

Department of Environmental Conservation

Agriculture, Forestry, and Other Land Use

2025 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #3

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Format of This Report

This sectoral report provides a detailed explanation of methods, data, and trends for the Agriculture, Forestry and Other Lands Use (AFOLU) sector. The accounting used in this sectoral report follows the requirements of the Climate Leadership and Community Protection Act (CLCPA) and is in alignment with the 6 NYCRR Part 496 regulation, “Statewide GHG Emission Limits.” This includes the use of a 20-Year Global Warming Potential metric provided in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC 2013). The organization of this report and specific methodologies are based on the IPCC Taskforce on National Greenhouse Gas Inventories approach (or “IPCC approach”) as applied in the U.S. national greenhouse gas emissions report (IPCC 2006 and 2019, EPA 2025b). The accompanying Summary Report provides a comparison with other accounting methods, including by economic sector or using conventional accounting formats. DEC also provides emission values for all years via the Open Data NY platform.

Figures, Tables, and Callout Boxes

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Agriculture, Forestry, and Other Land Use

This sectoral report provides information on greenhouse gas emissions and emission removals following the organizational structure of the Intergovernmental Panel on Climate Change guidance for governmental greenhouse gas inventories (e.g., IPCC 2006). For the purposes of the Climate Leadership and Community Protection Act (CLCPA), an additional distinction is made between sources covered by the statewide gross versus net emission totals, as described in the accompanying *Summary Report*. Finally, two additional sources of emissions are provided as informational items. Emissions from Soil Organic Carbon (SOC) are included in the Forest Inventory Analysis; here we report a recalculation of those emissions based on IPCC Tier 2 methods for informational purposes only. Methane emissions from wetlands are included in the Wetlands, Waterbodies, and Flooded Lands Analysis; estimated emissions are provided but are not included in net totals, per IPCC accounting approach.

In 2023, total agricultural emissions were 22.13mmt CO_2e or 41% higher than in 1990 (Table SR3.1). Most agricultural emissions are from livestock (91%). In 2023, agriculture represented approximately 6.3% of gross statewide emissions, when measured using CLCPA accounting. Further information on the relative contribution of the agricultural emission sources is described in the sections below. Agricultural practices also contribute to the removal of carbon dioxide from the atmosphere. These emission removals are considered a part of Land Use in the IPCC approach and are captured as “net emission removals” (Table SR3.2).

Table SR3.1 AFOLU Agriculture Emissions, 1990-2023 (mmt CO_2e GWP20)

Emission Category	1990	2005	2019	2020	2021	2022	2023
Livestock	13.58	15.10	19.53	19.94	20.09	19.44	20.19
Soil Management	2.08	2.04	2.01	2.02	2.00	1.95	1.95
Gross Total	**15.66**	**17.14**	**21.54**	**21.95**	**22.10**	**21.39**	**22.13**
% of statewide gross total	*3.8%*	*3.7%*	*5.9%*	*6.7%*	*6.4%*	*6.0%*	*6.3%*
Net Total	**15.66**	**17.14**	**21.54**	**21.95**	**22.10**	**21.39**	**22.13**
% of statewide net total	*4.3%*	*4.1%*	*6.8%*	*7.9%*	*7.4%*	*7.0%*	*7.3%*

Note: Totals may not sum due to independent rounding.

The two forms of net emission removals in New York State today are via the long-term storage of carbon in harvested wood products (HWPs) and the net carbon uptake and storage by various land use categories, particularly forest land (Table SR3.2). Land use and land use change drove 97% of net emission removals in 2023, but these removals have declined 2% since 1990 primarily because of forest land conversions to other land use categories.

Table SR3.2 AFOLU Net Emission Removals, 1990-2023 (mmt CO_2e GWP20)

Emission Category	1990	2005	2019	2020	2021	2022	2023
Harvested Wood Products	-1.54	-1.86	-1.31	-1.33	-1.45	-1.31	-1.24
Land Use	-37.01	-37.49	-36.25	-36.29	-36.62	-36.48	-36.24
Net Emission Removals	**-38.55**	**-39.35**	**-37.56**	**-37.62**	**-38.06**	**-37.79**	**-37.48**
Excluded Wetland Emissions	12.68	12.58	12.62	12.62	12.62	12.62	12.62

"+" less than 0.01mmt; "na" not applicable; Note: Totals may not sum due to independent rounding.

This report includes methane (CH_4) emissions from freshwater wetlands, water bodies, flooded land that has remained flooded, and land that has been converted to flooded land. Only the CH_4 emissions from the latter two flooded land categories are included in the net 'Land Use' totals in Table SR3.2 and contribute to the AFOLU sector's total emissions. This is because these emissions result from human activities and land management decisions (EPA 2025b). In contrast, CH_4 emissions from freshwater wetlands and water bodies that are not considered flooded land are reported separately as 'Excluded Wetland Emissions' in Table SR3.2. This is in keeping with the IPCC approach, which capture anthropogenic emissions and sequestration by 'managed lands,' but do not count non-anthropogenic emissions from unmanaged, naturally functioning ecosystems toward net emission totals.

In the U.S., the EPA interprets flooded lands and coastal wetlands as managed lands, and therefore includes the CH_4 emissions and CO_2 sequestration fluxes attributed to these ecosystems in the national GHG inventory (EPA 2025b). However, the contributions of freshwater wetlands are only counted in the EPA's national inventory if the wetlands are harvested for peat (EPA 2025b). DEC continues to seek feedback on whether all freshwater wetlands in New York should be considered managed lands that contribute toward the sectoral total in a similar manner to coastal wetlands. In the interim, annual CH_4 emissions from wetlands and water bodies are provided for informational purposes only, whereas the CO_2 sequestered by freshwater wetland biomass and soil carbon is counted toward the sectoral total.

These decisions regarding emission removals affect accounting for the CLCPA net zero emission reduction goal, but they do not affect accounting for achievement of the statewide GHG emission limits established in ECL § 75-0107 and promulgated as 6 NYCRR Part 496. Finally, it should be noted that the net impact of the CH_4 emitted relative to the CO_2 sequestered by freshwater wetlands depends on the time horizon over which these are estimated. The CLCPA requires DEC to report all non-CO_2 emissions as CO_2 equivalents by using the Global Warming Potentials (GWPs) estimated over a 20-year time horizon. Using a 20-year rather than a 100-year GWP weights CH_4 emissions more heavily relative to an amount of CO_2 sequestered. However, protected wetland ecosystems can function over longer timescales than 20 or even 100 years, and their ability to both sequester CO_2 while also emitting CH_4 may have a net-cooling effect on climate when considered over these longer timescales (Neubauer 2014).

Agricultural Emissions

Agriculture contributes to anthropogenic emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Livestock and soil nutrient management practices produce these emissions (Table SR3.1). Livestock sources include animal feeding (enteric fermentation) and manure storage systems. Soil nutrient management practices include liming, urea application, and soil nitrogen (N) management. These emission estimates were developed by Peter Woodbury and Jenifer Wightman (Cornell University) using IPCC methodology (IPCC 2019). Estimates of CO_2 sequestration by soils in cropland that remains cropland, and emissions that occur when other land use categories (for example, forest land) are converted to cropland were developed by the EPA (EPA, 2024a and 2025b) and are included under Land Use (Table SR3.10) in the Net Emission Removals section of this report. Data for this year's report includes the most recently updated Census of Agriculture (USDA 2024), which affects the time series from 2017-2022 due to data interpolations between each census (every five years). The agricultural industry also contributes other emissions and emission removals that are not captured in this section. For example, agriculture is a source of Energy sector emissions related to the use of fuels on farms (*Sectoral Report #1: Energy)*.

Livestock

Livestock management practices are the largest source of emissions in the agricultural sector, and they have increased 49% since 1990 (Table SR3.3). Although animal feeding is the larger source of emissions, the greatest increase in emissions is related to manure management, which more than tripled since 1990 (Table SR3.3). This trend reflects a change in policies regarding the collection and storage of manure to improve and protect water quality.

Table SR3.3 Livestock Emissions, 1990-2023 (mmt CO_2e GWP20)

Emission Category	1990		2005		2019	2020	2021	2022	2023
Animal Feeding	11.67		11.34		13.52	13.66	13.53	13.46	13.72
Manure Management	1.91		3.76		6.00	6.28	6.56	5.97	6.46
Gross Total	**13.58**		**15.10**		**19.53**	**19.94**	**20.09**	**19.44**	**20.19**

"+" less than 0.01mmt; "na" not applicable; Note: Totals may not sum due to independent rounding.

Animal Feeding

Ruminant animals produce CH_4 as they digest the organic carbon in their feed. Specifically, anaerobic microbes present in the animals' digestive systems convert some of the feed into CH_4 that is then exhaled or belched by the animals.

