Agricultural Greenhouse Gas Emissions in Ontario: A Comprehensive Assessment

National Farmers Union, December 2023

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Suggested citation: John Mills, Darrin Qualman, and National Farmers Union, *Agricultural Greenhouse Gas Emissions in Ontario: A Comprehensive Assessment* (Saskatoon: NFU, December 2023).

For more NFU analysis and an exploration of emission-reduction solutions, please see:

- *Agricultural Greenhouse Gas Emissions in Canada: A New, Comprehensive Assessment*, Third Edition, 2023
- *Tackling the Farm Crisis and the Climate Crisis*, 2019, and
- *Imagine If.... A Vision of a Near-Zero-Emission Farm and Food System for Canada*, 2021.

All are available at www.nfu.ca

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Introduction

This report presents a single detailed picture of nearly all sources of greenhouse gas (GHG) emissions from Ontario agricultural production and production of associated farm inputs. See Figure 1. Ontario has the most farmers of any province and makes up almost 20% of Canada's GHG emissions from agriculture. Thus, a comprehensive, fine-grained picture of agricultural emissions in Ontario is crucial to farmers' and policymakers' efforts to reduce emissions from Canadian agriculture as a whole.

This report builds on previous work by the NFU to compile comprehensive information on greenhouse gas emissions from Canadian agriculture.[1] Please refer to the most recent edition of those reports for a more detailed description of each category of emissions as well as methodological notes and data sources.

Canada has committed to reduce economy-wide GHG emissions by at least 40 percent by 2030 and to reach net zero by 2050. Specific to agriculture, the federal government has committed to work with farmers and industry to reduce emissions from fertilizer use to 30 percent below 2020 levels by 2030[2] and to reduce methane emissions from livestock production as part of Canada's larger pledge to reduce *overall* methane emissions to 75 percent below 2012 levels by 2030.[3] Big changes are coming, fast, for every sector of the Canadian economy, including farming.

To properly plan and implement the many on-farm changes needed to achieve emissions reductions and to design and fund the government programs needed to accelerate and *support* those on-farm changes, farmers and policymakers need to understand emissions: we need detailed, comprehensive numbers. In almost all cases, however, the data is presented in incomplete and inadequately detailed formats. Many analyses omit key emission sources such as farm fuel use or input production. Clear, accessible, *complete* analyses and graphs are often lacking. This report is a contribution to filling that gap.

Many current analyses omit key agricultural emissions data because they are based on categorization schemes stipulated by the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) or UN Framework Convention on Climate Change (UNFCCC)—categorizations that lead to a reporting of only a subset of agricultural emissions, most often including those from:

1. livestock enteric fermentation, i.e., digestion of grass and forage (methane, CH_4);
2. manure management (methane, CH_4, and nitrous oxide, N_2O);
3. agricultural soils, including emissions triggered by the addition of synthetic nitrogen fertilizer and manure (nitrous oxide, N_2O);
4. burning of crop residues (methane, CH_4, and nitrous oxide, N_2O, but not carbon dioxide, CO_2); and
5. urea fertilizer, other carbon-containing fertilizers, and lime (carbon dioxide, CO_2).

IPCC/UNFCCC-based reporting categorizes emissions from the production of machinery and fertilizer under "industrial processes and product use," not agriculture. Emissions from farm fuel and electricity use are reported under the categories "transport" and "energy," respectively. To form the basis for planning on-farm emission-reduction measures or government policies or programs, more detailed and complete assessments are needed. Such assessments are presented on the next page.

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1 Darrin Qualman and National Farmers Union, "Agricultural Greenhouse Gas Emissions in Canada: A New, Comprehensive Assessment," Third Edition, August 2023.

2 Environment and Climate Change Canada, "A Healthy Environment and a Healthy Economy: Canada's Strengthened Climate Plan to Create Jobs and Support People, Communities and the Planet" (Ottawa: ECCC, December 2020), https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-plan/healthy_environment_healthy_economy_plan.pdf.

3 Environment and Climate Change Canada, "Canada to Launch Consultations on New Climate Commitments This Month, Establish Emissions Reduction Plan by the End of March 2022," news releases, December 3, 2021, https://www.canada.ca/en/environment-climate-change/news/2021/12/canada-to-launch-consultations-on-new-climate-commitments-this-month-establish-emissions-reduction-plan-by-the-end-of-march-2022.html.

