Extension
University of Missouri

Agriculture and Greenhouse Gas Emissions

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The Fourth National Climate Assessment report, released in 2018, uses the highest estimates of greenhouse gas emissions (called RCP 8.5) of the Intergovernmental Panel on Climate Change to forecast substantial economic losses in the U.S. The section on agriculture warns that food and forage production will decline, soil and water resources will degrade, and human and livestock health will be challenged. While the potential to adapt to climate change exists within many parts of the agriculture sector, the report predicts large economic burdens come along with these adaptations.

The section on Midwest U.S. agriculture states "increased rainfall from April to June has been the most impactful climate trend for agriculture." The report warns the five-day maximum temperatures could move further above optimum conditions and closer to reproductive failure temperatures. Danger of reduced environmental quality from land use decisions increases if the climate change estimates they rely on materialize.

Farmers face two pressures from climate change. First, productivity and profitability may decrease. The variability of yields from extreme weather is more difficult to manage. Second, many think agriculture, particularly animal agriculture, is a significant contributor to climate change. Farmers are under pressure to reduce their emissions of greenhouse gases (GHG). A Food and Agriculture Organization of the United Nations report estimates worldwide GHG emissions from agriculture have been increasing, but acknowledge most of the increase occurred in developing countries.

This guide presents basic information on agriculture's role in GHG emissions. It draws heavily upon a report issued in 2018 by the EPA entitled *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2016*.

Greenhouse gases

Greenhouse gases are gases in the atmosphere which capture solar radiation and warm the surface of the earth. Without GHG, the temperature of the earth would be about minus 2 degrees F rather than its current temperature of about 59 degrees F. The concern among many scientists is that the concentration of GHG has increased significantly since the beginning of the industrial revolution in the 1800s. Scientists hypothesize these increased concentrations of GHG can warm the surface of the earth and cause changes in climatic conditions.

Naturally occurring GHGs, in order of relative abundance, include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. GHGs which are not naturally occurring are substances containing fluorine, chlorine, and bromine.

Global warming potential

- Carbon dioxide: 1
- Methane: 25
- Nitrous oxide: 298

This guide focuses on the GHG concentrations affected by agricultural activity: carbon dioxide, methane, and nitrous oxide. Carbon dioxide is the most well-known GHG because it is the most prevalent, making up more than 80 percent of greenhouse gas emissions related to human activity. Carbon dioxide is associated with burning fossil fuels. However, methane and nitrous oxide actually capture more heat in the atmosphere than carbon dioxide. In order to compare the impact of each gas on global warming, scientists have developed the global warming potential (GWP) concept which uses carbon dioxide as the reference with a value of 1. Methane and nitrous oxide have values of 25 and 298, respectively. This means, pound for pound, methane contributes 25 times the impact of carbon dioxide to global warming. Similarly, a given amount of nitrous oxide in the atmosphere exerts 298 times the effect on global warming as the same amount of carbon dioxide. All GHGs are reported as carbon dioxide equivalents (abbreviated CO_2e).

Definitions

- **Gross domestic product**
  The total market value of all goods and services produced within a country in any one year.
- **Carbon sequestration**
  The capture and removal of carbon from the atmosphere.

In 2016, U.S. GHG emissions totaled 6,511 million metric tons (MMT) CO_2e.

Total annual 2016 U.S. GHG emissions were 2 percent higher than in 1990. During this same time period of 1990 to 2016, the U.S. population increased by 29 percent and the country's real gross domestic product increased by 87 percent (Figure 1). Changes in emissions frequently are associated with changes in population, economic growth, energy price, seasonal temperatures, and technology. The declining GHG emissions per capita and per dollar of gross domestic product indicate increased efficiency.

A portion of GHG emissions can be offset when carbon in the atmosphere is taken and stored, or sequestered, by plants and soil. In 2016, the EPA estimated carbon sequestration by forests, trees in urban areas, agricultural soils, and other sources offset 755 MMT CO_2e, or 12 percent of total emissions.