Methodology

This analysis includes the historic and current CH_4 contribution of NY dairy cattle and non-dairy ruminant animal herds including non-dairy cattle, sheep, swine, horses, mules and asses, goats, American bison, llamas, alpacas, and deer and elk in captivity. Separate methodologies were used to estimate emissions from dairy and non-dairy animals. For non-dairy animals, herd population data were from the U.S. Department of Agriculture National Agricultural Statistics

Service (NASS) (USDA 2020a) and CH_4 emissions were estimated using IPCC emission factors (Table 10.10 and 10.11, IPCC 2019). For dairy cattle, the dry matter intake (DMI) of the New York dairy herd was estimated using the number and size of cows (to calculate the energy required for maintaining body mass), milk production, and percent milkfat (to calculate the energy required to produce the milk). The NASS provided historical data on percent milkfat, animal number, and milk production (USDA 2020a). The DMI values were used to calculate an emission factor (kg CH_4 per head per year; equation 10.21A, IPCC 2019).

Results

From 1990 to 2023, CH_4 emissions from animal feeding (enteric fermentation) increased 18% (Table SR3.3). The largest annual contributions to emissions were made by dairy cattle. Emission trends primarily reflect herd size, except among dairy cattle, whose herd sizes have decreased but whose milk production has increased over time. Annual emissions by beef cattle, for example, follow the population trends in which herd sizes increased 1990 through 2023.

Manure Management

Manure management systems (MMS) that are used to treat and store livestock and poultry waste also emit CH_4 and N_2O. Manure stored in conditions that promote anaerobiosis will produce CH_4 (e.g., as liquid/slurry, in lagoons, ponds, tanks, or pits). Specifically, the volatile solids or organic carbon component of the manure is converted to CH_4 by certain microorganisms. In contrast, if manure is handled as a solid (e.g., in stacks or dry lots) or deposited on pasture, range, or paddock lands, it can decompose aerobically and will produce little or no CH_4 (see Box SR3.1 for more details in Anaerobic Digesters). Microorganisms also produce N_2O as they act on the N compounds present in livestock and poultry waste. The series of microbial reactions that yield N_2O are known as nitrification and denitrification. They may

Box SR3. 1: Manure Storage

Animal manure, like other sources of degradable organic carbon, can be a source of methane to the atmosphere when it is subject to anaerobic conditions and microbial activity. Manure is also a nutrient source that is spread onto agricultural fields to fertilize crops. DEC requires concentrated animal feeding operations (CAFOs) to hold manure in storages[1] during periods when manure nutrients are more likely to run off and pollute local water bodies. A side effect of holding liquid or slurry manure in storages is that anaerobic conditions develop and promote methane generation and emissions. Uncovered storages allow this methane to escape to the atmosphere. These methane emissions can be mitigated using storage covers that are designed to reduce methane release and then allow ignition of the accumulated methane using flares that convert most of it to carbon dioxide.

Anaerobic digesters[2] are another manure management strategy that can mitigate methane emissions while also helping to manage nutrient pollution to water bodies. These enclosed vessels are designed to promote methane generation by preventing air from reaching the manure and may also heat manure to temperatures that accelerate microbial methane generation. Methane collected inside the digester may be burned on the farm as a fuel source, sold as biogas, or flared and emitted as carbon dioxide. Some amount of collected methane may also leak directly to the atmosphere. Of the 448 active CAFOs that submitted State Pollutant Discharge Elimination System (SPDES) annual compliance reports to the Department for the year 2023, 31 indicated that they treat waste in anaerobic digesters and 28 reported having cover-and-flare waste storage facilities. Of these, three CAFOs reported treating waste with anaerobic digesters as well as having cover-and-flare waste storages. The reporting CAFOs also included 30 that did not report using uncovered waste storages; three of these reported using cover-and-flare storages and none of them reported using anaerobic digesters. In other words, the vast majority of CAFOs in NY use one or more uncovered storages to handle waste.

Volatile solids are the component of animal manure that contributes to methane generation under anaerobic conditions. Based on the 2023 CAFO annual reports described above, the total annual volatile solids generated at CAFOs that reported accessing anaerobic digesters was estimated to be 0.372 million metric tons versus 1.660 million metric tons generated on CAFOs that do not report accessing anaerobic digesters[3]. Thus, 18% of the manure volatile solids generated by reporting CAFOs are produced at CAFOs that access anaerobic digesters. By comparison, CAFOs that use cover-and-flare waste storage systems generate 0.146 million metric tons of volatile solids (7% of the total in 2023). In total, 0.487 million metric tons of volatile solids (24%) are generated by CAFOs that report using either or both anaerobic digesters and cover-and-flare manure storages. CAFOs that do not report using uncovered waste storages generate 0.061 million metric tons of manure volatile solids (3%) so that CAFOs with at least one uncovered waste storage were responsible for nearly all (97%) of the manure volatile solids generated at reporting CAFOs in 2023.

The State's methane emissions from manure management scale with access to and adoption of these methane-control technologies at CAFOs. The IPCC's guidance for national inventories characterizes the tendencies of different manure management strategies to emit methane to the atmosphere with 'methane conversion factors' (MCFs)[4]. A manure management system's MCF is the estimated fraction of its potential methane generation that will be emitted to the atmosphere. This value is several-fold higher for uncovered manure storages (27.4% to 41.8% depending on the county-specific climate) than it is for anaerobic digesters (1.00% to 12.97% depending on the climate and gas-tightness of the manure handling systems)[4]. The Department plans to undertake additional work to characterize manure and other process wastewater handling practices on NY CAFOs so that these emission factors can be verified and adopted.

[1] USDA Natural Resources Conservation Service. Code 313. 'Conservation Practice Standard: Waste Storage Facility'

[2] USDA Natural Resources Conservation Service. Code 366. 'Conservation Practice Standard: Anaerobic Digester'

[3] Volatile solids in this box were estimated using animal numbers reported through the Department's SPDES annual compliance reporting for 2024 and average volatile solids production rates collated by the USEPA in their 2025 National Greenhouse Gas Inventory (see Tables A-154, A-155, and A-156 for typical animal mass and per-animal volatile solids production rates).

[4] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Chapter 10

the waste mobilize and stimulate nitrification and denitrification in another location. Two pathways produce indirect N_2O emissions. In the first, volatile manure N (mainly NH_3 and NOx) moves through the air and is deposited on soils and the surfaces of lakes and other water bodies where it stimulates N_2O production. In the second pathway, water in runoff and manure leachate carries N compounds into groundwater, riparian zones, ditches, streams, rivers, and estuaries that have hydrological connections to farmland. Direct and indirect N_2O emissions that are associated with manure application to soils are accounted for in the soil N management section below.

Methodology

Animal number and body weight data were gathered from the NASS (USDA 2020a). Cattle farm MMS data were gathered on DEC-regulated concentrated animal feeding operations (CAFOs) from notices of intent, change of operation, and annual compliance reports. Note that CAFOs in New York are smaller than CAFOs in other parts of the U.S. where animals may number in the tens of thousands. State permits for livestock farms in New York are based on livestock numbers alone, regardless of discharge status. Since 1999, all CAFOs operate under the no-discharge CAFO General Permit issued under the state Environmental Conservation Law (ECL) and must follow a Comprehensive Nutrient Management Plan. Data on smaller cattle farms were gathered from the NYS Agricultural Non-Point Source Abatement and Control Grant Program (AgNPS) as well as other State data sources. Data on non-cattle MMS were gathered from livestock specialists and from annual compliance reports for non-cattle, CAFO-regulated farms.

CH_4 emissions from dairy cattle and non-dairy animals were estimated separately. IPCC emission factors were applied to each type of animal: CH_4 emissions for non-dairy animal MMS emissions were estimated using equation 10.22; dairy cattle MMS emissions were estimated using equation 10.23 (IPCC 2019). Animal waste N content was estimated using equation 10.30 and IPCC default N_2O emissions factors were applied to the fraction of manure in each type of MMS (Table 10.21, IPCC 2019).

Results

Total N_2O emissions from manure management doubled between 1990 and 2023 and CH_4 emissions more than tripled (Table SR3.3, SR3.4). In 2023, total N_2O emissions from manure management were estimated to be 0.40mmt CO_2e; while in 1990 emissions were 0.19mmt CO_2e. These values include both direct and indirect N_2O emissions from manure management. To avoid double counting, these tables do not include emissions of N_2O from field applied manure at any time point (see the Soil Nitrogen Management section). CH_4 emissions from manure management increased from 1.72mmt CO_2e in 1990 to 6.06mmt CO_2e in 2023 as a result of increased liquid storage of dairy manure.

