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Climate Change: The Role of the U.S. Agriculture Sector

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Climate Change: The Role of the U.S. Agriculture Sector

Summary

The agriculture sector is a source of greenhouse gas (GHG) emissions, which many scientists agree are contributing to observed climate change. Agriculture is also a "sink" for sequestering carbon, which might offset GHG emissions by capturing and storing carbon in agricultural soils. The two key types of GHG emissions associated with agricultural activities are methane (CH_4) and nitrous oxide (N_2O). Agricultural sources of CH_4 emissions mostly occur as part of the natural digestive process of animals and manure management at livestock operations; sources of N_2O emissions are associated with soil management and fertilizer use on croplands. This report describes these emissions on a carbon-equivalent basis to illustrate agriculture's contribution to total national GHG emissions and to contrast emissions against estimates of sequestered carbon.

Emissions from agricultural activities account for 6%-8% of all GHG emissions in the United States. Carbon captured and stored in U.S. agricultural soils partially offsets these emissions, sequestering about one-tenth of the emissions generated by the agriculture sector, but less than 1% of all U.S. emissions annually. Emissions and sinks discussed in this report are those associated with agricultural production only. Emissions associated with on-farm energy use or with food processing or distribution, and carbon uptake on forested lands or open areas that might be affiliated with the farming sector, are outside the scope of this report.

Most land management and farm conservation practices can help reduce GHG emissions and/or sequester carbon, including land retirement, conservation tillage, soil management, and manure and animal feed management, among other practices. Many of these practices are encouraged under most existing voluntary federal and state agricultural programs that provide cost-sharing and technical assistance to farmers, predominantly for other production or environmental purposes. However, uncertainties are associated with implementing these types of practices depending on site-specific conditions, the type of practice, how well it is implemented, the length of time a practice is undertaken, and available funding, among other factors. Despite these considerations, the potential to reduce emissions and sequester carbon on agricultural lands is reportedly much greater than current rates.

The 110th Congress is considering a range of climate change policy options, including mandatory GHG emission reduction programs. The current legislative proposals would not require emission reductions in the agriculture and forestry sectors. However, some of the GHG emission reduction programs would allow the agriculture and forestry sectors to generate carbon offsets, whereby participating farmers and landowners could generate (and sell) carbon offsets and credits associated with carbon capture and storage, emissions reductions, and/or other implemented environmental improvements. Also, as part of the pending omnibus farm bill debate, there are provisions in the House and Senate versions of the bill (H.R. 2419) that could expand the scope of existing farmland conservation programs that contribute to emissions reductions and carbon storage in agricultural activities.

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The debate in Congress over whether and how to address possible future climate change is intensifying. Often, the role of the U.S. agriculture sector is invoked in this debate. Agriculture is a source of greenhouse gas (GHG) emissions, which many scientists agree are contributing to observed climate change. Agriculture is also a "sink" for sequestering carbon, which partly offsets these emissions. Carbon sequestration (the capture and storage of carbon) in agricultural soils can be an important component of a climate change mitigation strategy, limiting the release of carbon from the soil to the atmosphere.

The 110th Congress is considering a range of climate change policy options. The current legislative proposals would not require emission reductions in the agriculture and forestry sectors. However, many of the GHG emission reduction programs would either mandate or authorize a cap-and-trade program to reduce GHG emissions. Some of these cap-and-trade programs would allow the agriculture and forestry sectors to generate offsets in support of the program, thus indirectly involving the agriculture and forestry sectors as a source of carbon offsets. Other proposals would allow participating farmers and landowners to receive emissions allowances (or credits) for sequestration and/or emission reduction activities. These allowances could be sold to facilities (e.g., power plants) covered by a cap-and-trade program.

The pending omnibus farm bill (H.R. 2419)[1] might also expand the scope of existing voluntary farm and forestry conservation programs that promote conservation and land management practices in ways that could more broadly encompass certain aspects of these climate change initiatives. Principally, both the House and Senate versions of the farm bill seek to expand existing voluntary conservation programs and incentives that promote conservation and land management practices, predominantly for other production or environmental purposes. However, these types of practices also contribute to reduced emissions and increased carbon storage on agricultural and forested lands. Program incentives include cost-sharing and technical assistance, research programs and demonstration projects, and farmer or landowner access to low-cost loans, loan guarantees, grants, incentive payments, and tax credits. In addition, there are provisions in both the House and Senate versions of bill that seek to expand the scope of existing farmland conservation programs by facilitating the development of private-sector markets for a range of environmental goods and services from farmers and landowners, including carbon storage. This could further facilitate participation by the agriculture and forestry sectors in a GHG emission reduction program as a source of carbon offsets and credits.

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[1] The current omnibus farm bill, the Farm Security and Rural Investment Act of 2002 (P.L. 107-171), and many of its provisions expire in 2007. Hereafter referred to as "farm bill."

This report is organized in three parts. First, it discusses the extent of GHG emissions associated with the U.S. agriculture sector, and cites current and potential estimates for U.S. agricultural soils to sequester carbon and partly offset national GHG emissions. Second, the report describes the types of land management and farm conservation practices that can reduce GHG emissions and/or sequester carbon in agricultural soils, highlighting those practices that are currently promoted under existing voluntary federal agricultural programs. The Appendix provides a summary primer of the key background information presented in these first two sections. Finally, the report describes ongoing legislative action within both the climate change and farm bill debates, and discusses the types of questions that may be raised regarding the role of the U.S. agriculture sector in the broader climate change debate.

This report does not address the potential effects of global climate change on U.S. agricultural production. Such effects may arise because of increased climate variability and incidence of global environmental hazards, such as drought and/or flooding, pests, weeds, and diseases, or temperature and precipitation changes that might cause locational shifts in where and how agricultural crops are produced.[2]

This report also does not address how ongoing or anticipated initiatives to promote U.S. bioenergy production may effect efforts to reduce GHG emissions and/or sequester carbon, such as by promoting more intensive feedstock production and by encouraging fewer crop rotations and planting area setbacks, which could both raise emissions and reduce carbon uptake.[3]

Agricultural Emissions and Sinks

Agriculture is a both a source and a sink of greenhouse gases, generating emissions that enter the atmosphere and removing carbon dioxide (CO_2) from the atmosphere through photosynthesis and storing it in vegetation and soils (a process known as sequestration). Sequestration in farmland soils partially offsets agricultural emissions. Despite this offset, however, the U.S. agriculture sector remains a net source of GHG emissions.

Source of National Estimates

Estimates of GHG emissions and sinks for the U.S. agriculture sector presented in this report are the official U.S. estimates of national GHG emissions and carbon uptake, as published annually by the U.S. Environmental Protection Agency (EPA) in its *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.[4] EPA's *Inventory* data reflect annual national emissions by sector and fuel, including estimates for the agriculture and forestry sectors. EPA's estimates rely on data and information from

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[2] See CRS Report RL33849, *Climate Change: Science and Policy Options,* by Jane Leggett.

[3] See CRS Report RL34265, *Selected Issues Related to an Expansion of the Renewable Fuel Standard (RFS),* by Brent D. Yacobucci and Randy Schnepf.

[4] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005,* April 2007, at [http://epa.gov/climatechange/emissions/usinventoryreport.html].

the U.S. Department of Agriculture (USDA), the Department of Energy, the Department of Transportation, the Department of Defense, and other federal departments. The EPA-published data are rigorously and openly peer reviewed through formal interagency and public reviews involving federal, state, and local government agencies, as well as private and international organizations. For the agriculture and forestry sectors, USDA publishes a supplement to EPA's *Inventory*, which builds on much of the same data and information, but in some cases provides a more detailed breakout by individual states and sources.[5]

In this CRS report, emissions from agricultural activities are aggregated in terms of carbon dioxide or CO_2-equivalents, and expressed as million metric tons ($MMTCO_2$-Eq.).[6] This aggregation is intended to illustrate agriculture's contribution to national GHG emissions and to contrast emissions against estimates of sequestered carbon.

Agricultural Emissions

Direct GHG Emissions. The types of GHG emissions associated with agricultural activities are methane (CH_4) and nitrous oxide (N_2O), which are two of the key gases that contribute to GHG emissions.[7] These gases are significant contributors to atmospheric warming and have a greater effect warming than the same mass of CO_2.[8]

Agricultural sources of CH_4 emissions mostly occur as part of the natural digestive process of animals and manure management in U.S. livestock operations. Sources of N_2O emissions are mostly associated with soil management and commercial fertilizer and manure use on U.S. croplands, as well as production of nitrogen-fixing crops.[9] Emissions of N_2O from agricultural sources account for about two-thirds of all reported agricultural emissions; emissions of CH_4 account for about one-third of all reported emissions. Across all economic sectors, the U.S. agriculture

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[5] USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001*, TB1907, March 2004, at [http://www.usda.gov/oce/global_change/gg_inventory.htm].

[6] "Carbon-equivalents" equate an amount of a GHG to the amount of carbon that could have a similar impact on global temperature. EPA's data are in teragrams (million metric tons). Alternative ways to express emissions and offsets are in carbon equivalents (MMTCE), which assume a multiplier of 0.272 to convert from EPA-reported equivalent CO_2-Eq. units.

[7] The principal gases associated with climate change from human activities are CO_2, CH_4, N_2O, and ozone-depleting substances and chlorinated and fluorinated gases, such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. See CRS Report RL33849, *Climate Change: Science and Policy Implications*, by Jane Leggett.

[8] Methane's ability to trap heat in the atmosphere is 21 times that of CO_2; nitrous oxide is 310 times that of CO_2 (measured over a 100-year period). Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007*, Technical Summary of the Working Group I Report, Table TS-2, at [http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_TS.pdf].

[9] USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001*, TB1907, Figure 3-6, March 2004, at [http://www.usda.gov/oce/global_change/gg_inventory.htm]. Nitrogen-fixing crops refer to beans, legumes, alfalfa, and non-alfalfa forage crops.

sector was the leading source of N_2O emissions (80%) and a major source of CH_4 emissions (30%) in 2005.[10]

Other Types of Emissions. Agricultural activities may also emit other indirect greenhouse gases, such as carbon monoxide, nitrogen oxides, and volatile organic compounds from field burning of agricultural residues.[11] These emissions are not included in EPA's annual *Inventory* estimates because they contribute only indirectly to climate change by influencing tropospheric ozone, which is a greenhouse gas. Agricultural activities may also release other types of air emissions, some of which are regulated under the federal Clean Air Act, including ammonia, volatile organic compounds, hydrogen sulfide, and particulate matter.[12] These types of emissions are typically not included in proposals to limit GHG emissions.

The sector also emits CO_2 and other gases through its on-farm energy use, for example, through the use of tractors and other farm machinery. These emissions are generally aggregated along with other transportation and industrial emissions in the "energy" sources, where they constitute a very small share of the overall total. Therefore, these emissions are not included in reported estimates for the U.S. agriculture sector.

Total GHG Emissions. In 2005, GHG emissions from U.S. agricultural activities totaled nearly 540 MMTCO_2-Eq., expressed in terms of CO_2-equivalent units, and accounted for about 7% of the total GHG emissions in the United States (**Table 1**).[13] Although the agriculture sector is a leading economic sector contributing to national GHG emissions, its share of total emissions is a distant second compared to that for the energy sector. Fossil fuel combustion is the leading source of GHG emissions in the United States (about 80%), with the energy sector generating 85% of annual emissions across all sectors.[14]

Recent trends in GHG emissions associated with the U.S. agriculture sector suggest emissions reductions in recent years. In 2005, emissions from agricultural activities were lower compared to estimates for 2000 and the most recent five-year average. However, emissions in 2005 were higher compared to reported emissions for 1990 and 1995 (**Table 1**).