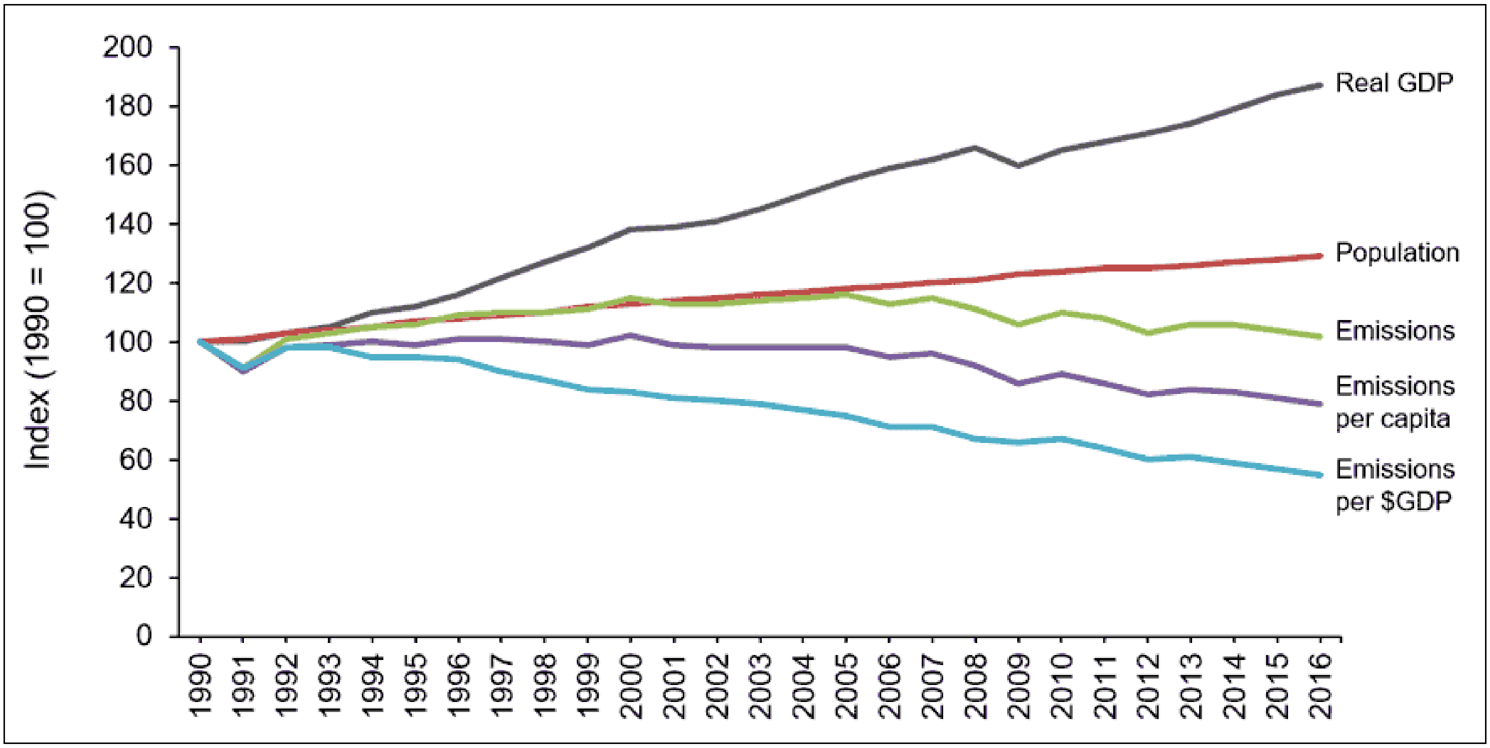
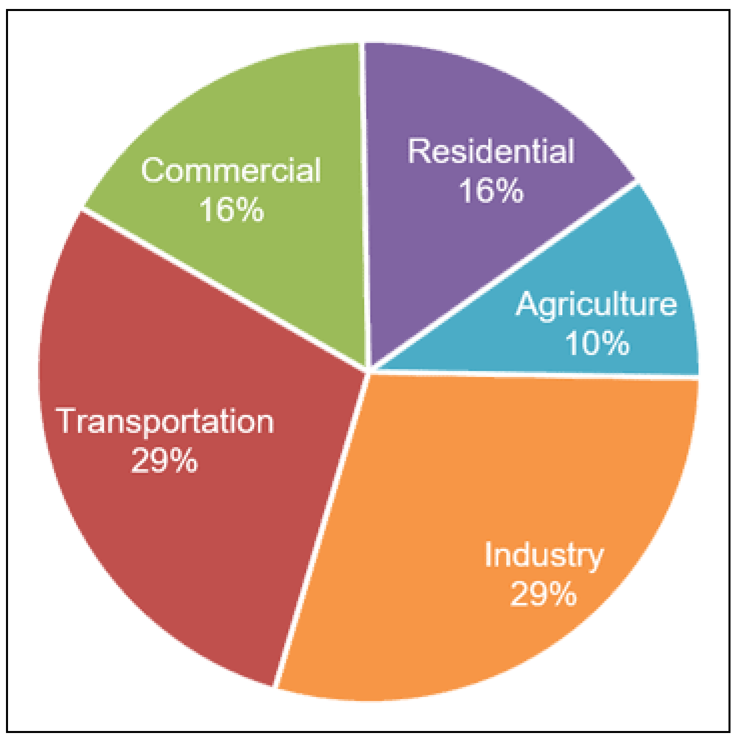