Part 1. A comprehensive, detailed picture of agricultural GHG emissions

Figure 1, below, presents a comprehensive picture of Ontario agricultural emissions and soil-atmosphere fluxes.

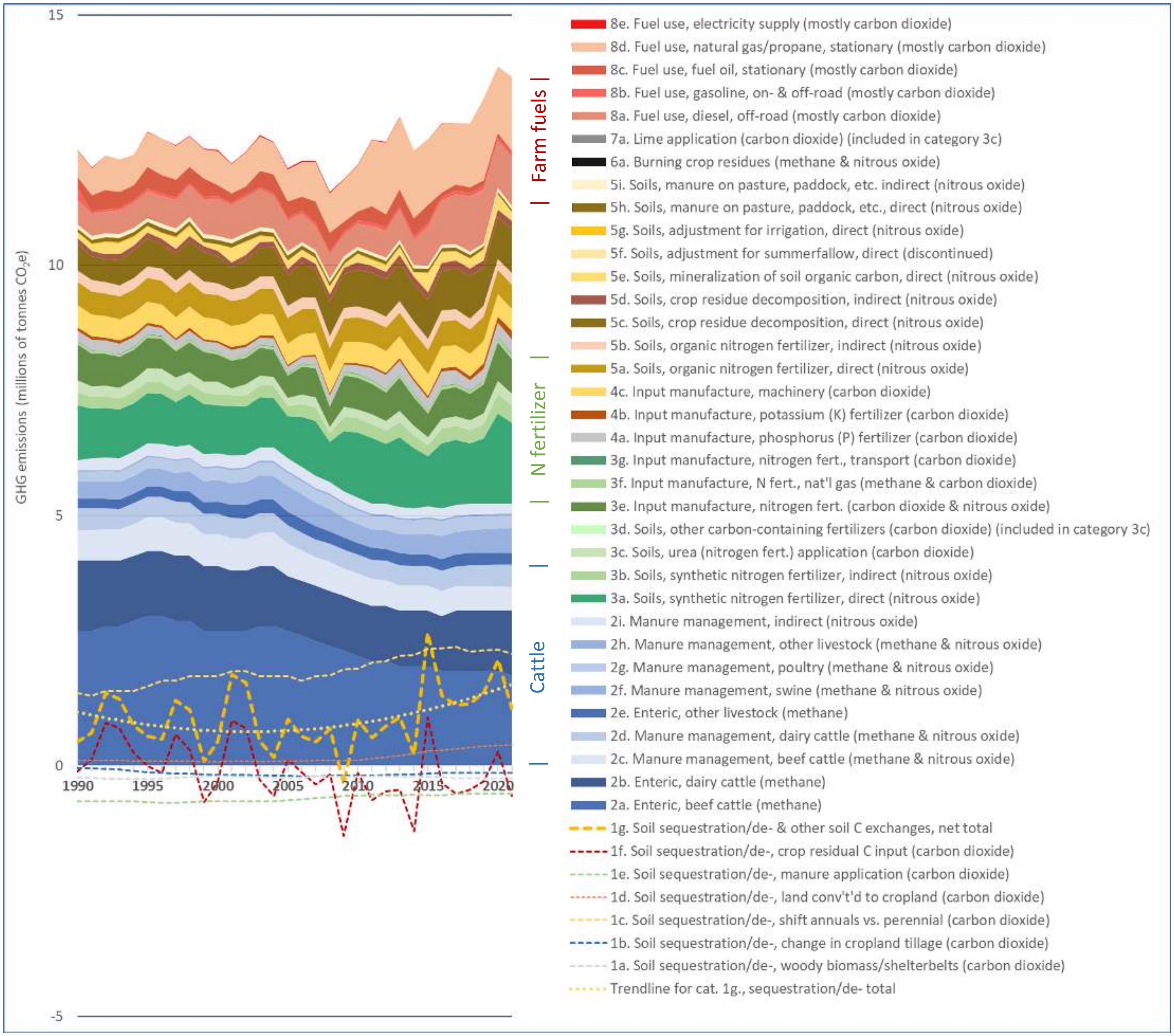

Figure 1. Comprehensive, detailed picture of Ontario agricultural emissions and fluxes, 1990–2021
Sources: Data provided by ECCC upon request corresponding to National Inventory Report 1990–2021, Part 1, Tables 5-1, 6-1, and 6-9; Additional data and sub-categorizations of published data provided by ECCC upon request; Data from Dyer et al.; other sources; and NFU own calculations. The vast majority of categories are based on ECCC NIR data.

