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Greenhouse Gas Emissions and Sinks in U.S. Agriculture

Agriculture and land-use activities continue to play a central role in the broader debate about energy and climate policy options in the United States and abroad. Such activities offer opportunities to remove greenhouse gases (GHGs) from the atmosphere, potentially reducing the nation's *net emissions*: the metric of emissions targets for the Paris Agreement (PA), the binding international climate change treaty. Pursuant to the PA, the Biden Administration released a Nationally Determined Contribution (NDC) in 2021 specifying a new U.S. target of reducing net GHG emissions by 50%-52% below 2005 levels by 2030. Most federal legislative proposals to reduce U.S. GHG emissions would not require reductions in agriculture, but some would incentivize voluntary actions to do so. For example, the Growing Climate Solutions Act (S. 1251/H.R. 2820, 117th) would support the creation and use of agriculture and forestry offset credits in carbon markets by establishing qualifications for technical assistance providers and third-party verifiers and by developing a list of U.S. Department of Agriculture (USDA)-backed offset protocols.

Agriculture is both a *source* and a *sink* of GHGs (**Figure 1**). Sources generate GHG emissions that are released into the atmosphere and contribute to global climate change. Sinks remove carbon dioxide (CO_2) from the atmosphere and store carbon through physical or biological processes. Agricultural emissions include many GHGs of interest to policymakers: CO_2, methane (CH_4), and nitrous oxide (N_2O). Agricultural sinks remove CO_2 through photosynthesis and store carbon in plants and soil. Despite these sinks, U.S. agriculture is a net GHG source. This In Focus discusses emissions from the agriculture sector, as defined by the Environmental Protection Agency (EPA), and the most recent data available (from 2019).

U.S. GHG Inventory

Since the 1990s, EPA has prepared an annual *Inventory of U.S. GHG Emissions and Sinks*. USDA and other federal agencies contribute data and analyses. The *Inventory* reports GHG estimates by sector, source, and GHG type. The *Inventory* presents GHG estimates as CO_2-equivalents, aggregated to millions of metric tons (MMTCO_2-Eq.). CO_2-equivalents convert an amount of a GHG, such as N_2O, to the amount of CO_2 that could have a similar impact on global temperature over a specific duration (100 years in the *Inventory*). This common measurement can help compare the magnitudes of various GHG sources and sinks.

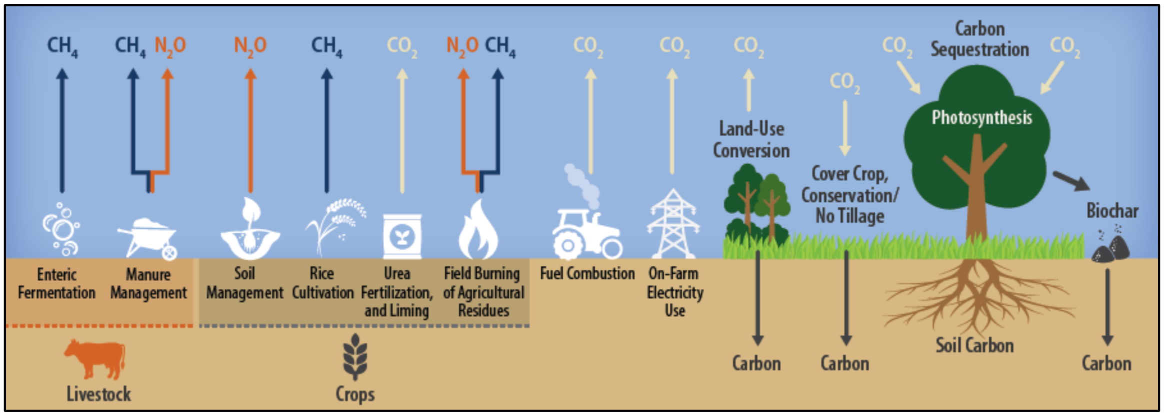
The *Inventory* presents GHG estimates for two types of sector classifications. One classification follows international standards. Every country preparing its national inventory considers the same GHG sources and sinks for the same standard sectors. These include an agriculture sector and a *land-use, land-use change and forestry* (LULUCF) sector. The *Inventory* also reports estimates for several EPA-defined economic sectors, including agriculture, transportation, electricity, industry, commercial, and residential. Under this format, the agriculture sector includes emissions from fuel-combustion by farm equipment (e.g., tractors) as well as the emission sources already accounted for in the international standard sector for agriculture.