Figure 1. U.S. greenhouse gas emissions per capita and per dollar of gross domestic product, 1990–2016. Source: Bureau of Economic Analysis (2017), U.S. Census Bureau (2017) and emission estimates from U.S. Environmental Protection Agency report (2018).

Sources of greenhouse gases

The EPA distributes GHG emissions among five economic end-user sectors — industrial, transportation, residential, commercial, and agriculture. Agriculture is estimated to be responsible for 10 percent of the GHGs emitted in the United States in 2016 (Figure 2).

The EPA's estimate of all agricultural activities contributing 10 percent of human induced greenhouse gas emissions in the United States is considerably lower than the often quoted United Nations estimate of 18 percent attributable to livestock alone.



Two details of the U.N. report need to be understood in context. First, in 2010, one of the authors of this U.N. report admitted the often quoted comparison of meat to transportation sources of GHGs was flawed because it used different methods to estimate percentage of emissions from the two different sectors. Nevertheless, the comparison continues to be often quoted in the media.

Second, The UN report divides the impact between intensive livestock systems (common in the United States) and extensive systems (pastoral-type systems). The intensive systems produce the most food (meat, milk or eggs) with the least amount of GHG emissions. Extensive systems are responsible for two-thirds of the GHG emissions, due mainly to deforestation to obtain grazing land.

Figure 2. Greenhouse gas emissions by economic sector, 2016.

The largest contributors to GHG emissions in the U.N. report are deforestation (34 percent) and enteric fermentation, or ruminant digestion (25 percent). Both of these categories are predominately a problem in extensive systems where land is being converted from forests to grazing land and where poor quality feed increases enteric fermentation per unit of meat produced. The carbon footprint per unit of meat produced is decreasing in the U.S. due to the increased use of intensive livestock production techniques.

The UN report admits many estimates are relatively imprecise because of the lack of data in many countries. Of the estimated seven billion metric tons of CO_2e emitted in livestock production, 52 percent is designated as "imprecise estimates." The 7 billion metric ton GHG estimate could be viewed as an upper bound rather than an accurate estimate as would be provided by the U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks.

Agricultural GHG emissions

Agriculture contributes to GHG through crop and soil management, enteric fermentation in domestic livestock, and livestock manure management. Greenhouse gas emissions associated with the production and use of electricity occur within each of these activities. Agriculture is estimated to have directly released 612 MMT of CO_2e in 2016. When electric-related emissions are distributed to the economic sectors, agriculture released an additional 39 MMT CO_2e, for a total of 651 MMT of CO_2e in 2016.

Nitrous Oxide (N_2O) and methane (CH_4) are the two major greenhouse gasses emitted by agricultural activities. Carbon dioxide accounts for only about 9 percent of direct agriculture-related GHG emissions.

Total N_2O emissions from agriculture were 302 MMT CO_2e, or 46 percent of total agricultural CO_2e in 2016.

In 2016, 26 percent of CO_2e released in agriculture came from enteric fermentation release of CH_4; another 10 percent of CO_2e in the form of CH_4 was from manure management.

The U.N. Intergovernmental Panel on Climate Change (IPCC) report entitled Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories recommends setting priorities among GHG sources and sinks within the national inventory. A source is designated a key category when it has a "significant influence on the country's total inventory of GHG in terms of the absolute level of emissions, the trend in emissions, or both." The EPA considered the following agriculture GHG sources as key categories in 2016: CH_4 emissions from enteric fermentation, manure management, and rice cultivation; direct N_2O emissions from agricultural soil management; indirect N_2O emissions from applied nitrogen and emissions from land use change.

Crop and soil management

Major GHG emissions associated with crop and soil management come mainly from crop production (95 percent), with much less attributed to field burning, and rice cultivation. The EPA estimated crop and soil management was responsible for 298 MMT of CO_2e in 2016.