Note that in the graph (Figure 1) and other parts of this report we use the term “soil sequestration/de-” to refer to categories that can include sequestration (atmospheric CO_2 captured as soil carbon) and the reverse: *desequestration* (soil carbon released as atmospheric CO_2). A key concept is that this is a *reversible* process: soils can sequester carbon for a time and then changes in farming practices or land use or even climatic conditions (e.g., hotter, drier weather) can cause those soils to release/desequester carbon and later another change can cause them to again sequester, and so on and so on.

Figure 2, below, provides a comparison of agricultural emissions and soil-atmosphere fluxes between Ontario (left) and Canada as a whole (right). The legend is the same as for Figure 1, above.

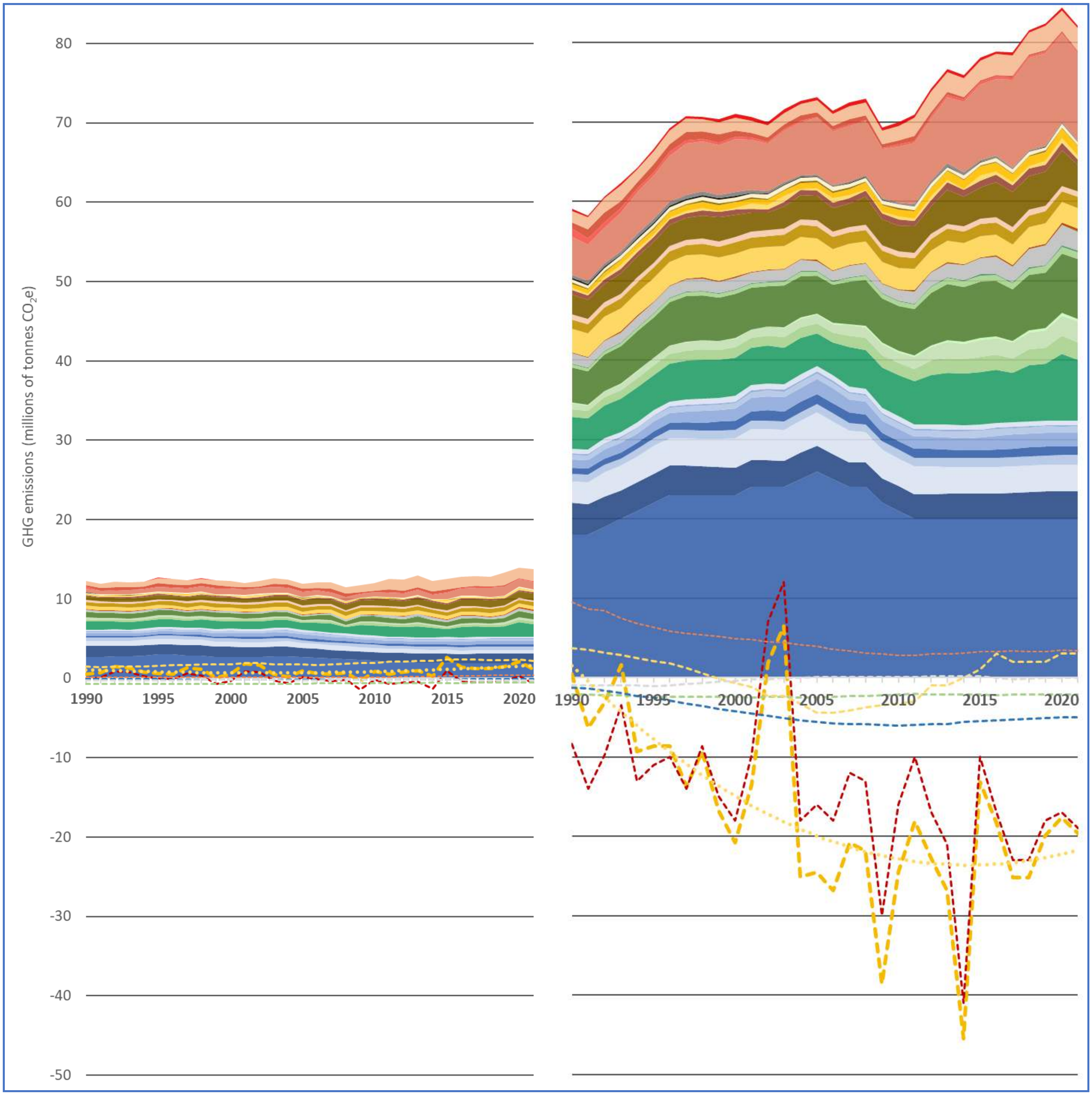

Figure 2. Comparison of Ontario (left) and Canadian (right) agricultural emissions and fluxes, 1990–2021
Sources: See Figure 1

Part 2. A high-level analysis of Ontario agricultural emissions and trends

In this Part, we provide general observations on some of the major components of the emissions depicted in Figure 1.

A. Agricultural GHG emissions in Ontario are rising

The graph's top line rises from 12.3 million tonnes (Mt) carbon dioxide equivalent (CO_2e) in 1990 to 13.8 Mt in 2021[4] (i.e., agricultural emissions increased by roughly 10% over the thirty-one-year period). Over a more recent period, agricultural emissions