Table SR3.4 Manure Management Emissions, 1990-2023 (mmt CO_2e GWP20)

Gas	1990	2005	2019	2020	2021	2022	2023
CH_4	1.72	3.46	5.61	5.89	6.17	5.58	6.06
N_2O	0.19	0.30	0.39	0.39	0.39	0.39	0.40
Gross Total	**1.91**	**3.76**	**6.00**	**6.28**	**6.56**	**5.97**	**6.46**

Note: Totals may not sum due to independent rounding

Soil Management

The IPCC approach include multiple emission sources under the AFOLU subcategory, "aggregated sources and non-CO_2 emissions on land." Since the relevant sources in New York are all associated with soil amendments, we refer to this as "soil management" in this report (Table SR3.5). Other sources of emissions that are not considered relevant in New York are related to the burning of biomass as a land management practice and rice cultivation. The IPCC approach also include harvested wood products in the aggregated sources subcategory but are treated as a component of net emission removals in this report (see next section).

Soil management emissions in 2023 were 7% lower than in 1990 (Table SR3.5). Most of these emissions are associated with soil nitrogen management (91% in 2023) that encompasses fertilizer application practices resulting in N_2O emissions.

Table SR3.5 Soil Management Emissions, 1990-2023 (mmt CO_2e GWP20)

Gas/Source	1990	2005	2019	2020	2021	2022	2023
CO_2	**0.14**	**0.15**	**0.16**	**0.17**	**0.17**	**0.17**	**0.17**
Liming	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Urea Application	0.02	0.02	0.05	0.05	0.05	0.05	0.05
N_2O	**1.94**	**1.89**	**1.85**	**1.85**	**1.84**	**1.78**	**1.78**
Soil Nitrogen Management	1.94	1.89	1.85	1.85	1.84	1.78	1.78
Gross Total	**2.08**	**2.04**	**2.01**	**2.02**	**2.00**	**1.95**	**1.95**

Note: Totals may not sum due to independent rounding.

Liming

Crushed limestone and dolomite are added to soils by land managers to increase soil pH. CO_2 emissions occur when these minerals react with soil acidity. Reaction rates of limestone and dolomite applications depend on soil conditions, soil type, and climate. Emissions associated with use of these minerals in industrial processes (e.g., cement production) are accounted for in *Sectoral Report #2: Industrial Processes and Product Use.*

Methodology

The average lime use over time was calculated using data from USGS (2018) and adjusted for cropland area in New York using the EPA State Inventory Tool (EPA 2025a) as well as older data from the Census of Agriculture (Bureau of the Census 1989). The CO_2 emissions for each census year were calculated using the emission factors from West & McBride (2005) for limestone and dolomite and summed to estimate total CO_2 emissions due to agricultural liming.

Results

Emissions from liming of soils have fluctuated very little over the past 25 years in New York and contribute 0.12 or 0.13mmt CO_2e for each year since 1990 (Table SR3.5). Since the area of cropland changes slowly, if at all, from one year to the next, the use of lime also does not vary much.

Urea Application

Adding urea fertilizer to soils causes emission of CO_2 when the organic carbon that is integral to urea molecules is oxidized by soil microorganisms. An industrial fertilizer production process uses pressure and heat to fix CO_2 and NH_3 into urea molecules. This fixation and emission cycle is rapid, and accurately accounting for its net impact on CO_2 emissions is difficult. However, the CO_2 emitted by urea is included here to assure complete accounting for urea across sectors.

Methodology

Calendar year data on the amount of urea fertilizer applied were extracted from the SIT tool (EPA 2025a). The SIT uses information on state-level fertilizer sales provided by The Tennessee Valley Authority (1991 through 1994) and the Association of American Plant Food Control Officials. Complete conversion of all carbon in urea to CO_2 was assumed.

Results

CO_2 emissions from field application of synthetic urea increased nearly three-fold from 0.02mmt CO_2e in 1990 to 0.05mmt CO_2e in 2023 (Table SR3.5), following increased use of urea fertilizers.

Soil Nitrogen Management

Emission sources from soil nitrogen management practices include direct and indirect N_2O emissions from managed soils, and indirect N_2O emissions from field application and management of manure. Agricultural activities that lead to direct N_2O emissions include the application of N fertilizer, the application of managed livestock manure or other organic materials such as biosolids (i.e., treated sewage sludge), the deposition of manure on soils by domesticated animals in pastures, range, and paddocks, retention of crop residues (both N-fixing legumes and non-legume crops and forages), and drainage of organic soils. Agricultural soil management activities such as irrigation, drainage, tillage, cover cropping, and fallowing of land can also influence the rates at which microorganisms produce N_2O through nitrification and denitrification and add N to soil through N fixation.

Methodology

Nitrogen from a variety of sources can be added to soil. The IPCC provides default N_2O emission factors associated with each source of added soil N (IPCC 2019). Inventoried sources of added N included synthetic fertilizer, animal manure, biosolids, and crop residues. In addition,

N_2O emissions from organic soils that have been drained for agricultural activity were estimated based on the area under this type of soil and land use, and an IPCC default emission factor per unit area (IPCC 2019).

Annual estimates of synthetic N fertilizer application were from the Association of Plant Food Control Officials and The Fertilizer Institute as reported in Brakebill and Gronberg (2017) for years up until 2012. Fertilizer application was assumed to remain at 2012 levels in subsequent years. An IPCC default emission factor of 0.016 kg N_2O per kg N was used for synthetic fertilizer (Table 11.1, IPCC 2019).

Livestock manure N that was estimated for the manure management emission category (above) was assumed to be applied to soil, whether directly or after a storage period. A fraction of this applied manure N was assumed to be lost, and was subtracted from the total manure N. An IPCC default emission factor of 0.006 kg N_2O per kg N was assumed for the fraction of manure N remaining in the soil (IPCC 2019).

Data on biosolids (treated sewage sludge) applied to soil were from DEC (DEC 1999 and 2018) and Baker (2016). An emission factor of 0.006 kg N_2O per kg N (IPCC 2019) was applied to an estimate of the N added to soil calculated with the total dry mass, fraction applied to soil, and the average N content of the biosolids.

The N added to soil by crop residues was estimated using crop-specific area and yields from the USDA NASS census of agriculture for barley, dry edible beans, buckwheat, corn grain, corn silage, non-alfalfa hay, alfalfa hay, non-alfalfa haylage, alfalfa haylage, hops, oats, rye, sorghum grain, sorghum silage, soybeans, sunflower, triticale, and wheat (USDA 2019). The estimated N content of specific crop residues and the emission factor of 0.006 kg N_2O per kg N were the default values provided by the IPCC (2019).

The area of drained organic soil under agricultural production was estimated for the years 1998 and 2000 by Ropel and Smith (2001) and for 2008 by the New York State Crop Reporting Service (USDA 2008). Linear interpolation was used to extend these area estimates to other years. The IPCC's default emission factor of 13 kg N_2O-N per hectare per year was used to estimate the annual N_2O flux (IPCC 2014).

As a new approach for estimating emissions of N_2O from Histosols, the average direct emission of N_2O was estimated as the average of field measurements of the measured N_2O flux from multiple sites in New York and a site in Ohio (Duxbury & Peverly 1978, Elder & Lal 2008). Indirect emissions were calculated as part of the estimate made for mineral soils.

Results

Annual N_2O emissions from agricultural soils are estimated to be 8% lower in 2023 compared to 1990, based on available data on synthetic fertilizer sales (16% lower in recent years). Changes also reflect a decrease in N_2O emissions from daily spread of manure as dairy manure management practices have changed over time. In 2023, 75% of total N_2O emissions were direct, and 25% were indirect (Table SR3.6).

Table SR3.6 Soil Nitrogen Management N_2O Emissions, 1990-2023 (mmt CO_2e GWP20)

Emission Type	1990	2005	2019	2020	2021	2022	2023
Direct	1.43	1.4	1.37	1.37	1.37	1.34	1.34
Indirect	0.52	0.49	0.48	0.48	0.47	0.44	0.44
Gross Total	**1.94**	**1.89**	**1.85**	**1.85**	**1.84**	**1.78**	**1.78**

Note: Totals may not sum due to independent rounding; “ne” not estimated

Soil Organic Carbon

Soil organic carbon (SOC) is a major component of soil organic matter, which is a mixture of cropland residue, leaf litter, soil microbes, and products of decomposition and metabolic activity. SOC is the largest stock of carbon in the terrestrial ecosystem. Carbon is added to soil via photosynthesis and the application of materials containing carbon. Carbon is lost via respiration by plants and microbes and the rate of losses can be altered by management practices such as tillage. If the gains of carbon outweigh the losses, soil carbon stocks increase (the reverse is also true). The difference between gains and losses is carbon flux, or “net” carbon emissions (see Box SR3.2 for more detail).

Histosols, also known as “muck” soils, are highly organic soils formed in wetlands. When they are drained, Histosols can be used as very productive cropland. However, drained Histosols also lose carbon as carbon dioxide at a much higher rate than mineral soils, and therefore have been analyzed separately from mineral soils.

This report utilizes SOC net emissions by land use type derived from USDA Forest Inventory and Analysis (FIA) data, therefore these calculations are provided for informational purposes only and are not included in net totals.