The bulk of the CO_2e emitted via crop and soil management are in the form of N_2O. Nitrous oxide is produced naturally in the soil but is influenced by human activities that increase soil mineral nitrogen. The EPA considers the following activities to directly increase the amount of N2O emissions: fertilization, application of manure or other organic materials, retention of crop residues, production of nitrogen fixing crops and forages, and cultivation of soils with high organic matter content. Other practices which directly affect N_2O emissions are irrigation, drainage, tillage practices, and fallowing of land. Practices which indirectly increase N_2O emissions are volatilization and subsequent atmospheric deposition of applied nitrogen, and surface runoff and leaching of applied nitrogen.

The United States has more acres of grassland than cropland, but cropland emits more N_2O per acre than grassland. Cropland accounts for approximately 71 percent of direct N_2O emissions even though it constitutes only 47 percent of agricultural land. Grassland constitutes 53 percent of agricultural land but accounts for only 29 percent of direct N_2O emissions (latest available data from the EPA is 2012, Annex table A-196).

Direct N_2O emissions tend to be high in regions of high nitrogen fixation by soybeans and high nitrogen fertilization. Highest N_2O emissions include the Midwestern Corn Belt, the Lower Mississippi River Basin and the Central Valley in California.

Rice production contributes 14 MMT CO_2e. Flooded fields have microbes under anaerobic soil conditions, producing methane. This methane escapes to the atmosphere where it captures heat 25 times more effectively than CO_2.

Field burning of crop residues is not considered a net source of actual CO_2 emissions because it releases CO_2 that was captured from the atmosphere during the growing season. However, other gases released during the burning – CH_4, carbon monoxide (CO), N_2O and other nitrogen oxides (NO_x) – are considered a release of GHGs. Although residue burning is perhaps a visible release of gas into the atmosphere, it is a minor contributor. The EPA estimated 0.4 MMT of CO_2e, or approximately 0.1 percent of total agriculture-related emissions, resulted from field burning in 2016.

Manure management

Manure management is a source of CH_4 and N_2O emissions. The EPA estimated manure management was responsible for 86 MMT of CO_2e emissions in 2016. The manure application emissions counted as crop and soil management are not double counted here; this estimate includes only emissions from manure storage.

Methane is produced by the anaerobic decomposition of manure. Methane production occurs when manure is handled under anaerobic conditions such as in liquids and slurries. When manure is handled as a solid, little or no methane is produced. The amount of CH_4 produced is affected by temperature, moisture, time in storage, manure composition and storage system.

Nitrous oxide is produced from organic nitrogen in both manure and urine. Solid manure management systems produce N_2O because they have both aerobic and anaerobic decomposition which nitrifies and then denitrifies the nitrogen in the manure and urine.

Most GHG emissions from manure management are in the form of CH_4 and come from dairy and swine operations, which tend to use liquid manure management systems (Figure 3). Swine and dairy manure emissions increased during the 1990's when the industry moved towards confinement systems with liquid manure storage systems. The rate of increase in emissions has declined over the last decade.

