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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 about 6% 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 livestock 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. 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 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 debate in Congress over whether and how to address possible future climate change is intensifying. Historically, legislative initiatives have not specifically focused on emissions reductions in the agriculture sector. Instead, emissions reductions and carbon uptake are incidental benefits of existing voluntary conservation programs that provide financial and technical assistance to implement certain farm management practices, predominantly for other production or environmental purposes. The pending 2007 farm bill could expand the scope of these types of initiatives to more broadly encompass the agriculture sector in overall efforts to address climate change. Policies and incentives that might further encourage farmers to adopt such practices include expanding cost-sharing and technical assistance under existing conservation programs, low-cost loans, grants, incentive payments, and tax credits.

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

The debate in Congress over whether and how to address possible future climate change is intensifying. In the 109th Congress, more than 100 bills, resolutions, and amendments were introduced specifically addressing climate change. The role of the U.S. agriculture sector is often included 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.

Previous legislative initiatives involving the agriculture sector in addressing climate change have focused on sequestering carbon on agricultural lands, with most attention given to forestry activities and restoration projects where the potential to increase uptake and store carbon for long time periods is greatest. Historically, these legislative initiatives have not specifically focused on emissions reductions in the agriculture sector. Instead, emissions reductions and carbon uptake might best be viewed as incidental benefits of existing agricultural conservation programs. Many of these programs provide financial and technical assistance to voluntarily implement certain farm conservation and land management practices, predominantly for other production or environmental purposes.

The anticipated 2007 farm bill debate[1] could expand the scope of ongoing climate change initiatives to more broadly encompass the agriculture sector, promoting conservation and land management practices that could further reduce emissions and sequester carbon in the sector. Policies and incentives that might further encourage farmers to adopt such practices include expanding cost-sharing and technical assistance under existing conservation programs, expanding existing research programs and demonstration projects, and expanding access to low-cost loans, loan guarantees, grants, incentive payments, and income tax credits.

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. Third, the report discusses the types of questions that may be raised regarding the role of the U.S. agriculture sector in the

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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."

broader climate change debate, and also discusses the role of climate-related issues (e.g., GHG emissions reductions and carbon sequestration) in the context of farm program legislation that the 110th Congress may consider. The Appendix provides a summary primer of the key topics presented in this report.

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.

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*.[3] 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 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.[4]

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[2] See CRS Report RL33817, *Climate Change: Federal Expenditures*, by Jane Leggett.

[3] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004*, April 2006, at [http://epa.gov/climatechange/emissions/usinventoryreport.html].

[4] USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001*, TB1907,
(continued...)

In this CRS report, emissions from agricultural activities are aggregated in "carbon-equivalents" and expressed as million metric tons carbon-equivalent (MMTCE).[5] This aggregation is intended to illustrate agriculture's contribution to national GHG emissions and to contrast emissions against estimates of sequestered carbon. Other estimates used in other reports may alternatively be expressed in terms of equivalent CO_2 units.

Agricultural GHG 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.[6] These gases are significant contributors to atmospheric warming and have a greater effect warming than the same mass of CO_2.[7]

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.[8] Emissions of N_2O from agriculture sources account for about two-thirds of all reported agriculture emissions; emissions of CH_4 account for about one-third of all reported agriculture emissions. Across all economic sectors, the U.S. agricultural sector was the leading source of N_2O emissions (72%) and a major source of CH_4 emissions (29%) in 2004.[9]

Other Types of Emissions. Agricultural activities may also emit other indirect greenhouse gases, such as carbon monoxide, nitrogen oxides, and volatile

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[4] (...continued)
March 2004, at [http://www.usda.gov/oce/global_change/gg_inventory.htm].

[5] Estimates in this report are converted from EPA-reported data expressed as equivalent CO_2 units assuming a multiplier of 0.2727 to yield MMTCE. EPA's data are reported in teragrams, or million metric tons. "Carbon-equivalents" equate an amount of a GHG to the amount of carbon that could have a similar impact on global temperature.

[6] 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; and Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001,* at [http://www.ipcc.ch/pub/wg1TARtechsum.pdf].

[7] IPCC, *Climate Change 2001*, at [http://www.ipcc.ch/pub/wg1TARtechsum.pdf]; EPA's 2006 *Inventory,* Table ES-2. 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).