Methodology

Separate methods were used to account for SOC changes in mineral soils and Histosols (drained organic soils) from 1900-2023 as described below.

For mineral soils, the IPCC Tier 1 soil organic carbon (SOC) stock change method was used (IPCC 2019, Volume 4, Chapter 2). This method makes the following two key assumptions (IPCC 2019, Volume 4, Chapter 2, page 2.32). The first assumption is that over time, SOC stocks reach a spatially averaged, stable value specific to the soil, climate, land use and management practices. The second assumption is that SOC stock change during the transition to a new equilibrium SOC occurs in a linear fashion over a period of 20 years.

Two types of activity data were used in this analysis: land use change activity data and agricultural soil management data, the latter of which includes cover cropping, tillage, and addition of organic matter. Land area data for agriculture and all other land use categories were derived from the United States Coastal Change Analysis Program (C-CAP). The C-CAP land area data provide agricultural uses in two subcategories, Cultivated and Pasture-Hay, while the USDA National Agricultural Statistics Service (USDA-NASS) land area data provide agricultural uses in three sub-categories: Cultivated, Hay, and Pasture/Other. For this report, the total area of agriculture from C-CAP was divided into subcategories using USDA-NASS data. Agricultural land can include both cropland and grassland. Hay crops can be reported as either crops or grassland by different reporting bodies. For the IPCC SOC method, hay (continuous) is included in the definition of Grassland (IPCC 2019 Figure 6.1 on page 6.8). Therefore, all hay lands (both grass and alfalfa) were assigned to grassland in this report.

For Histosols, an IPCC Tier 3 soil organic carbon (SOC) stock change method was used. New, improved estimates were made of CO_2 emissions of that use measured gas flux data from New York State and nearby regions (Ohio) in addition to an estimate based on soil subsidence. The average CO_2 emission from Histosols in New York State under conventional tillage was estimated as an average of available data from New York and Ohio (Armentano 1979, Elder & Lal 2008, Duxbury personal communication). The fraction of cropped Histosols in New York State that use no-till was provided from a personal communication from Cornell Cooperative Extension Vegetable Specialist Ethan Grundberg.

Results

Net CO_2 emissions from soil carbon in all soils in the state were 0.80mmt CO_2e in 1990 and 0.66mmt CO_2e in 2023 (Table SR3.7). Emissions from Histosols (organic soils) predominated with 0.80mmt CO_2e in 1990 and 0.91mmt CO_2e in 2023. Net CO_2 emissions from all mineral soils were 0.00mmt CO_2e in 1990 and -0.24mmt CO_2e in 2023. Negative values indicate removal from the atmosphere, thus in 2023, mineral soils aggregated across all land use types in the state removed 0.24mmt CO_2e. Mineral soils were a source of CO_2 to the atmosphere in some years and removed CO_2 from the atmosphere in other years. Despite a 57% reduction in intensive tillage from 1990 to 2023, nearly all variation in annual SOC among years was due to changes in the area of cropland mineral soils (r^2 = 0.90). Carbon stocks tend to be smaller in mineral soils in cropland than in mineral soils in most other land cover types (e.g. wetland, forestland, settlement, grassland). Therefore, conversions of other land cover types to cropland release CO_2 to the atmosphere as carbon stocks on the land shrink.

Table SR3.7 Net CO_2 Flux from Soil Carbon in All Lands, 1990-2023 (mmt CO_2e GWP20)
Informational Purposes Only

Emission Category	1990	2005	2019	2020	2021	2022	2023
Mineral soils	-	0.03	-0.32	-0.24	-0.20	-0.25	-0.24
Drained Histosols	0.8	0.89	0.91	0.91	0.91	0.91	0.91
Total	**0.8**	**0.92**	**0.59**	**0.67**	**0.71**	**0.66**	**0.66**

Note: Totals may not sum due to independent rounding.
Note: Negative values are removals from the atmosphere

Net Emission Removals

The CLCPA sets three distinct emission reduction requirements, two of which relate to gross emissions to the atmosphere (Statewide GHG Emission Limits, Part 496) and a third that also relates to removals from the atmosphere, or net zero emissions. This section provides information on the two existing sources of emission removals: harvested wood products (HWPs) and land use. This information can be used to estimate net emission levels in the state.

Table SR3.8 illustrates the trend in net removals from 1990 through 2023 as described in more detail below. Overall net removals have decreased by 3% since 1990, but net removals associated with harvested wood products and most land use categories have remained relatively stable. For reasons discussed below, annual carbon sequestration by NY forest land has steadily declined since 1990. The excluded net emissions are CH_4 emissions from wetlands and water bodies.

Table SR3.8 Net CO_2 Removals, 1990-2023 (mmt CO_2e GWP20)

Emission Category	1990	2005	2019	2020	2021	2022	2023
Harvested Wood Products	-1.54	-1.86	-1.31	-1.33	-1.45	-1.31	-1.24
Land Use	-32.88	-33.45	-36.25	-36.29	-36.62	-36.48	-36.24
Net Emission Removals	**-34.42**	**-35.31**	**-37.56**	**-37.62**	**-38.06**	**-37.79**	**-37.48**
Excluded Net Emissions	12.68	12.58	12.62	12.62	12.62	12.62	12.62

Note: Totals may not sum due to independent rounding.

Harvested Wood Products

Most timber harvested from forest land in New York is used to produce HWPs, which include, for example, sawn wood used in housing construction and paper. HWPs sequester CO_2 for a duration that depends on the lifespan of the product and the rate at which it is converted back to CO_2 through decay in landfills or waste combustion.

Emission estimate methods for this section of the report were developed in conjunction with Robert Malmsheimer, HakSoo Ha, Timothy Volk, Tristan Brown, Danielle Kloster, Jenny Frank, Theodore Koch, Nehan Naim, and Obste Therasme (State University of New York, College of Environmental Science and Forestry) and the DEC Division of Lands and Forests Forest Utilization Program. Annual updates are provided by DEC Division of Lands and Forests Forest Utilization Program.

Methodology

The accounting approach taken includes carbon storage by sawtimber-based HWPs but does not include pulp logs used to produce paper or HWPs used to produce other products with shorter useful lives. Sourcing includes trees that are (1) grown in New York and consumed outside New York (NY/Out), (2) grown outside New York and consumed in New York (Out/NY), or (3) grown and consumed within NY (NY/NY). This approach captures out-of-state trees that are imported for use within New York, as well as trees that are grown within New York and exported for out-of-state use.

Mill survey data collected by DEC, known as the Timber Products Output (TPO) data, were used to estimate annual board feet of sawtimber-based HWPs used between 1999 and 2023, and were then converted to carbon storage. Trends from this data were extrapolated back through time to produce an estimate of the carbon stored in wood products harvested from 1990 to 1998, a period before the data collection program had started. This method converted board feet of lumber to carbon storage assuming a density (oven-dry mass / air-dry volume) of 0.56 metric tonnes per cubic meter for hardwood and 0.49 metric tonnes per cubic meter for softwood, and carbon fractions of 0.5 for both types of wood. Using this dataset as a proxy for HWPs may overestimate carbon storage in HWPs because conversion of sawtimber to HWPs is not complete and does not account for mill residuals that may be burned to produce energy. The dataset may underestimate carbon storage by non-lumber HWPs such as paper and cardboard that are produced from pulpwood and chips. Finally, this component of the report does not explicitly model the decay or combustion of HWPs in landfills and other solid waste facilities, although the solid waste sector analysis in *Sectoral Report #4: Waste* includes a decay model for organic carbon in landfills.

There may be other emissions associated with production of timber including from fertilizer application or the energy used to harvest, process, and transport the harvested materials. These emissions are captured in relevant agriculture and energy emission sectors. The impact of timber harvesting on carbon sequestration by forested lands is captured in the land use section below.

Results

Annual trends in CO_2 removal by HWP roughly correspond with those in new housing construction in the Northeast, peaking in 2001 at -1.97mmt CO_2, declining to a minimum of -1.17mmt CO_2 per year in 2009, recovering to an average of -1.57 from 2015 to 2018. Annual estimates can be reflective of mill survey response rates, which can by influenced by a number of factors including the COVID-19 pandemic.

Table SR3.9 Harvested Wood Products CO_2 Removals, 1990-2023 (mmt CO_2)

Origin/Destination	1990	2005	2019	2020	2021	2022	2023
NY/NY	-1.09	-1.21	-0.94	-0.92	-1.09	-1.05	-0.95
NY/Out	-0.42	-0.56	-0.26	-0.25	-0.25	-0.22	-0.24
Out/NY	-0.03	-0.09	-0.11	-0.16	-0.11	-0.04	-0.05
Net Emission Removals	**-1.54**	**-1.86**	**-1.31**	**-1.33**	**-1.45**	**-1.31**	**-1.24**

Note: Totals may not sum due to independent rounding.