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[10] EPA's 2007 *Inventory*, Table ES-2. Other major CH_4 sources were landfills, natural gas systems, and coal mining. Mobile combustion was the second largest source of N_2O.

[11] EPA's 2007 *Inventory*, Table 6-2. NO_X and CO influence the levels of tropospheric ozone, which is both a local pollutant and a GHG (called "indirect" greenhouse gases). Their contributions cannot be measured by emissions.

[12] See CRS Report RL32948, *Air Quality Issues and Animal Agriculture: A Primer*, by Claudia Copeland. Particulate emissions may also contribute to climate change, but their influence is predominantly local, short-term and poorly quantified.

[13] EPA's 2007 *Inventory*, Table 2-14 and Table 6-1.

[14] Aside from the energy and agriculture/forestry sectors, by source, other leading contributors are wood biomass/ethanol use (3%); nonenergy use of fuel; landfills; and substitution of ozone-depleting substances (2% each). By sector, leading sources are industrial processes (5%) and wastes (2%). EPA's 2007 *Inventory*, Tables ES-2 and ES-4.

Table 1. GHG Emissions and Carbon Sinks, Agricultural Activities, 1990-2005 (CO_2-Equivalent)

Source	1990	1995	2000	2005	Avg. 2001-2005
	million metric tons CO_2 equivalent ($MMTCO_2$-Eq)				
U.S. Agricultural Activities					
GHG Emissions (CH_4 and N_2O)					
Agriculture Soil Management[a]	366.9	353.4	376.8	365.1	370.9
Enteric Fermentation[b]	115.7	120.6	113.5	112.1	115.0
Manure management	39.5	44.1	48.3	50.8	45.6
Rice Cultivation	7.1	7.6	7.5	6.9	7.4
Agricultural Residue Burning	1.1	1.1	1.3	1.4	1.2
Subtotal	**530.3**	**526.8**	**547.4**	**536.3**	**540.1**
Carbon Sinks					
Agricultural Soils	(33.9)	(30.1)	(29.3)	(32.4)	(31.7)
Other	na	na	na	na	na
Subtotal	(33.9)	(30.1)	(29.3)	(32.4)	(31.7)
Net Emissions, Agriculture	**496.4**	**496.7**	**518.1**	**503.9**	**508.4**
Attributable CO_2 emissions:[c] Fossil fuel/mobile combustion	**46.8**	**57.3**	**50.9**	**45.5**	**52.6**
%All Emissions, Agriculture[d]	**8.5%**	**8.0%**	**7.7%**	**7.4%**	**8.0%**
%Total Sinks, Agriculture	**4.8%**	**3.6%**	**3.9%**	**3.9%**	**4.0%**
%Total Emissions, Forestry	0.2%	0.2%	0.2%	0.3%	0.3%
%Total Sinks, Forestry[e]	94.3%	92.0%	94.8%	94.7%	95.0%
Total GHG Emissions, All Sectors	6,242.0	6,571.0	7,147.2	7,260.4	6,787.1
Total Carbon Sinks, All Sectors	(712.8)	(828.8)	(756.7)	(828.5)	(801.0)
Net Emissions, All Sectors	5,529.2	5,742.2	6,390.5	6,431.9	5,986.1

Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, April 2007, [http://epa.gov/climatechange/emissions/usinventoryreport.html]. Table ES-2, Table 2-13, Table 6-1, Table 7-1, and Table 7-3. EPA data are reported in teragrams (Tg.), which are equivalent to one million metric tons each.

a. N_2O emissions from soil management and nutrient/chemical applications on croplands.

b. CH_4 emissions from ruminant livestock.

c. Emissions from fossil fuel/mobile combustion associated with energy use in the U.S. agriculture sector (excluded from EPA's reported GHG emissions for agricultural activities).

d. Does not include attributable CO_2 emissions from fossil fuel/mobile combustion.

e. Change in forest stocks and carbon uptake from urban trees and landfilled yard trimmings.

Uncertainty Estimating Emissions. EPA's estimates are based on annual USDA data on crop production, livestock inventories, and information on conservation and land management practices in the agriculture sector. Actual emissions will depend on site-specific factors, including location, climate, soil type, type of crop or vegetation, planting area, fertilizer and chemical application, tillage practices, crop rotations and cover crops, livestock type and average weight, feed mix and amount consumed, waste management practices (e.g., lagoon, slurry, pit, and drylot systems), and overall farm management. Emissions may vary year to year depending on actual growing conditions. The EPA-reported data reflect the most recent data and historical updates, and reflect underlying methodological changes, in keeping with Intergovernmental Panel on Climate Change (IPCC) guidelines.[15] More detailed information is in EPA's 2007 *Inventory*.

Other Estimated Emissions. EPA's reported emissions for the U.S. agriculture sector are based on agricultural production only and do not include emissions associated with on-farm energy use and forestry activities,[16] or emissions associated with food processing or distribution. Although EPA's GHG estimates for the U.S. agriculture sector do not include CO_2 emissions from on-farm energy use, estimates of these CO_2 emissions constitute a small share of overall GHG emissions. During the last few years, EPA's estimates of CO_2 emissions from on-farm fossil fuel and mobile combustion averaged about 50 $MMTCO_2$-Eq. per year[17] (**Table 1**). These emissions are generally aggregated with emissions for the transportation and industrial sectors. Even if these emissions were included with other attributed GHG emissions for the agriculture sector, this would not substantially raise agriculture's overall share of total GHG emissions.

Sources of GHG Emissions. EPA's *Inventory* estimates of CH_4 and N_2O emissions from agricultural activities are measured across five categories.

- **Agriculture soil management:** Nitrous oxide emissions from farmland soils are associated with cropping practices that disturb soils and increase oxidation, which can release emissions into the atmosphere. The types of practices that contribute to emissions releases are fertilization; irrigation; drainage; cultivation/tillage; shifts in land use; application and/or deposition of livestock manure and other organic materials on cropland, pastures, and rangelands; production of nitrogen-fixing crops and forages; retention of crop residues; and cultivation of soils with high organic content.
- **Enteric fermentation:** Methane emissions from livestock operations occur as part of the normal digestive process in ruminant animals[18] and are produced by rumen fermentation in metabolism and digestion. The extent of such emissions is often associated with the nutritional content and efficiency of feed utilized by the animal.[19] Higher feed effectiveness is associated with lower emissions.

[15] The IPCC was established to assess scientific, technical and socioeconomic information related to climate change, its potential impacts and options for adaptation and mitigation. IPCC's methodolgy to estimate emissions and sinks are consistent with those used by other governments and with established guidelines under the United Nations Framework Convention on Climate Change.

[16] Land use and forestry activities account for less than 1% of total estimated GHG emissions in the United States (EPA's 2007 *Inventory*, Table ES-4). See **Table 1**.

[17] EPA's 2007 *Inventory*, Table 2-14.

[18] Refers to livestock (cattle, sheep, goats, and buffalo) that have a four-chambered stomach. In the rumen chamber, bacteria breaks down food and degrades methane as a byproduct.

[19] R. A. Leng, "Quantitative Ruminant Nutrition — A Green Science," *Australian Journal of Agricultural Research*, 44: 363-380. Feed efficiency is based on both fermentive digestion in the rumen and the efficiency of conversion of feed to output (e.,g, milk, meat) as nutrients are absorbed.

- **Manure management:** Methane and nitrous oxide emissions associated with manure management occur when livestock or poultry manure is stored or treated in systems that promote anaerobic decomposition, such as lagoons, ponds, tanks, or pits.
- **Rice cultivation:** Methane emissions from rice fields occur when fields are flooded and aerobic decomposition of organic material gradually depletes the oxygen in the soil and floodwater, causing anaerobic conditions to develop in the soil, which releases methane.
- **Agricultural residue burning:** Methane and nitrous oxide emissions are released by burning residues or biomass.[20]

The share of GHG emissions for each of these categories is as follows: agriculture soil management (68% of emissions), enteric fermentation (21%), manure management (10%), rice cultivation (1%), and field burning of agricultural residues (less than 1%). Approximately 70% of agricultural emissions are associated with the crop sector and about 30% with the livestock sector (**Figure 1**).[21]

Potential for Additional Reductions. There is potential to lower carbon, methane, and nitrous oxide emissions from U.S. agricultural facilities at both crop and livestock operations through further adoption of certain conservation and land management practices. In most cases, such practices may both reduce emissions and sequester carbon in agricultural soils.

Improved Soil Management. Options to reduce nitrous oxide emissions associated with crop production include improved soil management, more efficient fertilization, and implementing soil erosion controls and conservation practices. In the past 100 years, intensive agriculture has caused a soil carbon loss of 30%-50%, mostly through traditional tillage practices.[22] In contrast, conservation tillage practices preserve soil carbon by maintaining a ground cover after planting and by reducing soil disturbance compared with traditional cultivation, thereby reducing soil loss and energy use while maintaining crop yields and quality. Practices include no-till and minimum, mulch, and ridge tillage. Such tillage practices reduce soil disturbance, which reduces oxidation and the release of carbon into the atmosphere. Therefore, conservation tillage practices reduce emissions from cultivation and also enhance carbon sequestration in soils (discussed later in this report). Nearly 40% of U.S. planted areas are under some type of conservation tillage practices.[23]

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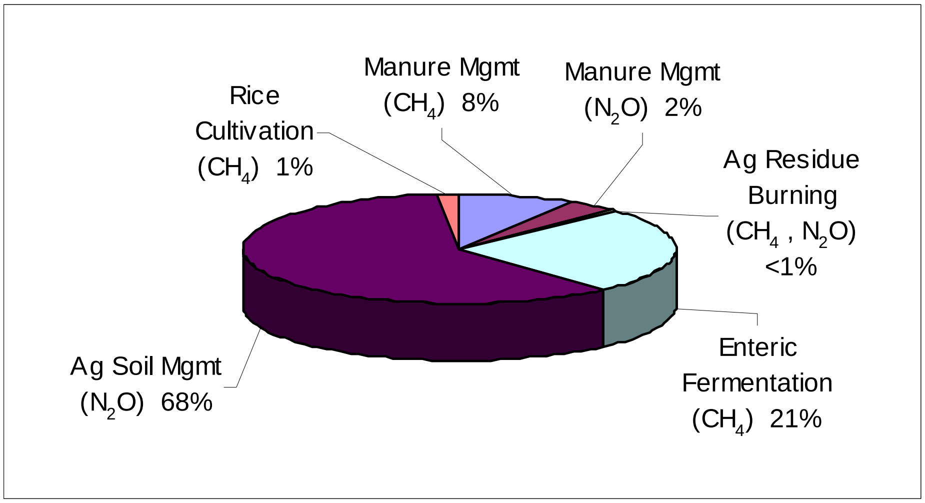
[20] Although carbon is released as well, it is predominantly absorbed again within a year as part of the cropping cycle, and so is assumed to be net zero emissions unless some goes into long-term soil carbon content.

[21] Previously estimates for the agriculture soil management category were lower. Current EPA estimates reflect methodological and input data changes.

[22] D. C. Reicosky, "Environmental Benefits of Soil Carbon Sequestration," USDA, at [http://www.dep.state.pa.us/dep/DEPUTATE/Watermgt/wsm/WSM_TAO/InnovTechForum/InnovTechForum-IIE-Reicosky.pdf].