[8] 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.

[9] EPA's 2006 *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.

organic compounds from field burning of agricultural residues.[10] 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.[11] 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 2004, GHG emissions from U.S. agricultural activities totaled 120 MMTCE, expressed in terms of carbon-equivalent units, and accounted for 6% of the total GHG emissions in the United States (**Table 1**). 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 (80%), with the energy sector generating about 86% of annual emissions across all sectors.[12]

Recent trends in GHG emissions associated with the U.S. agriculture sector suggest emissions reductions in recent years. In 2004, emissions from agricultural activities are lower compared to estimates for 1995 and 2000, and also lower than the most recent five-year average (**Table 1**).

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. More detailed information is reported in EPA's 2006 *Inventory*.

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[10] EPA's 2006 *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.

[11] 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.

[12] Other contributing sources include wood biomass and ethanol use (3%), nonenergy use of fuel (2%), and landfills (2%); by sector, industrial processes (5%) and waste (3%) are other main sources of emissions (EPA's 2006 *Inventory*, Tables ES-2 and ES-4).

Table 1. Methane (CH_4) and Nitrous Oxide (N_2O) Emissions and Carbon Sinks, Agricultural Activities, 1990-2004

Source	1990	1995	2000	2004	Avg. 2000-2004
	million metric tons carbon equivalent (MMTCE)				
U.S. Agricultural Activities					
GHG Emissions (CH_4 and N_2O)					
Agriculture Soil Management [a]	72.6	84.0	75.9	71.3	74.2
Enteric Fermentation [b]	32.2	33.5	31.5	30.7	31.2
Manure management	13.0	14.5	15.2	15.6	15.5
Rice Cultivation	1.9	2.1	2.0	2.1	2.0
Agricultural Residue Burning	0.3	0.3	0.4	0.4	0.3
Subtotal	**119.9**	**134.4**	**125.0**	**120.0**	**123.2**
Carbon Sinks					
Agricultural Soils	(14.6)	(14.7)	(11.6)	(12.4)	(12.1)
Other	na	na	na	na	na
Subtotal	**(14.6)**	**(14.7)**	**(11.6)**	**(12.4)**	**(12.1)**
Net Emissions, Agriculture	**105.2**	**122.8**	**113.4**	**107.6**	**111.1**
Attributable CO_2 emissions:[c] Fossil fuel/mobile combustion	12.7	15.6	13.8	13.9	13.7
%Total Emissions, Agriculture [d]	**7.2%**	**7.6%**	**6.6%**	**6.2%**	**6.5%**
%Total Sinks, Agriculture	**5.9%**	**7.0%**	**5.6%**	**5.8%**	**5.8%**
%Total Emissions, Forestry	0.1%	0.1%	0.1%	0.1%	0.1%
%Total Sinks, Forestry[e]	94.1%	93.0%	94.4%	94.2%	94.2%
Total GHG Emissions, All Sectors	1,665.9	1,768.0	1,904.1	1,929.2	1,899.3
Total Carbon Sinks, All Sectors	(248.2)	(167.7)	(207.1)	(212.7)	(210.0)
Net Emissions, All Sectors	1,417.7	1,600.3	1,697.0	1,716.5	1,689.3

Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004*, April 2006, [http://epa.gov/climatechange/emissions/usinventoryreport.html]. Table ES-2, Table 2-13, and Table 6-1. Converted from EPA-reported carbon dioxide equivalent units (CO_2 Eq.) using a multiplier of 0.2727 to yield carbon-equivalent, expressed in million metric tons (MMTCE). 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. agricultural 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.

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,[13] 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

[13] Land use and forestry activities account for less than 1% of total estimated GHG emissions in the United States (EPA's 2006 *Inventory*, Table ES-4).

and mobile combustion averaged about 14 MMTCE per year[14] (**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[15] 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.[16] Higher feed effectiveness is associated with lower emissions.
- **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 and methane to be released.
- **Agricultural residue burning:** Methane and nitrous oxide emissions are released by burning residues or biomass.[17]

The share of GHG emissions for each of these categories is as follows: agriculture soil management (about 60% of agriculture emissions), enteric

[14] EPA's 2006 *Inventory,* Table 2-14.

