Agriculture and Greenhouse Gas Emissions

Polls reveal that U.S. citizens consider global climate change to be a low-priority policy problem. However, the U.S. Environmental Protection Agency (EPA) is moving forward with plans to regulate greenhouse gas emissions. Agriculture remains in the middle of the discussion. A 2014 United Nations Food and Agriculture Organization report concludes that, from 2001 to 2010, greenhouse gas (GHG) emissions from crop and livestock production increased 14 percent and from land use changes decreased by 10 percent.

Although efforts to regulate GHG emissions have been sporadic and developing markets to address the issue have failed, crop and livestock farmers in the U.S. continue to show interest in the opportunity to be paid for sequestering carbon in the soil or for capturing GHG from manure storage.

This guide presents basic information on agriculture's role in GHG emissions. It draws heavily upon a report issued in 2014 by the EPA titled *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012*.

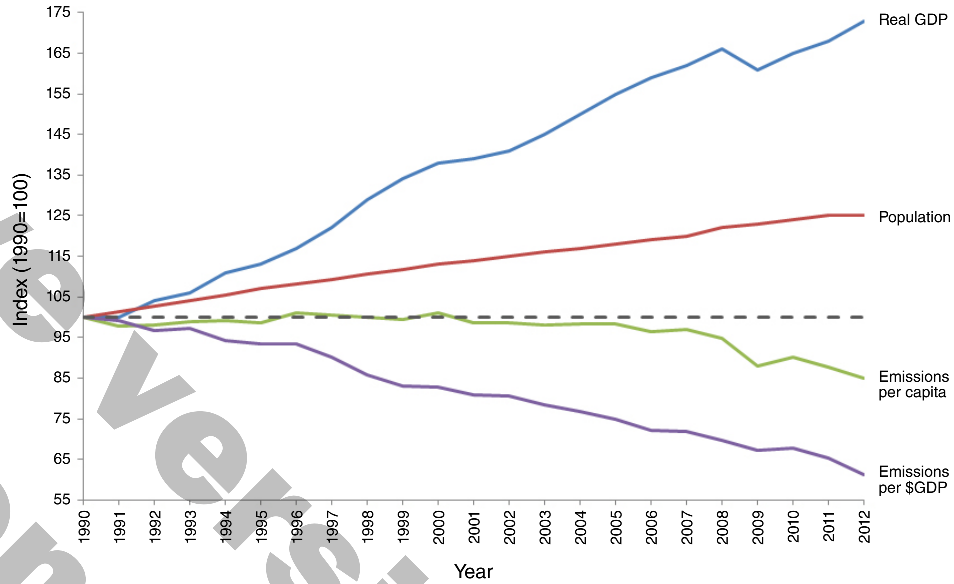

Figure 1. U.S. greenhouse gas emissions per capita and per dollar of gross domestic product. (Source: U.S. Environmental Protection Agency. 2014. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012*.)

Greenhouse gases

Greenhouse gases are gases in the atmosphere that 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. Some scientists hypothesize that 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 that are not naturally occurring are substances containing fluorine, chlorine or bromine.

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 emissions related to human activity, and 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 21 and 310, respectively. These values mean that, pound for pound, methane contributes 21 times the impact of carbon dioxide to global warming. Similarly, a given amount of nitrous oxide in the atmosphere exerts 310 times the effect on global warming as the same amount of carbon dioxide. All GHG are reported as carbon dioxide equivalents (abbreviated CO_2e).

Global warming potential

Carbon dioxide	1
Methane	21
Nitrous oxide	310

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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 2012, U.S. GHG emissions totaled 6,526 million metric tons (MMT) CO_2e. Total annual U.S. emissions increased 5 percent from 1990 to 2012. During this same period, the U.S. population increased by 25 percent and the country's real gross domestic product increased by 73 percent (Figure 1). Changes in emissions frequently are associated with changes in population, economic growth, energy price, seasonal temperatures and technology.

A portion of GHG emissions can be offset when carbon in the atmosphere is taken and stored, or sequestered, by plants and soil. In 2012, the EPA estimated that carbon sequestration by forests, trees in urban areas, agricultural soils and other sources offset 979 MMT CO_2e, or 15 percent of total emissions.

Sources of greenhouse gases

The EPA distributes GHG emissions among five economic end-user sectors: industry, transportation, residential, commercial and agriculture. Agriculture is estimated to be responsible for 9 percent of the GHGs emitted in the United States in 2012 (Figure 2).

The EPA's estimate of all agricultural activities contributing 9 percent of human-induced GHG emissions in the United States is considerably lower than the often-quoted United Nations estimate of 18 percent attributable to livestock alone.

In 2010, one of the authors of this U.N. report admitted that the comparison of meat sources to transportation sources of GHGs was flawed because it used different methods for the two sectors.

The U.N. estimate is based on all GHG emissions associated with livestock and meat production. In addition to emissions from crop production associated with livestock, the U.N. estimate includes emissions from livestock feeding and manure management, livestock transport to market, livestock processing, and transport of meat and products to retail. The EPA estimate for agriculture includes all crop production and livestock production but does not include transporting and processing of livestock and meat products. According to the U.N. report, transporting and processing account for less than 1 percent of GHG emissions in their accounting procedure, so including the emissions from these two activities in the U.S. estimate would probably result in little change.

