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Greenhouse Gas Emissions and Sinks in U.S. Agriculture

Agricultural and land use activities have played a central role in the broader debate regarding energy and climate policy options in the United States and abroad. Most U.S. climate-related proposals would not require emission reductions in the agricultural sectors but rather would incentivize reductions through voluntary measures. For example, previous energy and climate legislation considered by Congress would have established a carbon offset program for domestic farm- and land-based carbon storage activities and provided for tradeable allowances from certain agricultural and land use activities.

> Agriculture is both a source and a sink of greenhouse gases: *sources* generate emissions to the atmosphere and *sinks* remove carbon dioxide from the atmosphere and sequester it in plants and soil.

Agricultural activities are a source of greenhouse gas (GHG) emissions, but some activities can remove carbon dioxide (CO_2) from the atmosphere (sinks or emissions removals). **Figure 1** illustrates both GHG emissions from farming activities and carbon sequestration in agricultural soils. Agricultural sources generate GHG emissions that accumulate in the atmosphere and may contribute to global climate change. These sources account for many of the primary GHGs of interest to policymakers, including CO_2, methane (CH_4), and nitrous oxide (N_2O) (**Figure 1**). At the same time, some agricultural activities can remove CO_2 from the atmosphere (sink) through photosynthesis and storing (or sequestering) the carbon in vegetation and soils, either temporarily or more long term. Carbon sequestration—or the process of capturing and storing carbon—in farmland soils partially offsets agricultural emissions. Despite this offset potential, U.S. agriculture remains a net source of GHG emissions.

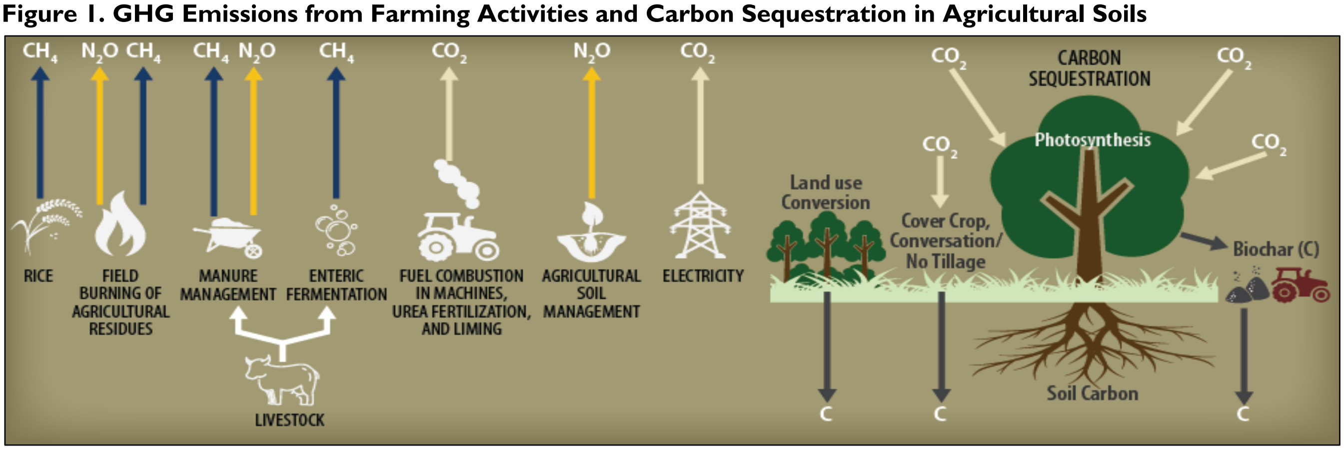
Official estimates of GHG emissions and sinks, as reported by the U.S. Environmental Protection Agency (EPA), have tracked emissions and sinks by source and economic sector since 1990. These estimates are reported annually in *EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks* (available at https://www.epa.gov/ghgemissions). For the U.S. agricultural sector, *EPA's Inventory* estimates are compiled, in part, using information from other federal agencies, including the U.S. Department of Agriculture (USDA). These data are expressed in terms of *CO_2-equivalents* and aggregated to millions of metric tons (MMTCO_2-Eq.). CO_2-equivalents equate an amount of a GHG to the amount of CO_2 that could have a similar impact on global temperature over a specific time period (typically 25 or 100 years). This aggregation helps illustrate agriculture's contribution to national GHG emissions and contrast emissions against estimates of sequestered carbon.

Agricultural GHG Emissions

EPA reports that GHG emissions from the U.S. agricultural sectors totaled 651 MMTCO_2-Eq. in 2016 (**Table 1**). These estimates are based on certain assumptions and cover both direct emissions and indirect emissions related to electricity use (see **text box** below). These estimates do not include emissions associated with food processing or distribution, which are typically aggregated with other transportation and industrial emissions. These estimates also do not include other types of emissions associated with some agricultural activities, such as carbon monoxide, nitrogen oxides, and volatile organic compounds. They also do not account for potential sequestered carbon by agricultural or land use activities.

Agriculture accounted for 10% of total U.S. GHG emissions in 2016, a smaller proportion of the total than other end-use sectors—transportation, industry, commercial and residential (**Figure 2**). Compared to 1990, when EPA estimates of GHG emissions associated with the U.S. agricultural sectors totaled 557 MMTCO_2-Eq., emissions from agricultural activities have been increasing (**Table 1**).

Figure 1. GHG Emissions from Farming Activities and Carbon Sequestration in Agricultural Soils



Source: CRS.