[15] 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.

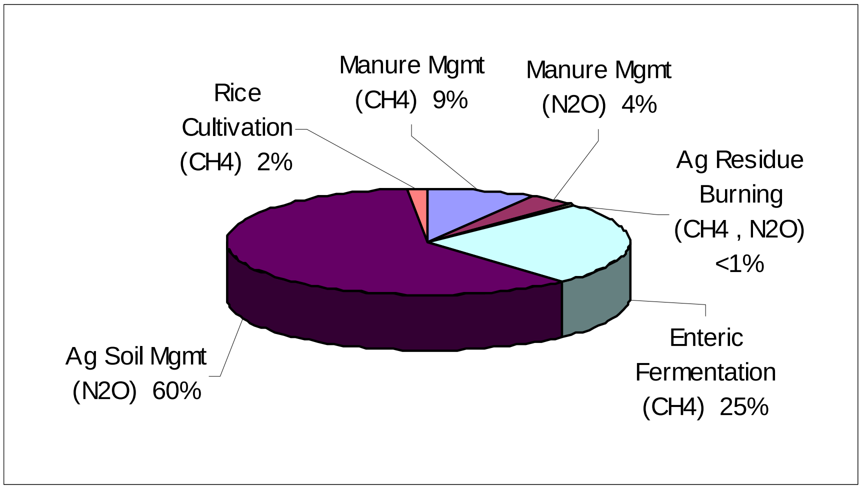
[16] R. A. Leng, "Quantitative Ruminant Nutrition — A Green Science," *Australian Journal of Agricultural Research*, 44: 363-380. Feed efficiency is based on both fermentive digestion in the rumen and the efficiency of conversion of feed to output (e.,g, milk, meat) as nutrients are absorbed.

[17] 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.

fermentation (25%), manure management (13%), rice cultivation (2%), and field burning of agricultural residues (less than 1%). About 60% of agriculture emissions are associated with the crop sector and about 40% with the livestock sector (**Figure 1**).

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.

Figure 1. Agricultural GHG Emissions, Average 2000-2004



Source: EPA, 2006 *Inventory* report, April 2006 [http://epa.gov/climatechange/emissions/usinventoryreport.html].

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.[18] 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.[19]

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[18] 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].

[19] USDA, "Conservation Tillage Firmly Planted in U.S. Agriculture," *Agricultural Outlook*, March 2001; USDA, "To Plow or Not to Plow? Balancing Slug Populations With

(continued...)

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[20] 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.[21] Many manure management systems also control flies, produce energy, increase the fertilizer value of any remaining biosolids, and destroy pathogens and weed seeds.[22]

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, 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.[23] 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.[24] Energy requirements to keep a digester heated are likely be lower in warmer climates.

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[19] (...continued)
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].

[20] 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.

[21] 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.

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

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

[24] 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.

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.[25] 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 fewer than 100 digester systems in operation at commercial U.S. dairy and hog farms, affecting well under 1% of all operations nationwide.[26]

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.[27] Purchasing feed supplements and more intensely managing animal nutrition and feeding practices may add additional costs and management requirements at the farm level.

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 2**).[28] 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. Conservation practices that raise biomass retention in soils and/or reduce soil disturbance, such as conservation tillage, also promote sequestration.

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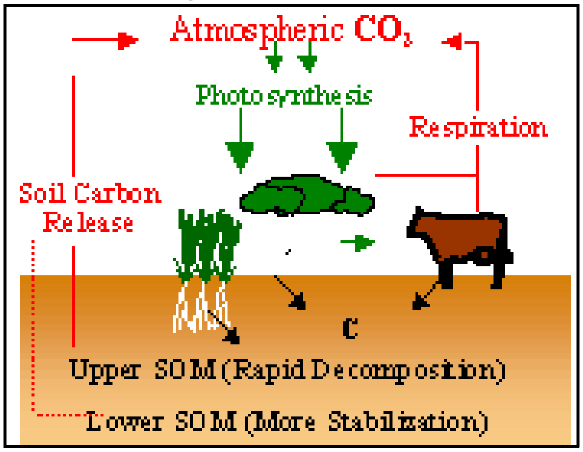
[25] Mostly Section 9006 and Section 6013 of the farm bill (P.L. 107-171), but also under other farm bill cost-share programs. CRS communication with USDA staff.