Land Use

The analysis of net emission removals by land in New York included an assessment of both land use and land use change for each year between 1990 and 2023. The annual fluxes of greenhouse gases into and out of natural and managed lands depends mainly on the growth and decay of trees, plants, and other organisms that can remove CO_2 from the atmosphere and sequester it as organic carbon. Certain landscapes, such as forests, sequester and store more organic carbon per unit area than other lands.

The six categories of land use that were considered here are forest land, wetlands, cropland, grassland, settlement, and other lands, following the IPCC approach (IPCC 2019). Quantifying the net emission removals through land use and land use change requires accounting for the differences in carbon sequestration and greenhouse gas emissions per unit area among land use and surveying changes in the areal extent of land use categories. Land parcels that have remained under the same category of land use for 20 years or more are classified as forest remaining forest, grassland remaining grassland, cropland remaining cropland, etc. Lands that have been converted from one land use category to another within 20 years are classified based on their land use categories before and after conversion (e.g., cropland converted to forest, forest converted to grassland, etc.).

The EPA has made available net emissions and emission removals estimates for cropland, grassland, and settlements in New York from 1990 through 2023 (EPA 2025a and Table SR3.10). These estimates are now included along with emission removals by forest land and wetlands. This aligns this report with the IPCC's guidance that emissions or emission removals associated with land that remains under a particular land use category (e.g., forest land) should be added to emissions or emission removals associated with any conversions to that land use category (e.g., cropland to forest land, grassland to forest land, settlement to forest land, etc.).

Table SR3.10 Land Use Net Emissions and Emission Removals, 1990-2023 (mmt CO_2e GWP20)

Land Type	1990	2005	2019	2020	2021	2022	2023
Forest land	-40.40	-38.66	-37.66	-37.43	-37.21	-36.98	-36.76
Forest converted to other land	2.95	3.01	3.05	3.05	3.05	3.05	3.04
Wetlands	-0.84	-0.70	-0.82	-0.82	-0.82	-0.82	-0.82
Flooded land	2.57	2.56	2.48	2.48	2.48	2.48	2.48
Cropland	0.74	0.35	0.70	0.36	-0.12	-0.21	-0.19
Grassland	-0.34	-1.05	-0.33	-0.19	-0.25	-0.23	-0.23
Settlement	1.82	2.38	2.01	1.98	1.98	2.00	2.01
Settlement trees	-3.51	-3.89	-4.22	-4.25	-4.27	-4.29	-4.30
Net Emission Removals	**-32.88**	**-32.88**	**-32.88**	**-31.88**	**-30.88**	**-29.88**	**-28.88**

Note: Totals may not sum due to independent rounding.

Forest Lands

New York is among the most forested states in the nation with roughly 19 million acres of forest land, covering over 60% of the land area. This is in large part why lands in New York remove more CO_2e than they emit on an annual basis. Specifically, forest land that has remained forest land removes additional CO_2 as organic carbon every year, equivalent to -36.76mmt CO_2 in 2023 (Table SR3.11). The conversion of other land use categories to forest land removed an additional -1.46mmt CO_2 in 2023 because forest land removes more CO_2 per unit area than any other land-use category.

Box SR3.2: Land-Use: Carbon Flux vs Carbon Storage

The total carbon stock on a land parcel is typically comprised of its living tree and plant biomass, soil organic carbon, and leaf litter and dead wood. The annual net carbon flux associated with that parcel is the amount of change in the size of the total carbon stock on the parcel from one year to the next. Thus, the net carbon flux can be assessed over time by measuring the parcel's total carbon stock at regular and appropriate time intervals (e.g., annually, biennially, every 5 years, etc.) and dividing this 'stock change' or difference in total carbon stock measurements made at consecutive time points by the amount of time between those timepoints. A land parcel's carbon stocks will tend to get bigger over time if the parcel is experiencing a period of net CO_2 removal from the atmosphere (i.e., a net carbon flux from the atmosphere into the land). In contrast, a parcel's carbon stocks will tend to shrink over time if it is experiencing a period of net CO_2 emission to the atmosphere (i.e., a net carbon flux from the land into the atmosphere).

Land management decisions can have an immediate effect on the parcel's carbon stock size, while also changing the trajectory of its future carbon fluxes. Short-term management decisions may include conversions of the parcel from one land use type to another, while shifts in harvest regimes, such as from even-aged forest (trees all of similar age) to uneven-aged forests, exemplify long-term management decisions that impact stocks and fluxes. For example, if a forested parcel is cleared, the wood is removed, with grubbing and soil excavation followed by construction of buildings and parking lots, its total carbon stock decreases immediately as lost tree biomass and topsoil are converted to a CO_2 flux to the atmosphere. At the same time, the change in the parcel's land use status from forest to settlement impacts its future ability to remove and store carbon from the atmosphere for at least as long as its land use status remains changed. In particular, the annual net carbon flux from the atmosphere into the parcel's tree biomass will stop, as will the accretion of soil carbon typical of intact forest soils.

Other aspects of land management that do not change a parcel's land use status can still shape its current and future influence on climate. For example, over a forested parcel's life history, the relationship between its carbon stock and its net carbon flux may change naturally. A mature forest can maintain a large stock of carbon as tree biomass and soil organic carbon even while the annual net flux of carbon into the parcel is smaller than that of a younger, rapidly growing secondary forest that has a comparatively small standing carbon stock. Tree removals (e.g., through fires, disease, storms, and flooding or harvesting) can also reduce carbon stocks, converting tree biomass back to CO_2 if the wood burns or decays. Harnessing both the bigger carbon stocks in mature trees and the rapid growth and carbon accumulation of younger trees may be possible on the same parcel if harvested trees are converted to long-lived wood products (harvested wood products or HWPs), and then replaced through replanting younger trees and/or protecting natural regeneration. This strategy also requires accounting for any changes in the parcel's stock of soil organic carbon through harvest and replanting cycles.

Like forests, undisturbed wetlands tend to accumulate significant carbon stocks, typically as organic matter that is preserved slowly over time in anaerobic wetland soils[1]. Disturbances that reduce soil inundation by lowering the water table or otherwise exposing wetland soils to the air trigger the decay of these stocks back to atmospheric CO_2. Historically, this type of land use conversion characterizes agricultural land used to grow onions and other crops that require organic-rich, drained soils (histosols). Organic carbon decaying to CO_2 in drained histosols constitutes an important flux of carbon to the atmosphere that can shrink the local stock of soil organic carbon. Once lost, these reserves may not be replaceable because they need both time[2] and functioning wetland hydrology in order to accumulate.[3] Carbon stocks in forested wetlands are particularly important given their capacity to store carbon as tree biomass and soil organic carbon[4]. Statewide mapping of forested wetlands is challenging because tree canopies can block satellite imaging, and these wetlands can be small and far from visible surface water.[4] Ongoing Department-funded research at the Holgerson Lab at Cornell University's College of Agriculture and Life Sciences and the NYS Natural Heritage Program, is using machine learning to convert digital soil maps, aerial lidar data and digital elevation models, and satellite imaging to generate wetland probability maps for the entire state. Once validated, these maps will be incorporated into the annual GHG inventory and updated regularly as new datasets become available.

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Methodology

This report uses state data from the EPA and U.S. Forest Service (Forest Service) on annual forest CO_2e emissions and sequestration (Domke et al. 2023; EPA 2024a; Walters et al. 2024). Additional input on this analysis was received from Colin Beier (State University of New York, College of Environmental Science and Forestry) as part of ongoing work (see the Planned Improvements section). The annual Forest Service analysis assesses the sequestration of CO_2 as organic carbon in five reservoirs: aboveground biomass, belowground biomass, dead wood, litter, and soil organic carbon. The rate of change in the organic carbon density of these reservoirs is assessed by sampling specific field plots over time and measuring biomass, dead wood, and litter. Soil organic carbon is modeled using latitude, elevation, precipitation, temperature, and moisture index data (Domke et al. 2017) as well as remote sensing information from the National Agriculture Imagery Program. The assessment implicitly incorporates any losses of organic carbon density and CO_2 emissions from fires, forest cutting, insects, disease, and weather events (Coulston et al. 2015). The impact of land use change on forest land is evaluated using measured annual rates of transitions among cropland, grassland, settlement, forest land, wetlands, and other land use categories. Observed conversions of field plots from one land use category to another are used to quantify the impact of the conversions on organic carbon stocks in the absence of other data. Conversions of forest to cropland or grassland include changes in soil organic carbon stocks, aboveground and belowground biomass, dead wood, and litter carbon stocks. 'Forest land converted to other land' is currently an orphan land use conversion type that is estimated by the U.S. Forest Service and will be combined into an 'other land' use category when a complete estimate becomes available. Trees located in settlements that remain settlements are reported as "settlement trees." The Forest Inventory and Analysis (FIA) program published a new model in 2023 for predicting tree cubic-foot volume, biomass, and carbon attributes. This National Scale Volume and Biomass (NSVB) Estimators system provides a more consistent and accurate accounting of structural components of trees across the U.S. for total tree cubic-foot volume, biomass, and carbon (Westfall et al. 2024). The new model has informed the FIA data used in this report, and thus the current report reflects these changes in forested lands, land conversions, land use, and settlement trees.

