Appendix F. Agriculture

Overview

The emissions discussed in this appendix refer to non-energy methane (CH_4) and nitrous oxide (N_2O) emissions from enteric fermentation, manure management, and agricultural soils. Emissions and sinks of carbon in agricultural soils are also covered. Energy emissions (combustion of fossil fuels in agricultural equipment) are included in the residential, commercial, and industrial (RCI) fuel consumption sector estimates.

There are two livestock sources of greenhouse gas (GHG) emissions: enteric fermentation and manure management. Methane emissions from enteric fermentation are the result of normal digestive processes in ruminant and non-ruminant livestock. Microbes in the animal digestive system breakdown food and emit CH_4 as a by-product. More CH_4 is produced in ruminant livestock because of digestive activity in the large fore-stomach. Methane and N_2O emissions from the storage and treatment of livestock manure (e.g., in compost piles or anaerobic treatment lagoons) occur as a result of manure decomposition. The environmental conditions of decomposition drive the relative magnitude of emissions. In general, the more anaerobic the conditions are, the more CH_4 is produced because decomposition is aided by CH_4 producing bacteria that thrive in oxygen-limited conditions. Under aerobic conditions, N_2O emissions are dominant. Emissions estimates from manure management are based on manure that is stored and treated on livestock operations. Emissions from manure that is applied to agricultural soils as an amendment or deposited directly to pasture and grazing land by grazing animals are accounted for in the agricultural soils emissions.

The management of agricultural soils can result in N_2O emissions and net fluxes of carbon dioxide (CO_2) causing emissions or sinks. In general, soil amendments that add nitrogen to soils can also result in N_2O emissions. Nitrogen additions drive underlying soil nitrification and de-nitrification cycles, which produce N_2O as a by-product. The emissions estimation methodologies used in this inventory account for several sources of N_2O emissions from agricultural soils, including decomposition of crop residues, synthetic and organic fertilizer application, manure application, sewage sludge, nitrogen fixation, and histosols (high organic soils, such as wetlands or peatlands) cultivation. Both direct and indirect emissions of N_2O occur from the application of manure, fertilizer, and sewage sludge to agricultural soils. Direct emissions occur at the site of application and indirect emissions occur when nitrogen leaches to groundwater or in surface runoff and is transported off-site before entering the nitrification/denitrification cycle. Methane and N_2O emissions also result when crop residues are burned. Methane emissions occur during rice cultivation; however, rice is not grown in Alaska.

The net flux of CO_2 in agricultural soils depends on the balance of carbon losses from management practices and gains from organic matter inputs to the soil. Carbon dioxide is absorbed by plants through photosynthesis and ultimately becomes the carbon source for organic matter inputs to agricultural soils. When inputs are greater than losses, the soil accumulates carbon and there is a net sink of CO_2 into agricultural soils. In addition, soil disturbance from the cultivation of histosols releases large stores of carbon from the soil to the atmosphere. Finally, the practice of adding limestone and dolomite to agricultural soils results in CO_2 emissions.

Emissions and Reference Case Projections

Methane and Nitrous Oxide

GHG emissions for 1990 through 2005 were estimated using the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SGIT) and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for the sector.[1] In general, the SGIT methodology applies emission factors developed for the US to activity data for the agriculture sector. Activity data include livestock population statistics, amounts of fertilizer applied to crops, and trends in manure management practices. This methodology is based on international guidelines developed by sector experts for preparing GHG emissions inventories.[2]

Data on crop production in Alaska from 1990 to 2005 and the number of animals in the state from 1990 to 2002 were obtained from the United States Department of Agriculture (USDA), National Agriculture Statistical Service (NASS) and incorporated as defaults in SGIT.[3] Future reference case emissions from enteric fermentation and manure management were estimated based on the annual growth rate in emissions (million metric ton [MMt] carbon dioxide equivalent [CO_2e] basis) associated with historical livestock populations in Alaska for 1990 to 2002. The default data in SGIT accounting for the percentage of each livestock category using each type of manure management system was used for this inventory. Default SGIT assumptions were available for 1990 through 2002.

Data on fertilizer usage came from *Commercial Fertilizers*, a report from the Fertilizer Institute. Data on crop production in Alaska from 1990 to 2005 from the USDA NASS were used to calculate N_2O emissions from crop residues and CH_4 emissions from agricultural residue burning through 2005. Emissions for the other agricultural crop production categories (i.e., synthetic and organic fertilizers) were calculated through 2002. Production data from NASS was available for only two (i.e., barley and oats) of the types of crops included in SGIT, and these crops do not use nitrogen; therefore, N_2O emissions were not estimated for crops that use nitrogen (i.e., nitrogen fixation). Also, data were not available to estimate nitrogen released by the cultivation of histosols (i.e., the number of acres of high organic content soils). In addition, net carbon fluxes from agricultural soils are not reported in the US Inventory of Greenhouse Gas Emissions and Sinks[4] and the US Agriculture and Forestry Greenhouse Gas Inventory.