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

[27] 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].

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

Figure 2. 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 2004, carbon sequestration by agricultural soils was estimated at 12.4 MMTCE. Compared to estimates for the most recent five-year average, estimates for 2004 show possible gains in carbon uptake and storage in recent years. Compared to 1990 and 1995, however, estimated carbon sequestration in agricultural soils is lower (**Table 1**).

Estimated Emission Offsets. Carbon sequestration in the U.S. agricultural sector currently offsets about one-tenth of the carbon-equivalent of reported GHG emissions generated by the agriculture sector each year. Thus the sector remains a net source of GHG emissions. Compared to total national GHG emissions from all sources, carbon sequestration by the agriculture sector offsets less than 1% of total U.S. 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 agricultural sector. Forests and trees account for a majority (94%) of all estimated carbon uptake in the United States, mostly through forest restoration and tree-planting.[29] Carbon uptake in soils on U.S. agricultural lands accounts for 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

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[29] Estimated from net forest growth, increased forest area, accumulated forest carbon stocks, growth in urban trees, and also landfilled yard trimmings (EPA's 2006 *Inventory*, Table ES-5). See also CRS Report RL31432, *Carbon Sequestration in Forests*, by Ross Gorte.

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 potential of practices that might already be in place.[30] 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 nearly double from current levels by 2012, adding roughly an additional 11 MMTCE of sequestered carbon attributable to the sector.[31] 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%).

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[30] 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.

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

Other longer term estimates from USDA report the potential for net increases in carbon sequestration ranging from 10 to 160 MMTCE per year in the United States, or roughly 2-14 times current levels.[32] Comparable estimates reported by EPA forecast a higher sequestration potential for the U.S. agriculture sector, ranging from 40 to 270 MMTCE per year.[33] EPA also reports additional sequestration potential from livestock manure management, biofuels substitution, and other farm management practices. USDA reports that other studies have forecast an even greater potential to sequester carbon in the United States, ranging from about 90 to 320 MMTCE annually. Various estimates will differ depending on the extent that estimates may include sequestration activities for the forestry sector.

Under USDA's forecast, an additional carbon uptake of 160 MMTCE per year would more than offset the agriculture sectors' annual GHG emissions, or offset 8% of total national emissions from all sources. Currently, carbon uptake in agriculture soils sequesters under 1% of total national GHG emissions annually (**Table 1**).[34]

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 forecast of an additional sequestration potential of 10-160 MMTCE is associated with an estimated annual value ranging from $10/mt to $125/mt of carbon permanently sequestered.[35] 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, ranging from 40 to 270 MMTCE per year, is estimated across a range of about $20/mt-$110/mt of sequestered carbon per year.[36]

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

[33] EPA, "Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture," Tables 4-10 and 4-5, November 2005, at [http://www.epa.gov/sequestration/greenhouse_gas.html]. Annualized over 15-years. Converted from EPA-reported CO_2 equivalent.

[34] Currently, about 11% of total GHG emissions are sequestered annually through the U.S. agriculture and forestry sectors, with the bulk sequestered through growth in forest stocks.

[35] USDA, *Economics of Sequestering Carbon in the U.S. Agricultural Sector*, April 2004; measured by the amount of carbon that could be measured over a 15-year time period across a range of costs. The associated total cost to sequester carbon across this range is estimated from $0.95 billion to $2 billion per year.

[36] EPA, "Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture," Table 4-10, November 2005, at [http://www.epa.gov/sequestration/greenhouse_gas.html]. Converted

(continued...)

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.

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 2** shows estimated representative carbon sequestration rates for agricultural practices.

