are legal agreements between a landowner and a third party—usually a land trust or a government agency—that are designed to permanently restrict the use of the land. The restrictions commonly protect natural areas or resources, such as wildlife habitats or water quality, but they are also increasingly being used to preserve farmland and prevent it from being converted to non-farm

(2008); Lisa Pfeiffer & C.-Y. Cynthia Lin, *Does Efficient Irrigation Technology Lead to Reduced Groundwater Extraction? Empirical Evidence*, 67 J. Envtl. Econ. Mgmt. 189 (2014).

255. Melissa Bailey & Kathleen Merrigan, *Rating Sustainability: An Opinion Survey of National Conservation Practices Funded Through the Environmental Quality Incentives Program*, 65 J. Soil & Water Conservation 21A, 23A (2010).

256. *CAFOs and Cover Crops: A Closer Look at 2015 EQIP Dollars*, Nat'l Sustainable Agric. Coalition, Nov. 20, 2015, http://sustainableagriculture.net/blog/fy15-general-eqip-update/.

257. U.S. EPA, *AgSTAR—Is Anaerobic Digestion Right for Your Farm?*, https://www.epa.gov/agstar/anaerobic-digestion-right-your-farm (last updated June 8, 2017).

258. Nat'l Agric. Statistics Serv., USDA, 2012 Census of Agric., U.S. National Level Data 21 tbl. 17.

259. In 2007, for example, a coalition of 26 organizations called on Congress to prohibit funding for AFOs with more than 1,000 animals. Letter from the Campaign for Family Farms and the Environment et al., to the Senate (May 8, 2007).

260. 16 U.S.C. §3839aa-2(i).

261. 7 C.F.R. §1470.26 (2016).

262. News Release, USDA NRCS, USDA Announces Changes for Largest Conservation Program (Sept. 1, 2016); Marc Heller, *Revamps to Conservation Program Boost Options for Farmers*, Greenwire, Sept. 2, 2016.

263. 16 U.S.C. §3838g.

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uses. As of 2012, farmland owners had protected more than 13 million acres from development through conservation easements.[264] Agricultural easements, which protect agricultural land from development, can also have important climate benefits since even conventional farms generally have much lower emissions than developed land. An analysis of emissions in California's Central Valley, for example, found that emission rates on urbanized land were 70 times higher than emissions on an equivalent area of irrigated cropland.[265]

USDA conservation easements have preserved more than four million acres of farmland and environmentally sensitive lands.[266] Conservation easements that protect wetlands and other environmentally sensitive land from being converted to farmland offer substantial climate benefits and should be expanded. The Environmental Working Group, for instance, estimates that the conversion of wetlands to farmland between 2008 and 2012 resulted in greenhouse gas emissions totaling 25-74 million metric tons of carbon dioxide equivalent annually[267]—the equivalent of adding five to 15 million cars to the road each year.[268]

The 2014 Farm Bill consolidated USDA's three existing easement programs into the Agricultural Conservation Easement Program (ACEP).[269] For permanent wetland easements, NRCS pays farm owners the lowest of the fair market value of the land or an offer made by the farm owner.[270] Alternatively, farm owners can apply for "long-term" wetland easements, which typically run for 30 years, and provide 50-75% of the compensation due to an equivalent permanent easement.[271] For agricultural land easements, which protect working agricultural land, NRCS generally pays farm owners up to 50% of the fair market value of the easement, although NRCS may contribute up to 75% of the fair market value of an easement protecting grasslands of "special environmental significance."[272]

The ACEP receives slightly more than one-half of the funding of its predecessor programs—about $368 million annually.[273] Congress should substantially expand the ACEP and ensure that protecting environmentally sensitive lands that provide the greatest climate benefits is among the program's priorities. Wetlands, for example, are estimated to emit between 405 and 1,215 metric tons of carbon dioxide equivalent per acre when converted to agricultural land.[274] The program should also be expanded to allow for easements on additional types of environmentally sensitive land, allowing USDA to protect terrestrial carbon pools in a wider variety of ecosystems.[275]

5. Conservation Compliance Requirements

Producers enrolled in a number of federal farm programs are prohibited from producing agricultural products on highly erodible land without a conservation plan[276] or on unconverted wetlands under any circumstances.[277] These requirements apply to the crop insurance program, each of the conservation programs, as well as many of the smaller programs administered by the Farm Service Agency and NRCS. They offer potentially important climate benefits since conventional farming on highly erodible land and wetlands results in significant greenhouse gas emissions.[278] Despite their clear environmental benefits, however, the agency has failed to consistently enforce these conservation requirements.[279] A 2016 USDA Office of Inspector General report, for example, found that the agency's auditing process had completely bypassed at least 10 states in 2015, apparently in error.[280]

At a minimum, USDA should vigorously enforce the farm bill's current conservation compliance provisions, withholding benefits from farmers that fail to meet their requirements. Since compliance is often relatively easy to determine visually, including by satellite, USDA should be able to increase inspections at little additional cost. If USDA fails to do so, Congress should shift enforcement responsibility to EPA, while also enabling states, localities, and citizens to enforce the requirements, as is possible under most federal environmental statutes.[281]

Congress should also extend the conservation compliance requirement to farm programs that are not currently covered by the requirement, ensuring that all producers who receive federal subsidies are not causing significant environmental harm. In addition, Congress should expand

264. Nat'l Agric. Statistics Serv., *supra* note 258, at 50 tbl. 50.
265. Cal. Energy Comm'n Climate Change Ctr., U.C. Davis, Adaptation Strategies for Agricultural Sustainability in Yolo County, California 106 (2012).
266. Nat'l Sustainable Agric. Coal., *Agriculture Conservation Easement Program*, http://sustainableagriculture.net/publications/grassrootsguide/conservation-environment/agricultural-conservation-easement-program/ (last updated Oct. 2016).
267. Emily Cassidy, Envtl. Working Group, Ethanol's Broken Promise: Using Less Corn Ethanol Reduces Greenhouse Gas Emissions 4 (Nils Bruzelius ed., 2014).
268. Calculated by the authors using EPA estimates for passenger vehicle emissions. *See* EPA, *supra* note 209.
269. 16 U.S.C. §3865.
270. *Id.* §3865c(b)(6)(a)(i).
271. *Id.* §3865c(b)(6)(a)(ii).
272. *Id.* §3865b(2).
273. 7 C.F.R. §1468 (2016); *see also* Bradley Lubben & James Pease, *Conservation and the Agricultural Act of 2014*, 29 Choices 1 (2014).
274. Richard Plevin et al., *Greenhouse Gas Emissions From Biofuels' Indirect Land Use Change Are Uncertain but May Be Much Greater Than Previously Estimated*, 44 Envtl. Sci. & Tech. 8018 (2010).
275. *See* Todd Neeley, *Conservation Controversy*, DTN/ Progressive Farmer, Oct. 17, 2016, https://www.dtnpf.com/agriculture/web/ag/news/business-inputs/article/2016/10/17/ewg-voluntary-conservation-programs.
276. 16 U.S.C. §§3811-3812.
277. *Id.* §3821. Wetlands drained or filled before December 23, 1985, are not protected. *Id.* §3822(b)(1)(A).
278. As mentioned above, wetlands are estimated to emit between 405 and 1,215 metric tons of CO_2 eq. per acre when converted to agricultural land. Plevin et al., *supra* note 274.
279. Laurie Ristino & Gabriela Steier, *Losing Ground: A Clarion Call for Food System Reform to Ensure a Food Secure Future*, 42 Colum. J. Envtl. L. 59, 96-102 (2016).
280. USDA Office of Inspector Gen., USDA Monitoring of Highly Erodible Land and Wetland Conservation Violations—Interim Report 3 (2016) (Audit Rep. 50601-0005-31); *see* Ristino & Steier, *supra* note 279, at 97.
281. Most federal environmental statutes empower citizens to enforce compliance through citizen suit provisions, which have proven to be among the most effective methods available for holding regulatory subjects and government agencies accountable. Joshua Ulan Galperin, *Trust Me I'm a Pragmatist: A Partially Pragmatic Critique of Pragmatic Activism*, 42 Colum. J. Envtl. L. 426, 487 (2017).

