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Introduction

The purpose of this publication is to 1) provide an overview of atmospheric gases and the role some play in moderating global temperature, 2) discuss the relative contribution of greenhouse gases from global and U.S. sources, including agriculture, and 3) examine the major sources of and extent to which livestock and poultry contribute to greenhouse gas emissions.

What are Greenhouse Gases?

Earth's atmosphere consists mainly of nitrogen, oxygen, argon, and trace gases whose concentration varies little over time and location. Other gases such as water vapor, sulphur dioxides, and nitrogen oxides can vary substantially over time and location depending on air circulation patterns, temperature gradients, land use practices, and industrial emissions. Greenhouse gases are those that can absorb and emit thermal radiation (or heat) that would otherwise be lost to space. Many greenhouse gases occur naturally in the atmosphere, such as water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (N_2O), while others are synthetic. Synthetic greenhouse gases include the chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), and per fluorocarbons (PFCs), as well as sulfur hexafluoride (SF_6). Although they constitute only a small

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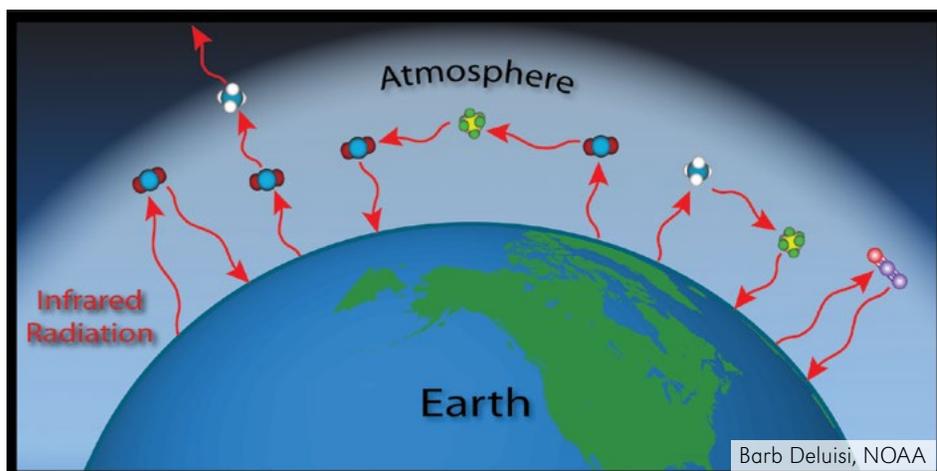


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fraction of all gases contained in the atmosphere, these gases serve a key role in regulating earth's temperature. The average global surface temperature of Earth is approximately 15 degrees Celsius (about 59 degrees Fahrenheit), (Pidwirny, 2006). Without greenhouse gases, average global surface temperature would be about -18 degrees Celsius (0 degrees Fahrenheit).

Greenhouse gases differ in the amount of heat they will absorb and how long they persist in the atmosphere. Table 2 compares the global warming potential (GWP) of common greenhouse gases. The GWP relates the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. It is usually calculated over a 100-year time interval. For example, GWP of methane over a 100-year period is 25, which means if the same mass of methane and carbon dioxide were emitted into the atmosphere, methane will trap 25 times more heat than carbon dioxide.

Constant Components	
Proportions remain the same over time and location.	
Nitrogen (N ₂)	78.08%
Oxygen (O ₂)	20.95%
Argon (Ar)	0.93%
Neon, Helium, Krypton	trace

Table 1. Earth's atmospheric gases.

Variable Components	
Amounts vary over time and location.	
Water vapor (H ₂ O)	0-4%
Carbon Dioxide (CO ₂)	0.039%
Methane (CH ₄)	trace
Sulfur Dioxide (SO ₂)	trace
Ozone (O ₃)	trace
Nitrogen Oxides (NO, NO ₂ , N ₂ O)	trace

Relative Contribution of Natural & Anthropogenic GHGS

Water Vapor: By far the most abundant greenhouse gas and the biggest contributor to the greenhouse effect, water vapor constitutes up to four percent by volume of the atmosphere, and 95 percent by volume of all greenhouse gases. On average, about 60 percent of the greenhouse effect is attributed to water vapor (Kiehl and Trenberth, 1997). Many scientists suggest that a warmer earth results in more water vapor in the atmosphere due to increased evaporation, further increasing the amount of heat retained globally. Climate model projections of future temperature rise are largely dependent upon this positive feedback mechanism, although the role of water vapor and cloud formation remains an area of great uncertainty.