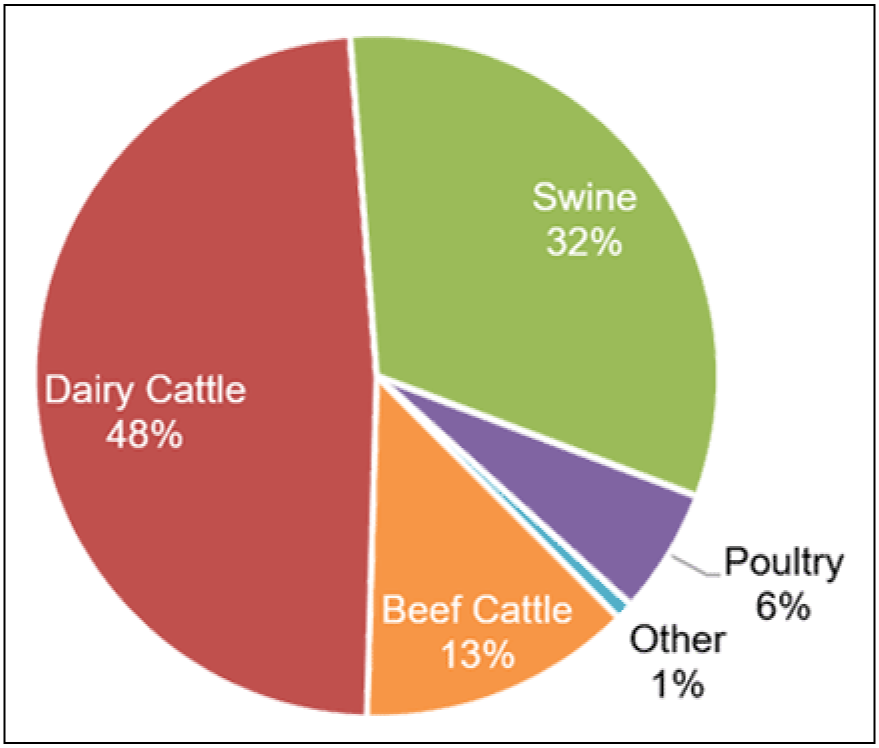


Figure 3. Carbon dioxide equivalent emissions from manure management, 2016.

In 2009, the EPA finalized a rule requiring certain industries which release GHG to report their emissions. Animal feeding operations expected to release 25,000 MT of CO_2e were required reporters. However, no reports are available because Congress prohibited the EPA from expending funds to implement the portion of the rule directed at manure management. This prohibition is still in effect in 2018.

Enteric fermentation

Methane production by enteric fermentation is a part of normal digestive processes in animals, especially ruminant animals such as cattle, sheep, and goats. The amount of CH_4 produced is affected by the number of livestock in the United States and by the amount and type of feed they consume. Livestock fed higher quality feed produce less methane than those grazing low quality forages.

The EPA estimated enteric fermentation was responsible for 170 MMT of CO_2e emissions in 2016. Beef and dairy cattle were responsible for the overwhelming majority of CH_4 emissions (Figure 4). All other classes of livestock contributed 4 percent of CH_4 emissions.

Agricultural carbon sequestration

Land use and forestry activities resulted in a net carbon sequestration of about 755 MMT of CO_2e, roughly 12 percent of total U.S. CO_2 emissions, in 2016. Although most of this sequestration occurs in trees and forests, U.S. crop and livestock farmers continue to express interest in sequestration opportunities in crop and rangeland management.

Land use and carbon emissions

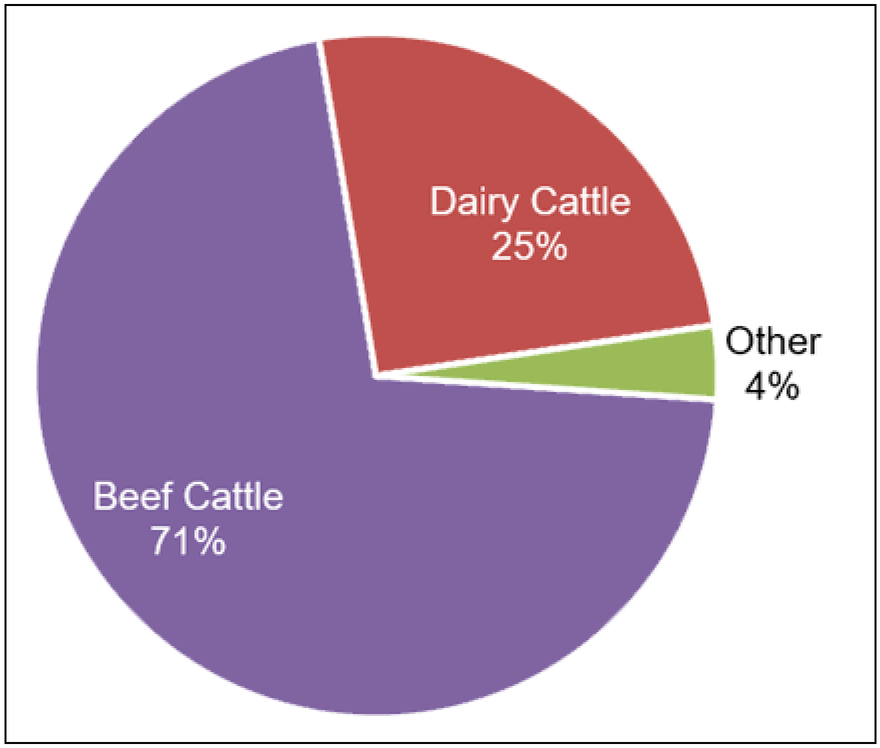


Figure 4. Methane emissions by livestock type, 2016.

Land activities cause both emissions and sequestrations of carbon. The emission and removal of carbon from the atmosphere is called a GHG flux. Following the IPCC Good Practice Guidance report, the EPA reports agricultural fluxes in the following land use/change categories: cropland remaining cropland, land converted to cropland, grassland remaining grassland, and land converted to grassland. Net U.S. carbon emissions from these four categories was 34 MMT of CO_2e in 2016.