Improved Soil and Land Management. The main carbon sinks in the agriculture sector are cropland conversion and soil management, including improved manure application.[37] 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. Land retirement and grassland conversion stores between 0.3 and 0.5 metric tons (mt) of carbon per acre annually.[38] Compared with other types of systems, this is about twice the amount of carbon stored through tree plantings and wetlands conversion, and about four times that stored on croplands.[39]

Table 2. Representative Carbon Sequestration Rates

(mt C/acre per year)

Reduced tillage (e.g., no-till, reduced-till)	0.2 - 0.3
Change in grassland management	0.02 - 0.5
Cropland conversion (grassland)	0.3 - 0.5
Riparian buffers	0.1 - 0.3
Biofuel substitution	1.3 - 1.5

Source: EPA, "Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture," Table 2-1. Converted from reported CO_2 equivalent units.

Conservation tillage is another major source of sequestration on farmlands, accounting for about 40% of the carbon sequestered by the U.S. agricultural sector.[40]

[36] (...continued)
from a reported range of $5-$30 per CO_2 equivalent.

[37] 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].

[38] EPA, "Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture," Table 2-1, November 2005, at [http://www.epa.gov/sequestration/greenhouse_gas.html]. Converted from reported CO_2 equivalent units.

[39] 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.

[40] USDA, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001*, TB1907,
(continued...)

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 0.2-0.3 mt of carbon per acre annually.[41] Among conservation tillage practices, no-till 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.[42] 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

At the federal and state levels, existing conservation programs encourage the types of agricultural practices that can reduce GHG emissions and/or sequester carbon. Few federal programs specifically address climate change concerns in the agriculture sector; however, several states have begun to adopt programs and requirements intended to address such concerns.

Conservation Programs

Agricultural conservation 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;

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[40] (...continued)
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.

[41] EPA, "Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture," Table 2-1, November 2005, at [http://www.epa.gov/sequestration/greenhouse_gas.html]. Converted from reported CO_2 equivalent units.

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

- efficient fertilizer/nutrient (including manure) and chemical application;
- crop rotations;
- cover cropping;
- 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. USDA's conservation and land management programs are geared to taking land out of production and to improving land management practices on land in production, commonly referred to as "working lands." Most of these programs are in Title II (Conservation) of the 2002 farm bill[43] (**Table 3**).

- **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

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[43] For a list of the USDA programs, see USDA, "Farm Bill, Title II: Conservation," at [http://www.ers.usda.gov/Features/Farmbill/titles/titleII conservation.htm].

Grasslands Reserve Program (GRP), the Farmland Protection Program (FPP), among other programs.

- **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).

In addition, there are forestry programs administered by USDA's Forest Service. 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.[44] USDA's agriculture conservation programs also include its Healthy Forests Reserve Program, which has 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.[45] In addition to cost-sharing programs provided under Title II programs, two other important renewable energy programs under the 2002 farm bill are under Title IX (Section 9006) and Title VI (Section 6013). Section 9006 authorized loans, loan guarantees, and grants to farmers, ranchers, and rural small businesses to purchase renewable energy systems and make energy efficiency improvements. Section 6013 authorized the business and industry program to make loans and loan guarantees for renewable energy systems, including wind energy systems and anaerobic digesters. Section 9006 and Section 6013 under the 2002 farm bill, as well as other cost-share programs, account for the majority of federal program spending to support construction of anaerobic digesters in the livestock sector.[46] Limited information indicates that USDA funded eight projects totaling more than $60 million under Section 6013[47] and provided another $20 million in funding assistance under Section 6009[48] for anaerobic digesters (FY2002-FY2005).

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

[45] See CRS Report RL32712, *Agriculture-Based Renewable Energy Production*, by Randy Schnepf; and CRS Report RL33572, *Biofuels Incentives: A Summary of Federal Programs*, by Brent Yacobucci.

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

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

[48] USDA, "USDA Funding Assistance for Rural Renewable Energy and Energy Efficiency:
(continued...)

Table 3. 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.