Carbon Dioxide: At a concentration of 400 part per million (0.04 percent by volume), there are approximately 3,084 billion metric tons of carbon dioxide in the atmosphere. About 26 percent of the greenhouse warming effect is attributed to carbon dioxide (Kiehl and Trenberth, 1997). Natural sources emit about 770 billion metric tons of carbon dioxide each year from the ocean, animal and plant respiration, organic matter decomposition, forest fires, and volcanic eruptions. Anthropogenic (or human-related) carbon dioxide emissions originating from fossil fuel burning, cement production and farmland plowing produce an additional 34 billion metric tons of carbon dioxide annually (4 percent of natural carbon dioxide emissions), (NASA, 2013). Natural biological processes such as plant photosynthesis absorb the equivalent of all natural emissions plus about 57 percent of man-made emissions, leaving an extra 13 billion metric tons of carbon dioxide in the atmosphere annually (Knorr, 2009).

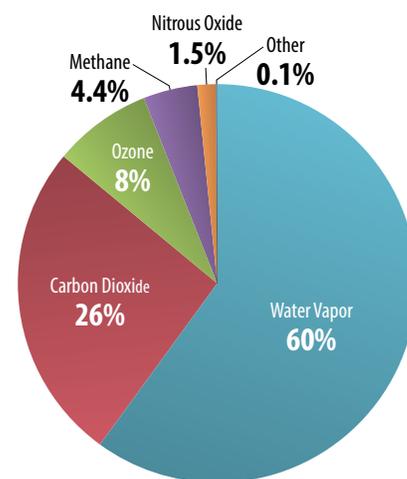


Figure 1. Relative contribution to the greenhouse effect. Adapted from Kiehl and Trenberth, 1997.

Ozone: Ozone is found in two different layers of the atmosphere—the stratosphere (upper atmosphere) and the troposphere (lower atmosphere). Stratospheric ozone protects life on earth from harmful effects of the sun’s ultraviolet rays. Tropospheric ozone is an air pollutant formed by the reaction of sunlight on air containing hydrocarbons and nitrogen oxides. Ozone is also a greenhouse gas, attributing up to 8 percent to the total greenhouse warming effect (Kiehl and Trenberth, 1997). The current estimate for global tropospheric ozone is 370 million metric tons, equivalent to a concentration of 50 parts per billion (GHG Online, 2013). The largest net source of tropospheric ozone is influx from the stratosphere. Large amounts of ozone are also produced in the troposphere by photochemical reactions which increase with high levels of air pollution. Tropospheric ozone has a short lifespan and varies widely from place to place. Increasing emission of atmospheric pollutants, such as those from biomass and fossil fuel burning has led to large increases in tropospheric ozone concentrations in the last 100 years.

Methane: Atmospheric methane concentration is approximately 1.9 parts per million (0.00019 percent by volume). On average, the atmosphere holds about 5 billion metric tons of methane. Wetland methane emissions are thought to comprise around 80 percent of the total natural methane source, with methane release from termites, methane hydrates (frozen deposits of methane), and the emission from the oceans also being important. Total annual methane emissions from natural sources are estimated to be around 250

million metric tons. Emissions resulting from human activities constitute about 60 percent of all annual methane emission and are believed to exceed those from natural sources. Anthropogenic sources include oil, coal and gas extraction, waste treatment systems, landfill sites, rice cultivation and biomass burning. Annual methane emissions from human activities are currently about 320 million metric tons (The Encyclopedia of Earth, 2013).