[23] USDA, "Conservation Tillage Firmly Planted in U.S. Agriculture," *Agricultural Outlook*, (continued...)

Figure 1. Agricultural GHG Emissions, Average 2001-2005



Source: EPA, 2007 *Inventory* report, April 2007, at [http://epa.gov/climatechange/emissions/usinventoryreport.html].

Improved Manure and Feed Management. Methane emissions associated with livestock production can be reduced through improved manure and feed management. Improved manure management is mostly associated with installing certain manure management systems and technologies that trap emissions, such as an anaerobic digester[24] or lagoon covers. Installing such systems generates other principal environmental benefits. Installing an anaerobic digester to capture emissions from livestock operations, for example, would also trap other types of air emissions, including air pollutants such as ammonia, volatile organic compounds, hydrogen sulfide, nitrogen oxides, and particulate matter that are regulated under the federal Clean Air Act. Other benefits include improved water quality through reduced nutrient runoff from farmlands, which may be regulated under the federal Clean Water Act.[25] Many manure management systems also control flies, produce energy, increase the fertilizer value of any remaining biosolids, and destroy pathogens and weed seeds.[26]

Manure management systems, however, can be costly and difficult to maintain, given the typically high start-up costs and high annual operating costs. For example,

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[23] (...continued)
March 2001; USDA, "To Plow or Not to Plow? Balancing Slug Populations With Environmental Concerns and Soil Health," *Agricultural Research*, October 2004; Conservation Technology Information Center (CTIC), "Conservation Tillage Facts," at [http://www.conservationinformation.org/?action=learningcenter_core4_convotill].

[24] An enclosed tank that promotes decomposition using anaerobic conditions and naturally occurring bacteria, while producing biogas as a byproduct that can be used as energy.

[25] See CRS Report RL32948, *Air Quality Issues and Animal Agriculture: A Primer*; and CRS Report RL31851, *Animal Waste and Water Quality: EPA Regulation of Concentrated Animal Feeding Operations (CAFOs)*, by Claudia Copeland.

[26] R. Pillars, "Farm-based Anaerobic Digesters," Michigan State University Extension, at [http://web2.msue.msu.edu/manure/FinalAnearobicDigestionFactsheet.pdf].

the initial capital cost of an anaerobic digester with energy recovery is between $0.5 million and $1 million at a large-sized dairy operation, and annual operating costs are about $36,000. Initial capital costs for a digester at a larger hog operation is about $250,000, with similar operating costs.[27] Upfront capital costs tend to be high because of site-specific conditions at an individual facility, requiring technical and engineering expertise. Costs will vary depending on site-specific conditions but may also vary by production region. Costs may be higher in areas with colder temperatures, where some types of digesters may not be appropriate or may require an additional heat source, insulation, or energy requirements to maintain constant, elevated temperatures.[28] Energy requirements to keep a digester heated are likely be lower in warmer climates.

Incentives are available to assist crop and livestock producers in implementing practices and installing systems that may reduce GHG emissions. Such incentives include cost-sharing and also low-interest financing, loan guarantees, and grants, as well as technical assistance with implementation. Funding for anaerobic digesters at U.S. livestock operations occurs under various programs under the 2002 farm bill.[29] Despite the availability of federal and/or state-level cost-sharing and technical assistance, adoption of such systems remains low throughout the United States. There are currently about 100 digester systems in operation or planned at commercial dairy and hog farms, accounting for about 1% of all operations nationwide (**Figure 2**).[30]

Improved feed strategies may also lower methane emissions at livestock operations. Such strategies may involve adding supplements and nutrients to animal diets, substituting forage crops for purchased feed grains, or instituting multi-phase feeding to improve digestive efficiency. Other options involve engineering genetic improvements in animals.[31] Purchasing feed supplements and more intensely managing animal nutrition and feeding practices may add additional costs and management requirements at the farm level.

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[27] EPA, *Development Document for the Final Revisions to the NPDES Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations*, January 2003.

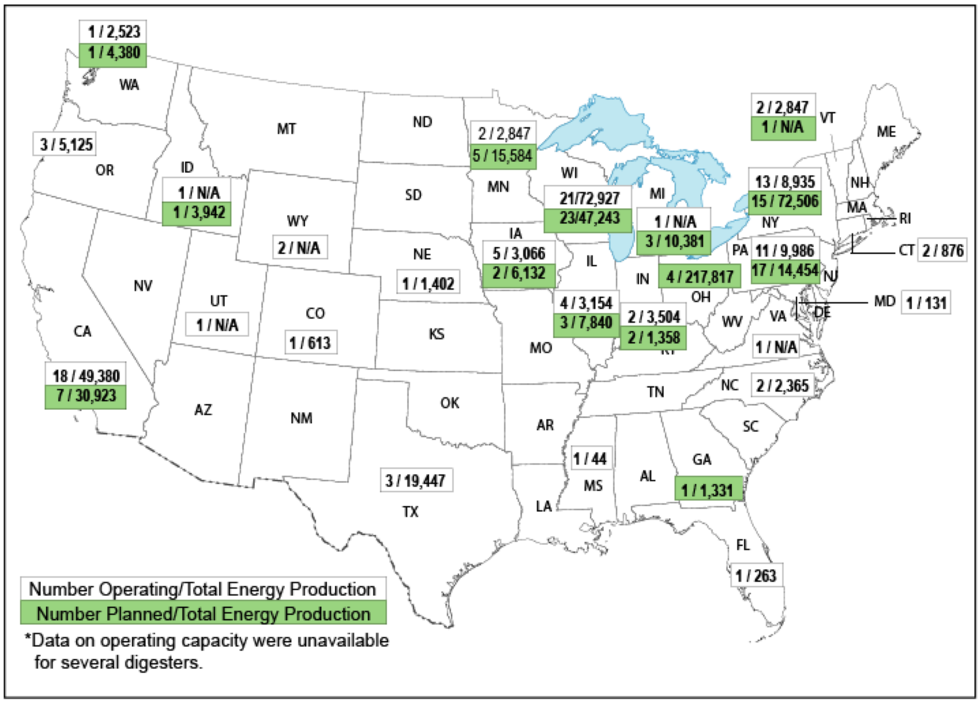
[28] C. Henry and R. Koelsch, "What Is an Anaerobic Digester?" University of Nebraska, Lincoln, at [http://manure.unl.edu/adobe/v7n10_01.pdf]; and Pennsylvania State University, "Biogas and Anaerobic Digestion," at [http://www.biogas.psu.edu/]. For optimum operation, anaerobic digesters must be kept at a constant, elevated temperature, and any rapid changes in temperature could disrupt bacterial activity.

[29] Mostly Section 9006 and Section 6013 of the farm bill (P.L. 107-171), but also under other farm bill cost-share programs. CRS communication with USDA staff.

[30] As of 2005. EPA, *AgStar Digest*, Winter 2006, at [http://www.epa.gov/agstar/].

[31] R. A. Leng, "Quantitative Ruminant Nutrition — A Green Science," *Australian Journal of Agricultural Research*, 44: 363-380; H. Steinfeld, C. de Haan, and H. Blackburn, *Livestock-Environment Interactions, Issues and Options*, chapter 3 (study commissioned by the Commission of the European Communities, United Nations, and World Bank), at [http://www.virtualcentre.org/es/dec/toolbox/FAO/Summary/index.htm].

Figure 2. National Distribution of Anaerobic Digester Energy Production, Operating and Planned



Source: Adapted by CRS, Map Resources (7/2007) from data reported by USEPA, *AgStar Digest*, Winter 2006.

Agricultural Carbon Sinks

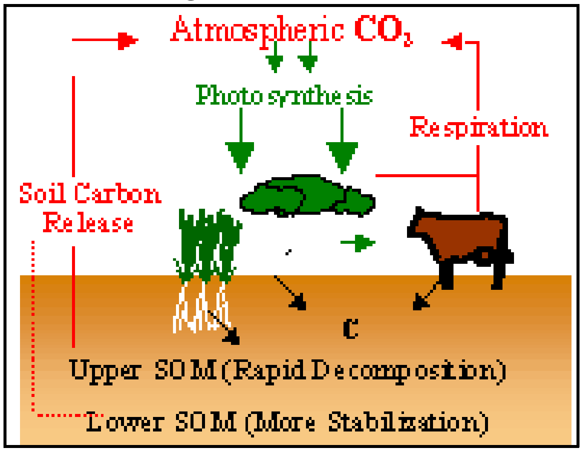
Carbon Loss and Uptake. Agriculture can sequester carbon, which may offset GHG emissions by capturing and storing carbon in agricultural soils. On agricultural lands, carbon can enter the soil through roots, litter, harvest residues, and animal manure, and may be stored primarily as soil organic matter (SOM; see **Figure 3**).[32] Soils can hold carbon both underground in the root structure and near the soil surface and in plant biomass. Loss of soil carbon may occur with shifts in land use, with conventional cultivation (which may increase oxidation), and through soil erosion. Carbon sequestration in agricultural soils can be an important component of a climate change mitigation strategy, since the capture and storage of carbon may limit the release of carbon from the soil to the atmosphere.

Voluntary land retirement programs and programs that convert or restore grasslands and wetlands promote carbon capture and storage in agricultural soils. Related practices include afforestation (including the conversion of pastureland and cropland), reforestation, and agro-forestry practices. Conservation practices that raise biomass retention in soils and/or reduce soil disturbance, such as conservation tillage and/or installing windbreaks and buffers, also promote sequestration. More detailed

[32] U.S. Geological Survey (USGS), "Carbon Sequestration in Soils," at [http://edcintl.cr.usgs.gov/carbonoverview.html].

information is provided in the following section, "Mitigation Strategies in the Agriculture Sector."

Figure 3. Carbon Sequestration in Agricultural Soils



Source: USGS, "Carbon Sequestration in Soils," at [http://edcintl.cr.usgs.gov/carbonoverview.html]. SOM = Soil organic matter

Total Carbon Sequestration. In 2005, carbon sequestration by agricultural soils was estimated at about 30 $MMTCO_2$-Eq.[33] Compared to estimates for the most recent five-year average, as well as estimates for 1995 and 2000, recent data show possible gains in carbon uptake and storage in recent years (**Table 1**).

The agriculture and forestry sectors are a small part of the overall carbon sequestration debate. Carbon sequestration by these sectors is usually referred to as indirect or biological sequestration.[34] Biological sequestration is considered to have less potential for carbon sequestration than direct sequestration, also referred to as carbon capture and storage, and is typically associated with oil and gas production.

Estimated Emission Offsets. Carbon sequestration in the U.S. agriculture sector currently offsets only about 5% of the carbon-equivalent of reported GHG emissions generated by the agriculture sector each year. Thus the sector remains a

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[33] EPA's 2007 *Inventory*, Table 2-14 and Table 7-1. Based on estimates for the following categories: land converted to grassland; grassland remaining grassland; land converted to cropland; cropland remaining cropland.

[34] Congressional Budget Office (CBO), *The Potential for Carbon Sequestration in the United States*, September 2007, at [http://www.cbo.gov/ftpdocs/86xx/doc8624/09-12-Carbon Sequestration.pdf]. Biological sequestration refers to the use of land to enhance its ability to uptake carbon from atmosphere through plants and soils. Direct sequestration refers to capturing carbon at its source and storing it before its release to the atmosphere. Examples include capture and storage in geologic formations, such as oil fields, natural gas fields, coal seams, and deep saline formations. See CRS Report RL33801, *Carbon Capture and Sequestration (CCS)*, by Peter Folger.

net source of GHG emissions. Compared to total national GHG emissions, the agriculture sector offsets well under 1% of emissions annually. It should be noted that these estimates do not include estimates for the forestry sector, or sequestration activities on forested lands or open areas that may be affiliated with the agriculture sector. Forests and trees account for a majority (about 95%) of all estimated carbon uptake in the United States, mostly through forest restoration and tree-planting.[35] Carbon uptake in soils on U.S. agricultural lands accounts for the bulk of the remainder.