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the required practices to include those that protect soil carbon and water. For example, requiring buffer zones around streams or, where appropriate, cover crops, would have significant climate benefits and co-benefits such as improved soil health, nutrient cycling, pest regulation, and crop productivity.[282] Requiring farm operations to adhere to basic climate-friendly practices in order to receive government benefits would be a cost-effective, quick, and fair way to catalyze widespread change.

6. Renewable Fuel Standard Grassland Conservation Compliance

In the United States in 2017, close to 30 million acres of corn were grown as feedstock for ethanol.[283] Yet, the purported climate change benefits of corn ethanol are widely disputed and modest at best. Ideally, Congress should reform the RFS to support only those biofuels with significant climate benefits.

Conversion of native ecosystems for cultivation releases vast amounts of carbon dioxide. A 2008 study found that converting forest, grassland, or peatland for biofuel production can release 17-420 times more carbon dioxide than the annual greenhouse gas reductions these biofuels would provide by replacing fossil fuels.[284] To prevent this conversion of natural ecosystems, Congress in 2007 revised the 2005 RFS to exclude crops "harvested from land cleared or cultivated" after December 19, 2007, from its definition of "renewable biomass."[285]

EPA regulations implementing this provision, however, have rendered it meaningless. Though EPA's proposed rule required crop producers to comply with recordkeeping requirements to verify that feedstocks met Congress' definition, the Agency then worked with USDA to write a final rule that differed significantly from that proposal. In the final rule, the Agency adopted an "aggregate compliance" approach that instead deems all producers compliant with the standard as long as the net land area used for agriculture in the United States does not exceed its 2007 level of 402 million acres.[286] This approach has demonstrably failed to prevent significant land conversion, with satellite data analysis estimating that 4.2 million acres of land have been converted to agriculture for biofuel production since the adoption of the standard.[287]

This "aggregate compliance" approach is also facially ineffective as millions of acres of agricultural land are converted each year for many reasons, such as urban development, roads, or energy production. Thus, an overall cap cannot prevent conversion. EPA should repeal the "aggregate compliance" standard and replace it with a mandate to demonstrate feedstock was produced on land cleared before December 7, 2007.

7. Transforming the Farm Safety Net Through Legislative Action

The federal government radically transformed the farm sector in the 1930s through a series of laws that created a robust system of subsidies for commodity crop production, and provided for an ambitious set of new research and loan programs.[288] This flurry of legislation saved countless farms from bankruptcy during the Great Depression, but it also led to the rapid expansion of large-scale, capital-intensive farms and feedlots,[289] with scant concern for agriculture's environmental and social impacts. This policy shift was accompanied by significant technological change and mechanization as well.[290] These laws have since been modified, but their basic framework persists today—as does their emphasis on the large-scale production of commodity crops and meat.

Agricultural law is long overdue for another transformation for a number of reasons, including the need to incorporate climate stability and resilience as a major goal. The new framework must recognize that the agricultural sector is now vastly different than it was when the laws were first shaped. It has evolved from a diversified and labor-intensive enterprise to a capital-intensive, specialized, and heavily mechanized operation, typically conducted on a massive scale.[291] The pastoral "family farm"—which has always been more myth than reality—is of little relevance to today's agricultural industry: 80% of food is produced by only 7% of farms and only 43% of farms earn a gross income of $10,000 or more.[292]

Environmental laws typically exempt (or have been interpreted to exempt) most aspects of agricultural production from pollution limits and other safeguards. These exemptions are sometimes presented as protecting small

282. Meagan Shipanski et al., *A Framework for Evaluating Ecosystem Services Provided by Cover Crops in Agroecosystems*, 125 Agric. Sys. 12, 13 (2014).
283. This figure was estimated for MY 2015/2016 as the proportion of 88 million acres planted to corn equal to the proportion of corn production used for ethanol for fuel. In that year, 43% of the corn supply was used for ethanol for fuel, and 88% of the corn supply was produced in the same year (88 million x 0.43 x 0.88 = 33 million). All data were obtained from USDA Econ. Research Serv., *Feed Grains: Yearbook Tables*, https://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables (last updated July 18, 2017).
284. Joseph Fargione et al., *Land Clearing and the Biofuel Carbon Debt*, 319 Science 1235, 1235 (2008).
285. 42 U.S.C. §7545.
286. 40 C.F.R. §80.1454(g) (2016).
287. Christopher K. Wright, *Recent Grassland Losses Are Concentrated Around U.S. Ethanol Refineries*, 12 Envtl. Res. Letters 1 (2017).
288. By 1935, USDA's budget had expanded 12-fold from pre-Depression levels, making it the single largest agency in the United States. Ernest C. Pasour Jr., Agriculture and the State: Market Processes and Bureaucracy 235 (1990). Phillip D. Winters, Cong. Research Serv., Federal Spending by Agency and Budget Function, FY2001-FY2005, at 10 (2006) (RL 33228).
289. Nathan A. Rosenberg & Bryce Wilson Stucki, *The Butz Stops Here: Why the Food Movement Needs to Rethink Agricultural History*, 13 J. Food L. & Pol'y 12, 13-14 (2017).
290. The benefits of technological changes and mechanization were disproportionately distributed to large-scale landowners as the result of highly favorable federal programs. *Id.* at 20-21.
291. Carolyn Dimitri et al., Econ. Research Serv., USDA, The 20th Century Transformation of U.S. Agriculture and Farm Policy (2005) (EIB-3).
292. Calculated by the authors using USDA data. *See* Nat'l Agric. Statistics Serv., *supra* note 258, at 9 tbl. 2.

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and mid-sized farms, but they often instead externalize the costs of large-scale, capital-intensive operations. The new framework should further recognize that industrial agriculture is now the largest source of water quality impairments, a major source of air pollution,[293] and a driver for much degradation of natural resources. This pollution often threatens human health, as do the predominant crops grown and subsidized—about 60% of federal farm subsidies support corn, soy, and wheat, which are often processed into less healthy foods.

As climate change intensifies, the need for programs designed around a different set of goals will become even more pressing. Instead of serving to expand the capital-intensive production of commodities, the farm safety net should directly compensate farmers for protecting the environment, mitigating climate change, growing healthy food, and strengthening rural communities.[294] As demonstrated above, USDA has significant leeway under current law to revise programs and move agriculture toward, and even to, carbon neutrality. However, a system providing for robust payments for ecosystem services could help realize this goal more quickly and efficiently than the current farm safety net, even with the changes recommended above.

Ecosystem services are benefits that humans derive from ecological resources such as farms, including food, carbon sequestration, wildlife habitat, and recreational enjoyment, among others.[295] A payments-for-ecosystem-services (PES) program is one that provides incentives to farmers or other landowners for provisioning such services. A 2014 study examining the societal value of soil carbon determined that farmers should be compensated at a rate of $16 an acre for implementing best management practices.[296] It would cost less than $15 billion annually to implement a PES program at this rate for all 914 million acres of farmland in the United States—billions less than we currently spend on crop insurance, commodity, and conservation programs each year.