Nitrous Oxide: Atmospheric nitrous oxide concentration is approximately 325 parts per billion (0.0000325 percent by volume), (EPA, 2013a). Approximately 18.8 million metric tons of nitrous oxide is emitted annually into the atmosphere. Natural emissions account for about 12.1 million metric tons per year, primarily due to nitrification and denitrification processes in the soil, releases from the oceans, rivers, and estuaries, and from wildfires. Together, vegetative soils and oceans contribute nearly 95 percent of all natural nitrous oxides produced naturally. Another 6.7 million metric tons (36 percent of all nitrous oxide emissions) are due to human activities including fertilization and cultivation of farmland, industrial and fossil fuel use, and biomass burning (EPA, 2010).

Other GHGs: There are numerous synthetic compounds that originate from the production and use of foams, aerosols, refrigerants, and solvents. These include chlorinated and fluorinated compounds. While present at an extremely low concentration in the atmosphere, they are 10,000 to 25,000 times more efficient at trapping thermal radiation than an equivalent amount of carbon dioxide. These compounds contribute about 0.1 percent to the overall greenhouse warming effect (Kiehl and Trenberth, 1997).

GWP and Atmospheric Lifetime for Various Greenhouse Gases

Greenhouse Gases	Chemical Formula	Global Warming Potential (GWP) for a 100-year Time Horizon	Lifetime (Years)
Carbon Dioxide	CO ₂	1	Variable
Methane	CH ₄	25	12
Nitrous Oxide	N ₂ O	289	114
HCFC-12	CHClF ₂	1,810	12
Tetrafluoroethane	CF ₄	7,390	50,000
CFC-12	CCl ₂ F ₂	10,900	100
Hexafluoroethane	C ₂ F ₆	12,200	10,000
Nitrogen Trifluoride	NF ₃	17,200	740
Sulphur Hexafluoride	SF ₆	22,800	3,200

Table 2. Global warming potential (GWP) and atmospheric lifetime for various greenhouse gases.

Globally: Agriculture contributes from 10 to 12 percent of total anthropogenic emissions, the equivalent of 5,120 to 6,116 million metric tons of carbon dioxide (Denman et al., 2007; EPA, 2006a). Agriculture is both a source and sink for greenhouse gases. Agricultural lands both generate and extract large amounts of carbon dioxide to and from the atmosphere (IPCC, 2001). The U.S. Environmental Protection Agency (EPA) estimated a net carbon dioxide emission of 40 million metric tons from agricultural soils in 2000, less than 1 percent of global anthropogenic carbon dioxide emissions (EPA, 2006b). Carbon dioxide emissions from agricultural soils are not normally estimated separately, but are included in the land use, land use change and forestry sectors of national GHG inventories.

The largest contributions of greenhouse gases in agriculture come from methane and nitrous oxide. On a global scale, agriculture emits about 47 percent and 58 percent of total anthropogenic emissions of methane and nitrous oxide, respectively (IPCC, 2007b). Nitrous oxide from soils and methane from enteric fermentation constituted the largest sources of non-CO₂ greenhouse gas emission from agriculture in 2005, 38 percent and 32 percent respectively (EPA, 2006a). Biomass burning (12 percent), rice production (11 percent), and manure management (7 percent) accounted for the rest.

Agricultural Emissions



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United States: Agricultural activities produce about eight percent of the total anthropogenic U.S. greenhouse gas emissions (the equivalent of 461 million metric tons of carbon dioxide). This estimate does not include fuel combustion and agricultural carbon dioxide changes due to land use change. Electric power, transportation, and industry account for 33 percent, 28 percent, and 20 percent, respectively. When emissions from electricity use are distributed among respective economic sectors, agriculture consistently contributes less than industry, transportation, residential and commercial sectors. However, agricultural sources of greenhouse gas emissions have increased nearly 10 percent since 1990 with just over 612 million metric tons of CO₂ equivalents (EPA, 2013b).

Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including enteric fermentation in domestic livestock, animal manure management systems, rice cultivation, agricultural fertilization and soil management, and burning of agricultural residues. Methane and nitrous oxide were the primary greenhouse gases emitted by agricultural activities. Methane and nitrous oxide emissions from agriculture accounted for 32 percent and 69 percent, respectively, of all anthropogenic activities in 2011 (EPA, 2013c).

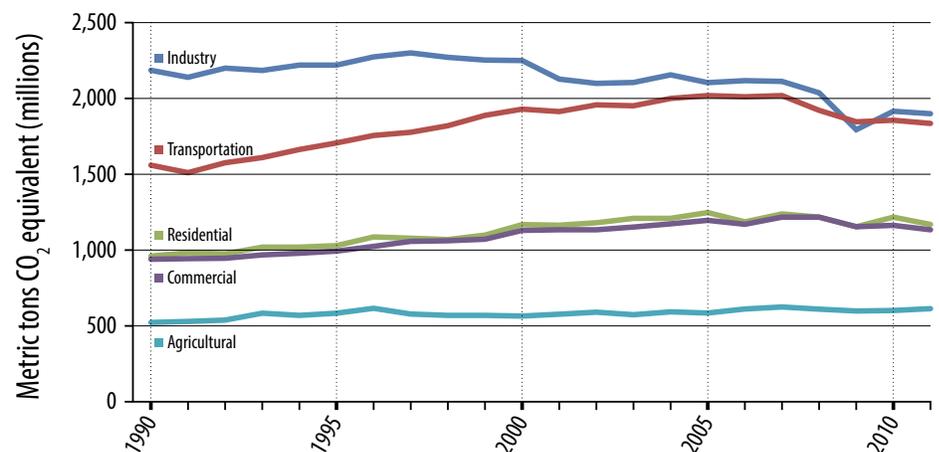


Figure 2. Greenhouse gas inventory with electricity distributed to economic sectors. Adapted from EPA, 2013b.

Livestock/Poultry Emissions



USDA-NRCS

Enteric Fermentation: In ruminant animals, enteric fermentation is a natural part of digestion where microbes in the first of four stomachs, the rumen, and break down feed and produce methane as a by-product. The methane is released primarily through belching. In 2011, an estimated 137 million metric tons of methane (in CO₂ equivalents) was produced in the U.S. from enteric fermentation, comprising about 70 percent of the total agricultural methane emissions. Beef cattle are by far the largest species contributor of enteric methane, producing nearly 100 million metric tons of CO₂ equivalents annually in the U.S., nearly three times that of dairy cattle and 50 times greater than swine.

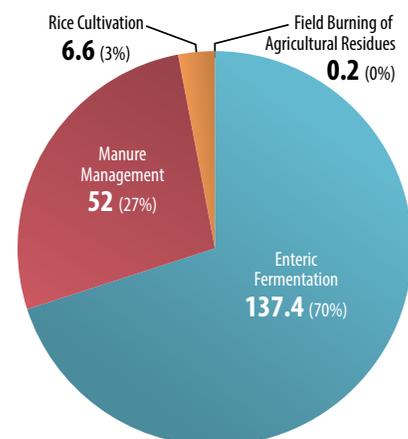
Manure Management: A similar microbial process to enteric fermentation leads to methane production from stored manure. When manure sits for more than a couple days in an anaerobic (without oxygen) environment, methane will likely be produced. Methane can be generated in animal housing, manure storage, and during manure application. Additionally, small amounts of methane are produced from manure deposited on grazing lands. In 2011, an estimated 52 million tons of CO₂ equivalents of methane were produced from animal manure deposition, storage, and application. About one-half of all manure methane emissions are attributed to dairy cattle, followed by swine (19 percent), beef cattle (5 percent), and poultry (5 percent), (EPA, 2013d).

Nitrous oxide is also produced from manure storage surfaces, during land application, and from manure in bedded packs and feed lots. In 2011, nitrous oxide from manure totaled 18 metric tons of CO₂ equivalents. This constitutes about nine percent of total livestock/poultry emissions in the U.S. Beef cattle were responsible for about 44 percent of the total nitrous oxide emissions from manure, followed by dairy cattle (31 percent), and swine (11 percent), (EPA, 2013d).