Uncertainty Estimating Carbon Sinks. EPA's *Inventory* estimates of carbon uptake in agricultural soils are based on annual data and information on cropland conversion to permanent pastures and grasslands, reduced summer fallow areas in semi-dry areas, increased conservation tillage, and increased organic fertilizer use (e.g, manure) on farmlands, as well as information on adoption rates and use of certain conservation and land management practices.

However, actual carbon uptake in agricultural soils depends on several site-specific factors, including location, climate, land history, soil type, type of crop or vegetation, planting area, tillage practices, crop rotations and cover crops, and farm management in implementing certain conservation and land management practices. Estimates of the amount of carbon sequestered may vary depending on the amount of site-specific information included in the estimate, as well as on the accounting procedures and methodology used to make such calculations.

In general, the effectiveness of adopting conservation and land management practices will depend on the type of practice, how well the practice is implemented, and also on the length of time a practice is undertaken. For example, time is needed for a certain conservation practice to take hold and for benefits to accrue, such as buildup of carbon in soils from implementing conservation tillage or other soil management techniques, and growing time for cover crops or vegetative buffers. The overall length of time the practice remains in place is critical, especially regarding the sequestration benefits that accrue over the time period in which land is retired. In addition, not all conservation and land management practices are equally effective or appropriate in all types of physical settings. For example, the use and effectiveness of conservation tillage practices will vary depending on soil type and moisture regime, which may discourage some farmers from adopting or continuing this practice in some areas.

The potential impermanence of conservation and land management practices raises concerns about the effectiveness and limited storage value of the types of conservation practices that sequester carbon, given that the amount of carbon stored depends on the willingness of landowners to adopt or continue to implement a particular voluntary conservation practice. There are also concerns that the addition of other conservation practices may not significantly enhance the sequestration

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[35] EPA's 2007 *Inventory,* Table 2-14 and Table 7-1. Based on estimates for the following categories: forestland remaining forestland; and growth in urban trees. Other uptake not included in the estimates is from landfilled yard trimmings.

potential of practices that might already be in place.[36] This raises questions about the cost-effectiveness of sequestering carbon on farmlands relative to other climate change mitigation strategies in other industry sectors. Finally, implementing conservation practices and installing new technologies may be contingent on continued cost-sharing and other financial incentives contained in the current farm bill; programs funded through this legislation help offset the cost to farmers for these practices and technologies, which some farmers may not be willing to do otherwise.

Potential for Additional Uptake. USDA reports that the potential for carbon uptake in agricultural soils is much greater than current rates. USDA forecasts that the amount of carbon sequestered on U.S. agricultural lands will more than double from current levels by 2012, adding roughly an additional 40 $MMTCO_2$-Eq. of sequestered carbon attributable to the sector.[37] This additional uptake is expected through improved soil management (roughly 60%), improved manure and nutrient management (about 30%), and additional land-retirement sign-ups (about 10%).

Other longer-term estimates from USDA report that the potential for net increases in carbon sequestration in the agriculture sector could range from 40 to 590 $MMTCO_2$-Eq. per year, or roughly 2-20 times current levels.[38] Afforestation, or the creation of forested areas mostly through conversion of pastureland and cropland, reflects the majority of the estimated uptake potential, with agricultural soil carbon sequestration accounting for a smaller share at the high end of this estimated range. Comparable estimates reported by EPA forecast a higher sequestration potential for the U.S. agriculture sector, ranging from 160 to 990 $MMTCO_2$-Eq. per year.[39] EPA also reports additional sequestration potential from livestock manure management, biofuels substitution, and forest land management. Estimates from various studies may differ depending on the extent that estimates may include sequestration activities in the forestry sector. Combined, the potential carbon uptake from both the agriculture and forestry sectors is estimated from 800 to 1,200 $MMTCO_2$-Eq. per year.[40]

An additional carbon uptake potential of 590 to 990 $MMTCO_2$-Eq. per year would more than offset the agriculture sector's annual GHG emissions, or offset 8% to 14% of total current national emissions from all sources. Currently, carbon uptake

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[36] See, for example, T. A. Butt and B. A. McCarl, "Implications of Carbon Sequestration for Landowners," *2005 Journal of the American Society of Farm Managers and Rural Appraisers*; Government Accountability Office (GAO), *Conservation Reserve Program: Cost-Effectiveness Is Uncertain*, March 1993; H. Feng, J. Zhao, and C. Kling, "Carbon: The Next Big Cash Crop," *Choices*, 2nd quarter 2001; and H. Feng, C. Kling, and P. Glassman, "Carbon Sequestration, Co-Benefits, and Conservation Programs," *Choices*, Fall 2004.

[37] W. Hohenstein, "USDA Activities to Address Greenhouse Gases and Carbon Sequestration," presentation to Senate Energy Committee staff, February 15, 2007.

[38] USDA, *Economics of Sequestering Carbon in the U.S. Agricultural Sector*, April 2004.

[39] EPA, *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture*, Tables 4-10 and 4-5, Nov. 2005, at [http://www.epa.gov/sequestration/greenhouse_gas.html].

[40] As summarized by CBO, *The Potential for Carbon Sequestration in the United States*, Sept. 2007, at [http://www.cbo.gov/ftpdocs/86xx/doc8624/09-12-CarbonSequestration.pdf].

in agricultural soils sequesters under 1% of total national GHG emissions annually (**Table 1**). An estimated 11% of all GHG emissions are currently sequestered annually, with the bulk sequestered through growth in forest stocks.

Per-Unit Value Estimates. Compared to other mitigation options in other sectors, USDA reports that U.S. agriculture can provide low-cost opportunities to sequester additional carbon in soils and biomass. The estimated per-unit value (or cost) of carbon removed or sequestered, expressed on a dollar per metric ton (mt) of carbon basis, will vary depending on the type of practice. Actual per-unit values and the cost-effectiveness of different practices may vary considerably from site to site.

USDA's estimate of an additional carbon uptake potential of 40 to 590 $MMTCO_2$-Eq. per year is associated with a range of costs from about $3/mt to $35/mt of permanently sequestered carbon dioxide (**Table 2**).[41] The low end of this range reflects the sequestration potential associated with cropland management practices; higher-end values are associated with land retirement and conversion, and a longer sequestration tenure. USDA's report also notes that if producers discontinue the land and cropland management practices at the end of a typical contract period, the carbon sequestered may only be worth a small share of its overall program costs, because most of the carbon will be released when these practices are terminated, which may lower the cost-effectiveness of such programs. EPA's forecast of an additional sequestration potential for the agriculture sector of 160 to 990 $MMTCO_2$-Eq. per year are estimated across a range of $5/mt-$30/mt of sequestered carbon dioxide.[42] The low end of this range is associated with sequestration in agricultural soils and with soil management practices; high-end values are associated with afforestation, or converting open land into a forest by planting trees or their seeds.

Table 2. Carbon Sequestration Potential in the U.S. Agriculture Sector, Alternative Scenarios and Payment Levels

(dollars per million metric ton of sequestered CO_2)

Source	$3-5 range	$14-15 range	$30-34 range
	(million mt of sequestered CO_2)		
USDA Estimate			
Afforestation	0 - 31	105 - 264	224 - 489
Agricultural soil carbon sequestration	0.4 - 4	3 - 30	13 - 95
Total	**0.4 - 35**	**108 - 295**	**237 - 587**
EPA Estimate			
Afforestation	12	228	806
Agricultural soil carbon sequestration	149	204	187
Total	**161**	**432**	**994**

Sources: EPA, *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture*, Nov. 2005, Table 4-10, at [http://www.epa.gov/sequestration/greenhouse_gas.html]. Compares USDA estimates (*Economics of Sequestering Carbon in the U.S. Agricultural Sector*, Apr. 2004) with EPA estimates.

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[41] USDA, *Economics of Sequestering Carbon in the U.S. Agricultural Sector*, April 2004 (measured by the amount of carbon sequestered over a 15-year time period across a range of costs). USDA estimates that the associated total cost to sequester carbon across this range is $0.95 billion to $2 billion per year.

[42] EPA, *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture*, Table 4-10.

Enhancing Carbon Sinks. There is potential to increase the amount of carbon captured and stored in U.S. agricultural lands by adopting certain conservation and land management practices. In most cases, such practices may both sequester carbon in farmland soils and reduce emissions from the source. **Table 3** shows estimated representative carbon sequestration rates for agricultural practices.

Table 3. Representative Carbon Sequestration Rates

Type of land Management System	Sequestration Rate (mt CO_2/acre/year)
Afforestation	2.2 - 9.5
Reforestation	1.1 - 7.7
Reduced tillage (e.g., no-till, reduced-till)	0.6 - 1.1
Change in grassland management	0.07 - 1.9
Cropland conversion to grassland	0.9 - 1.9
Riparian buffers (nonforest)	0.4 - 1.0
Biofuel substitution for fossil fules	4.8 - 5.5

Source: Compiled by EPA, *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture*, Table 2-1, Nov. 2005, at [http://www.epa.gov/sequestration/greenhouse_gas.html]. Saturation rates and duration periods apply. EPA's report provides a list of the original source citations.

Improved Soil and Land Management. The main carbon sinks in the agriculture sector are cropland conversion and soil management, including improved manure application.[43] More than half of all carbon sequestered on U.S. agricultural lands is through voluntary land retirement programs and programs that convert or restore land (e.g., conversion to open land or grasslands, conversion to cropland, restoration of grasslands or wetlands, etc.). Undisturbed open lands, grasslands and wetlands can hold carbon in the soil both underground in the root structure and above ground in plant biomass. The amount of carbon sequestered will vary by the type of land management system. Afforestation and cropland conversion have the greatest potential to store the most carbon per acre annually, compared with other types of systems, such as tree plantings and wetlands conversion, or storage in croplands.[44]

Conservation tillage is another major source of sequestration on farmlands, accounting for about 40% of the carbon sequestered by the U.S. agriculture sector.[45] Improved tillage practices improve biomass retention in soils and reduce soil disturbance, thereby decreasing oxidation. The amount of carbon sequestered will vary by the type of tillage system: reduced tillage stores between 0.6-1.1 mt of carbon dioxide per acre annually (**Table 3**). Among conservation tillage practices, no-till

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[43] USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001*, TB1907, Figure 3-8, March 2004, at [http://www.usda.gov/oce/global_change/gg_inventory.htm].

[44] Bongen, A.,"Using Agricultural Land for Carbon Sequestration," Purdue University, at [http://www.agry.purdue.edu/soils/Csequest.PDF]. 1999 data for carbon storage in Indiana.

[45] USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001*, TB1907, March 2004, at [http://www.usda.gov/oce/global_change/gg_inventory.htm]; USDA, "Depositing Carbon in the Bank: The Soil Bank, That Is," *Agricultural Research*, Feb. 2001.

stores about 30% more than the amount of carbon stored by reduced tillage but more than five times that stored on intensive tilled croplands. (Conservation tillage practices are explained above, in the section on "Potential for Additional Reductions").