This year's report includes data from the U.S. Department of Agriculture (USDA) National Resources Inventory (NRI) data through 2017, data from the USDA-Natural Resources Conservation Service (NRCS) Conservation Effects Assessment Program (CEAP) survey data for 2013 to 2016, as well as cover crop and tillage management information from the OpTIS remote-sensing data product from 2008 to 2020 (EPA 2024a). Land representation estimates were recalculated from updated FIA data from 1990-2023, NRI data from 1990-2017, and NLCD data from 2001-2019. Updates to the FIA also reflect multiple years of new data resulting from delays because of the COVID-19 pandemic (EPA 2025b). Several changes in the FIA methodologies included reclassification of pastureland as grassland and classifying all water bodies as wetlands to more closely align with NRI data.

Updated FIA data and adjustments to the NSVB methods have been fully implemented in forest lands, with increases to understory aboveground biomass, understory belowground biomass, and, most significantly, downed dead wood in this report (EPA 2025b). Additionally, this report includes estimates of perennial woody biomass and perennial crop biomass carbon stock changes and biomass carbon stock changes from croplands and lands converted to and from croplands, which were not included in previous national GHG inventories (EPA 2025b). Updates in this report are implemented consistently across the previous report's time series (i.e. 1990 to 2022) to ensure that the trend is accurate, and past year's data have also been updated and reflect these changes.

Table SR3.10 "Flooded Lands" data shows a significant change from the previous year's report. In addition to updated NID data, this reflects an error in last year's report, which has been corrected and updated with the above-mentioned recalculations across the timeseries. The previous year's (2024) report should have reported an additional 1.00mmt CO_2e throughout the timeseries. Thus, this year's report shows an increase of more than 2.00mmt CO_2e across the time series compared to last year.

Achieving a wall-to-wall assessment of carbon sequestration and emissions by the different land use categories will require additional work to reconcile the area considered "forest" according to the Forest Service's inventory, and the areas that may be mapped as forest by satellite-based land-cover products (such as those used to assess wetlands in this report). The land use definition of forest land that is used here may include some harvested areas that are replanted or left to regenerate and forested areas that lose biomass through forest fires or other disturbances. Land-cover maps may classify these areas into categories other than forest (Coulston et al. 2015), causing overlaps in coverage. Furthermore, some forested areas that do not meet the Forest Service's definition of forest are not counted in this report, including areas that are too small (less than 120 feet wide and 1 acre in area with at least 10% cover; Oswalt et al. 2019) and agroforestry systems (EPA 2025b). Forests found in settlement areas, such as municipal parks, are not counted as forests as defined by the forest service; however, settlement trees are included in the National GHG Report as well as this Inventory as "Settlement Trees" and "Urban Trees," respectively.

A subset of land defined as forest land in the Forest Service's inventory is also wetland. These lands were excluded from the wetlands component of this report to avoid double-counting (an average of -3.94mmt CO_2 sequestered per year from 1990 to 2023). However, forested wetlands also have the potential to produce CH_4 and N_2O emissions as well as sequester CO_2. The Forest Service inventory does not currently include these emissions, so they are also omitted in the forest land estimates in this report, but they are discussed in the wetlands section (below).

Results

Previous reports included flux from land use conversions to agriculture, settlement, and other lands as part of forest land carbon loss. As an example, forested land converted to cropland would be reported as a net loss from forest land use change. For this report, forest land conversions are reported with the specific land use categories that defines their use post-conversion. Most net emission removals in 2023 were by forest land that remained forest land, but approximately -1.46mmt CO_2 was also removed through the conversion of cropland, grassland, settlements, wetlands, and other lands to forest land. However, emission removals by conversions to forest land were more than offset by emissions, over 3.04mmt CO_2 annually, from forest land converted to other land use categories. Finally, emissions of CH_4 and N_2O from forest fires were estimated and reported by the Forest Service and are accounted for in the net emission removals attributed to forest land (Walters et al. 2024).

Table SR3.11 Forest Net Emissions and Emission Removals, 1990-2023 (mmt CO_2e GWP20)

Land Use Change	1990	2005	2019	2020	2021	2022	2023
Forest Remaining Forest	-38.90	-38.66	-37.66	-37.43	-37.21	-36.98	-36.76
Land Converted to Forest	-1.50	-1.48	-1.46	-1.46	-1.46	-1.46	-1.46
Forest Converted to Land	2.95	3.01	3.05	3.05	3.05	3.05	3.04
Forest Fire	nd	+	nd	+	+	+	+
Net Emission Removals	**-37.45**	**-37.14**	**-36.07**	**-35.84**	**-35.62**	**-35.39**	**-35.18**

"nd" no data; "+" positive values less than 0.01mmt

Forest Land Remaining Forest Land

Forest land remaining forest land sequesters far more CO_2 than any other land use category; −38.66mmt CO_2 was sequestered in 2005 and -36.76mmt CO_2 was sequestered in 2023. The declining trend in annual CO_2 sequestration is due in part to the conversion of forest land to other land use categories. Future reports may include an assessment of the impact of interannual changes in the rate at which forest land that remains forest land sequesters CO_2 and stores it as organic carbon.

Land Converted to Forest Land

Cropland conversion to forest land sequestered an average of -0.57mmt CO_2 per year from 2005 to 2023. Settlement conversions to forest land sequestered an average of -0.62mmt CO_2 per year from 2005 to 2023. Wetlands converted to forest land sequestered an average of --0.11mmt CO_2 per year from 2005 to 2023. Other lands converted to forest land sequestered -0.16mmt CO_2 per year from 2005 to 2023. Grassland converted to forest sequestered an average of -0.01mmt CO_2 per year from 2005 to 2023.

Forest Land Converted to Land

Conversion of forest land to cropland resulted in an average of 0.98mmt CO_2 emitted per year between 2005 and 2023. Conversion to settlements resulted in an average of 1.81mmt CO_2 emitted per year between 2005 and 2023. Smaller emissions were caused by conversion to wetlands (an average of 0.47mmt CO_2 emitted per year between 2005 and 2023), grasslands (an average of 0.18mmt CO2 emitted per year between 2005 and 2023) and other lands (an average of 3.04mmt CO_2 emitted per year between 2005 and 2023).

Wetlands, Water Bodies, and Flooded Land

Emissions and emission removals attributed to wetlands and CH_4 emissions from other water bodies are reported here along with EPA's estimates of CO_2 and CH_4 emissions from land flooded as a direct result of human interventions such as dam and pond construction (EPA 2025b). Wetlands contribute most of the emissions and emission removals estimates in this section. Wetlands, like forest land, sequester CO_2 and store it as organic carbon in plant biomass and soils, storing 30% of global soil organic carbon (SOC) within six percent of the land surface (Stewart et al. 2024 and references therein). Unlike forest land, whose area is estimated by the Forest Service according to a land use definition, the areal extent of wetlands is estimated here using land cover observations (see Box SR3.2). All New York wetlands are inventoried here, even those that do not directly undergo management activities, such as peat harvesting. New York has both coastal wetlands, which are exposed to tidal cycles and are often adapted to brackish and saltwater inundation, and upland wetlands, which are not tidal and whose soils are saturated with freshwater.

Vegetated wetlands are particularly effective at sequestering CO_2 as organic carbon and storing it in their soils. This is because water-saturated soils tend to be low-oxygen soils, and oxygen scarcity slows the rate of decay that would normally convert organic carbon back into CO_2 (IPCC 2014). Wetland soils can also be important sources of CH_4 and N_2O. Freshwater wetlands are an important source of CH_4 whereas CH_4 production is suppressed in tidal wetlands that are inundated by brackish and salt water above a certain salinity threshold (Holmquist et al 2018; IPCC 2014). CH_4 emissions from freshwater wetlands are provided for informational purposes and are not included in net totals. N_2O production may occur in either type of wetland and is stimulated by the discharge of nitrogen (e.g., nitrate and ammonium) from the watershed, as well as atmospheric deposition of nitrogen compounds generated by fossil fuel combustion or volatilized when nitrogen fertilizers are applied to soil.

