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 (fossil fuel combustion in agricultural equipment) are included in the RCI 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 methane as a by-product. More methane is produced in ruminant livestock because of digestive activity in the large fore stomach. Methane and nitrous oxide emissions from livestock manure 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 methane is produced because decomposition is aided by methane producing bacteria in these conditions. Under aerobic conditions, nitrous oxide emissions are dominant. Emissions of N_2O also occur away from a manure management operation when nitrogen leached to groundwater or in surface runoff enters the nitrification/denitrification cycle. Finally, N_2O emissions occur when manure deposited by grazing animals decomposes.

The management of agricultural soils can result in N_2O emissions and net fluxes of carbon dioxide causing emissions or sinks. In general, soil amendments that add nitrogen to soils can also result in nitrous oxide emissions. Nitrogen additions drive underlying soil nitrification and de-nitrification cycles, which produce N_2O as a by-product. The emissions estimation methodologies employed here 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. Methane and nitrous oxide emissions also result when crop residues are burned. Methane emissions occur during rice cultivation; however rice is not grown in Colorado. Carbon dioxide emissions from the use of limestone and dolomite on croplands are captured within the industrial sector estimates for these materials.

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 SGIT and the methods provided in the EIIP guidance document for the sector.[1] In general, the SGIT methodology applies emission factors developed for the U.S. 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 greenhouse gas emissions inventories.[2] Details on the SGIT methodology can be found in Volume VIII, Chapter 8 of the Emissions Inventory Improvement Program guidelines.

Data on crops and number of animals in the state from 1990 to 2002 within SGIT come from the USDA National Agriculture Statistical Service (NASS). SGIT data on fertilizer usage came from *Commercial Fertilizers*, a report from the Fertilizer Institute. The default data in SGIT accounting for the percentage of each livestock category using each type of manure management system were also used. Emissions from enteric fermentation and manure management were forecast based on projected livestock populations. The average annual growth rates for 2015-2020 were assumed to continue through 2030. Dairy cattle populations used for manure management projections were adjusted to account for Vermont's Cow Power program.[3]

Crop production data from USDA NASS were available through 2002; therefore, N2O emissions from crop residues and N-fixation were calculated through 2002. Emissions for the other agricultural crop production categories (synthetic and organic fertilizers, agricultural residue burning) were also available through 2002. SGIT data indicate that agricultural residue burning is not a common practice in Vermont agriculture. Historical emissions from agricultural soils, based on USDA NASS data, do not show a significant positive or negative trend. Therefore, emissions for this source were held constant from 2002 – 2030.

Soil Carbon
Carbon dioxide is either emitted or sequestered as a result of agricultural practices. Net carbon fluxes from agricultural soils have been estimated by researchers at the Natural Resources Ecology Laboratory at Colorado State University and are reported in the U.S. Inventory of

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[1] GHG emissions were calculated using SGIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter 8, "Methods for Estimating Greenhouse Gas Emissions from Livestock Manure Management", 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] Dave Dunn, Central Vermont Public Service (CVPS). VT Cow Power Program projected dairy cattle populations: 1,000 head in 2005, 4,000 head in 2007, and 10,000 head in 2009, translating to an emission reduction of 0.008 MMtCO2e/year in 2009.

Greenhouse Gas Emissions and Sinks[4] and the U.S. Agriculture and Forestry Greenhouse Gas Inventory. The estimates are based on the IPCC methodology for soil carbon adapted to conditions in the U.S. Preliminary state-level estimates of CO_2 fluxes from mineral soils and emissions from the cultivation of organic soils were reported in the U.S. Agriculture and Forestry Greenhouse Gas Inventory.[5] Currently, these are the best available data at the state-level for this category. The inventory did not report state-level estimates of CO_2 emissions from limestone and dolomite applications; hence, this source is not included in this inventory at present.

Carbon dioxide fluxes resulting from specific management practices were reported. These practices include: conversions of cropland resulting in either higher or lower soil carbon levels; additions of manure; participation in the Federal Conservation Reserve Program (CRP); and cultivation of organic soils (with high organic carbon levels). For VT, Table F1 below shows a summary of the latest estimates available from the USDA.[5] The latest data available are for 1997 agricultural practices. These data show that changes in agricultural practices are estimated to result in a net sink of 0.2 $MMtCO_2e$/yr in CO. Since data are not yet available from USDA to make a determination of whether the emissions are increasing or decreasing, the net sink of 0.2 $MMtCO_2e$/yr is assumed to remain constant.