Improved Manure and Feed Management. Mitigation strategies at U.S. livestock operations are not commonly associated with carbon uptake and are not included in EPA's carbon sink estimates. However, installing manure management systems, such as an anaerobic digester, captures and/or destroys methane emissions from livestock operations and may be regarded as avoided emissions or as a form of direct sequestration capturing emissions at the source. As a result, some carbon offset programs are beginning to promote manure management systems as a means to capture and store methane at dairy operations, which may also be sold as carbon offset credits and as a renewable energy source.[46] Given that there are currently few anaerobic digesters in operation, estimates of the actual or potential uptake may be difficult to estimate. (Manure management systems are further explained above, in the section on "Potential for Additional Reductions.")

Mitigation Strategies in the Agriculture Sector

Existing conservation and farmland management programs administered at both the federal and state levels often encourage the types of agricultural practices that can reduce GHG emissions and/or sequester carbon. These include conservation, forestry, energy, and rural development programs within existing farm legislation. These programs were initiated predominantly for other production or environmental purposes. Currently, few federal programs specifically address climate change concerns in the agriculture sector. However, some USDA and state-level conservation programs have started to place additional attention on the potential for emissions reduction and carbon sequestration.

Agricultural conservation and other farmland practices broadly include land management, vegetation, and structures that can reduce GHG emissions and/or sequester carbon in the agriculture sector, such as:

- land retirement, conversion, and restoration programs (e.g., conversion to grasslands, restoration of grasslands or wetlands, etc.);
- soil conservation practices, including conservation tillage (e.g., reduced/medium- till, no/strip-till, ridge-till);
- soil management and soil erosion controls;
- precision agriculture practices and recognized agricultural best management practices;
- efficient fertilizer/nutrient (including manure) and chemical application;
- crop rotations;
- cover cropping;

[46] See Iowa Farm Bureau's carbon credit project at [http://www.iowafarmbureau.com].

- manure management (e.g., improve manure storage and technologies using anaerobic digestion and methane recovery);
- feed management (e.g., improve feed efficiency, dietary supplements);
- rotational grazing and improved forage/grazing management;
- vegetative and riparian buffers, and setbacks;
- windbreaks for crops and livestock;
- bioenergy and biofuels substitution and renewable energy use (e.g., replacing use of fossil fuels); and
- energy efficiency and energy conservation on-farm.

Conservation programs administered by USDA and state agencies encourage farmers to implement certain farming practices and often provide financial incentives and technical assistance to support adoption. Participation in these programs is voluntary, and farmers may choose to discontinue participating in these programs. Also, as previously noted, the effectiveness of these practices depends on the type of practice, how well the practice is implemented, and also on the length of time a practice is undertaken.

The fact that the types of conservation and land management practices being promoted under existing agricultural conservation programs may also lower GHG emissions and increase carbon uptake in agricultural soils should be regarded as an incidental benefit of these programs. With few exceptions, these types of conservation and land management programs were not initiated for the purpose of reducing GHG emission or sequestering carbon, and the eligibility requirements under these programs do not explicitly require emissions reductions or carbon sequestration as objectives or selection criteria for participation. These programs are generally designed to address site-specific improvements based on a conservation plan developed with the assistance of USDA or state extension technical and field staff that considers the goals and land resource base for an individual farmer or landowner. Such a conservation plan is typically a necessary precursor to participating in USDA's conservation programs.

Federal Programs

Conservation Programs. Conservation programs administered by USDA are designed to take land out of production and to improve land management practices on land in production, commonly referred to as "working lands" (**Table 4**).

- **Land retirement/easement programs.** Programs focused on land management, including programs that retire farmland from crop production and convert it back into forests, grasslands, or wetlands, including rental payments and cost-sharing to establish longer term conservation coverage. Major programs include the Conservation Reserve Program (CRP), the Wetlands Reserve Program (WRP), the Grasslands Reserve Program (GRP), the Farmland Protection Program (FPP), among other programs.

Table 4. Conservation and Land Management Practices

USDA Program	Conservation Practice and Land Management	General Benefits	Benefits for Climate Change
EQIP, CSP, AMA	Conservation tillage and reduced field pass intensity	Improves soil/water/air quality. Reduces soil erosion/fuel use.	Sequestration, emission reduction
	Crop diversity through crop rotations and cover cropping	Reduces erosion/water needs. Improves soil/water quality.	Sequestration
	Efficient nutrient (nitrogen) management, fertilizer application	Improves water quality. Saves expenses, time, and labor.	Sequestration, emission reduction
	Improved soil management and soil erosion controls	Improves soil/water/air quality.	Sequestration, emission reduction
EQIP CSP AMA Other[a]	Manure management (e.g., storage/containment, anaerobic digestion and methane recovery)	Improves soil/water/air quality. On-farm fuel cost-savings. Alternative income source. Nutrients for crops.	Emission reduction
EQIP CSP AMA	Feed management (e.g., raise feed efficiency, dietary supplements)	Improves water/air quality. More efficient use of feed.	Emission reduction
	Rangeland management (e.g., rotational grazing, improved forage)	Reduces water requirements. Helps withstand drought. Raises grassland productivity.	Sequestration, emission reduction
EQIP CSP AMA WHIP	Windbreaks for crops and livestock, vegetative/riparian buffers, grassed waterways, setbacks, etc.	Improves crop/livestock protection and wildlife habitat. Alternative income source (e.g., hunting fees).	Sequestration, emission reduction
FLEP EQIP CSP AMA	Agroforestry / silvopasture with rotational grazing and improved forage	Provides income from grazing and wood products.	Sequestration, emission reduction
CRP WRP GRP FPP	Land management, including retirement, conversion, restoration (cropland, grasslands, wetlands, open space)	Improves soil/water/air quality.	Sequestration
EQIP CSP AMA Other[a]	Energy efficiency/conservation	Improves soil/water/air quality. Cost-savings.	Emission reduction
	Biofuel substitution and renewable energy use	Improves soil/water/air quality. On-farm fuel cost-savings. Alternative income source.	Emission reduction

Source: Compiled by CRS staff from USDA and EPA information. Listed programs: Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP), Grasslands Reserve Program (GRP), Farmland Protection Program (FPP), Environmental Quality Incentives Program (EQIP), Conservation Security Program (CSP), Agricultural Management Assistance (AMA), Wildlife Habitat Incentives Program (WHIP), and Forest Land Enhancement Program (FLEP).

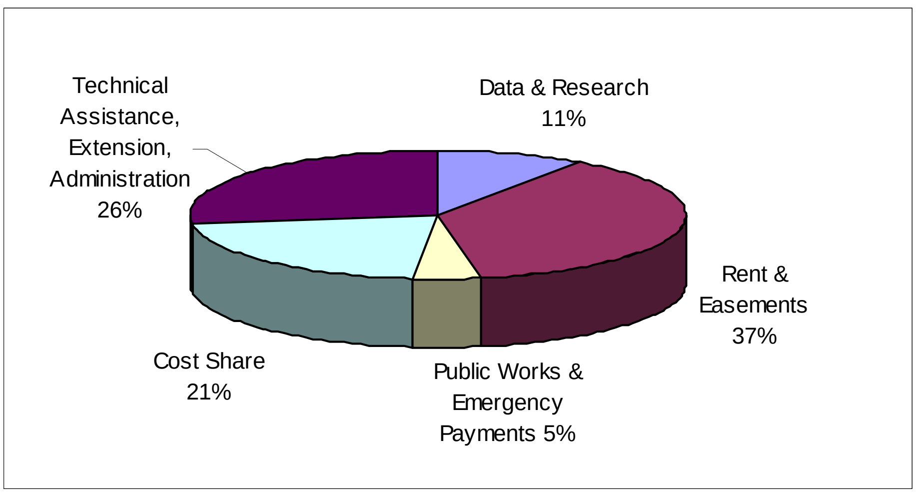
a. Renewable energy projects receive additional program funding in farm bill under Title IX (Energy) and Title VI (Rural Development), as well as other federal and state program.

- **Working lands programs.** Programs focused on improved land management and farm production practices, such as changing cropping systems or tillage management practices, are supported by cost-sharing and incentive payments, as well as technical assistance. Major programs include the Environmental Quality Incentives Program (EQIP), the Conservation Security Program (CSP), the Agricultural Management Assistance (AMA) program, and the Wildlife Habitat Incentives Program (WHIP).

These programs are provided for in Title II (Conservation) of the 2002 farm bill. Recent legislative action to reauthorize the farm bill in the 110th Congress seeks to expand authority and funding for these conservation programs.[47]

Total funding for USDA's conservation and land management programs totaled $5.6 billion in FY2005. Voluntary land retirement programs and programs that convert or restore land account for roughly 37% annually of all USDA conservation spending (**Figure 4**). Programs that provide cost-sharing and technical assistance to farmers to implement certain practices, such as EQIP, CSP, and AMA, provide another 21% annually.[48] USDA's conservation technical assistance and extension services account for about one-fourth of all funding. Other federal funding through other programs also generally promotes natural resource protection on U.S. farms. Generally, the decision on how and where this funding is ultimately used is made at the individual state level.

Figure 4. USDA Conservation Spending, FY2005



Source: USDA, Office of Budget and Planning.
Note: FY2005 total spending = $5.6 billion.

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[47] For a list of the USDA programs, see USDA, "Farm Bill, Title II: Conservation," at [http://www.ers.usda.gov/Features/Farmbill/titles/titleIIconservation.htm]. Also see CRS Report RL34060, *Conservation and the 2007 Farm Bill*, by Jeffrey A. Zinn.

[48] EQIP and CSP were originally set to expire in FY2007 with most farm bill programs, but were extended in the most recent budget reconciliation (P.L. 109-171). EQIP, the largest program, is authorized through FY2010 and will reach $1.3 billion annually.

Currently, few USDA conservation programs are specifically intended to address climate change concerns in the agriculture sector. One exception is USDA's Conservation Innovation Grants program, a subprogram under EQIP that provides for competitive awards, and is intended to accelerate technology transfer and adoption of innovative conservation technologies, mostly through pilot projects and field trials. However, recently USDA has started to explore the possibility of expanding some of its farmland conservation programs to focus more broadly on the potential for GHG emission reductions and carbon sequestration.[49] Past grants have supported development of approaches to reduce ammonia emissions from poultry litter, promote conservation tillage and solar energy technologies, and develop private carbon sequestration trading credits.[50]

USDA has identified three of its existing conservation programs that encourage greenhouse gas reductions and carbon sequestration. These include CRP, EQIP, and CSP.[51] Under EQIP and CSP, many of the practices encouraged under the program reduce net GHG emissions. For EQIP, USDA is providing additional national guidance to technical staff to make GHG a priority resource concern as part of its ranking system and scoring criteria for participation. Examples include giving greater weight to projects that promote anaerobic digestion, nutrient management plans, and other types of cropland practices, such as installing shelter belts and windbreaks, and encouraging conservation tillage. Resources also are available for biomass energy projects.

Under CRP, USDA has issued a new rule that explicitly allows the private sale of carbon credits for land enrolled in the program. USDA also has modified its "Environmental Benefits Index" to score and rank offers to enroll land in CRP in a way that places greater weight on installing vegetative covers that sequester more carbon. USDA also has announced a program under CRP's continuous enrollment provision to plant up to 500,000 acres of bottomland hardwoods, which are among the most productive U.S. lands for sequestering carbon.