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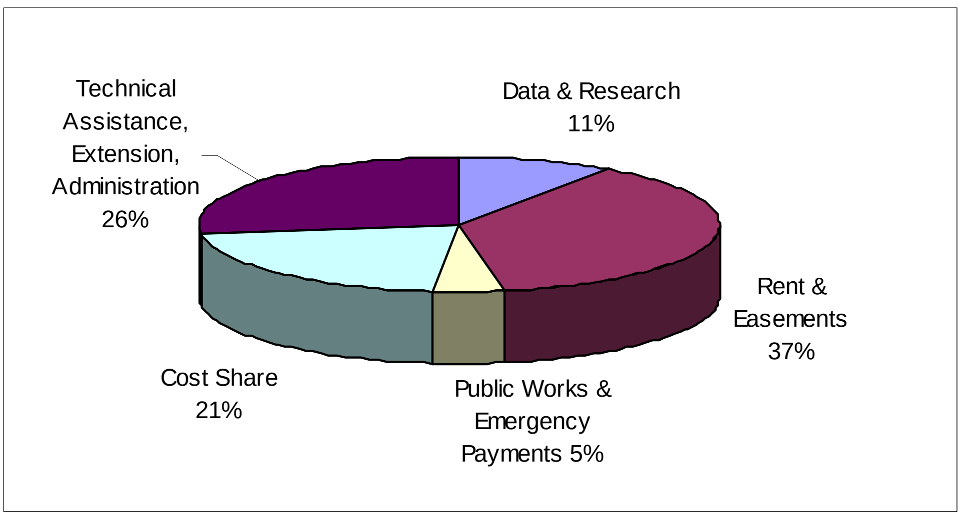
[48] (...continued)
Section 9006 of the 2002 Farm Bill," at [http://power.wisconsin.gov/pdf/USDA Presentation.pdf].

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 3**). Programs that provide cost-sharing and technical assistance to farmers to implement certain practices, such as EQIP, CSP, and AMA, provide another 21% annually.[49] 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.

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 agricultural agencies and extension staff. No single current compendium exists outlining the different types of agricultural conservation programs across all states; instead information is available through individual state government websites.[50]

Figure 3. USDA Conservation Spending, FY2005



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

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 may provide technical assistance and up to 75% of the

[49] 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.

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

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 within a state, such as Nebraska, Missouri, and Oregon, will tend to have more stable funding and staffing to support conservation improvements.

Climate Change Programs

Federal Programs. Currently, few USDA programs or conservation practices 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, which is intended to accelerate technology transfer and adoption of innovative conservation technologies, mostly through pilot projects and field trials. Past grants have supported development of approaches to reduce ammonia emissions from poultry litter, promote conservation tillage, promote solar energy technologies, and develop private carbon sequestration trading credits.[51]

USDA is evaluating how to better incorporate climate concerns into its conservation programs.[52] One option might include modifying its evaluation criteria for ranking applications to its conservation programs by giving additional consideration to projects that propose to reduce GHG emissions or sequester carbon. Other options might include supporting market-based approaches, such as the development of environmental services markets and trading, that might supplement existing conservation and forestry programs.[53] USDA also 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.[54] USDA also participates in the multi-agency Climate Change

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[51] 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]

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

[53] 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 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.

[54] 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 Expenditures*, by Jane Leggett.

Science Program, integrating federal research on climate and global change across 13 federal agencies, including USDA.[55]

State Programs. The Pew Center on Global Climate Change reports that many ongoing state programs and demonstration projects are intended to promote carbon storage and emissions reduction in the U.S. agriculture sector.[56] 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 in the agriculture sector.[57]

Also in California, numerous efforts connected to the state's climate change initiatives involve the agriculture sector. For example, California has a manure digester cost-share program to expand the use of dairy digesters as part of its broader climate change initiative. Other agriculture projects include 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.[58] Many of California's programs provide support to comply with the state's recently enacted emission reductions legislation.[59]

Other Programs and Incentives. Carbon offset or carbon credit trading programs involving U.S. farmers and landowners have also been initiated and are currently operating on a pilot basis in several states. Such market-based approaches are intended to reward early adopters and help offset farm costs to install emissions controls and/or practices that sequester carbon by providing a means for them to earn

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[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 Expenditures*, by Jane Leggett.

[56] Pew Center on Global Climate Change, *State Activities*, [http://www.pewclimate.org/docUploads/state_activities.pdf]; and *Learning from State Action on Climate Change*, [http://www.pew climate.org/docUploads/PewStatesBrief Feb2006%2Epdf].