Carbon farming will require new infrastructure and equipment, both off and on the farm. Paying farmers for implementing climate-friendly practices will facilitate this transition, helping to offset decades of experience and sunk costs in conventional agricultural practices. Reducing the waste that runs through the entire agriculture and food system would provide ample land and resources for a PES system.[297] Replacing a portion of the current farm safety net with a PES program would reduce or eliminate payments for crops with high climate impacts, especially those grown for animal feed, while increasing payments for crops with lower climate impacts, thus helping to make healthy food more affordable. Adopting a progressive payment system could also help small and mid-sized farms, thus increasing the economic well-being of rural communities, and reduce costs. Limiting payments to the first 1,000 acres of a farm, for example, would reduce the number of eligible acres by more than one-half.

A PES approach has the advantages of fostering transparency, using market mechanisms to achieve clearly articulated goals, and increasing efficiency. Congress should reform the farm safety net as soon as possible to shift to greater reliance on payments based on provision of what the country now needs most—climate stabilization and a healthier environment. In so doing, Congress would also be supporting a substantially more transparent, equitable, and sustainable agricultural system.

C. Trade Policy

Exports have played an increasingly important role in the domestic production of agricultural goods in recent years, accounting for roughly 20% of U.S. agricultural production by volume. Commodities such as cotton, rice, soybeans, and wheat generally have much higher export rates, often relying on foreign markets for the majority of their sales.[298]

Title III of the 2014 Farm Bill funds programs to assist industry efforts to expand market demand for U.S. agricultural products abroad. The federal government spends approximately $5.5 billion on these programs annually,[299] although this may increase in future years as agribusiness groups have increasingly focused on expanding export markets.[300] Congress should integrate climate concerns into agricultural trade policy, mandating that USDA and other government agencies focus on developing markets for climate-friendly products and discontinue support for carbon-intensive commodities.

D. Tax Policy

While many aspects of tax policy may influence farming or ranching decisions, just as they can affect the decisions of any business, most are too complicated, indirect, or uncertain to allow generalizations as to how they would effectuate climate-friendly practices. However, there are a few

293. *See* D. Bruce Harris et al., Office of Research & Dev., U.S. EPA, Ammonia Emission Factors From Swine Finishing Operations 1 (2001) (noting that livestock facilities are responsible for 73% of ammonia emissions). *See generally* Dick Heederik et al., *Health Effects of Airborne Exposures From Concentrated Animal Feeding Operations*, 115 Envtl. Health Persp. 298 (2007) (summarizing research on toxic gases, vapors, and particles emitted from CAFOs).

294. *See* Alison Power, *Ecosystem Services and Agriculture: Tradeoffs and Synergies*, 365 Phil. Transactions Royal Soc'y B, 2959, 2966-67 (2010) (noting that farm management can considerably enhance the ecosystem services provided by agriculture).

295. J.B. Ruhl, *Agriculture and Payments for Ecosystem Services in the Era of Climate Change*, *in* Research Handbook on Climate Change and Agricultural Law 315-16 (Mary Jane Angelo & Anél Du Plessis eds., Edward Elgar 2017).

296. Rattan Lal, *Societal Value of Carbon*, 69 J. Soil & Water Conservation 186A, 190A (2014).

297. *See* Peter Lehner, *Feed More With Less*, 34 Envtl. F. 42 (2017).

298. USDA Econ. Research Serv., *Exports Expand Market for U.S. Agricultural Products*, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58396 (last updated Apr. 11, 2016).

299. Mark A. McMinimy, Cong. Res. Serv., R43696, Agricultural Exports and 2014 Farm Bill Programs: Background and Issues 14 tbl. 6 (2014).

300. Press Release, USDA, Secretary Perdue Announces Creation of Undersecretary of Trade and USDA Reorganization (May 11, 2014) (on file with authors).

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direct taxing approaches that would be effective in enhancing climate-friendly practices.

The majority of agricultural emissions are from nitrous oxide produced in soils, much of which is caused by the application of nitrogen fertilizer. Since most producers routinely apply excess fertilizer, federal or state legislators should consider adopting a fertilizer fee that could both encourage more judicious use of fertilizer and help fund training on how to ensure no yield losses with less fertilizer and other climate-friendly agricultural practices. Evidence indicates that rising fertilizer prices have made farmers examine fertilizer use more carefully.[301] A 2011 study in the United States estimated that for every 1% increase in price for synthetic fertilizers, demand for the product would drop 1.87%.[302] At this rate, a 10% tax on nitrogen fertilizers would reduce application rates by 2.4 million tons annually,[303] and result in hundreds of millions of dollars of revenue, while having an insignificant effect on overall costs and prices.[304]

States and local governments can also discourage carbon-intensive practices through taxation. Many states and local governments currently provide significant property tax reductions for farm owners, regardless of how large or profitable their farm operations are.[305] While protecting farmland from development can have climate benefits, states should also take farm practices into account when assessing farmland values. Highly profitable, highly polluting hog CAFOs are often eligible to receive agricultural use exemptions, for example. States and local governments should condition tax reductions for agriculture on the adoption of more climate-friendly practices, perhaps targeting more stringent requirements on larger farms or those with a larger than average carbon impact.[306]

A number of federal, state, and local tax expenditures also support conservation easements. In 2015, Congress permanently extended an enhanced tax deduction for landowners donating a conservation easement to a land trust or government agency.[307] Conservation easement donations also reduce state and local tax revenues by reducing the assessed value of the land, and in some cases, through tax deductions and credits.[308] Thirty states allow tax deductions for conservation easement donations,[309] while 16 states grant tax credits, including New York and California.[310] Federal, state, and local governments should all consider requiring farm owners to comply with basic climate-friendly practices, such as installing buffer strips next to streams, in order to receive tax benefits for agricultural easements.

E. *Regulatory Options*

Methane and nitrous oxide are the two main direct sources of agricultural emissions. EPA has several direct regulatory tools available to reduce emissions of these greenhouse gases. These tools include recognizing the harm or "endangerment" caused by these pollutants and promulgating regulatory programs to require or support their reduction. These regulatory programs could include direct limits, prohibitions on certain activities or practices known to emit significant amounts, or increased support for known practices that reduce emissions.

Federal and state governments can also reduce greenhouse gas emissions as incidental to their regulation of water or other pollution. Programs to reduce nitrate runoff from fields into rivers would (depending on the precise practices incentivized) likely reduce nitrous oxide emissions; programs to reduce erosion and sediment pollution from grazing could likely increase soil carbon; and programs to change manure management could reduce methane emissions.

The CWA establishes a national pollutant discharge elimination system (NPDES) to regulate operations that discharge pollutants directly into waters. While most field operations and irrigation water return flows are exempted from direct regulation,[311] other agricultural operations including CAFOs and the spreading of manure are covered.[312] The law requires point source dischargers to obtain an NPDES permit from EPA or authorized state authorities in order to operate.[313] States that have been authorized to act as a permitting authority may impose more stringent requirements than the federal government.[314] In addition, the CWA requires states to develop programs to address nonpoint source (runoff) pollution, including agricultural sources.[315]

301. After fertilizer prices rose in 2006, 32% of surveyed farmers in the United States reported reducing their fertilizer use. Jayson Beckman et al., Econ. Research Serv., USDA, Agriculture's Supply and Demand for Energy and Energy Products 17 (2013) (EIB-112).

302. James Williamson, *The Role of Information and Prices in the Nitrogen Fertilizer Management Decision: New Evidence From the Agricultural Resource Management Survey*, 36 J. Agric. & Resource Econ. 552, 568 (2011).