USDA continues to evaluate how to better incorporate climate concerns into its conservation programs. One potential option includes modifying its evaluation criteria for ranking applications for its conservation programs by giving additional consideration to projects that propose to reduce GHG emissions or sequester carbon, as USDA has done with EQIP. Other possible options include supporting market-based approaches, such as the development of environmental services markets and trading, that might supplement existing conservation and forestry programs.[52]

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[49] USDA, "USDA Targeted Incentives for Greenhouse Gas Sequestration," Release No. 0194.03, June 6, 2003.

[50] USDA, "Reducing Agricultural Greenhouse Gas Emissions Through Voluntary Action," Statement by Bruce Knight of USDA's Natural Resources Conservation Service at the United Nations Framework Convention on Climate Change, December 2004, at [http://www.nrcs.usda.gov/news/speeches04/climatechange.html]

[51] W. Hohenstein, "USDA Conservation Programs are Targeting Greenhouse Gases and Carbon Sequestration." Provided to Senate Energy Committee staff, February 15, 2007.

[52] USDA, *USDA's 2007 Farm Bill Proposals*, Conservation Title, January 31, 2007, at [http://www.usda.gov/documents/07title2.pdf]; statement by Mark Rey, USDA Under

(continued...)

USDA participates in several ongoing federal interagency initiatives intended to address climate change concerns. For example, USDA participates in a multi-agency research and development program for climate change technology, as part of the U.S. National Climate Change Technology Initiative.[53] It also has developed new GHG reporting guidelines for forestry and agriculture for use in the 1605(b) Voluntary Greenhouse Gas Registry.[54] USDA also participates in the multi-agency Climate Change Science Program, integrating federal research on climate and global change across 13 federal agencies, including USDA.[55]

Other Farm Programs. In addition to farm conservation programs, other programs may also encourage the types of agricultural practices that can reduce GHG emissions and/or sequester carbon. These include forestry, energy, and rural development programs provided for under existing farm legislation.

Forestry programs are administered by USDA's Forest Service; many of these programs are provided for in Title VIII (Forestry) of the farm bill. Typically, however, there is often little overlap between the various agriculture and forestry programs administered by USDA, and few forestry programs provide support to agricultural enterprises. One exception is the Forest Service's Forest Land Enhancement Program (FLEP), which has an agroforestry component that provides funding for agriculture and silvopasture practices with rotational grazing and improved forage. Funding for agroforestry activities under this program constitutes a small share of total FLEP funding.[56] (Recent legislative action to reauthorize the farm bill in the 110th Congress would implement changes to existing forestry programs and allow FLEP to expire.[57]) Another program is USDA's agriculture conservation programs also include its Healthy Forests Reserve Program, which has

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[52] (...continued)
Secretary for Natural Resources and Environment, at USDA's 2007 Outlook Forum, March 2, Arlington, VA; statement by USDA staff at the 4th USDA Greenhouse Gas Conference, February 6, Baltimore MD.

[53] Established in 2001, the program conducts multi-agency review of the federal R&D portfolio. The program is under the direction of the U.S. Department of Energy, in coordination with the U.S. Department of Commerce [http://www.climatetechnology.gov/]. See CRS Report RL33817, *Climate Change: Federal Funding and Tax Incentives*, by Jane A. Leggett.

[54] A voluntary reporting program for companies to record their GHG emissions reductions. The program is administered by the Department of Energy and was created by section 1605b of the Energy Policy Act of 1992.

[55] Established in February 2002, the program is a collaborative interagency program, designed to improve the government-wide management of climate science and climate-related technology development; see [http://www.climatescience.gov/]. See CRS Report RL33817, *Climate Change: Federal Funding and Tax Incentives*, by Jane A. Leggett.

[56] Primary efforts under FLEP are afforestation and reforestation, improved forest stand, constructing windbreaks, and riparian forest buffers.

[57] For information on USDA forestry programs, see CRS Report RL33917, *Forestry in the 2007 Farm Bill*, by Ross W. Gorte.

an agroforestry component, but program funding is usually limited to a few states.

Renewable energy projects receive additional program funding across three farm bill titles: Title II (Conservation), Title IX (Energy), and Title VI (Rural Development). Other funding is also available through other federal programs.[58] In addition to cost-sharing provided under USDA's conservation programs, two important programs in the farm bill are under Title IX (Section 9006, Renewable Energy Systems and Energy Efficiency Improvements) and Title VI (Section 6013, Loans and Loan Guarantees for Renewable Energy Systems).

- **Section 9006.** Authorizes loans, loan guarantees, and grants to farmers, ranchers, and rural small businesses to purchase renewable energy systems and make energy efficiency improvements.
- **Section 6013.** Authorizes the rural development business and industry program to make loans and loan guarantees for renewable energy systems, including wind energy systems and anaerobic digesters.

Funding through these two programs, along with that of other cost-share programs, account for the majority of federal program spending to support construction of anaerobic digesters in the livestock sector.[59] Limited information indicates that USDA funded eight projects totaling more than $60 million under Section 6013[60] and provided another $20 million in funding assistance under Section 6009[61] for anaerobic digesters (FY2002-FY2005).

State Programs

State-level agriculture conservation and land management programs are available to farmers in most states, and operate in much the same manner as federal conservation programs. These programs may also provide financial and technical assistance to farmers to implement certain practices, using additional state resources and in consultation with state agriculture agencies and extension staff. No single current compendium exists outlining the different types of agriculture conservation programs across all states; instead information is available through individual state government websites.[62]

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[58] See CRS Report RL34130, *Renewable Energy Policy in the 2007 Farm Bill*, and CRS Report RL32712, *Agriculture-Based Renewable Energy Production*, both by Randy Schnepf; and CRS Report RL33572, *Biofuels Incentives: A Summary of Federal Programs*, by Brent Yacobucci.

[59] CRS communication with USDA staff, February 8, 2007.

[60] USDA, "Farm Bill Forum: Rural Development Title," March 2006, at [http://www.usda.gov/documents/RURAL_DEVELOPMENT_TITLE.pdf].

[61] USDA, "USDA Funding Assistance for Rural Renewable Energy and Energy Efficiency: Section 9006 of the 2002 Farm Bill," at [http://power.wisconsin.gov/pdf/USDA Presentation.pdf].

[62] State and Local Government directory at [http://www.statelocalgov.net/index.cfm].

Many states have cost-share programs that provide financial assistance to landowners to implement practices that benefit a state's forests, fish, and wildlife. Many of these programs provide technical assistance and up to 75% of the eligible costs of approved conservation projects to qualified landowners. Several states also provide low-interest financing to farmers and landowners to encourage conservation practices or to implement best management practices for the agriculture sector. Many states also have buffer strip programs, which may provide rental payments to landowners who agree to create or maintain vegetative buffer strips on croplands near rivers, streams, ponds, and wetlands. Typically states that have taxing authority for conservation purposes, such as Nebraska, Missouri, and Oregon, tend to have more stable funding and staffing to support conservation improvements.

The Pew Center on Global Climate Change has identified several ongoing state programs and demonstration projects specifically intended to promote carbon storage and emissions reduction in the U.S. agriculture sector.[63] For example, several states, including Oregon, Wisconsin, Vermont, and North Carolina, are promoting methane recovery and biofuels generation from livestock waste. A program in Iowa is providing support and funding to promote switchgrass as a biomass energy crop. In Maryland, income tax credits are provided for the production and sale of electricity from certain biomass combustion. Georgia has a program that leases no-till equipment to farmers. In addition, several states, including Nebraska, Oklahoma, Wyoming, North Dakota, and Illinois, have formed advisory committees to investigate the potential for state carbon sequestration. In California, an accounting program is being developed to track possible future costs to mitigate GHG emissions in the U.S. agriculture sector.

An even greater number of state programs and initiatives are geared toward climate change mitigation strategies in sectors other than agriculture.[64] For example, many of California's programs support the state's recently enacted emission reductions legislation.[65] California's climate change statute requires state agencies to identify GHG emissions reduction strategies that can be pursued before most of the law takes effect in 2012. The state has identified several agriculture sector strategies that it plans to consider as early actions, including (1) adopting a manure digester protocol for calculating GHG mitigation; (2) establishing collaborative research on how to reduce GHG emissions from nitrogen land application; (3) replacing stationary diesel agricultural engines with electric motors; and (4) evaluating potential measures for enclosed dairy barns, modified feed management,

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[63] Pew Center, *Learning from State Action on Climate Change*, Nov. 2005, [http://www.climatechange.ca.gov/climate_action_team/reports/2005-12-08_PEW_CENTER_REPORT.PDF].

[64] See CRS Report RL33812, *Climate Change: Actions by States to Address Greenhouse Gas Emissions*, by Jonathan L. Ramseur.

[65] California's Global Warming Solutions Act of 2006 (AB 32), which was enacted in September 2006, codified the state's goal of requiring California's GHG emissions be reduced to 1990 levels by 2020.

and manure removal strategies to reduce methane emissions at dairies.[66] These early action strategies would be in addition to funding for the state's manure digester cost-share program and other agriculture projects, including carbon sequestration projects involving rice straw utilization, energy and water conservation, biofuels support, soil management, and other types of renewable energy and manure management programs for dairies.[67]

Other Programs and Incentives

The voluntary carbon offset market allows businesses, interest groups, and individuals the opportunity to purchase carbon credits generated from projects that either prevent or reduce an amount of carbon entering the atmosphere, or that capture carbon from the atmosphere. Companies and individuals purchase carbon credits for varied reasons. For example, some may purchase credits to reduce their "carbon footprint," using credits to offset all or part of a GHG-emitting activity (e.g., air travel, corporate events, or personal automobile use); others may purchase credits to bank the reductions in anticipation of a mandatory GHG reduction program.[68] In the United States, the current offset framework operates on a voluntary basis since there is no federal requirement that GHG emissions be curtailed. Some states and/or regional GHG reduction initiatives may limit the use of carbon offsets.

Several states have programs that support the voluntary carbon offset exchange, often involving U.S. farmers and private landowners. One program operated by the Iowa Farm Bureau involves more than 1,400 producers in 12 states (mostly Iowa, Kansas, and Nebraska, but also Illinois, Ohio, Michigan, Wisconsin, Minnesota, South Dakota, Missouri, Indiana, and Kentucky),[69] whose carbon credits may be sold on the Chicago Climate Exchange.[70] Similar types of programs also have been initiated in North Dakota (operated by the North Dakota Farmers Union), Illinois (Illinois Conservation and Climate Initiative), Indiana (Environmental Credit Corporation), and the Northwest (Upper Columbia Resource Conservation and

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[66] California Environmental Protection Agency, *Expanded List of Early Action Measures to Reduce Greenhouse Gas Emissions in California Recommended for Board Consideration*, Oct. 2007, at [http://www.arb.ca.gov/cc/ccea/meetings/ea_final_report.pdf].

[67] California Climate Change Portal, "State of California Agencies' Roles in Climate Change Activities," at [http://climatechange.ca.gov/policies/state_roles.html#dfg].

[68] For additional general information on voluntary carbon markets, see CRS Report RL34241, *Voluntary Carbon Offsets: Overview and Assessment*, by Jonathan L. Ramseur. For trading purposes, one carbon credit is considered equivalent to one metric ton of carbon dioxide emission reduced.

[69] Iowa Farm Bureau, Carbon Credit Aggregation Pilot Project, at [http://www.iowafarmbureau.com/special/carbon/]; CRS staff communication with Iowa Farm Bureau staff, January 2007.

[70] The Exchange is a voluntary, self-regulated, rules-based exchange. Its emission offset program constitutes a small part of its overall program, which includes methane destruction, carbon sequestration, and renewable energy. See [http://www.chicagoclimatex.com/].