are up from 11.9 Mt in 2005—Canada's reference year for its international commitments. These emission values do not include adjustments for soil carbon sequestration or other carbon/CO_2 exchanges between soils and the atmosphere.

B. Cattle remain the largest source of agricultural emissions in Ontario

Emissions directly attributed to cattle totalled 4.0 Mt CO_2e in 2021 and are reported in four categories:

- 2a. Enteric, beef cattle (CH_4);
- 2b. Enteric, dairy cattle (CH_4);
- 2c. Manure management, beef cattle (N_2O and CH_4); and
- 2d. Manure management, dairy cattle (N_2O and CH_4).

Emissions attributed to cattle have been declining since the mid 1990s, as the size of the herd has declined. Figure 3 shows cattle numbers in Ontario. Note how the shape of the top line echoes the shape of the emissions curves at the bottom of Figure 1. Efficiency gains have also helped decrease emissions.

Even as the overall herd size declines, cattle operations have generally intensified: the number of cattle in feedlots has risen while the number of cattle in cow calf and stocker operations has fallen, and the average number of cattle per dairy farm increased by over 65% between 1990 and 2021.[5]

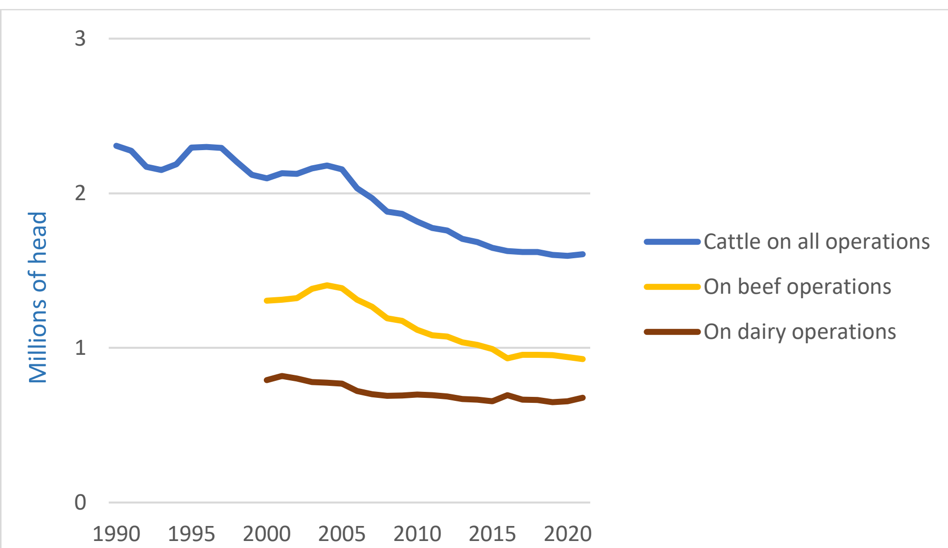

Figure 3. Cattle on farms in Ontario, 1990–2021.
Source: Statistics Canada Table 32-10-0130-01.

4 Unless otherwise specified, emissions units are millions of tonnes of carbon dioxide equivalent per year, i.e., Mt CO_2e per year.