303. A total of 12,840,000 tons of nitrogen fertilizer were applied in the United States in 2011. Econ. Research Serv., USDA, U.S. Consumption of Nitrogen, Phosphate, and Potash, 1960-2011, at 1 tbl. 1 (2013).

304. Nitrogen fertilizer prices have ranged from $351 to $847 per ton in recent years. *Id*.

305. *See*, *e.g.*, N.M. Stat. Ann. §7-36-20 (2016). For a complete list, see Lincoln Inst. of Land Policy, *Tax Treatment of Agricultural Property*, http://datatoolkits.lincolninst.edu/subcenters/significant-features-property-tax/Report_Tax_Treatment_of_Agricultural_Property.aspx (last visited Aug. 1, 2017).

306. Many states have similar tax reduction programs for lands held for forestry. *See* Jane Malme, Preferential Property Tax Treatment of Land 9-11 (Lincoln Inst. of Land Policy, Working Paper Prod. Code WP93JM1, 1993). Originally designed to encourage forest products industries, these programs should also be redesigned to prioritize carbon-friendly forestry programs and to require carbon-friendly core practices.

307. I.R.C. §170(b)(1)(E) (2016).

308. Gerald Korngold, *Government Conservation Easements: A Means to Advance Efficiency, Freedom From Coercion, Flexibility, and Democracy*, 78 Brook. L. Rev. 467, 471 (2013).

309. Jeffrey O. Sundberg, State Income Tax Credits for Conservation Easements: Do Additional Credits Create Additional Value? 3 (Lincoln Land Inst. Working Paper WP11JSS1, 2011).

310. Land Trust Alliance, *Income Tax Incentives for Land Conservation*, https://www.landtrustalliance.org/topics/taxes/income-tax-incentives-land-conservation (last visited Aug. 1, 2017).

311. 33 U.S.C. §1362(14).

312. *Id*.

313. *Id*. §1342.

314. 40 C.F.R. §123.25(a) (2016).

315. *Id*. §130.6 (2016).

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EPA should strengthen its nationwide regulations in ways that would reduce greenhouse gas emissions as well as water pollution. Moreover, since states can be more stringent than the federal government, states with NPDES permitting authority should strengthen their programs in similar ways. For example, NPDES programs should clearly prohibit CAFOs from spreading manure on frozen or saturated lands, insist on vegetated buffer zones along water courses, limit application rates, or require dry manure management, which can also reduce methane emissions. Similarly, management of crop production should require or incentivize buffer zones to reduce nitrate emissions, and thus also nitrous oxide emissions.

Other statutes also give EPA regulatory options for reducing agricultural greenhouse gas emissions. The most common waste management systems at industrial livestock facilities produce massive quantities of toxic fumes of ammonia and hydrogen sulfide in addition to the greenhouse gases methane and nitrous oxide. EPA estimates that livestock facilities are responsible for 73% of the country's ammonia air emissions.[316] Many of the practices that would reduce these hazardous air emissions would also reduce methane and nitrous oxide emissions, and EPA should thus use its regulatory tools to achieve such reductions.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980[317] and the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986[318] require all facilities that release hazardous substances to report these emissions to federal, state, and local governments and emergency responders.[319] In 2008, EPA exempted livestock facilities from this reporting requirement.[320] In 2017, the U.S. Court of Appeals for the District of Columbia (D.C.) Circuit struck down EPA's loophole as illegal.[321] Although there is pressure from the animal production industry to reinstate the exemption, EPA should not do so, ensuring that an estimated 33,000 facilities are covered.[322]

Similarly, the Resource Conservation and Recovery Act (RCRA)[323] has been successfully used by neighbors of a large animal facility to require the better management of stored and spread manure to limit groundwater contamination.[324] Again, manure management changes instigated by concerns for groundwater, including more significant changes such as to dry manure handling or installation of digesters, can also reduce greenhouse gases. Both EPA and Congress should resist efforts by the industry to amend RCRA to exempt animal manure.

In considering regulatory approaches, the largest 0.4% of farms in the United States produce almost one-third of all agricultural products in the country, while the top 7% are responsible for more than 80%.[325] The top 7% of producers also owns 60% of the harvested cropland,[326] receives almost one-half of all government farm payments,[327] and takes in almost 90% of all net farm income.[328] Policymakers should be attentive to the genuine challenges farming operations face when transitioning to climate-friendly practices, but most of these large commercial farms, which often earn millions each year, can afford to adopt basic conservation practices. Congress and USDA should require large-scale operations to curb their most environmentally damaging practices in exchange for support from government programs.

Finally, state and local governments should improve on current federal regulations by passing their own legislation designed to reduce emissions from agricultural operations. The California State Legislature, for example, passed a law in 2014 directing the California Air Resources Board (ARB) to develop a comprehensive strategy to reduce short-lived climate pollutants, including methane.[329] Subsequent legislation required ARB to begin implementing the plan by 2018.[330] ARB's strategy calls for significant decreases in emissions from dairy manure management with reductions of at least 20% in 2020, 50% in 2025, and 75% in 2030.[331] In 2015, Minnesota passed a pioneering law requiring permanent vegetative buffers on farmland abutting lakes and streams.[332] The law was designed to reduce runoff, but will also increase soil carbon sequestration on the new strips, thereby reducing greenhouse gas emissions within the state.

There are a variety of practices that state legislatures and environmental agencies and local governments should require—such as riparian buffers—or prohibit—such as spreading manure on frozen land—in order to further reduce the environmental harms of modern industrial agriculture. This would provide models for future federal initiatives, while also producing immediate climate and environmental benefits.

F. Financing Options

The Farm Credit System is a privately owned, federally chartered network of lending institutions that focus on

316. D. Bruce Harris et al., U.S. EPA, Presentation at EPA Emissions Inventory Conference, Ammonia Emission Factors From Swine Finishing Operations (May 3, 2001).
317. 42 U.S.C. §§9601-9675, ELR Stat. CERCLA §§101-405.
318. 42 U.S.C. §§11001-11050, ELR Stat. EPCRA §§301-330.
319. 42 U.S.C. §§9603(a), 11004.
320. 40 C.F.R. §§302.6(e)(3), 355.31(g), (h) (2016).
321. Waterkeeper Alliance v. Environmental Prot. Agency, 853 F.3d 527, 47 ELR 20062 (D.C. Cir. 2017).
322. EPA estimated that 33,000 facilities were exempted by its rule from CERCLA reporting. See regulatory docket at EPA-HQ-SFUND-2007-0469-1361.
323. 42 U.S.C. §§6901-6992k, ELR Stat. RCRA §§1001-11011.
324. Community Ass'n for Restoration of the Env't, Inc. v. Cow Palace LLC, 80 F. Supp. 3d 1180, 45 ELR 20008 (E.D. Wash. 2015). *See* Caroline Simson, *Wash. Dairy Settles Enviros' Manure Contamination Suit*, Law360, May 12, 2015.
325. Calculated by the authors using data from the Census of Agriculture. *See* Nat'l Agric. Statistics Serv., *supra* note 258, at 9 tbl. 2.
326. *Id.* at 100 tbl. 65.
327. They receive 44% of farm subsidies and 52% of crop insurance payments. *Id.* at 94, 100 tbl. 65.
328. *Id.* at 98 tbl. 65.
329. Cal. Health & Safety Code §39730 (West 2017).
330. *Id.* §39730.5 (West 2017).
331. ARB, Cal. Envtl. Prot. Agency, Proposed Short-Lived Climate Pollutant Reduction Strategy 7 (2016).
332. *See generally* 2016 Minn. Sess. Law ch. 85, S.F. No. 2503 (2016) (to be codified at scattered sections of Minn. Stat. Ann. chs. 103A-114b).