Development Council). Another, Terrapass, has among its projects two large-scale dairy farms that use anaerobic digesters and methane capture for energy production.[71]

Current estimates indicate that farmer participation in voluntary carbon credit trading programs involves a reported 2,000 farmers across 15 states covering more than 1 million acres. Farm-based offset programs generally cover some or all aspects of the following types of carbon capture and storage activities: sustainable agriculture practices (such as conservation tillage, grass seedlings); planting of unharvested grasslands; tree plantings; methane capture/biogas production with manure digesters; wind, solar, or other renewable energy use; controlled grasslands or pasture management; and forest restoration. Farmer participation in such programs may help offset farm costs to install emissions controls and/or practices that sequester carbon by providing a means for them to earn and sell carbon credits.

Recent Congressional Action

The 110th Congress is considering a range of climate change policy options, including mandatory GHG emission reduction programs. The current legislative proposals would not require emission reductions in the agriculture and forestry sectors. However, some of the GHG proposals would allow for regulated entities (e.g., power plants) to purchase carbon offsets, including those generated in the agriculture and forestry sectors. Also, as part of the pending omnibus farm bill, there are provisions in both the House and Senate versions of the bill that could expand the scope of existing farmland conservation programs by facilitating the development of private-sector markets for a range of environmental goods and services from farmers and landowners, including carbon storage. Other provisions in the farm bill expand existing farm conservation programs that may indirectly encourage emissions reductions and carbon capture and storage. These and related bills and issues are currently being debated in Congress.

Climate Change Legislation

In the 110th Congress, several proposals have been introduced that would either mandate or authorize a cap-and-trade program to reduce GHG emissions. A cap-and-trade program provides a market-based policy tool for reducing emissions by setting a cap or maximum emissions limit for certain industries. Sources covered by the cap can choose to reduce their own emissions, or can choose to buy emission credits that are generated from reduction made by other sources. Applying this type of market-based approach to GHG reductions and trading would be similar to the acid rain reduction program established by the 1990 Clean Air Act Amendments. For more information about these GHG legislative proposals and the carbon offset provisions in these bills, see CRS Report RL33846, *Greenhouse Gas Reduction: Cap-and-Trade Bills in the 110th Congress,* by Larry Parker and Brent D. Yacobucci;

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[71] For more information, see North Dakota Farmers Union [http://www.ndfu.org], Illinois Conservation and Climate Initiative [http://www.illinoisclimate.org], Environmental Credit Corporation [http://www.envcc.com]; and Terrapass [http://www.terrapass.com/projects].

and CRS Report RL34067, *Climate Change Legislation in the 110th Congress,* by Jonathan L. Ramseur and Brent D. Yacobucci.

In general, the current legislative proposals do not include the agriculture sector as a covered industry.[72] In part, this may reflect the general consensus, as reflected by the House Energy and Commerce Committee, that GHG "emissions from the agriculture sector generally do not lend themselves to regulation under a cap-and-trade program," given the "large number of sources with small individual emissions that would be impractical to measure."[73] However, some bills provide authority to EPA to determine covered entities by applying cost-effective criteria to reduction options.

Several of the cap-and-trade proposals do incorporate the agriculture and forestry sectors either as a source of carbon offsets[74] or as a recipient of set-aside allowances.[75] In the context of these legislative proposals, a carbon offset is a measurable avoidance, reduction, or sequestration of carbon dioxide (CO_2) or other GHG emissions, expressed in carbon-equivalent terms.[76] A set-aside allowance refers to a set percentage of available allowances under the overall emissions cap that is allocated to non-regulated entities, in this case domestic agriculture and forestry entities. Some bills also specify that the proceeds from auctioned allowances be used to promote certain objectives, which could further encourage farmland conservation and bio-energy technologies and practices, among other activities.[77]

Many of the GHG bills — S. 280 (McCain/Lieberman), S. 317 (Feinstein), S. 1168 (Alexander/Lieberman), S. 1177 (Carper), S. 1766 (Bingaman/Specter), S. 2191 (Lieberman/Warner), and H.R. 620 (Olver) — would allow for the use of carbon offsets, including agricultural activities and other land-based practices, under a cap-and-trade framework. This builds on the concept, also expressed by the House Energy and Commerce Committee, that emissions reductions and carbon

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72 Historically, climate-related legislative initiatives have not specifically focused on emissions reductions in the agriculture sector.

73 Committee on Energy and Commerce, "Climate Change Legislation Design White paper: Scope of a Cap-and-Trade Program," prepared by committee staff, Oct. 2007, available at [http://energycommerce.house.gov/Climate_Change/White_Paper.100307.pdf].

74 GHG bills that provide for agriculture or forestry offsets are S. 2191 (Lieberman/Warner), S. 280 (McCain/Lieberman), S. 317 (Feinstein), S. 1168 (Alexander/Lieberman), S. 1177 (Carper), S. 1766 (Bingaman/Specter), and H.R. 620 (Olver).

75 Primarily S. 2191 and also S. 1766 (Bingaman/Specter).

76 In the context of credit trading, an offset is a certificate representing the reduction of one metric ton of carbon dioxide emissions, the principal greenhouse gas. Offsets generally fall within the categories of biological sequestration, renewable energy, energy efficiency, and reduction of non-CO_2 emissions. For more information concerning offsets, see CRS Report RL34436, *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns,* by Jonathan L. Ramseur.

77 For more information on allowances and auction proceeds in current GHG bills, see *Allocations for Carbon Allowances and Auctions under S. 2191*, by Brent D. Yacobucci, CRS general distribution memorandum, February 22, 2008.

sequestration by the agriculture sector may provide an appropriate source of credits or offsets within a cap-and-trade program.[78] Some bills — S. 309 (Sanders/Boxer), S. 485 (Kerry), S. 1201 (Sanders), S. 1554 (Collins/Lieberman), and H.R. 1590 (Waxman) — would not allow for offsets, but would set aside a percentage of allowances for various purposes, including biological sequestration. Participating farmers and landowners who receive these allowances for sequestration and/or emission reduction activities could sell them to facilities (e.g., power plants) that could become covered by a cap-and-trade program.

One Senate bill that was ordered reported by the Senate Committee on Environment in December 2007 is the Lieberman-Warner Climate Security Act of 2008 (S. 2191), which contains several agriculture-based provisions.[79] The cap-and-trade framework outlined in S. 2191 establishes a tradeable allowance system that includes a combination of auctions and free allocation of tradeable allowances. As part of this overall framework, S. 2191 includes three design mechanisms that may provide financial incentives to encourage land-based agricultural and forestry activities: carbon offsets, set-aside allowances, and auction proceeds. S. 2191 provides for a range of agriculture and forestry offset projects, including agricultural and rangeland sequestration and management practices, land use change and forestry activities, manure management and disposal, and other terrestrial offset practices identified by USDA. S. 2191 also would directly allocate 5% of the overall emissions allowances to domestic agriculture and forestry entities, and allocate a set percentage of available auction proceeds to carry out a cellulosic biomass ethanol technology deployment program. For more information on the agriculture and forestry provisions in S. 2191, see CRS Report RS22834, *Agriculture and Forestry Provisions in Climate Change Legislation (S. 2191)*, by Renée Johnson.

The inclusion of these types of provisions could provide opportunities to some farmers and landowners by allowing them to directly participate in and, in some cases, gain a significant part of this emerging market. The offset and allowance provisions would allow farmers and landowners to participate in the emerging market by granting them the use of allowances and credits for sequestration and/or emission reduction activities. These allowances and credits could be sold to regulated facilities (e.g., power plants) covered by a cap-and-trade program to meet their emission reduction obligations. The agriculture and forestry sectors also would receive proceeds from the sale of these allowances, credits, and auctions to further promote and support activities in these sectors that reduce, avoid, or sequester emissions.

However, the inclusion of carbon offsets from the agriculture and forestry sectors within a cap-and-trade program has remained controversial since the Kyoto Protocol negotiations.[80] During those negotiations, there was marked disagreement

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[78] Ibid.

[79] This analysis is based on legislative text in S. 2191, as ordered reported by EPW, available at Sen. Lieberman's website, [http://lieberman.senate.gov/documents/lwcsa.pdf].

[80] See, for example, E. Boyd, E. Corbera, B. Kjellén, M. Guitiérrez, and M. Estrada, "The (continued...)

among countries and interest groups, arguing either for or against the inclusion of offsets from the agriculture and forestry sectors.[81] The EU's GHG emission program, the Emission Trading System (ETS), which was established in 2005, does not provide for agricultural or forestry projects and activities. Among the reasons are (1) pragmatic concerns regarding measurement and verification, given the sheer number of farmers and landowners, and (2) ideological concerns about granting too much flexibility in how emission reductions are met, which could undermine overall program goals. Among the areas of concern regarding biological sequestration offsets are those highlighted in two previous sections of this report, "Uncertainty Estimating Emissions" and "Uncertainty Estimating Carbon Sinks." In summary, primary areas of concern include:

- **Permanence/Duration**, given that land uses can change over time (e.g., forest lands to urban development, other natural events such as fires or pests);
- **Measurement/Accounting**, given that biological sequestration measurement is difficult and estimates can vary, actual emission reduction or sequestration depends on site-specific factors (e.g., location, climate, soil type, crop/vegetation, tillage practices, farm management, etc.);
- **Effectiveness**, the success of the mitigation practice will depend on the type of practice, how well implemented and managed by the farmer or landowner, and the length of time the practice is undertaken;
- **Additionality**, given that some of the activities generating offsets would have occurred anyway under a pre-existing program or practice, and thus may not go beyond business as usual (BAU);
- **Leakage**, given that reductions in one place could result in additional emissions elsewhere; and
- **Double counting**, given that some reductions may be counted by another program (e.g., attributable to other environmental goals under various farm conservation programs) or towards more than one GHG reduction target.

A more detailed discussion of some of these issues is available in CRS Report RL34436, *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns*, by Jonathan L. Ramseur.

2007 Farm Bill

[80] (...continued)
Politics of 'Sinks' and the CDM: A Process Tracing of the UNFCCC Negotiations (pre-Kyoto to COP-9)," Feb. 2007, draft submitted for International Environmental Agreements; also see two articles in *Nature*, no. 6812, Nov. 2000, "Deadlock in the Hague, but Hope Remains for Spring Climate Deal," and "Critical Politics of Carbon Sinks."

[81] Commonly referred to as "land use, land use change, forestry," or abbreviated as LULUCF.

As part of the ongoing climate change debate, there are legislative initiatives within both the House and Senate versions of the 2007 farm bill that could expand the scope of existing agriculture conservation programs to more broadly encompass aspects of the ongoing initiatives. Such provisions would expand funding for conservation and land management practices that contribute to emissions reductions and carbon storage in agricultural activities, and also would facilitate the development of private-sector markets for a range of environmental goods and services from farmers and landowners, including carbon storage.

Conservation and Related Farm Bill Programs. In general, both the House-passed and Senate-reported versions of the 2007 farm bill (H.R. 2419) expand the scope of and funding for many of the existing farm conservation, forestry, bioenergy, and rural development programs that contribute to GHG emissions reductions and carbon storage in the farm sector. Despite their differences, both bills generally expand funding and activities under existing cost-sharing and technical assistance programs, such as EQIP, CSP, and CRP, as well as existing land retirement, conversion and restoration programs, such as CRP, WRP, and GRP. Both bills also generally expand access to low-cost loans, loan guarantees, grants, incentive payments, and income tax credits to farmers, ranchers, and rural small businesses.