5 Statistics Canada, Table 32-10-0130-01 and Agriculture and Agri-Food Canada, Report D056

Had cattle numbers in Ontario stayed at mid 1990s levels, overall agricultural emissions today (the top line in Figure 1) would be around 15.1 Mt CO_2e per year, rather than at 13.8 Mt. Declining emissions from cattle serve to countervail rising emissions from farm fuel use and nitrogen fertilizer—moderating the overall rate of increase in agricultural emissions.

C. Emissions from non-cattle livestock in Ontario are larger than they appear

Emissions from other livestock (hogs, poultry, etc.) appear to be small—totalling just 1.0 Mt CO_2e per year, mostly from manure management. However, these values omit emissions from feedgrain production—emissions reported in categories such as 3a: N_2O emissions from soils as a result of synthetic nitrogen application. Feedgrain-related emissions probably make up the bulk of emissions related to pork and poultry meat production, thereby obscuring the emissions footprint from these production systems.

Compared to shrinking cattle herds, hog and chicken populations in Ontario have both grown over the past thirty years, and consequently so have emissions from these industries.

D. There is no clear boundary for quantifying livestock-related emissions

It is easy to think of emissions from enteric fermentation and manure management as comprising "emissions from livestock" and to think of nitrogen-related emissions or similar categories as "emissions from the crop sector." But, of course, a large portion of crops is feedgrain and a significant portion of total farm fuel is used to raise animals. Hence, a significant portion of nearly every category in Figure 1 could be counted toward emissions from livestock. This report does not seek to assail farmers who raise cattle, pigs, chickens, etc. To the contrary, farm animals are vital parts of biodiverse, nutrient-cycling agro-ecosystems—core to regenerative agriculture, agroecology, mixed farming, and a range of solutions we would be wise to consider. That said, however, we must also acknowledge that emissions from current livestock production systems go far beyond manure and enteric emissions; encompass millions of tonnes reported under fertilizer and energy use; and are very high. These high emissions mean that we must make changes if we are to reduce overall agricultural emissions in line with Canada's commitments and planetary limits.

E. Rising emissions from fuel use are driving up total agricultural emissions in Ontario

Farm fuel use in Ontario emitted 2.6 Mt of CO_2e in 2021. In Figure 1, emissions from farm fuel and energy use are divided into five categories (all mostly CO_2):

- 8a. diesel fuel, off-road only (farmers' on-road diesel use would add very little, especially as we have set the boundary for this analysis at the farm gate, i.e., excluding post-farm road transport);
- 8b. gasoline, on- and off-road;
- 8c. fuel oil, light and heavy, for stationary uses;
- 8d. natural gas and propane for stationary applications such as building heating and grain drying; and
- 8e. emissions from fossil-fuel-fired electricity-generating stations that supply some farms in Ontario.

Fuel use is the fastest growing category of agricultural emissions in Ontario, increasing by 75% between 1990 and 2021. Emissions from natural gas and propane grew even faster than the overall average, nearly tripling during the thirty-one-year-period. In 2021, Ontario made up roughly half of national agricultural emissions from natural gas and propane.

This trend does not have a single cause but rather a number of drivers that distinguish agriculture in Ontario from other provinces: Ontarian farmers primarily rely on natural gas and propane to heat roughly two thirds of Canada's greenhouse area, barns containing more than a third of the Canadian chicken population, and dryers for more than two thirds of the corn for grain grown in Canada.

F. Nitrogen fertilizer is a significant source of emissions

In 2021, total GHG emissions related to nitrogen fertilizer were 3.0 Mt CO_2e. Emissions from the production and use of nitrogen fertilizer are recorded in seven categories:

3a. Direct emissions from farm fields (nitrous oxide, N_2O);
3b. Indirect emissions—off-site and delayed emissions from nitrogen fertilizer runoff, leaching, or volatilization (N_2O);
3c. Emissions from the carbon in granular urea fertilizer (carbon dioxide, CO_2);
3d. Emissions from the carbon in some other nitrogen fertilizers (CO_2)[6];
3e. Emissions from nitrogen fertilizer production facilities (mostly CO_2, but also N_2O);
3f. Upstream emissions from the production and processing of the natural gas used in the production of nitrogen fertilizer (methane, CH_4, and CO_2); and
3g. Emissions from transport of fertilizer to distribution and retail facilities and onward to farms (mostly CO_2).