Agricultural GHG Emissions

EPA reports that agriculture sector emissions totaled 669.5 MMTCO_2-Eq. in 2019 (**Table 1**), equal to 10.2% of total U.S. GHG emissions (**Figure 2**). This estimate is based on certain assumptions and includes direct emissions from agricultural activities (see text below for major emissions sources in agriculture). It does not include

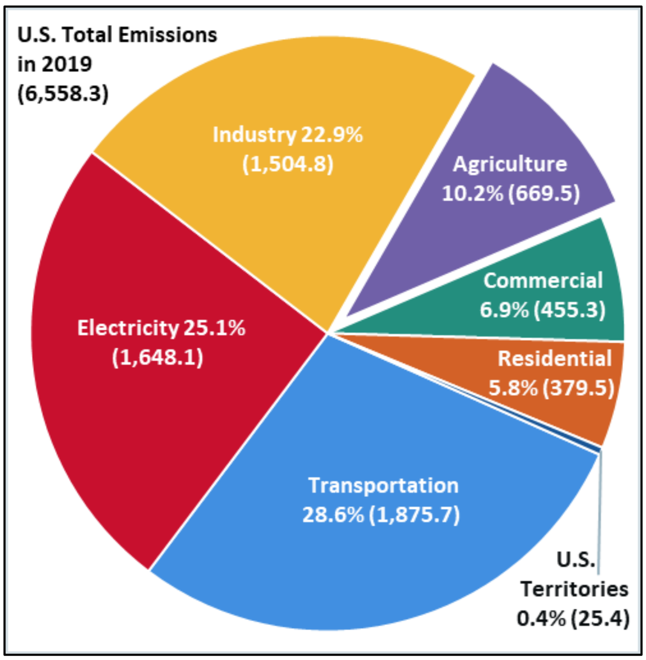
- Potentially offsetting agricultural sinks.
- Forestry activities, which are accounted for in LULUCF.
- Emissions from generating the electricity that farms use.
- Emissions from activities in the food system more broadly, such as production of agricultural inputs and post-harvest transportation and processing of foods.

Figure 1. Greenhouse Gas Emission Sources and Sinks from Agricultural Activities



Source: CRS. **Note:** *Enteric fermentation* refers to digestive processes in ruminant animals, which result in GHG emissions.

Figure 2. U.S. GHG Emissions, by Economic Sector



Source: CRS from *EPA Inventory*, 2019 data.

Notes: Emissions are presented in parentheses in $MMTCO_2$-Eq.

In 2019, three activity types accounted for 90.4% of U.S. agriculture sector emissions:

1. **Soil management (51.5%, 344.6 $MMTCO_2$-Eq.)**. N_2O emissions from soils, associated with agricultural practices that disturb soils and increase oxidation, releasing emissions into the atmosphere. Associated with fertilization, irrigation, drainage, cultivation and tillage, shifts in land use, and application and/or deposition of livestock manure and other organic materials on cropland and other farmland soils.
2. **Enteric fermentation (26.7%, 178.6 $MMTCO_2$-Eq.)**. CH_4 emissions from livestock occurring as part of normal digestive process in ruminant animals during metabolism and digestion. Associated with feed nutrient content and efficiency of feed use by the animal.
3. **Manure management (12.2%, 82.0 $MMTCO_2$-Eq.)**. CH_4 and N_2O emissions associated with livestock and poultry manure occurring from manure/waste that is stored and treated in systems that promote anaerobic decomposition (e.g., lagoons, ponds, tanks, pits).