Soil Management: While only about three percent of agricultural greenhouse gas emissions in the U.S. are due to animal agriculture, crop and animal production systems are closely integrated (EPA, 2013c). It is therefore difficult to precisely attribute greenhouse gas emissions to one particular production system or sector. For example, many farms and ranches are highly diversified and integrate pasture, grain, and row crop production utilizing animal manure as the primary or secondary source of plant nutrients.

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Methane



Nitrous Oxide

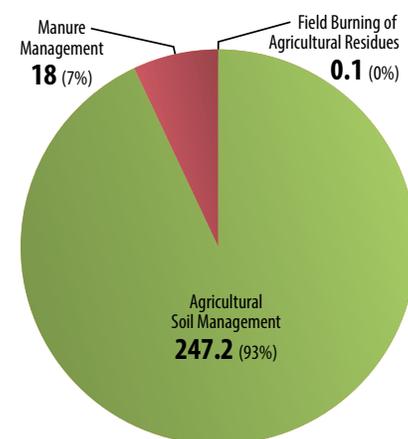


Figure 3. U.S. agriculture emissions (million metric tons CO₂ equivalent, %). Source U.S. EPA, 2013c.

Soil management activities are the greatest source of nitrous oxide emissions in agriculture. Nitrous oxide is released in soils after the application of synthetic and organic fertilizers (including manure). Fifty-four percent of all agricultural greenhouse gas emissions and 93 percent of all agricultural nitrous oxide emissions are from soil management activities (EPA, 2013d).

Other Sources: There are many smaller sources of greenhouse gases on farms. Combustion engines exhaust carbon dioxide from fossil fuel (previously stored carbon) powered vehicles and equipment. Manufacturing of farm inputs, including fuel, electricity, machinery, fertilizer, pesticides, seeds, plastics, and building materials also produce greenhouse gas emissions. Another source of emissions is burning of agricultural residues, often done to prepare land for pasture or crop production.