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agricultural loans. Created by Congress in 1916 to provide a reliable source of credit for agricultural producers,[333] it now holds nearly 41% of the farm sector's total debt—a larger share than that held by commercial banks.[334] The Farm Credit System benefits from a range of publicly funded guarantees, subsidies, and exemptions.

USDA also manages the Farm Service Agency (FSA), which, among other things, acts as a lender of last resort for farmers and ranchers. In addition to offering direct loans to farmers, the agency also issues guarantees on loans made by commercial lenders for farmers that would not otherwise qualify. While FSA's overall impact on the agricultural credit market is relatively small—it holds 2.1% of all farm debt through direct loans and guarantees another 4-5% of loans—it has come to play an important role in supporting beginning, minority, and female farmers.[335] In exchange for guarantees and other benefits, Congress should require FSA and the Farm Credit System lending institutions to offer programs providing favorable credit to farmers and ranchers using climate-friendly practices recognized by NRCS and to require minimum climate-friendly practices relating to all loans.

G. Grazing Practices on Government Land

Overgrazing by livestock increases soil erosion, water pollution, and the loss of soil carbon.[336] While grazing occurs on hundreds of millions of acres of private land, more than 40% of all grazing lands in the United States—approximately 330 million acres—are on federal public lands,[337] managed by BLM and USFS.

A reduction in grazing intensity would help restore the lost carbon.[338] BLM and USFS lease land to ranchers on the condition that they will uphold conservation values,[339] including soil health. However, public interest groups allege that BLM and USFS have done little to enforce these lease provisions.[340] These agencies should not only enforce these provisions, but should also add new ones designed to reduce the climate impacts of grazing systems. Even small improvements in practices could have a significant impact due to the immense size of federal grazing lands. Just as on private lands, intense rotational or carefully managed grazing can have numerous ecological and climate benefits, so BLM and USFS should, through pricing or other preferences, seek to incentivize such practices.

A key term in any lease or grazing permit is the grazing intensity—how many animals can graze a certain allotment in a certain period. It appears that the grazing intensity established in many leases is now outdated, in part because beef cattle live weights have increased by about 30% over the past 30 years,[341] and decades of overgrazing and now climate change reduce forage availability in many regions.[342] Both BLM and USFS should undertake a process to update the grazing intensity limit in leases to reflect current conditions.

Even if they do not update leases, the agencies should give ranchers the flexibility to graze fewer than the allotted number of animals in order to preserve the range over the longer term and increase their profitability. However, BLM regulations provide for canceling permits of ranchers who fail to make "substantial use" of allotted forage for two consecutive years.[343] The term "substantial use" is undefined and this ambiguity has prompted many ranchers to maximize their use of allotted forage to ensure compliance with BLM requirements.[344] Similarly, USFS generally requires ranchers to graze at least 90% of allotted forage or risk revocation of their leases.[345] BLM and USFS should revise their policies to allow ranchers to graze only at intensities they believe are optimal, allowing them to restore the range and increase soil carbon.

Finally, courts have held that, under the existing law governing grazing on land that is "chiefly valuable for grazing and raising forage crops,"[346] permits and leases cannot be used solely for conservation.[347] This has prevented even those who have paid fair market value for leases to retire the allotments from grazing. Congress should let the market work and clarify that the purchaser of a lease or permit can graze as few animals as desired in order to preserve ecological values such as soil carbon.

H. Greenhouse Gas Pricing

Carbon pricing for all greenhouse gases from agriculture would be a highly effective policy lever.[348] While economic uncertainties make it difficult to predict precise impacts, a carbon price creates a broad signal affecting the decisions of most or all actors and can spur innovation toward lower greenhouse gas technologies and practices. A system that allowed agricultural producers to earn revenue by storing

333. Farm Credit Act of 1933, Pub. L. No. 73-75, 48 Stat. 257.
334. Jim Monke, Cong. Research Serv., Farm Credit System 1 (2015) (RS 21278).
335. *Id*.
336. Richard T. Conant & Keith Paustian, *Potential Soil Carbon Sequestration in Overgrazed Grassland Ecosystems*, 16 Global Biogeochemical Cycles 90-1, 90-1 (2002).
337. *See* USDA U.S. Forest Serv., *About Rangeland Management*, https://www.fs.fed.us/rangeland-management/aboutus/index.shtml (last visited Aug. 1, 2017).
338. *Id*.
339. 43 C.F.R. §4180.2 (2016).
340. Pub. Employees for Envtl. Responsibility, *About the BLM Grazing Data*, http://www.peer.org/campaigns/public-lands/public-lands-grazing-reform/blm-grazing-data.html (last visited Aug. 1, 2017).
341. Bryan McMurry, *Cow Size Is Growing*, Beef, Feb. 1, 2009, http://www.beefmagazine.com/genetics/0201-increased-beef-cows.
342. Daniel W. McCollum et al., *Climate Change Effects on Rangelands and Rangeland Management: Affirming the Need for Monitoring*, 3 Ecosystem Health & Sustainability 1, 7 (2017).
343. 43 C.F.R. §4170.1-2 (2016).
344. Steven C. Forrest, *Creating New Opportunities for Ecosystem Restoration on Public Lands: An Analysis of the Potential for Bureau of Land Management Lands*, 23 Pub. Land & Resources L. Rev. 21, 39 (2002).
345. U.S. Forest Serv., USDA, Range Management ch. 2230, at 18 (2005).
346. Taylor Grazing Act, 43 U.S.C. §315.
347. Public Lands Council v. Babbitt, 529 U.S. 728, 30 ELR 20566 (2000).
348. See Guri Bang et al., *California's Cap-and-Trade System: Diffusion and Lessons*, 17 Global Envtl. Pol. 18-21 (2017), for a comparison of California's cap-and-trade system with the Regional Greenhouse Gas Initiative and other systems.

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soil carbon or reducing methane or nitrous oxide emissions, especially if such payment were in lieu of current federal farm subsidies, could be an effective way to quickly cut emissions while increasing the carbon sink.

A carbon pricing mechanism would need to cap all greenhouse gases, otherwise it could shift practices to those with a greater climate impact. Given the difficulty of precisely measuring emissions of nitrous oxide and methane from agricultural operations, however, it would be difficult to have a precise fee applied to such emissions. Whether as an offset or within a cap or tax regime, it would be necessary to create methodologies that can model emissions based on practices, at least until precise measurement tools become available.

IV. Non-Public Law Approaches to Reducing Net Agricultural Emissions

There are five main ways that the private and philanthropic sectors can boost carbon farming and help reduce net agricultural emissions. Sustained funding and support for agricultural research will be critical, especially during periods when the executive branch is indifferent or hostile to scientific research. Access to capital, already a significant issue, will continue to be a need for producers adopting new and innovative practices designed to sequester carbon or decrease emissions. Absent the involvement of the federal government, nonprofit organizations will also need to take a leading role in developing and dispersing tools for carbon farmers, whether they are practical, such as inexpensive methods for measuring soil carbon content, or legal, such as conservation easements. Finally, there is significant enthusiasm among some industry and environmental groups for agricultural carbon markets.

In the 1970s and 1980s, a number of private research organizations such as the Rodale Institute, the Aprovecho Institute, and the Michael Fields Agricultural Institute were created to conduct and support research into organic and ecological farming.[349] Their work to develop and proliferate new practices was instrumental in the growth of sustainable agriculture. Foundations and private donors should support the work these research organizations are conducting on climate-friendly practices, in addition to helping fund new organizations devoted to carbon farming.