GHG Emissions from Agricultural Activities

Direct Emissions

- **Soil management.** N_2O emissions from farmland soils are associated with cropping practices that disturb soils and increase oxidation, which can release emissions into the atmosphere. These practices include fertilization, irrigation, drainage, cultivation and tillage, shifts in land use, application and/or deposition of livestock manure and other organic materials on cropland and other farmland, and other types of practices.
- **Enteric fermentation.** CH_4 emissions from livestock operations occur as part of the normal digestive process in ruminant animals and are produced by rumen fermentation in metabolism and digestion. Emissions are associated with the nutritional content and efficiency of feed utilization by the animal.
- **Manure management.** CH_4 and N_2O emissions are associated with livestock or poultry manure that is stored and treated in systems that promote anaerobic decomposition, such as lagoons, ponds, tanks, or pits.
- **Other production methods.** CH_4 and N_2O emissions are also associated with rice cultivation, urea fertilization, liming, and biomass burning, as well as CO_2 emissions from fossil fuel combustion by motorized farm equipment, such as tractors.

Electricity-Related Emissions. Mostly CO_2 emissions are associated with on-farm electricity use (e.g., other farm machinery and buildings). Estimated emissions do not include energy emissions from value-added food processing or fuel combustion from food distribution/transportation.

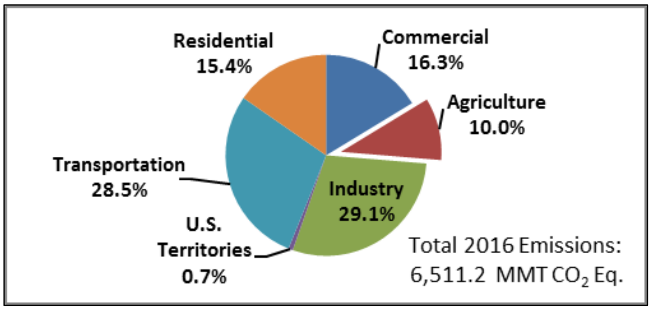
In 2016, the majority of U.S. emissions from agricultural sources were attributable to soil management (52%), enteric fermentation (30%), and manure management (15%), with the remaining emissions associated with other production methods. The **text box** describes both direct and indirect GHG emissions associated with U.S. agricultural activities.

Agricultural Carbon Sequestration

On agricultural lands, carbon can enter the soil through roots, litter, cover crops, harvest residues, and animal manure and may be stored primarily as soil organic matter (**Figure 1**). *EPA's Inventory* expresses such estimates as *Land Use, Land Use Change, and Forestry* (LULUCF). LULUCF estimates measure additional removals from a range of land use and land management activities, including forestry and land use conversion—for example, from less-resource conserving to forestland, grassland, wetlands, and croplands. These estimates measure both removals and any offsetting changes in emissions—for example, higher emissions from the conversion of forested lands to less resource-conserving uses—thus reflecting net changes in carbon stocks. EPA's LULUCF estimates rely on data from USDA and the Departments of Energy, Transportation, and Defense, among other federal agencies.

EPA's LULUCF estimate for 2016 indicates that U.S. forestry and land use changes contributed to a net carbon reduction of 730 MMTCO_2-Eq. in 2016 (**Table 1**). About 98% of all estimated uptake is associated with maintaining and conserving forests, wetlands, and grasslands, as well as converting land to more resource conserving uses. Land improvements through practices such as reforestation, forest management, and tree-planting activities would also contribute to carbon uptake on forested and also crop land.

Figure 2. U.S. GHG Emissions, by End-Use Sector



Source: CRS from EPA's Inventory (Table 2-12). 2016 data.

Table 1. Emissions and Net Total Sequestration

Source	1990	2016	Avg. 2012-16
	(MMTCO_2-Eq)		
GHG Emissions			
U.S. total, all sources	6,355.6	6,511.3	6,630.1
Agricultural activities	556.9	650.7	638.6
Direct emissions	522.0	611.8	596.9
Electricity-related	34.8	38.9	41.8
% agriculture, total	8.8%	10.0%	9.6%
Carbon Uptake			
U.S. net total, LULUCF	(819.6)	(716.8)	(728.3)
Cropland remaining cropland	(40.9)	(9.9)	(12.2)
% Cropland, net total	5.0%	1.4%	1.7%

Source: CRS from *EPA's Inventory* (Tables 2-12, 5-1, and 6-4). May not add due to rounding.

Carbon uptake from agricultural lands accounts for a small share of net LULUCF estimates. Among EPA's estimate categories, removals associated with "cropland remaining cropland" accounts for less than 2% of net removals and has been decreasing since 1990 (**Table 1**). This estimate does not reflect possible offsetting higher emissions from the conversion of farmland to other uses.

Practices That Offset GHG Emissions

Farming practices that either sequester carbon or destroy GHG emissions could play a role in future legislation involving establishing a carbon offset or carbon banking program. In general, converting industrial land to agricultural use, or keeping agricultural land in farming, will sequester carbon in soil compared to other types of industrial, commercial, or residential uses. Other types of practices that could improve carbon capture and storage in agricultural soils include land retirement or restoration and farmland conversion to more resource-conserving uses. Carbon uptake may also be increased through practices that raise biomass retention in soils or reduce soil disturbance, such as conservation tillage practices. Installing windbreaks and buffers also promote sequestration.

Among the types of farming practices that reduce GHG emissions are improved soil management and improved feed and manure management. Manure management systems that collect manure in an uncovered lagoon release CH_4 into the atmosphere. Installing an anaerobic digester to manage manure destroys CH_4 emissions and is usually part of most voluntary carbon offset programs.

Renée Johnson, Specialist in Agricultural Policy

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