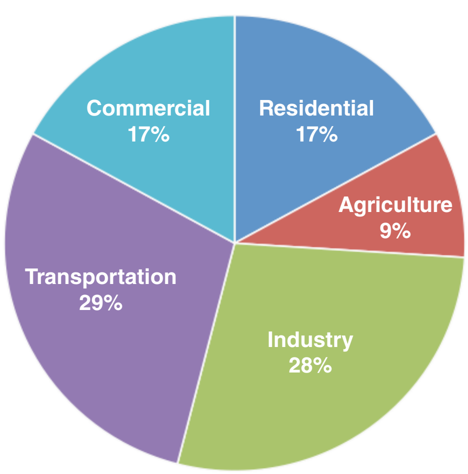

Figure 2. Greenhouse gas emissions by economic sector.

The U.N. 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.

The largest contributors to GHG emissions 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 intensive livestock production system common in the U.S. has a reduced carbon footprint per unit of meat produced.

The U.N. report admits that many estimates are relatively imprecise because of lack of data in many countries. Of the estimated 7 billion metric tons of CO_2e emitted in livestock production, 52 percent is designated as "imprecise estimates." The 7 billion metric tons of CO2e 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 526 MMT of CO_2e in 2012. When electric-related emissions are distributed to the economic sectors, agriculture released an additional 62 MMT CO_2e, for a total of 588 MMT of CO_2e in 2012.

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

Agricultural crop and soil management was the largest source of N_2O emissions, contributing 307 MMT CO_2e, or 48 percent of total agricultural CO_2e, in 2012. The N_2O emissions for agriculture decreased from 1990 to 2009 but rose between 2009 and 2012.

In 2012, 21 percent of CO_2e released in agriculture came from enteric fermentation release of CH_4; another 8 percent of CO_2e in the form of CH_4 was from manure management.

The U.N. Intergovernmental Panel on Climate Change (IPCC) report titled *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 listed the following agriculture GHG sources as key categories in 2012: CH_4 emissions from enteric fermentation, CH_4 emissions from manure management, direct N_2O emissions from agricultural soil management, indirect N_2O emissions from applied nitrogen, and emissions from land use change such as land converted to cropland.

Crop and soil management

Major GHG emissions associated with crop and soil management come mainly from crop production (98 percent), with much less attributed to field burning and rice cultivation. The EPA estimated that crop and soil management was responsible for 314 MMT of CO_2e in 2012.

The bulk of the CO_2e emitted via crop and soil management is 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 N_2O 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 that directly affect N_2O emissions are irrigation, drainage, tillage practices and fallowing of land. Practices that indirectly increase N_2O emissions are volatilization and subsequent atmospheric deposition of applied nitrogen, and surface runoff and leaching of applied nitrogen.

Cropland emits more N_2O per acre than grassland, but the United States has more acres of grassland than cropland. Cropland accounts for about 61 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 39 percent of direct N_2O emissions.

Direct N_2O emissions tend to be high in the Corn Belt (because of nitrogen fertilization on corn and nitrogen fixation in soybean cropping), where irrigation is prevalent, and where land is intensively cropped (such as portions of California and of states along the Mississippi Valley).

Rice production contributes 7 MMT CO_2e because rice is grown on flooded fields where microbes under anaerobic soil conditions produce methane. This methane escapes to the atmosphere where it captures heat 21 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 that growing season. However, other gases released during the burning — CH_4, carbon monoxide (CO2), 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 that 0.4 MMT of CO_2e, or about 0.1 percent of total agricultural-related emissions, resulted from field burning in 2012.

Manure management

Manure management is a source of CH_4 and N_2O emissions. The EPA estimated that manure management was responsible for 71 MMT of CO_2e emissions in 2012. 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

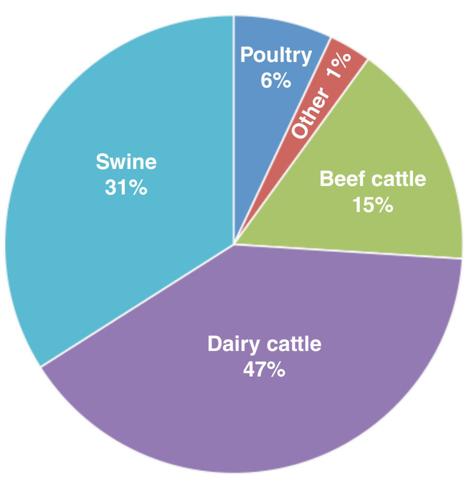

Figure 3. Carbon dioxide equivalent emissions from manure management.

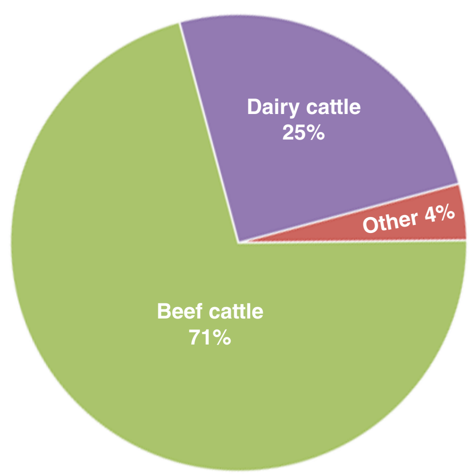

Figure 4. Methane emissions by livestock type.