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

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

[59] 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 sell carbon credits.[60] 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),[61] whose carbon credits may be sold on the Chicago Climate Exchange.[62] Similar types of programs have also 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 Development Council).[63] These programs generally cover some or all aspects of the following types of carbon capture and storage activities: sustainable agriculture practices (including conservation tillage and grass seedlings); planting of unharvested grasslands or tree-plantings; methane capture and biogas production with manure digesters; wind, solar, or other renewable energy use; controlled grasslands or pasture management; and also forest restoration.

Considerations for Congress

In the 109th Congress, more than 100 bills, resolutions, and amendments were introduced addressing climate change.[64] Legislative initiatives involving the agriculture sector have been geared to increasing carbon sequestration on agricultural lands, with most attention given to forestry activities and restoration, where the potential to increase uptake and store carbon for long time periods is much greater. Historically, climate-related legislative initiatives have not specifically focused on emissions reductions in the agriculture sector. Instead, GHG emissions reductions and carbon uptake are an incidental benefit of existing voluntary agricultural conservation programs that provide financial and technical assistance to implement certain farm management practices, predominately for other production or environmental purposes.

The 2007 farm bill debate could expand the scope of ongoing climate change initiatives to more broadly encompass the agriculture sector, promoting conservation

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[60] In the case of agriculture, refers to verifiable emissions credits that are earned by crop or livestock operations for capturing and storing carbon either by reducing GHG emissions or sequestering carbon. For trading purposes, one carbon credit is considered equivalent to one metric ton of carbon dioxide emission reduced.

[61] 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.

[62] 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/].

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

[64] CRS Report RL32955, *Climate Change Legislation in the 109th Congress*; Pew Center on Global Climate Change, *Legislation in the 109th Congress related to Global Climate Change*, [http://www.pewclimate.org/what_s_being_done/in_the_congress/109th.cfm].

and land management practices that could further address climate change issues in the sector. Other types of policy options to further encourage crop and livestock producers to adopt the types of conservation practices that may also reduce GHG emissions and sequester carbon include:

- expanding existing cost-sharing and technical assistance programs, such as EQIP, CSP, and AMA, and other financial programs under current farm legislation;
- expanding existing land retirement, conversion and restoration programs, such as CRP, WRP, and GRP;
- modifying existing cost-sharing and land retirement programs to give additional consideration to projects that propose to reduce GHG emissions or sequester carbon;
- expanding existing research programs and demonstration projects, such as funding under USDA's Conservation Innovation Grants program; and
- expanding access to low-cost loans, loan guarantees, grants, incentive payments, and income tax credits to farmers, ranchers, and rural small businesses, such as Section 9006 and Section 6013 under the current farm bill legislation.

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.

- **2007 Farm Bill Debate.** 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 agricultural 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 agricultural 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 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 agricultural 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 agricultural 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 2004, GHG emissions from U.S. agricultural activities totaled 120 MMTCE (million metric tons of carbon equivalent units), accounting for 6% of the annual national GHG emissions (**Table 1**). Fossil fuel combustion is the leading source of national GHG emissions (80%), with the energy sector generating about 86% of annual emissions across all U.S. sectors.
How much carbon is sequestered in U.S. agricultural soils?	In 2004, agricultural soils sequestered about 12.4 MMTCE of carbon, or one-tenth of the carbon-equivalent of reported annual emissions generated from agriculture. Compared to total national GHG emissions, the agriculture sector offsets less than 1% of emissions annually. These estimates do not include uptake from forested lands or open areas that account for a majority (94%) 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. agricultural soils is much greater than current rates, with estimated net increases in carbon sequestration ranging from 10-160 MMTCE per year, or even higher. This could offset total national GHG emissions by as much as 2-15% or higher, which is substantially greater than the current estimate that farmland soils offset about 1% of annual national GHG emissions. Practices that may reduce emissions and/or sequester carbon on U.S. farmlands include land retirement, conversion, and restoration; improved soil management and conservation tillage on U.S. croplands; and improved manure management and feeding strategies at U.S. 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 10-160 MMTCE is associated with an estimated per-unit value ranging from $10-$125/mt of carbon per year. EPA's reported potential of 40-270 MMTCE per year is forecast across a range of about $20-$110/mt of carbon sequestered per year. The low-end of this range reflect the sequestration potential associated with cropland management practices; higher-end values are associated with land retirement and afforestation. 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 agricultural 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 2** for more information. See **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.