The seasonal nature of farming makes loans particularly important for farmers. In 2015, more than 1.3 million non-real estate loans, mostly for seasonal operating costs, were made to farmers.[350] Most of these loans are granted by small banks, some of which rely on agricultural loans for a substantial part of their business. Agricultural lenders often hesitate to make loans to farmers using new or experimental practices, however. This can make it difficult for farmers to adopt innovative carbon farming techniques, regardless of their actual exposure to risk.

The private philanthropic sector (either directly or through advocacy organizations) or USDA should support agricultural banks in lending for practices that are perhaps less well-known and widely accepted. At a minimum, USDA and environmental organizations should ensure that agricultural banks are familiar with the benefits of carbon farming, which makes farms more resilient to weather disturbances and therefore exposes the lending institution to less risk. Finally, Congress or state legislatures should create lending institutions, or existing ones could create specialty divisions, aimed at financing farms using climate-friendly practices.

Private financing also has a role to play. While there has been an increase in venture capital funding for "ag-tech,"[351] most of the funding has focused on precision agriculture and a narrow range of practices. Philanthropists, impact investors, and foundations should focus investment on a broader range of carbon farming practices, accelerating its development.

Measuring soil carbon is currently a time-intensive, expensive, and complicated exercise. There are also few established protocols for measuring precisely the greenhouse gas benefits of climate-friendly practices, making it difficult to pay farmers in offset markets for implementing such practices.[352] Nonprofit organizations and land-grant universities should prioritize funding to develop and distribute cost-effective monitoring, measurement, and verification tools, while the private for-profit, not-for-profit, and philanthropic sectors should work together with the research community to standardize measuring techniques.

Because many government easement programs are designed and administered by nonprofits, the private sector can play an important role in adapting and expanding agricultural easement programs to support climate-friendly practices. Agricultural easements can be drafted to give both farmers and land conservation agencies greater flexibility to monitor and reduce net emissions. Land conservation agencies and agricultural land trusts should incorporate climate change mitigation into easement purposes, ensuring that farmers' efforts to mitigate climate change do not conflict with their easements.[353] Additionally, easements should be written to allow for ecological monitoring, scientific research, and publicly accessible data sources.[354]

Carbon offset markets allow greenhouse gas polluters to pay another party to reduce emissions or sequester carbon instead of reducing their own emissions. These purchased

349. Niggli et al., *supra* note 185, at 55-56.
350. Fed. Reserve Bank of Kan. City, Agricultural Finance Databook tbl. A-1 (2017).
351. *See* AgFunder, AgTech Investing Report: Year in Review 2015, at 3 (2016) (noting that funding for agricultural technology doubled between 2014 and 2015).
352. *See, e.g.*, Robert Pallasser et al., *A Novel Method for Measurement of Carbon on Whole Soil Cores*, *in* Soil Carbon (Alfred Hartemink & Kevin McSweeney eds., Springer 2014).
353. For example, conservation easements often prohibit new structures, including wind turbines and processing facilities for new agricultural products. Jessica Owley, *Conservation Easements at the Climate Change Crossroads*, 74 L. & Contemp. Probs. 199, 207-08 (2011).
354. Adena Rissman et al., *Adapting Conservation Easements to Climate Change*, 8 Conservation Letters 68, 73 (2015).

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reductions, called offsets, can help finance the transition to carbon farming, compensating farmers for sequestering carbon or reducing emissions.[355] The market for agricultural offsets in the United States as of 2017 is small and confined to rice production in California,[356] although agencies and others in California are also closely studying manure management at confined animal production facilities.

A current limitation is the ability to measure greenhouse gas reductions from altered practices, so it would be beneficial for organizers of offset systems such as state governments to explore different payment schemes; for example, instead of paying for offsets per ton (as is generally the case), payments could be based on practices implemented per acre, with a price set by calculations of average benefits, or based on measurements of surrogate indicators. Finally, offset markets should prioritize year-to-year reductions such as in methane from rice production or animal production or permanent (or long-term) changes in land use. Short-term soil carbon sequestration practices, which can be quickly reversed and are poorly understood, are a less reliable strategy for offsetting fossil fuel emissions at this time.[357]

V. Reducing Food System Emissions

A. *Upstream: Greenhouse Gas Emissions From Farm Inputs*

Conventional agriculture in the United States is heavily reliant on fossil fuels. Most commercial farms rely on energy-intensive equipment to perform a wide range of farm tasks, including weeding, planting, and harvesting, in order to reduce their labor needs. In addition, the manufacturing process for farm inputs such as pesticides and particularly fertilizer requires a substantial amount of energy.[358]

Significant benefits are possible from reducing emissions from the production of nitrogen fertilizer and on-farm fuel usage, which together account for almost two-thirds of upstream emissions.

Nitrogen-based fertilizers accounted for 59% of total U.S. fertilizer consumption,[359] but were responsible for approximately 90% of emissions from the fertilizer production process. (Indeed, emissions from the production of nitrogen fertilizer could be about one-fourth of the typical emissions from its application.[360]) New ammonia production facilities are approximately 30% more energy-efficient than older ones, indicating that this sector's emissions could be significantly reduced by modernizing production processes.[361] There is also some promise in facilities that can produce nitrogen fertilizer from biomass instead of natural gas,[362] and in facilities that produce both electricity and fertilizer accompanied by carbon capture and storage (or reuse),[363] which could produce fertilizer with very low greenhouse gas emissions. Governmental support for such projects should be explored.

Despite progressively tightening its fuel economy standards for light-duty vehicles, EPA has yet to promulgate any standard for off-road diesel vehicles. Fuel efficiency for on-farm vehicles has consequently lagged. EPA should promulgate fuel economy standards for off-road diesel vehicles such as tractors to reduce their carbon dioxide emissions, which remain a significant source of on-farm emissions. Since turnover among off-road vehicles is slower than turnover among light-duty vehicles, however, significant improvements in emissions reduction will be slow. Moreover, farm programs implemented by USDA should also be designed to encourage farmers, preferably through incentives, to adopt less fuel-intensive practices. For example, tractors on no-till farms only emit one-sixth as much carbon dioxide equivalent as tractors on farms practicing complete tillage.[364]

B. *Downstream: Emissions From Food Processing, Packaging, Marketing, and Waste*

Postproduction greenhouse gas emissions, while significant, have not been comprehensively catalogued in the United States. The main contributors to emissions beyond the farm gate are energy expenditures associated with food processing, packaging, marketing, and distribution. Food waste contributes to emissions indirectly, through emissions resulting from the production, distribution, and marketing of the wasted food, and directly, through methane emissions from landfills.