There is some agricultural residue burning conducted in Alaska. The SGIT methodology calculates emissions by multiplying the amount (e.g., bushels or tons) of each crop produced by a

---

[1] GHG emissions were calculated using SGIT, with reference to EIIP, Volume VIII: Chapter 8. "Methods for Estimating Greenhouse Gas Emissions from Livestock Manure Management", August 2004; Chapter 10. "Methods for Estimating Greenhouse Gas Emissions from Agricultural Soil Management", August 2004; and Chapter 11. "Methods for Estimating Greenhouse Gas Emissions from Field Burning of Agricultural Residues", August 2004.

[2] Revised 1996 1ntergovermental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, published by the National Greenhouse Gas Inventory Program of the IPCC, available at http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm; and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, published in 2000 by the National Greenhouse Gas Inventory Program of the IPCC, available at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/.

[3] USDA, NASS (http://www.nass.usda.gov/Statistics_by_State/Alaska/index.asp).

[4] US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2004 (and earlier editions), US Environmental Protection Agency, Report # 430-R-06-002, April 2006. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

series of factors to calculate the amount of crop residue produced and burned, the resultant dry matter, and the carbon/nitrogen content of the dry matter. For Alaska, the default SGIT method was used to calculate emissions because activity data in the form used in the SGIT were not readily available. Future work on this category should include an assessment to refine the SGIT default assumptions.

Table F1 shows the annual growth rates applied to estimate the reference case projections by agricultural sector. Emissions from enteric fermentation and agricultural soils were projected based on the annual growth rate in historical emissions (MMtCO$_2$e basis) for these categories in Alaska for 1990 to 2002 (1990 to 2005 for crop residues and nitrogen fixing crops). For crop residues, data for 1990 through 1993 were not available; therefore, the annual growth rate is based on the last 11 years for which historical emissions were calculated. Note that during 2000, weather conditions caused a significant decline in barley and oat production (both the number of acres harvested and yields); however, production of these crops recovered to typical levels in 2001 through 2005.[5]

Table F1. Growth Rates Applied for the Agricultural Sector

Agricultural Category	Growth Rate	Basis for Annual Growth Rate*
Enteric Fermentation	2.7%	Historical emissions for 1990-2002.
Manure Management	6.1%	Historical emissions for 1997-2002.
Agricultural Burning	0.0%	Assumed no growth.
Agricultural Soils – Direct Emissions		
Fertilizers	-4.3%	Historical emissions for 1990-2002.
Crop Residues	2.0%	Historical emissions for 1994-2005.
Nitrogen-Fixing Crops	0.0%	No historical data available.
Histosols	0.0%	No historical data available.
Livestock	2.1%	Historical emissions for 1990-2002.
Agricultural Soils – Indirect Emissions		
Fertilizers	-4.3%	Historical emissions for 1990-2002.
Livestock	2.4%	Historical emissions for 1990-2002.
Leaching/Runoff	-2.8%	Historical emissions for 1990-2002.

* Except for manure management and crop residues, compound annual growth rates shown in this table were calculated using the growth rate in historical emissions (MMtCO$_2$e basis) from 1990 through the most recent year of data. These growth rates were applied to forecast emissions from the latest year of data to 2020. For crop residues, data for 1990 through 1993 were not available; therefore, the annual growth rate is based on the last 11 years for which historical emissions were calculated. For manure management, the growth rate is based on emissions calculated for 1997-2002 (see text for explanation).

For manure management, the 12-year historical growth rate is 15.4% and the 5-year growth rate (based on 1997 through 2002 emissions) is 6.1%. The high 12-year growth rate is driven by changes in the SGIT assumptions on the types of manure management systems applied for dairy cattle and heifers. For dairy cattle and heifers, the proportion of manure managed in systems that yield higher GHG emissions (e.g., anaerobic lagoons and liquid slurry) than other systems (e.g., pasture) increased from 0% in 1990 to over about 70% for 1997 through 2002. For this analysis, the 5-year growth rate was assumed to be more representative of future manure management practices in Alaska and was used to forecast emissions from 2002 to 2020.