As the tonnage of nitrogen fertilizer applied in Ontario has increased, emissions have also risen by roughly 25% from 1990 to 2021. For further analysis of the important and problematic role of nitrogen fertilizer in agriculture, please read the NFU's 2022 report on that subject.[7]

G. Manufacturing of fertilizers and other farm inputs is significant and thus so too are fossil fuels and CO_2

This report and its graphs and tables include emissions from the production of four types of farm inputs[8]:

- phosphorus fertilizer (category 4a);
- potassium fertilizer (4b);
- nitrogen fertilizer (3e, 3f, and 3g); and
- farm machinery (4c).

Farm input production is a significant part of overall agricultural emissions. Adding up all emissions from the production of agricultural machinery and fertilizers yields a total of 1.7 Mt CO_2e per year or 12.4 percent of total agricultural emissions.[9] Moreover, much of this is CO_2 from fossil fuels. When we add these emissions to those from farm fuel and energy use (another 17.4 percent of total emissions), we begin to see that almost a third of agricultural emissions in Ontario are directly related to fossil fuels and CO_2.[10] This is a different picture than the one often presented wherein almost all agricultural GHGs are methane and nitrous oxide. Though these latter gases are central to the project of reducing agricultural emissions, it is a mistake to think that reducing fossil-fuel-related CO_2 emissions is not equally important. Fossil fuels are, by far, the largest input into Ontario's food production systems.

Further, it may be that the *largest* portion of agricultural emissions reductions will eventually come from reductions in fossil-fuel use. Consider: Reducing enteric methane emissions from livestock by even 30 percent will be challenging. Similarly, reducing emissions from fertilizer use by 30 percent is possible, but

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6 National data from the CRF tables disaggregates liming, urea, and other carbon containing fertilizers. However, liming data is confidential at the provincial level, so this report groups the thee categories together. As most of the emissions from these categories can be attributed to urea in Ontario, the three categories are all attributed to 3c, recognizing that this understates emissions from other carbon containing fertilizers and liming.

7 Darrin Qualman and the National Farmers Union, "Nitrogen Fertilizer: Critical Nutrient, Key Farm Input, and Major Environmental Problem," August 2022.

8 It is likely that these four account for the bulk of emissions from the production/manufacturing of all farm inputs. Nonetheless, future editions of this report may be able to add categories for the manufacturing of pesticides, plastics, etc.

9 This is based on the sum of categories 3e, 3f, 3g, 4a, 4b, and 4c. Categories 3c and 3d are excluded.

10 The total would be much more than half if CO_2 from in-field hydrolysis of urea and UAN nitrogen fertilizer were included, and there are arguments for doing so because the C in that CO_2 is derived from fossil fuels and added in fertilizer production facilities.

it is hard to see how we can achieve, say, double that reduction. In contrast, it should be possible, as we move through the 2030s, 2040s, and beyond, to slash CO_2 emissions from fossil fuel and energy use—from manufacturing, mining, and other industrial processes; from the heating of farm homes and buildings; and, later and with more challenges, from farm machinery. Though perhaps a lower priority for agricultural emission reduction today, fossil fuel use may eventually yield the *largest* reductions.

H. Land use changes, carbon exchanges, and soil sequestration

The preceding focuses on agricultural greenhouse gas *emissions*. In addition to these emissions, there are also *exchanges* of carbon/CO_2 between the atmosphere and agricultural soils—some going one direction and some going the opposite. The most oft-mentioned example is soil carbon sequestration as a result of reductions in tillage: "no-till," "zero-till," "direct seeding," or even "strip tillage."

Taking our cues from ECCC, Figure 1 quantifies soil-atmosphere exchanges in six categories (all CO_2):

1a. Changes in woody biomass incl. additions or removals of tree rows, shelterbelts, etc.;
1b. Changes/reductions in tillage of croplands;
1c. Shifts in the balance between perennial and annual crop area;
1d. Land converted to cropland (mostly forest land cleared for farming);
1e. Manure application; and
1f. Crop residue carbon input.