In 2006, the food processing sector emitted approximately 117 million metric tons of carbon dioxide equivalent, making it one of only four industrial sectors in the United States responsible for more than 100 million metric tons of carbon dioxide annually.[365] Mitigation within the food processing sector will largely depend on reducing

355. Robert Parkhurst, *Carbon Markets in Agriculture Are the Next Big Thing*, Envtl. Def. Fund, Jan. 24, 2016, http://blogs.edf.org/growingreturns/2016/01/24/carbon-markets-in-agriculture-are-the-next-big-thing/.
356. Niina Heikkinen, *Rice Growers on the Front Lines of U.S. Carbon Markets*, E&E News, Jan. 20, 2016, https://www.eenews.net/stories/1060030839; Brian C. Murray, *Why Have Carbon Markets Not Delivered Agricultural Emission Reductions in the United States?*, Choices, 2015.
357. It is easier to track the sequestration benefits of above-ground biomass, such as trees and shrubs, making agroforestry and silvopasture safer options for offsetting emissions.
358. Mario Giampietro, *Energy Use in Agriculture*, *in* Encyclopedia of Life Sciences 4 (Nature Publishing Group 2003).
359. Jayson Beckman et al., Econ. Research Serv., USDA, Agriculture's Supply and Demand for Energy and Energy Products 10 (2013) (EIB-112).
360. Evan M. Griffing et al., *Life Cycle Assessment of Fertilization of Corn and Corn-Soybean Rotations With Swine Manure and Synthetic Fertilizer in Iowa*, 43 J. Envtl. Quality 709 (2014).
361. Int'l Fertilizer Indus. Ass'n, Feeding the Earth: Energy Efficiency and CO_2 Emissions in Ammonia Production 2 (2009).
362. SynGest, *Providing America's Strategic Fuel and Fertilizer*, http://www.syngest.com/company.html (last visited Aug. 1, 2017).
363. *See, e.g.*, SCS Engineers, *Home Page*, http://www.scsengineers.com/ (last visited Aug. 1, 2017).
364. Rattan Lal, *Carbon Emission From Farm Operations*, 30 Env't Int'l 981, 982 (2004).
365. Sabine Brueske et al., Oak Ridge Nat'l Lab., U.S. Manufacturing Energy Use and Greenhouse Gas Emissions Analysis 37 tbl. 2.1-16 (2012).

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energy intensity in addition to other cross-sector efforts, such as reducing reliance on fossil fuel energy sources. As a result, EPA and the U.S. Department of Energy should explore adopting energy-efficiency standards that would apply to this sector.

Diverting food and agricultural waste from landfills is an opportunity to significantly reduce greenhouse gas emissions.[366] Although in 2016 EPA issued new rules requiring installation of systems to capture landfill gas (usually comprising half methane and half carbon dioxide) at larger municipal waste landfills constructed after July 2014, and updated landfill gas capture systems for larger existing landfills constructed after 1987,[367] there is still great climate benefit to reducing organic waste in landfills. Older and smaller landfills are not covered; there is a long time lag before full compliance will be required; and the landfill gas capture is not complete.

Food waste makes up more than 20% of the materials discarded.[368] Once in a landfill, organic matter decomposes without the presence of oxygen, releasing large amounts of methane.[369]

Food waste decays more rapidly than other organics (wood, yard waste, paper) due to its high moisture content, making it an especially heavy emitter of methane soon after disposal. As a result, food waste is responsible for as much as 90% of methane emissions from landfills during their initial years when they are less likely to be capped.[370] While reliable data are lacking on the sources of food waste, one industry-funded report estimates that residential food waste is responsible for 44% of post-farm food waste.[371] The commercial sector, which includes restaurants and grocery stores, is estimated to dispose of 44% of post-farm food waste, while waste from institutions and industry operations made up the remaining 12%.[372]

Many jurisdictions have demonstrated that organics can be diverted from landfills in a cost-effective and environmentally beneficial way. European Union countries were required to reduce biodegradable waste to 35% of 1995 levels by 2016,[373] and several countries have gone beyond this requirement.[374] Similarly, several states and municipalities have also taken action to divert organic waste from landfills. In 2012, Vermont passed the Universal Recycling Law, which enacted a complete ban on food waste in landfills.[375] Shifting waste to composting facilities converts the waste into useful material and results in negative net emissions.[376] San Francisco passed an ordinance in 2009 requiring all businesses and households to sort organics for collection and composting.[377] San Francisco now collects more than 220,000 tons of organic waste each year, and is considered the country's most successful composting program.[378] These programs provide a model for Congress, states, and localities to follow when designing legislation banning food waste in landfills.

VI. Changing Consumption Patterns

Just as the federal government influences what farmers grow through its farm programs, it also influences what people consume through its dietary recommendations, labeling systems, and procurement policies. The private sector also plays an important role in influencing consumption patterns through advertising, labels, and menu options.

The dietary guidelines, updated every five years by USDA and the U.S. Department of Health and Human Services (HHS), include the federal government's recommendations regarding nutrition and diet; dictate how government agencies teach nutrition; determine what students, seniors, and other recipients of government-funded meals are fed; and guide government-funded research and nutrition projects.[379] In 2015, the Dietary Guidelines Advisory Committee recommended that the guidelines incor-

366. It is sometimes argued that reducing food loss will result in reduced food production and distribution. *See*, *e.g.*, Craig Hanson et al., *What's Food Loss and Waste Got to Do With Climate Change? A Lot, Actually*, World Resources Inst., Dec. 11, 2015, http://www.wri.org/blog/2015/12/whats-food-loss-and-waste-got-do-climate-change-lot-actually. While intuitively this makes sense, there are a number of variables that make it impossible to predict what impact reduced domestic demand would have on land use, including funding for farm programs, support for biofuels, and fluctuations in global consumer demand and international commodity markets. Additionally, the amount of cropland and grazing land in the United States has stayed more or less constant since 1945, despite a radically higher supply of agricultural commodities gained through higher yields.

367. News Release, U.S. EPA, EPA Issues Final Actions to Cut Methane Emissions From Municipal Solid Waste Landfills (July 15, 2016), https://www.epa.gov/newsreleases/epa-issues-final-actions-cut-methane-emissions-municipal-solid-waste-landfills; Standards of Performance for Municipal Solid Waste Landfills, 81 Fed. Reg. 59332 (Aug. 29, 2016) (regulating new and modified landfills under the New Source Performance Standards program of the CAA); Emission Guidelines and Compliance Times for Municipal Solid Waste Landfills, 81 Fed. Reg. 59276 (Aug. 29, 2016) (regulating existing landfills under CAA §111(d)).

368. *See* EPA, *supra* note 9, at 7-18 tbl. 7-6.

369. *Id*. at 7-3.

370. Dana Gunders, Natural Res. Def. Council, Wasted: How America Is Losing Up to 40 Percent of Its Food From Farm to Fork to Landfill 14 (2012).

371. Bus. for Soc. Responsibility, Food Waste: Tier 1 Assessment 12 (2012).

372. *Id*.

373. *See generally* Council Directive 1999/31/EC, 1999 (EU).

374. Peter Krause et al., Umwelt Bundesamt, Compulsory Implementation of Separate Collection of Biowaste 3-4 (2015). *See* Edward Perchard, *Technicality Scraps French Food Waste Law*, Resource, Aug. 21, 2015, http://resource.co/article/technicality-scraps-french-food-waste-law-10417.

375. Vt. Stat. Ann. tit. 10, §6602(29) (West 2017). California, Connecticut, and Massachusetts have also passed legislation or promulgated regulations requiring commercial businesses to divert food waste from landfills under certain circumstances. Cal. Pub. Res. Code §42649.81 (West 2017) (applies to businesses generating eight cubic yards of organic waste or more per week); Conn. Gen. Stat. Ann. §22a-226e (West 2017) (limits entities to no more than 52 tons of organic waste by 2020); Mass. Regs. Code tit. 310, §§19.006 & 19.017(3) (2017) (bans entities from disposing of more than one ton of food waste per week).

376. U.S. EPA, Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)—Organic Materials Chapters 1-29 to 1-30 (2016).

377. S.F., Cal., Ordinance 100-09 (June 9, 2009).

378. *See also* Sean Kennedy, *In Seattle, Compost Your Food Scraps—Or Else*, CNN, Oct. 3, 2014, http://www.cnn.com/2014/09/24/politics/seattle-composting-law/.

379. *See* 7 U.S.C. §5341(a)(1) ("Each such report . . . shall be promoted by each Federal agency in carrying out any Federal food, nutrition, or health program.").