Methodology

The distinction between wetlands that are inundated by freshwater versus brackish to saltwater is made here using land-cover maps from satellite images that are produced by the Coastal Change Analysis Program (C-CAP) within NOAA. These maps classify wetlands as either estuarine or palustrine, where palustrine wetlands are inundated by water with a nominal salinity that is less than 0.5 parts per thousand (ppt). Estuarine wetlands are assumed to produce no CH_4, whereas the emission factor for CH_4 from palustrine wetlands is assumed to be 157 kg CH_4 per hectare per year (see Section 4.3.1.2 and Annex 3A.3 in IPCC 2014). The CCAP maps further classify estuarine and palustrine wetlands as forested, scrub and shrub, or emergent vegetation, for a total of six wetlands land-cover categories. Annual changes in the areal extent of the six wetlands categories were estimated by comparing consecutive updates of the CCAP land-cover maps. Beginning in 1996, the maps have been issued approximately every 5 years, with the most recent update issued in 2016. The areas of wetlands that remain wetlands as well as conversions of other land-cover types to and from wetlands has been interpolated to cover years between map updates. After 2016, wetland areas have been held constant and will be updated with appropriate interpolations once the next CCAP land-cover classification map is made available.

Wetland carbon sequestration is assessed by the following organic carbon reservoirs: soil carbon and aboveground and belowground biomass. Annual CO_2 fluxes into soil carbon are geometric means of soil and sediment core measurements made using lead-210 and retrieved from publications and public databases by the Smithsonian's Environmental Research Center.[1] The carbon sequestration by aboveground biomass and belowground biomass are the same values used in the national GHG inventory (EPA 2025b). Aboveground wetland biomass is

[1] https://github.com/Smithsonian/Coastal-Wetland-NGGI-Data-Public

assumed to sequester -3.05 to -3.17mt of carbon per hectare per year. Belowground biomass sequesters -6.44 to -6.54mt carbon per hectare per year in estuarine wetlands, and -3.57 to -3.65mt carbon per hectare per year in palustrine wetlands. For conversions of other land-cover types to and from wetlands, the impact of biomass in the other land-cover types is captured here but changes in CO_2 sequestration in soil carbon or soil carbon stock changes are not captured.

Areas that are classified as palustrine forested wetlands in the CCAP land-cover maps are assumed to have been counted as forest land in the Forest Service's national inventory report data (Domke et al. 2023, Walters et al. 2024). Therefore, they have not been included in the CO_2 sequestration calculations for palustrine wetlands, but their CH_4 emissions are included here. No land areas classified as estuarine forested wetlands by CCAP are included in the Forest Service's inventory because data are needed to quantify the impacts of forestry activity on soil carbon stocks in forested coastal wetlands (Crooks et al. 2018, Lisa Schile-Beers personal communication). Therefore, these areas are included in calculations of CO_2 sequestration by estuarine wetlands. The CCAP maps also resolve 19 other land-cover classes that are grouped to approximate the other five IPCC land use categories in order to quantify conversions of wetlands to and from other types of land cover (IPCC 2019).

Seagrass is included in the calculation of CO_2 sequestration by estuarine wetlands. The areal extent of seagrass in NY waters is assumed to reflect a value reported in the 2009 Final Report of the New York State Seagrass Task Force.[2] In the absence of regular, state-wide survey data, this area is held constant from 1990 to 2023 and multiplied by the seagrass soil carbon sequestration fluxes reported by Salinas et al. (2020).

The USGS National Hydrography Dataset (NHD) maps (USGS 2016) were used to estimate CH_4 emissions from lakes, ponds, and other water bodies in New York. The water bodies were grouped into 7 size classes (<0.001 km^2 to >100 km^2) and their areas multiplied by the size-specific CO_2 and CH_4 emission fluxes according to Holgerson and Raymond (2016). Emissions from water bodies that cross state boundaries (Lake Erie, Lake Ontario, Lake Champlain, and the Allegheny Reservoir) are scaled to the proportions of the water bodies' total areas that fall within the state's political boundaries. Mapped stream and river features are not included in this estimate pending further method development. There is a small amount of overlap between water bodies mapped in the NHD and the emergent wetland areas mapped by CCAP. There are also areas of open water mapped by CCAP that are not mapped by NHD. Additional work is necessary to determine the extent and impact of these coverage differences between the two data sets. Emission factors for CH_4 ranged from 3.5 to 133.5kg CH4 per hectare per year for water bodies with areas greater than 100 km^2 to water bodies with areas smaller than 0.001 km^2, respectively (Holgerson and Raymond 2016). CO_2 emissions were not estimated to avoid double counting CO_2 derived from organic carbon sourced from other land use categories.

The EPA's state estimates of CH_4 and CO_2 emissions from land flooded as a result of direct human interventions includes reservoirs, canals and ditches, constructed freshwater ponds, and

[2] https://www.dec.ny.gov/docs/fish_marine_pdf/finalseagrassreport.pdf

inundation areas (EPA 2025b and 2024b; IPCC 2019). The emissions calculations distinguish between land that has been flooded for more than 20 years (flooded land remaining flooded land) and land that has been flooded for less than 20 years (land converted to flooded land) because emission factors are higher for recently flooded land. Flooded land was identified and areas estimated using NHD maps, the National Lakes Assessment (EPA 2024b), the National Inventory of Dams (USACE 2021), and the Navigable Waterways dataset (DHS 2023). All of these sources are updated regularly, with all updates incorporated and reflected in the full time series from 1990-2023 (EPA 2025b). Additionally, the EPA began using data from the Safe Drinking Water Information System (SDWIS) in the most recent national inventory (EPA 2025b, or for 1990-2023). The assumption is that any waterbody used as a public drinking water source is managed in some capacity by flow and/or volume control. Note that there may be overlap in the emissions estimated for water bodies, which include reservoirs and ponds, and the subset of reservoirs and ponds that are considered flooded land by the EPA. CO_2 emissions were not estimated for flooded land remaining flooded land to avoid double counting CO_2 derived from organic carbon sourced from other land use categories. The same surface emission factor of 183kg CH_4 per hectare per year was applied to all constructed freshwater ponds, regardless of their age. The highest CH_4 emission factor (416kg CH_4 per hectare per year) was applied to canals and ditches (IPCC 2019).

Results

The wetland category is broken into four types of land use and land use change (Table SR3.12). Palustrine wetlands were responsible for 94% of gross annual removals by wetlands in 2023. However, this accounting does not include CH_4 emissions from palustrine wetlands (Table SR3.13).

Table SR3.12 Wetland Net CO_2 Removals, 1990-2023 (mmt CO_2)

Land Use Change	1990	2005	2019	2020	2021	2022	2023
Estuarine Wetlands Remaining Estuarine Wetlands	-0.09	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
Palustrine Wetlands Remaining Palustrine Wetlands	-1.18	-1.13	-1.22	-1.22	-1.22	-1.22	-1.22
Land Converted to Wetlands	0.43	0.46	0.48	0.48	0.48	0.48	0.48
Wetlands Converted to Water	Nd	0.06	nd	nd	nd	nd	nd
Net Emission Removals	**-0.84**	**-0.70**	**-0.82**	**-0.82**	**-0.82**	**-0.82**	**-0.82**

“nd” no data

Wetlands Remaining Wetlands

Palustrine wetlands sequester more CO_2 (-1.22mmt CO_2 in 2023) than estuarine wetlands (-0.08mmt CO_2 in 2023), mainly because palustrine wetlands occupy more land in New York. Forested palustrine wetlands sequester more CO_2 than any other type of wetlands (-1.22mmt CO_2 in 2023) due to their larger area and capacity to form biomass. However, to avoid double counting, these removals are not included in the net emission removals by wetlands in Table SR3.12 because they are included in the forest land areas contributing net emission removals in Table SR3.11. Estuarine wetlands include -0.02mmt CO_2 sequestered per year as soil carbon accumulated by seagrass meadows in NY waters and -0.06mmt CO_2 sequestered per year by estuarine wetlands as biomass and soil carbon, for a total of -0.08mmt CO_2 (Table SR3.12). Estimated CH_4 emissions from palustrine wetlands and water bodies are 0.14mmt CH_4 per year (11.99mmt CO_2e) and 0.007mmt CH_4 (0.63mmt CO_2e) per year, respectively (Table SR3.13). Forested palustrine wetlands contribute 0.11mmt CH_4 (9.14mmt CO_2e) per year to the palustrine wetlands total, and this is reported here because the Forest Service does not currently include this CH_4 source in its forest inventory (Grant Domke, personal communication). The CH_4 emissions reported in this section are for informational purposes only, as discussed above.

Wetlands Converted to Water

Sea level rise, coastal subsidence and erosion can convert vegetated coastal wetlands to open water. When this happens, some of the organic carbon stored in wetland biomass and soil can be converted back to CO_2. Catastrophic coastal erosion can cause the release of many years of accumulated soil carbon stock (Crooks et al. 2018, Holmquist et al. 2018). In New York, conversion of wetlands to water resulted in the emission of 0.06mmt CO_2 per year between 2002 and 2010 but were less than 0.01mmt CO_2 per year from 1990 to 2001 and from 2011 to 2023.

Lands Converted to Wetlands

Conversion of forest land to wetlands emitted 0.49mmt CO_2 in 2022 (Walters et al. 2024). Because of a lack of data for 2023, the value from 2022 was carried forward. Conversion of other lands to wetlands contributed an average of 200 metric tons of CO_2 per year from 1990 to 2023.