Table F1. GHG Emissions from Soil Carbon Changes Due to Cultivation Practices ($MMtCO_2e$)

Changes in cropland			Changes in Hayland				Other			Total[4]
Plowout of grassland to annual cropland[1]	Cropland management	Other cropland[2]	Cropland converted to hayland[3]	Hayland management	Cropland converted to grazing land[3]	Grazing land management	CRP	Manure application	Cultivation of organic soils	Net soil carbon emissions
0.07	0.00	0.00	(0.11)	0.00	0.00	(0.04)	0.00	(0.11)	0.00	(0.19)

Based on USDA 1997 estimates. Parentheses indicate net sequestration.
[1] Losses from annual cropping systems due to plow-out of pastures, rangeland, hayland, set-aside lands, and perennial/horticultural cropland (annual cropping systems on mineral soils, e.g., corn, soybean, cotton, and wheat).
[2] Perennial/horticultural cropland and rice cultivation.
[3] Gains in soil carbon sequestration due to land conversions from annual cropland into hay or grazing land.
[4] Total does not include change in soil organic carbon storage on federal lands, including those that were previously under private ownership, and does not include carbon storage due to sewage sludge applications.

Results

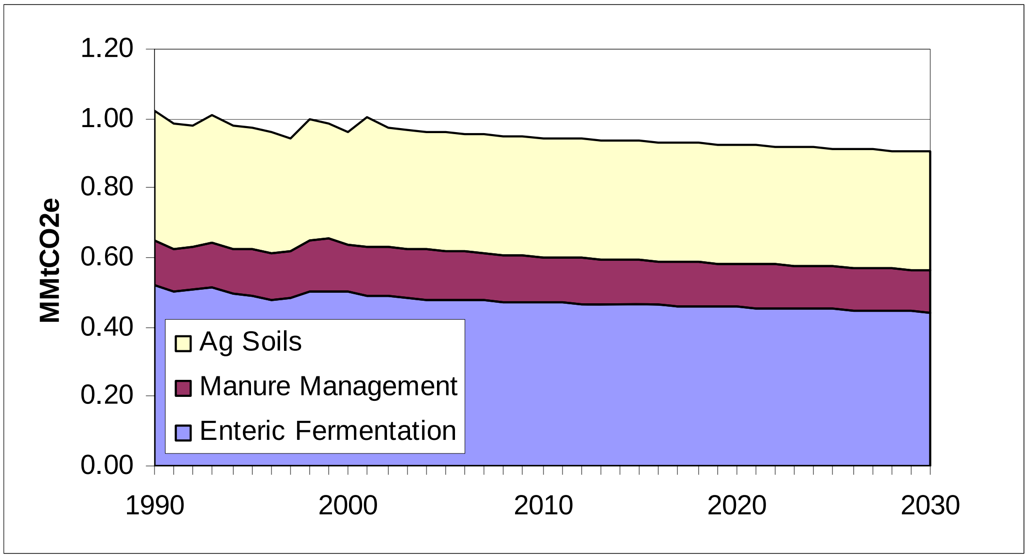
As shown in Figure F1, gross emissions from agricultural sources remained fairly stable at around 1 $MMtCO_2e$ from 1990 through 2030. The projections predict a decline in emissions

[4] U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2004 (and earlier editions), U.S. Environmental Protection Agency, Report # 430-R-06-002, April 2006. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.
[5] U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001. Global Change Program Office, Office of the Chief Economist, U.S. Department of Agriculture. Technical Bulletin No. 1907. 164 pp. March 2004. http://www.usda.gov/oce/global_change/gg_inventory.htm; the data are in appendix B table B-11. The table contains two separate IPCC categories: "carbon stock fluxes in mineral soils" and "cultivation of organic soils." The latter is shown in the second to last column of Table F1. The sum of the first nine columns is equivalent to the mineral soils category.

from these sources from 2002 to 2030, mainly due to a predicted decrease in the dairy cattle population. With the inclusion of soil carbon flux from agricultural soils (-0.19 $MMtCO_2e/yr$), the net agricultural sector emissions range from about 0.8 to 0.7 $MMtCO_2e/yr$ over the forecast period.

The only standard IPCC source category missing from this report is CO_2 emissions from limestone and dolomite application. Estimates for CO were not available; however the USDA's national estimate for soil liming is about 9 $MMtCO_2e/yr$.[5]

Figure F1. Gross GHG Emissions from Agriculture



Key Uncertainties

Key sources of uncertainty underlying the estimates are the projection data. Local projections of livestock populations were not available; therefore, national projections from USDA were used to project livestock populations. However, national livestock trends may not reflect the future of livestock in Vermont.

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, methane 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 emissions associated with changes in agricultural soil carbon levels, the only data currently available are for 1997. When newer data are released by the USDA, these should be reviewed to represent current conditions as well as to assess trends. In particular, if additional idle crop lands are returned to active cultivation prior to 2030, the current size of the CO_2 sink could be appreciably affected. As mentioned above, emission estimates for soil liming have not been developed for VT.