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porate sustainability in their dietary recommendations.[380] Although rejected in the final guidelines,[381] the agencies should revisit this decision.[382]

Such a move would not be without precedent. The dietary guidelines of several countries, including Brazil, Denmark, the Netherlands, and Sweden, explicitly acknowledge the interdependence of healthy diets and environmental sustainability.[383] Brazil's dietary guidelines, for example, encourage the use of minimally processed plant-based foods over animal products to reduce greenhouse gas emissions and deforestation.[384] By incorporating sustainability into the guidelines, USDA and HHS could quickly and effectively decrease the carbon intensity of the American diet.[385] More than one-half of American consumers claim that food sustainability is important and almost 80% are seeking to eat more fruits and vegetables, which generally have a much lower climate impact than animal products.

Congress and other governments should also prioritize climate change in procurement contracts as it has prioritized other values. The 2008 Farm Bill, for example, directed USDA to pass regulations encouraging institutions participating in child nutrition programs to purchase local agricultural products.[386] Additionally, Congress could pass legislation prioritizing low-carbon agricultural products for all government bodies, including large-scale purchasers such as the U.S. Department of Defense. States and local governments, of course, should pass similar laws. Large institutions and corporations seeking to improve their sustainability can also look to food purchasing as an important opportunity.

Finally, certification is another method that may help encourage the growth of carbon farming. Organic certification has helped create a price premium for organic products, leading to increased investment and innovation in the field.[387] As a result, organic food has grown from 1% of the market in 1997 to almost 5% of the market in 2014.[388] Several private organizations, such as the Rainforest Alliance and Fairtrade Netherlands, already have, or are in the process of developing, certifications for carbon-neutral coffee.[389] Environmental groups and other nonprofit organizations should expand on these initiatives by developing certification programs for other carbon-neutral food products, which could have the same impact over time as the organic certification and could help boost interest and investment in climate-friendly practices.[390]

In addition, restaurants should offer an expanded range of low-carbon options, helping to make climate-friendly diets more convenient and affordable.[391] Almost one-third of all calories consumed in the United States are from foods prepared away from home.[392] Studies also show that people tend to consume more calories and meat when eating out.[393] In this environment, climate-friendly diets are unlikely to catch on unless consumers have easy and inexpensive access to prepared foods that are climate-friendly. Currently, the average restaurant menu, whether fast-food or sit-down, principally offers carbon-intensive meat options for entrées.[394]

VII. Conclusion

Carbon neutrality in agriculture is achievable and should be a priority for the United States. As of 2015, agriculture was responsible for almost 10% of U.S. greenhouse gas emissions, while the nation's food system as a whole contributed approximately double that amount. This is avoidable. The climate-friendly agricultural practices included in this Article are proven to significantly reduce greenhouse gas emissions from farming, ranching, and livestock production. In addition, agriculture is unique among major sectors of the economy in possessing the potential not only to reduce emissions, but also to remove carbon from the atmosphere and sequester it in the soil. By both reducing emissions and increasing soil carbon sequestration, U.S. agriculture can become carbon-neutral.

Curbing climate change is not the only reason that policymakers and producers should support agricultural practices that reduce emissions or increase soil carbon. Vir-

380. USDA & HHS, Scientific Report of the 2015 Dietary Guidelines Advisory Committee, Part D. Chapter 5: Food Sustainability and Food Safety (2015).

381. Tom Vilsack & Sylvia Matthews Burwell, *2015 Dietary Guidelines: Giving You the Tools You Need to Make Healthy Choices*, USDA, Oct. 6, 2015, https://www.usda.gov/media/blog/2015/10/6/2015-dietary-guidelines-giving-you-tools-you-need-make-healthy-choices.

382. *E.g.*, Michele Simon, My Plate, My Planet: Food for a Sustainable Nation, Statutory Authority for Sustainability in the Dietary Guidelines for Americans: A Legal Analysis (2015).

383. Ministry of Health of Brazil, Dietary Guidelines for the Brazilian Population 18-19, 31-32 (2d ed. 2014); Megha Cherian, *Sustainability: A Growing Factor in Dietary Guidelines*, Global Citizen, May 11, 2016, https://www.globalcitizen.org/en/content/sustainability-growingfactor-in-dietary-guidelines/.

384. Ministry of Health of Brazil, *supra* note 383, at 31-32.

385. Int'l Food Info. Council Found., 2017 Food and Health Survey (2017).

386. Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-234, §1102, 122 Stat. 923, 1125-26.

387. *See* Toensmeier, *supra* note 1, at 369.

388. USDA Econ. Research Serv., *Organic Market Overview*, https://www.ers.usda.gov/topics/natural-resources-environment/organic-agriculture/organic-market-overview/ (last updated Apr. 4, 2017).

389. *Project Profile: Sustainable Climate-Friendly Coffee*, Rainforest Alliance, July 31, 2016, http://www.rainforest-alliance.org/work/climate/projects/oaxaca-carbon-coffee; Fairtrade Max Havelaar, *Klimaatneutrale Koffie [Climate-Neutral Coffee]*, http://www.fiks-maxhavelaar.nl/klimaatneutrale-koffie/ (last visited Aug. 1, 2017).

390. It remains to be seen whether environmental concerns will motivate consumers to purchase certified products. Research indicates that organic food consumers are largely motivated by health and taste. Renée Hughner et al., *Who Are Organic Consumers? A Compilation and Review of Why People Purchase Organic Food*, 6 J. Consumer Behav. 94, 101-03 (2007).

391. Such a development would likely require significant consumer demand and pressure. *See* Karen Ganz et al., *How Major Restaurant Chains Plan Their Menus: The Role of Profit, Demand, and Health*, 32 Am. J. Preventative Med. 383 (2007).

392. USDA Econ. Research Serv., *Food-Away-From-Home*, https://www.ers.usda.gov/topics/food-choices-health/food-consumption-demand/food-away-from-home.aspx (last updated Dec. 30, 2016).

393. Jessica E. Todd et al., Econ. Research Serv., USDA, The Impact of Food Away From Home on Adult Diet Quality 7-8 (2010) (ERRN-90).

394. In fact, "entrée" was generally used to refer to a "substantial meat course" in the United States until the Second World War. Dan Jurafsky, The Language of Food: A Linguist Reads the Menu 30 (2014).

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tually all of these practices—including, for example, more precise fertilizer application, cover crops, managed rotational grazing, agroforestry, silvopasture, and improved manure management—also provide other environmental benefits such as clean water or wildlife habitat. In addition, these practices make agricultural operations more resilient to changes in weather patterns that will come with climate change. Finally, many of these practices are cost-effective, especially over the longer term.

U.S. policymakers should support the widespread adoption of climate-friendly agricultural practices. For instance, USDA should fund additional research and the Extension Service should expand farmer training. Congress and USDA should reform the major farm support programs, including crop insurance, commodity payments, and conservation programs, to incentivize or even to require adoption of climate-friendly practices. Congress, USDA, and other federal agencies should also use the farm bill and trade, tax, regulatory, and financing tools to encourage these practices. State legislatures and agencies should employ similar tools. The private sector also has a significant role to play in encouraging and leveraging governmental action.

Climate change presents perhaps the most significant threat to agriculture and human well-being. However, it remains politically divisive. The many benefits of climate-friendly agricultural practices should make them attractive to all, regardless of one's views on climate change. Thus, while change has often been slow in the agricultural sector, there is a real opportunity to approach climate neutrality in agriculture, while improving other environmental attributes, rural communities, and producer income. To protect producers and the public at large, policymakers and others should take up this challenge with energy.

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