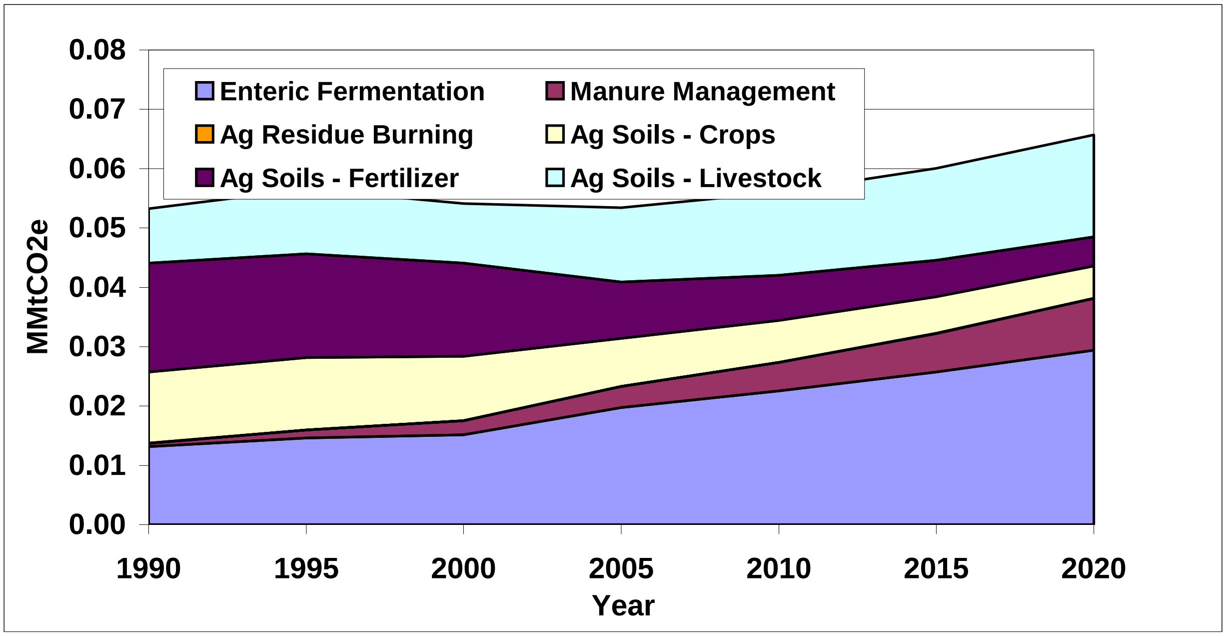
---

[5] Alaska Agricultural Statistics 2001, prepared by Alaska Agricultural Statistics Service, USDA, Palmer, Alaska.

Results

As shown in Figure F1, gross GHG emissions from agricultural sources range between about 0.053 and 0.066 MMtCO$_2$e from 1990 through 2020, respectively. In 1990, enteric fermentation accounted for about 25% (0.013 MMtCO$_2$e) of total agricultural emissions and is estimated to account for about 45% (0.029 MMtCO$_2$e) of total agricultural emissions in 2020. The manure management category, which shows the highest rate of growth relative to the other categories, accounted for 1% (0.001 MMtCO$_2$e) of total agricultural emissions in 1990 and is estimated to account for about 13% (0.009 MMtCO$_2$e) of total agricultural emissions in 2020. The agricultural soils category shows declining growth, with 1990 emissions accounting for 74% (0.039 MMtCO$_2$e) of total agricultural emissions and 2020 emissions estimated to be about 42% (0.028 MMtCO$_2$e) of total agricultural emissions.

Figure F1. Gross GHG Emissions from Agriculture



Source: CCS calculations based on approach described in text.
Notes: Ag Soils – Crops category includes crop residues (no cultivation of histosols estimated); emissions for agricultural residue burning are too small to be seen in this chart.

Agricultural burning emissions were estimated to be very small based on the SGIT activity data (<0.00001 MMtCO$_2$e/yr from 1990 to 2002). This agrees with the USDA Inventory which also reports a low level of residue burning emissions (0.02 MMtCO$_2$e).

The standard IPCC source categories missing from this report is CO$_2$ emissions from limestone and dolomite application and CO$_2$ fluxes in agricultural soils. Estimates for Alaska were not available; however, the USDA's national estimate for soil liming is about 9 MMtCO$_2$e/yr.[7] As mentioned above the USDA national estimates for soil carbon do not include Alaska.

Key Uncertainties

Emissions from enteric fermentation and manure management are dependent on the estimates of animal populations and the various factors used to estimate emissions for each animal type and manure management system (i.e., emission factors which are derived from several variables including manure production levels, volatile solids content, and CH_4 formation potential). Each of these factors has some level of uncertainty. Also, animal populations fluctuate throughout the year, and thus using point estimates introduces uncertainty into the average annual estimates of these populations. In addition, there is uncertainty associated with the original population survey methods employed by USDA. The largest contributors to uncertainty in emissions from manure management are the emission factors, which are derived from limited data sets.

As mentioned above, for Alaska data were not available for estimating emissions associated with changes in agricultural soil carbon levels and limestone and dolomite application. When newer data are released by the USDA, these should be reviewed to represent current conditions as well as to assess trends.

Alaska has reindeer husbandry operations which are not included in SGIT. The number of head of reindeer in Alaska has declined in recent years (from 24,000 head in 1998 to 15,000 in 2005).[6] Future work should consider developing data for estimating emissions associated with reindeer husbandry operations if this category is determined to be important.

Another contributor to the uncertainty in the emission estimates is the projection assumptions. This inventory assumes that the average annual rate of change in future year emissions will follow the historical average annual rate of change from 1990 through the most recent year of data. For example, the historical data show a decline in the use of fertilizers; however, there may be a leveling-off in fertilizer use trends due to recent efficiency gains that my be close to reaching their full technical potential.

---

[6] Alaska Agricultural Statistics 2006, prepared by Alaska Field Office, USDA NASS, Palmer, Alaska.