U.S. agriculture sector emissions were higher in 2019 compared with 1990, 2000, and 2010 (**Table 1**).

Table 1. U.S. Agriculture and Related Source Emissions

Emissions by Gas (Activity)	1990	2000	2010	2019
Total, Ag. Econ. Sector	**600.2**	**598.1**	**644.5**	**669.5**
N_2O (soil and manure mgmt.)	330.1	311.0	341.7	364.4
CH_4 (enteric ferment., manure mgmt., rice cultivation)	218.2	238.3	246.1	256.4
CO_2 (urea fertilization, liming)	7.1	7.5	8.6	7.8
CO_2, CH_4, and N_2O (fuel use)	44.8	41.2	48.2	40.8
Total Ag. w/Electricity-Related	**635.2**	**640.0**	**685.1**	**704.6**
CO_2, N_2O, SF_6 (electric.-rel.)	35.1	41.9	40.6	35.2
Tot. Emissions, All Sectors	**6,442.7**	**7,313.6**	**6,991.1**	**6,558.3**

Source: CRS from *EPA Inventory* (emissions in $MMTCO_2$-Eq.).

Agricultural GHG Sinks

On agricultural lands, carbon can enter the soil through plant roots, litter, cover crops, harvest residues, and animal manure. This carbon can be stored, primarily as soil organic matter (**Figure 1**). Other carbon sinks derive from a range of land-use and land-management activities, such as maintaining forested land, which primarily stores carbon in above-ground biomass (e.g., trees). The *Inventory* accounts for U.S. GHG sinks in the LULUCF sector. LULUCF net sinks account for both emissions and sinks from land use and land-use change. Federal agencies—including USDA and the Departments of Energy, Transportation, and Defense—contribute LULUCF data to the *Inventory*.

EPA reports a LULUCF net sink of 789.2 $MMTCO_2$-Eq. for 2019. The magnitude of this net sink is equivalent to about 12% of all U.S. GHG emissions. Most LULUCF sinks are associated with maintaining existing forested land and converting land from other land uses to forested land.

Agricultural lands account for a limited share of U.S. carbon sequestration. In 2019, "cropland remaining cropland" (14.5 $MMTCO_2$-Eq.) accounted for about 1.8% of LULUCF net sinks, decreased from 2.1% in 2018.

Practices That Reduce GHG Emissions

Farming practices that sequester carbon or reduce GHG emissions could play a role in legislative proposals seeking to reduce U.S. GHG emissions. One approach could involve establishing a *carbon offset* or *carbon banking* program. Other options include regulations or tax incentives. In general, converting industrial land to agricultural use, or keeping land in agriculture, would sequester more carbon in the soil than would other types of industrial, commercial, or residential land uses. For existing agricultural land, practices to increase carbon sequestration may include retiring or restoring land, converting it to forested land, using conservation tillage and other practices that increase biomass retention in soils or reduce soil disturbance, and installing vegetative windbreaks. Maintaining these actions indefinitely is a challenge; stored carbon may be released if practices change.

Practices in animal agriculture to reduce GHG emissions include improved feed efficiency and manure management. Some livestock feed can reduce CH_4 emissions from enteric fermentation and increase productivity. Manure management systems can reduce the CH_4 that is released into the atmosphere when manure is collected in uncovered lagoons and can use the captured CH_4 as an energy source. Anaerobic digesters installed to manage manure and capture and use the CH_4 emissions are often part of non-federal voluntary and compliance carbon offset programs.

Scientific research continues to investigate agricultural practices that may increase sinks and reduce emissions. Voluntary and state programs have applied and documented potential GHG emission reductions. Current research topics related to sinks include improving estimates of (1) carbon storage in soils and (2) the effects of different management practices on carbon sequestration. Topics related to reducing sources include improving manure management technology and livestock genetics and feed efficiency.

Genevieve K. Croft, Analyst in Agricultural Policy

IF11404

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