Neither bill, however, seeks to modify existing cost-sharing and land retirement programs to specifically mandate that USDA gives additional consideration to projects that propose to reduce GHG emissions or sequester carbon. Instead, GHG emissions reductions and carbon uptake would remain an incidental benefit of existing voluntary agriculture conservation programs that provide financial and technical assistance to implement certain farm management practices, predominately for other production or environmental purposes.

For more detailed farm bill information, see CRS Report RL34060, *Conservation and the 2007 Farm Bill*, by Jeffrey A. Zinn; and CRS Report RL34130, *Renewable Energy Policy in the 2007 Farm Bill*, by Randy Schnepf, among other CRS farm bill reports.

Market Development for Farm-Based Environmental Services. New conservation provisions in both the House and Senate bills also seek to facilitate the development of environmental services markets involving the farm and forestry sectors, which would include environmental goods and services associated with carbon storage and GHG emissions reduction.

Both the House and Senate farm bills include provisions that would facilitate the development of private-sector market-based approaches for a range of environmental goods and services (e.g., water and air quality, carbon storage, habitat protection, etc.) involving farmers and landowners. The House version would, among other things, establish a USDA-chaired board that would provide grants and a framework to develop consistent standards and processes for quantifying offsets from the farm and forestry sectors.[82] The Senate version differs in approach but also directs USDA to establish a framework to develop consistent standards and processes for quantifying environmental services from the agriculture and forestry sectors.[83]

The House version follows similar provisions recommended by USDA as part of its 2007 farm bill proposal to Congress,[84] and would cover a range of farm and forestry services, including improved water and air quality, increased carbon storage, and habitat protection, among other types of environmental services. The Senate farm bill also address a range of environmental goods and services in the farm and forestry sectors, but directs USDA to "give priority" to providing assistance to farmers and landowners participating in carbon markets.

For more detailed information about these provisions, see CRS Report RL34042, *Environmental Services Markets: Farm Bill Proposals*, by Renée Johnson.

Considerations for Congress

Following is a list of the types of questions that might be raised in the 110th Congress in legislation and debate about global climate change in general, as well as during the anticipated 2007 farm bill debate over existing federal conservation and land management programs for the U.S. agriculture and forestry sectors.

- **Farm Bill Programs.** Where are the opportunities to expand existing federal conservation and land management programs to achieve greater emissions reduction and carbon sequestration in the agriculture sector in the 2007 farm bill? How might emissions reduction and carbon sequestration be integrated with the many other goals of conservation programs? Should existing programs and policies intended to promote agriculture conservation practices be modified or augmented to better address climate change concerns? How explicitly should climate change goals be addressed in the 2007 farm bill? How might emissions reductions and carbon sequestration be promoted among the other broader environmental benefits of conservation activities in the agriculture sector, such as improved soil quality and productivity, improved water and air quality, and wildlife habitat? Which programs or practices are the most beneficial and cost-effective? Are there ways to rank applications from farmers under existing programs to grant a higher weight to proposals to address climate change goals? Are there existing state

[82] See "promotion of market-based approaches to conservation" (Sec. 2407) of the House-passed bill (H.R. 2419, H.Rept. 110-256).

[83] See "conservation programs in environmental services markets" (Section 2406) of the Senate-reported bill (S. 2302, S.Rept. 110-220). During Senate floor action, an amended Senate farm bill was offered as an amendment and substitute (S.Amdt. 3500) to H.R. 2419.

[84] USDA, *USDA's 2007 Farm Bill Proposals*, Jan. 31, 2007, at [http://www.usda.gov/documents/07finalfbp.pdf].

programs that effectively address climate change and could be adopted at the federal level?

- **Emissions reductions.** Should carbon sequestration efforts be balanced by incentives to obtain additional emissions reductions in the agriculture sector through improved conservation and farm management practices, which could have a more immediate, direct, and lasting effect on overall GHG emissions? How might the existing regulatory framework for controlling air pollutants affect the climate change debate? What are the potential options for reducing GHG emissions at U.S. farming operations? How might cost concerns be addressed that limit broader adoption of manure management systems and also feed management strategies at U.S. livestock operations?

- **Carbon sequestration.** What are the upper limits of carbon capture and storage initiatives in the agriculture sector? For example, are such carbon sinks temporary or long-lasting, and what limits exist on their storage value? Do they rely appropriately on the willingness of landowners to adopt or continue to implement a particular conservation practice? Do they rely too heavily on the willingness of landowners to convert existing farmland to open space or prevent the conversion of existing farmland to non-farm uses? Are they cost-effective when compared to sinks in other sectors? How might concerns regarding uncertainty be addressed when measuring and estimating the amount of carbon sequestered in agricultural soils?

- **Carbon offset or credit trading programs.** Is there a federal role in possibly expanding existing federal conservation programs in conjunction with efforts to create new market opportunities for farmers by developing a carbon credit trading system? What are the potential policy implications of establishing a carbon credit trading system? What are the potential measurement, monitoring, enforcement, and administrative issues of implementing such a program? For example, how could stored carbon be measured and verified; how much compensation is available and for how long; what are required management practices; which accounting methodologies should be used? Would such a system operate under a voluntary or a mandatory framework?

- **Bioenergy promotion.** How might ongoing or anticipated initiatives to promote U.S. bioenergy production, such as corn-based or cellulosic ethanol, affect the options for land management or conservation strategies that could increase carbon uptake on agricultural lands and in agricultural soils? Might broader climate change goals be affected by increased agricultural production in response to corn-based ethanol? For example, might previously retired land be brought back into corn production or might this result in more intensive corn production, including fewer crop rotations and planting area setbacks, which could raise emissions and reduce the amount of carbon sequestered? Are there other competing commercial crops that might be used as a feedstock for ethanol that could also affect emissions and carbon uptake potential?

- **Energy efficiency.** What are the opportunities for improved on-farm energy efficiency and conservation? How might these be integrated into the broader framework on climate change mitigation in the agriculture sector?

- **Safeguarding U.S. agricultural production.** Among the possible effects of global climate change on agricultural production are increased climate variability and increased incidence of global environmental hazards, such as drought and/or flooding, pests, weeds, and diseases, or location shifts in where agriculture is produced. Climate change in some locations increases the yields of some crops. Some U.S. production regions are likely to fare better than others. Are additional initiatives needed in the U.S. agriculture sector to prepare for the potentially effects of global climate change that might impact U.S. agricultural production and food security? Which regions and crops might be "winners" or "losers" and how can transitions be eased?

Appendix: Primer on the Role of the U.S. Agriculture Sector in the Climate Change Debate

Question	Discussion
What are the types of GHG emissions associated with U.S. agriculture?	Official estimates of greenhouse gas (GHG) emissions for the U.S. agriculture sector are based on emissions of methane (CH_4) and nitrous oxide (N_2O) associated with agricultural production only. These estimates do not include carbon dioxide (CO_2) emissions from on-farm energy use and other emissions associated with forestry activities, food processing or distribution, or biofuel production. See **Agricultural GHG Emissions** in this report for more information.
What are the sources of GHG emissions from agriculture?	Agricultural sources of CH_4 emissions are mostly associated with the natural digestive process of animals and with manure management on U.S. livestock operations. Sources of N_2O emissions are mostly associated with soil management and fertilizer use on U.S. croplands. **Figure 1** shows agricultural emissions by type and production category.
Why are CO_2 energy emissions excluded?	CO_2 emissions from on-farm energy use are aggregated with emissions for all transportation and industrial sectors, and comprise a small share of this total. Even if included in the estimates for the agriculture sector, this would not substantially raise agriculture's overall share of total GHG emissions.
What is agriculture's share of annual national GHG emissions?	In 2005, GHG emissions from U.S. agricultural activities totaled nearly 540 MMTCO_2-Eq (million metric tons CO_2-equivalent units, accounting for about 7% of annual national GHG emissions (**Table 1**). Fossil fuel combustion is the leading source of national GHG emissions (about 80%), with the energy sector generating about 85% of annual emissions across all U.S. sectors.
How much carbon is sequestered in U.S. agricultural soils?	In 2005, agricultural soils sequestered about 30 MMTCO_2-Eq., or roughly 5% of annual emissions generated from agricultural activities. Compared to total national GHG emissions, the agriculture sector offsets well under 1% of emissions annually. These estimates do not include uptake from forested lands or open areas that account for a majority (about 95%) of total U.S. sequestration. **Figure 2** shows carbon sequestration in agricultural soils. Also see **Agricultural Carbon Sinks** for more information.
Is there any uncertainty associated with estimates of carbon uptake for the agriculture sector?	Reasons for uncertainty associated with uptake estimates in U.S. soils include actual uptake depends on site specific conditions (e.g., location, climate, soil type, crop type, tillage practices, crop rotations, farm management, etc.); accounting methodology; type of practice, how well it is implemented, and the length of time undertaken; availability of federal/state cost-sharing or technical assistance; and other competing factors (including supply response for commercial crops and bioenergy crops). Actual GHG emissions may also vary according to many site-specific conditions. See **Uncertainty Estimating Carbon Sinks** for more information.
What is the potential to reduce emissions and/or increase carbon uptake in the agriculture sector?	The potential for carbon uptake in U.S. agriculture sector is much greater than current rates. USDA estimates net increases in carbon sequestration ranging from 40 to 590 MMTCO_2-Eq. per year (**Table 2**), or 2 to 20 times above current rates. This could offset total current national GHG emissions by as much as 8%. Other studies show an even greater carbon uptake potential in the agriculture sector. Practices that may reduce emissions and/or sequester carbon on U.S. farmlands include land retirement, pastureland and crop conversion, restoration; improved soil management and conservation tillage; and improved manure management and feeding strategies at livestock operations. See sections **Potential for Additional Uptake** and **Potential for Additional Reductions**.

Question	Discussion
How costly are the types of farming practices that help address climate change issues?	The estimated value (or cost) of sequestered carbon will vary by practice. USDA's forecast of an additional sequestration potential of 40 to 590 MMTCO_2-Eq. per year is associated with an estimated per-unit value ranging from $3-$34/mt of permanently sequestered carbon dioxide. The low-end of this range reflects the sequestration potential associated with cropland management practices; higher-end values are associated with afforestation and land retirement. See **Table 2** for more information See **Potential Mitigation Costs** for more information.
How can emissions from production be reduced? How can carbon uptake in agricultural soils be increased?	Most land management and agriculture conservation practices might both reduce GHG emissions and/or sequester carbon, including land retirement, conversion, and restoration; conservation tillage; soil management and soil erosion controls; efficient fertilizer/nutrient and chemical application; crop rotations; cover cropping; manure management; feed management; rotational grazing and improved forage; vegetative and riparian buffers; windbreaks for crops and livestock; bioenergy substitution and renewable energy use; and energy efficiency and energy conservation on-farm. See **Table 3** and **Mitigation Strategies in the Agriculture Sector** for more information.
Are there existing programs and/or legislation that promote farming practices that may help address climate change?	Existing federal and state farm conservation programs promote the types of land management and conservation practices that can reduce GHG emissions and/or sequester carbon. Also, many existing voluntary programs in the current farm bill, as well as under existing state-level programs provide cost-sharing and technical assistance to encourage farmers to implement such practices. These are voluntary programs and are generally designed to address site-specific improvements at an individual farming operation. See **Federal Programs** and other listed program information.

Source: Table prepared by the Congressional Research Service.