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 that 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 1990s when the industry moved towards confinement systems with liquid manure storage systems. The rate of increase in emissions has declined over the past decade.

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 fed low-quality feed.

The EPA estimated that enteric fermentation was responsible for 141 MMT of CO_2e emissions in 2012. 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 979 MMT of CO_2e, roughly 15 percent of total U.S. CO_2 emissions, in 2012. This carbon sequestration associated with land use and forestry increased 6 percent from the 1990 level. Although most of this sequestration occurs in trees and forests, U.S. crop and livestock farmers have expressed considerable interest in sequestration opportunities in crop and rangeland management.

Land use and carbon sequestration

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 and land use change categories: cropland remaining cropland, land converted to cropland, grassland remaining grassland, and land converted to grassland. Net U.S. carbon sequestration from these four categories was 12 MMT of CO_2e in 2012 (Figure 5).

Cropland remaining cropland includes all cropland that has been cropland for the past 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

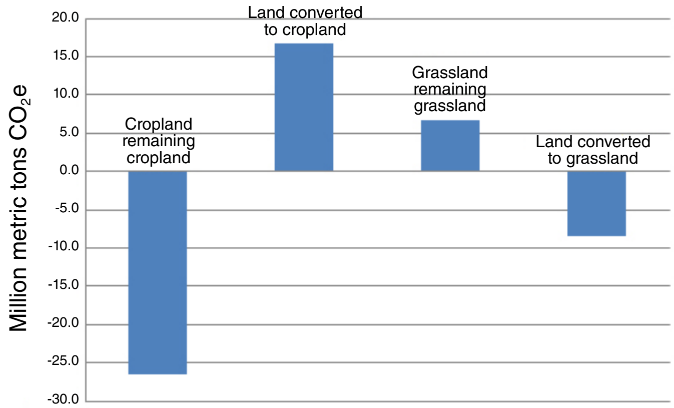

Figure 5. Carbon dioxide equivalent (CO_2e) emissions from land use, 2012.

net 27 MMT of CO_2e. Soils containing 1 to 6 percent soil organic matter sequestered 49 MMT of CO_2e, whereas soils containing 12 to 20 percent soil organic matter released 22 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 4 MMT CO_2e.

Land converted to cropland includes all land designated as cropland that had a different designation in an earlier USDA NRI land use survey. Lands are kept 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 2012, these soils released an estimated 17 MMT of CO_2e.

Grassland remaining grassland includes all grassland areas that have been designated as grassland for the past 20 years. Grassland is normally considered to sequester carbon. Grassland remaining grassland released about 7 MMT CO_2e in 2012. From 2005 to 2012, grassland remaining grassland released a total of about 31 MMT CO_2e, largely due to droughts causing small losses of carbon per acre over large geographic areas.

Land converted to grassland includes all land designated as grassland that had a different designation in an earlier USDA NRI land use survey. Lands are kept in this category for 20 years, after which time they are considered grassland remaining grassland. Carbon sequestration of 9 MMT CO_2e in 2012 was due primarily to conversion of cropland to continuous pasture throughout the United States.

Trees and carbon sequestration

The largest sources of carbon sequestration in the U.S. are attributed to forestland and urban trees. Forestlands sequestered an estimated 867 MMT of CO_2e in 2012, whereas urban trees sequestered 88 MMT. Both estimates take into account GHGs 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

When burned as a fuel, ethanol 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 72 MMT CO_2e in 2012. Countering this net reduction, ethanol production emitted 40 MMT CO_2e in its wastewater treatment in 2012.

Summary

Agriculture directly released 526 MMT of CO_2e and sequestered 12 MMT in 2012. Land use changes and forests sequestered 878 MMT CO_2e. Land management for agriculture and forests resulted in a net sequestration of 352 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)	**6,526**
Total agriculture‡	**526**
Crop and soil management	314
Enteric fermentation	141
Manure management	71
Sequestration	**-878**
Land use changes	-12
Forestlands	-867
Total	**-352**

† 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. From 2003 through 2010, the Chicago Climate Exchange credited conservation tillage in most of the nation as sequestering CO_2 that could be used in a cap-and-trade program. No opportunities have been available for farmers to receive payment for sequestering soil carbon since 2010.

Farmers need to be aware of what is happening in the debate over GHG emissions. Compensation for sequestering carbon offers them an opportunity to benefit from their stewardship of resources. It also presents 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 that have a significant influence on the country's total inventory of GHGs. Although regulating the use of nitrogen fertilizer, because of its presence across much of the landscape, may be difficult, it is not impossible. The EPA has expressed a desire to have nutrient management plans on land receiving fertilizer. A logical next step would be to target emissions from livestock manure management, as they are already associated with larger businesses that are subject to permitting requirements.

For further information

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