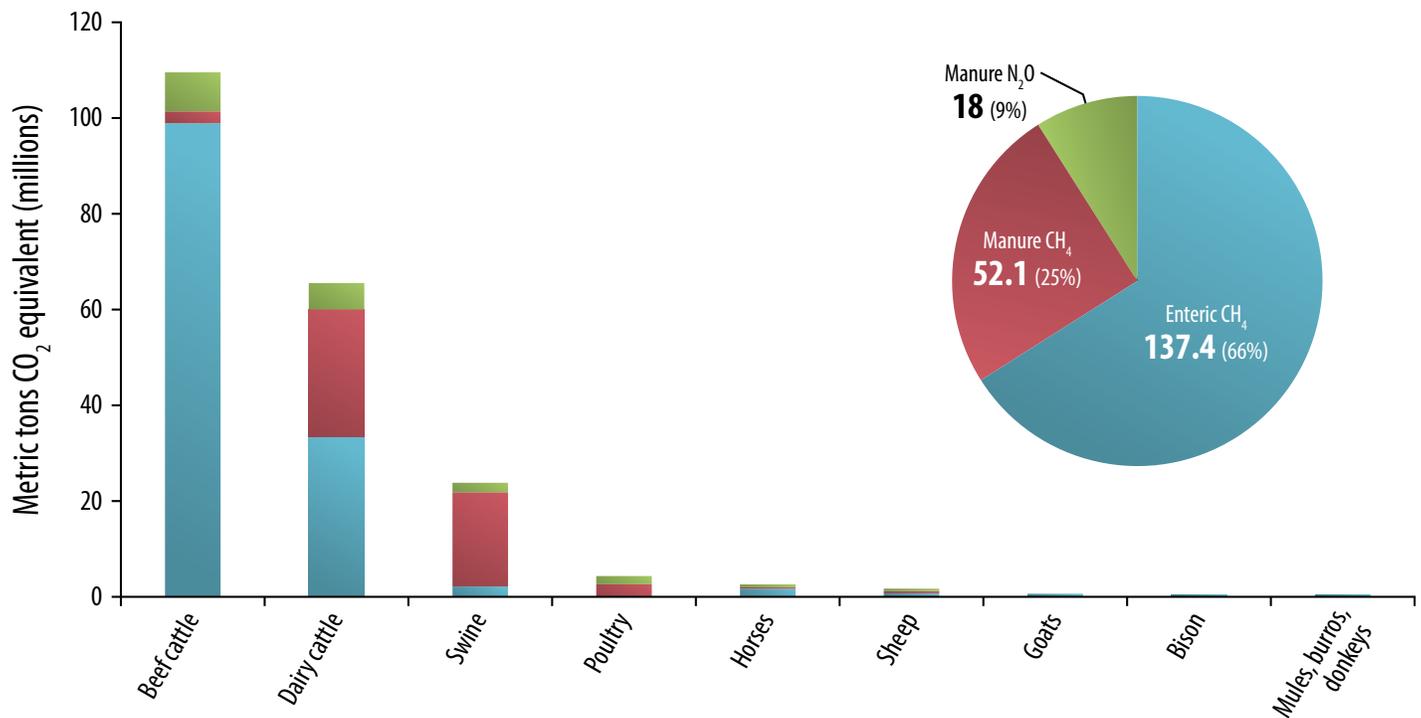


Figure 4. 2011 greenhouse gas emissions from livestock/poultry. Adapted from EPA, 2013c.

Summary

In the U.S., the total agriculture-related emissions of greenhouse gases are relatively small when compared to other economic sectors such as industry and transportation. However, agriculture has significant contributions of two important greenhouse gases, methane and nitrous oxide. Major sources of emissions in animal agriculture include enteric fermentation in ruminant animals and animal manure. The fact sheet titled “Mitigation of Greenhouse Gas Emissions in Animal Agriculture” in this series provides several proven and potential options for reducing emissions in beef, dairy, swine, and poultry operations.

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Document Reviewer(s)

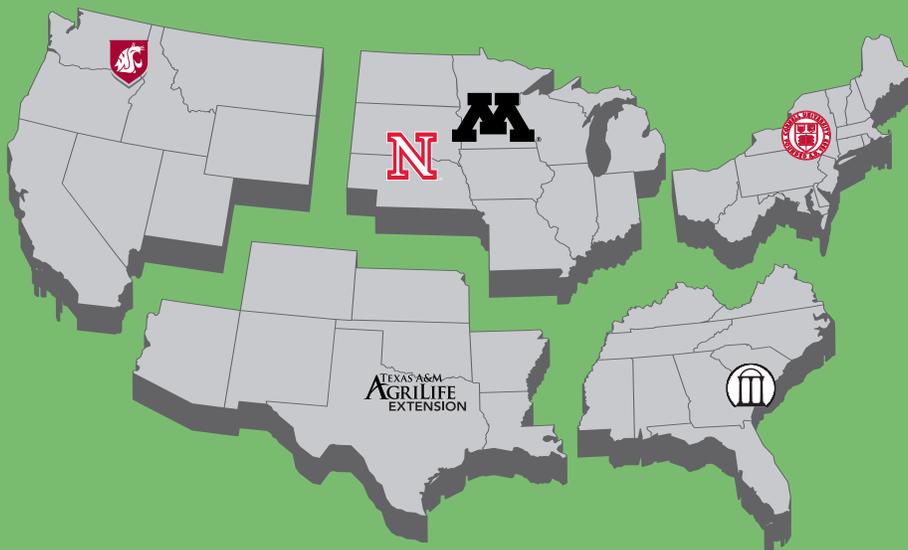
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ANIMAL AGRICULTURE IN A CHANGING CLIMATE



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- Cornell University
- Texas A&M University
- University of Georgia
- University of Minnesota
- University of Nebraska–Lincoln
- Washington State University



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