Cropland remaining cropland includes all cropland that has been cropland for the last 20 years according to the USDA Natural Resources Inventory (NRI) land use survey. Soil organic carbon stocks are the main source and sink for most atmospheric CO_2 in soils. Across the United States, cropland remaining cropland was estimated to sequester a net 10 MMT of CO_2e. Soils containing 1 to 6 percent soil organic matter sequestered 40 MMT of CO_2e, whereas soils containing 12-20 percent soil organic matter released 30 MMT of CO_2e. Organic soils constitute about 1 percent of U.S. cropland, but emit significant amounts of GHG when cropped. Limestone added to acidic soils generated four MMT CO_2e.

Land converted to cropland includes all land designated as cropland which had a different designation, predominately grassland, in an earlier USDA NRI land use survey. Lands remain in this category for 20 years, after which time they are considered cropland remaining cropland. These areas release CO_2 as they equilibrate to a new, lower soil organic carbon level. In 2016, these soils were estimated to release 24 MMT of CO_2e.

Grassland remaining grassland includes all grassland areas which have been designated as grassland for the past 20 years. Grassland is normally considered to sequester carbon. Grassland remaining grassland sequestered about two MMT CO_2e in 2016.

Land converted to grassland includes all land designated as grassland which had a different designation in an earlier USDA NRI land use survey. Lands remain in this category for 20 years, after which time they are considered grassland remaining grassland. Conversion of land, predominately forest land, to grassland throughout the United States was estimated to release 22 MMT CO_2e in 2016.

Trees and carbon sequestration

The largest sources of carbon sequestration in the U.S. are attributed to forest land and urban trees. Forest lands were estimated to sequester 671 MMT of CO_2e in 2016 while urban trees sequestered 104 MMT. Both estimates take into account GHGs emissions other than CO_2 released from burning. CO_2

released during burning is not considered an addition to GHG emitted because that CO_2 is part of the natural carbon cycle.

Ethanol and greenhouse gases

Ethanol, when burned as a fuel, releases CO_2 into the environment. However, the EPA does not consider ethanol to increase atmospheric CO_2. Emissions of CO_2 from the production and use of ethanol are captured in the agriculture and transportation sectors and not directly in the energy sector. Because ethanol is a substitute for gasoline produced from fossil fuels, the use of ethanol actually reduced CO_2 emissions associated with the transportation industry by 78 MMT CO_2e in 2016.

Summary

Agriculture released 563 MMT of CO_2e in 2016. In addition, 34 MMT CO_2e was released by agricultural land use changes in 2016. Forest lands sequestered 739 MMT CO_2e. Land management for agriculture and forests resulted in a net sequestration of 142 MMT of CO_2e. A summary of this information can be found in Table 1.

Table 1. Summary of carbon dioxide equivalent emissions and sinks.

Sector	MMT CO_2e†
Total U.S. (all sectors)	6,511
Total agriculture‡	563
— Crop and soil management	307
— Enteric fermentation	170
— Manure management	86
Agricultural land use flux	34
Sequestration by forest lands	-739
Total	-142

† Million metric tons carbon dioxide equivalent.
‡ Total agriculture does not include sequestration in forestland and does not include electricity used in agriculture.

Many farmers have been optimistic about the opportunities to be compensated for sequestering carbon by reducing tillage or capturing methane emissions from manure storage structures. The Chicago Climate Exchange initially offered opportunity for farmers to be compensated for sequestering carbon. However, they ceased the program in 2010. No opportunities have been available for farmers to receive payment for sequestering soil carbon since 2010.

Agriculture needs to be aware of what is happening in the debate over GHG emissions. Compensation for sequestering carbon would offer an opportunity for farmers to benefit from their stewardship of resources, but there is also an opportunity for the government to limit farmers' production activities to reduce GHG emissions.

The EPA recognizes agriculture as a net emitter of GHGs and lists five agricultural sources of GHGs as key categories which have a significant influence on the country's total inventory of GHGs. While the use of nitrogen fertilizer, because of its ubiquity over the landscape, may be difficult to regulate, it is not impossible. The EPA has expressed a desire to have nutrient management plans on land receiving fertilizer. It would be a logical next step to target emissions from livestock manure management since they are already associated with larger businesses that are subject to permitting requirements.

Further information

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