Excluded Wetland Emissions

As indicated in the introduction to this report, this assessment omits CH_4 emissions by freshwater wetlands and water bodies (Table SR3.14) from total net removals by wetlands. If these emissions were included, they would be subtracted from net emission removals attributed to the land use categories above (Table SR3.13). These estimates are also preliminary, and these emissions are not included in the national GHG inventory (EPA 2025b).

Table SR3.13 Excluded Wetland CH_4 Emissions, 1990-2023 (mmt CO_2e GWP20)
Informational Purposes Only

Emission Source	1990	2005	2019	2020	2021	2022	2023
Palustrine Wetlands	12.05	11.95	11.99	11.99	11.99	11.99	11.99
Water Bodies	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Excluded Net Emissions	**12.68**	**12.58**	**12.62**	**12.62**	**12.62**	**12.62**	**12.62**

Flooded Land

Emissions of CO_2 and CH_4 from land flooded through direct human intervention are included in total net emissions (Table SR3.14). These estimates are included in the national GHG inventory (EPA 2025b) and the net emissions of this report. Nearly all emissions were CH_4 (2.51mmt CH_4 in 2023) and reservoirs were responsible for most of the emissions (61% in 2023).

Table SR3.14 Flooded Land Emissions, 1990-2023 (mmt CO_2e)

Type	1990	2005	2019	2020	2021	2022	2023
CH_4	**2.51**	**2.51**	**2.48**	**2.52**	**2.51**	**2.51**	**2.51**
Reservoirs	1.55	1.55	1.52	1.55	1.55	1.55	1.55
Constructed Ponds	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Canals and Ditches	0.31	0.31	0.31	0.31	0.31	0.31	0.31
CO_2	**0.05**	**0.05**	**0.00**	**0.05**	**0.05**	**0.05**	**0.05**
Reservoirs	0.05	0.05	0.00	0.05	0.05	0.05	0.05
Constructed Ponds	+	+	+	+	+	+	+
Net Emissions	**2.57**	**2.56**	**2.48**	**2.57**	**2.57**	**2.57**	**2.56**

"+" positive values less than 0.01mmt

Cropland and Grassland

Cropland, grassland, and settlement areas are defined using the USDA's National Resources Inventory (NRI) (USDA 2020b) and the National Land Cover Dataset (USGS 2000). Land converted to cropland includes all cropland that was in another land use category within the previous 20 years. The same timeframe applies to land converted to grassland. Estimates of annual CO_2 sequestration in soil organic carbon on cropland remaining cropland and land converted to cropland were made based on soil organic carbon stock changes modeled with the Daycent biogeochemical model (EPA 2025b). Stock changes in biomass, litter and dead organic matter on cropland are not counted but are included for other land use categories (e.g., forest land) that are converted to cropland. Emissions resulting from land converted to cropland more than offset the annual CO_2 sequestration by the soil of cropland remaining cropland (Table SR3.15). Conversions of land to cropland dominated these emissions, averaging 0.97mmt CO_2 per year from 2005 to 2023 (Walters et al. 2024, EPA 2025b).

Table SR3.15 Cropland, Grassland, and Settlement Net Emissions and Removals, 1990-2023 (mmt CO_2)

Land Use Change	1990	2005	2019	2020	2021	2022	2023
Cropland Remaining Cropland	-0.32	-0.57	-0.34	-0.68	-1.14	-1.23	-1.22
Land Converted to Cropland	1.06	0.92	1.04	1.04	1.02	1.02	1.03
Grassland Remaining Grassland	-0.32	-0.49	-0.10	-0.03	-0.02	-0.02	-0.01
Land Converted to Grassland	-0.02	-0.56	-0.23	-0.16	-0.23	-0.21	-0.22
Settlement Remaining Settlement	0.31	0.32	0.42	0.43	0.44	0.45	0.46
Land Converted to Settlement	1.51	2.07	1.59	1.55	1.54	1.54	1.55

Settlement Trees	-3.51		-3.89		-4.22	-4.25	-4.27	-4.29	-4.30
Net Emission Removals	**-1.29**		**-2.21**		**-1.84**	**-2.10**	**-2.66**	**-2.74**	**-2.72**

"-" negative values greater than 0.01mmt

Settlements

Settlement trees are located in settlement lands and other land use categories that are converted to settlements. They contributed a significant amount to annual carbon sequestration (-4.30mmt CO_2 in 2023). However, conversion of forest land to settlements is also a large source of CO_2 as stored forest carbon is released to the atmosphere (1.55mmt CO_2 in 2023 and an average of 1.81mmt CO_2 per year since 2005 (EPA 2025b)). Emissions associated with settlements remaining settlements are produced by organic soils in these areas, which are assumed to emit CO_2 at a similar rate to cropland on drained organic soil (EPA 2025b).

Planned Improvements

Improvements to the AFOLU sectoral report are ongoing. Like the “key categories” prioritized by the IPCC, certain areas of improvement will be prioritized here because they are expected to have a significant influence on statewide emission calculations.

Forest Lands, Settlement Trees, and Harvested Wood Products

Future reports may incorporate forest land-cover maps based on satellite images that are available from the National Land Cover Dataset (NLCD). The NLCD land-cover maps incorporate CCAP land-cover data and should therefore reduce any overlap or gaps that currently exist between the inventoried forest land and mapped wetlands land cover. LiDAR data may be used when and where they are available to estimate aboveground biomass in forest land. Comparisons between LiDAR-based biomass estimates and the Forest Service’s field plot measurements may be used to extrapolate coverage.

Expanded collection of survey data from sawtimber producers and manufacturing data for other wood products (for example, paper and particle board), as well as analyses of recent historical trends may be incorporated into future inventories. Product-specific models of emissions as HWPs decay in landfills may also be developed to account for the impact that these products have once they have exceeded their useful lives.

Soil Organic Carbon

Future inventories may incorporate calculations for soil organic carbon emissions from agricultural mineral soils and drained Histosols based on the IPCC (2019) to have a more consistent and localized estimation of SOC emissions than is currently utilized from national data.

Croplands and Grasslands

Future work will specify how soil carbon stock changes are affected by tillage, crop types, and crop residue management practices, either in Daycent model results or by using literature-based or IPCC-recommended factors (IPCC 2019).

Wetlands and Other Water Bodies

Improvements to the wetland CH_4 emission factors and CO_2 removal estimates are planned for future inventories. Field research undertaken this year and over the next three years by Meredith Holgerson (Cornell University, College of Agriculture and Life Sciences) will directly measure CH_4 emission factors that are specific to the state’s freshwater wetland ecosystem types. These will be paired with field measurements of CO_2 sequestration in wetland soils and sediment organic carbon to replace estimates made using IPCC default emission factors. Other planned improvements include revising the spatial boundaries that separate wetlands that emit CH_4 from those that do not using regional salt water interface maps. Although the IPCC default threshold is 18 ppt (Section 4.3.1.2 in IPCC 2014), a salinity threshold of 0.5 ppt is incorporated into the CCAP land-cover maps used here. The lower salinity threshold means that this report does not capture any CH_4 emissions from wetlands inundated by water with a salinity higher than 0.5 ppt. Holmquist et al. (2018) provide probability distributions of wetland CH_4 emission across salinity gradients that can then be paired with salinity maps to improve emissions estimates. Finally, constructed ponds, such as farm ponds, are like wetlands in that they potentially sequester CO_2 as organic carbon in sediment and also emit CH_4. Additional work undertaken through the Cornell University project will measure CO_2 and CH_4 emissions and CO_2 sequestration at a range of different constructed ponds. The goal is to identify the net contribution of their GHG emissions and removals and the impacts of different land use and soil management regimes on this contribution.

Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
CCAP	NOAA Coastal Change Analysis Program
CH_4	Methane
CLCPA	NYS Climate Leadership and Community Protection Act
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DEC	NYS Department of Environmental Conservation
DHS	U.S. Department of Homeland Security
DMI	Dry matter intake
ECL	Environmental Conservation Law
EPA	U.S. Environmental Protection Agency
FIA	Forest Inventory and Analysis
GHG	Greenhouse gas
GWP	Global Warming Potential
GWP100	100-Year Global Warming Potential
GWP20	20-Year Global Warming Potential
HWP	Harvested wood product
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
MMS	Manure Management System
mmt	Million metric tons
mt	Metric tons
N	Nitrogen
N_2O	Nitrous oxide
NA	Not applicable
NAIP	USDA National Agriculture Imagery Program
NASS	USDA National Agriculture Statistics Service
NE	Not estimated
NFI	National forest inventory
NH_3	Ammonia
NHD	USGS National Hydrography Dataset
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen oxides
NRI	National Resources Inventory
NYCRS	New York State Crop Reporting Service
NYCRR	New York Codes, Rules and Regulations

ppt	Parts per thousand
SIT	EPA State Inventory Tool
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey

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