Ontario LULUCF Sector Net GHG Flux Estimates, Selected Years

Sectoral Category		Net GHG Flux (kt CO2 eq)						
		1990	2005	2017	2018	2019	2020	2021
b.	**Cropland**	**590**	**940**	**1300**	**1400**	**1600**	**2200**	**1300**
	Cropland Remaining Cropland	470	850	970	1000	1200	1800	860
	Land Converted to Cropland	120	96	340	370	400	410	420
c.	**Grassland**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
	Grassland Remaining Grassland	NO	NO	NO	NO	NO	NO	NO
	Land Converted to Grassland	NO	NO	NO	NO	NO	NO	NO
d.	**Wetlands**	**6.2**	**8.4**	**9.2**	**9.2**	**9.3**	**9.4**	**9.4**
	Wetlands Remaining Wetlands	5.5	8.2	9	9.1	9.2	9.3	9.3
	Land Converted to Wetlands	0.7	0.25	0.11	0.11	0.11	0.11	0.11

Base and Recent Year Emissions and Removals Associated with Various Land Management Changes on Cropland Remaining Cropland in Ontario

Categories	Land Management Change (LMC)	Emissions/Removals (kt CO_2)[a]						
		1990	2005	2017	2018	2019	2020	2021
Total Cropland Remaining Cropland		**470**	**850**	**970**	**1000**	**1200**	**1800**	**860**
Cultivation of histosols		70	70	70	70	70	70	70
Perennial woody crops		-230	-230	-250	-250	-240	-240	-240
Total mineral soils		**620**	**1000**	**1100**	**1200**	**1400**	**1900**	**1000**
Change in crop mixture	Increase in perennial	-540	-1000	-820	-810	-790	-770	-760
	Increase in annual	2000	2800	3200	3100	3100	3100	3000
Change in tillage	Conventional to reduced	-25	-39	-33	-32	-30	-30	-30
	Conventional to no-till	-22	-140	-120	-120	-120	-120	-120
	Other[b]	-0.081	-8.2	21	20	20	19	18
Crop residual C input		-110	140	-560	-470	-300	300	-590
Manure application		-710	-680	-560	-560	-560	-550	-550
Land conversion—Residual emissions[c]		2.8	30	35	35	35	36	36

Notes:

a. Negative sign indicates removal of CO_2 from the atmosphere.

b. Other includes reduced to no-till as well as other changes in tillage with relatively less significant impacts on emissions/removals, namely: reduced to conventional, no-till to conventional, and no-till to reduced

c. Net residual CO_2 emissions from the conversion of Forest Land and Grassland to Cropland that occurred more than 20 years prior to the inventory year, including emissions from the decay of woody biomass and DOM.

Table 1. Two ECCC/NIR tables showing exchanges of carbon/CO_2 between soils and the atmosphere.
Source: Data provided upon request by ECCC.
Notes: Yellow-highlighted rows indicate categories used in this report.

Above are two tables corresponding to Tables 6-1 and 6-9—respectively—from the 2023 NIR, Part 1. Negative values denote carbon/CO_2 flowing from the atmosphere into agricultural soils (sequestration) and positive values denote carbon/CO_2 flowing from agricultural soils to the atmosphere (desequestration).

Note several points about the values in these tables:

A. In every year since 1990 but one (2009), agricultural soils in Ontario have experienced net losses of carbon (i.e. desequestration).
B. Overall, desequestration—the transfer of carbon/CO_2 from soils to the atmosphere—appears to be increasing in Ontario, though variable from year to year. Averaging the most recent five years for which data is available (2017–2021, inclusive) the six categories averaged +1.4 Mt per year, i.e., desequestration of that amount. But several years earlier (2010–2014, inclusive), those same six categories together averaged +0.7 Mt per year—about half the current rate.
C. The most significant factor driving net desequestration in Ontario is changes in the mix of annual versus perennial crops. Shifts that result in a larger area of annual crops and a smaller area of perennials are reported as net transfers of carbon/CO_2 from soils to the atmosphere. In the table above, the overall balance of those changes in crop mix have resulted in desequestration ranging from +1.5 Mt in 1990 to +2.2 Mt in 2021.
D. Crop residue carbon input (which subsumes the now-discontinued category "Reduction in summerfallow area") is highly variable. In the most recent two years of data, this category flipped from desequestration of +0.3 Mt in 2020 to sequestration of -0.6 Mt in 2021.
E. "Land converted to cropland" (the creation of new farmland, mainly from forest) also creates carbon/CO_2 exchanges—annual desequestration averaging 0.4 Mt in the past five years, up from around 0.1 Mt for most of the preceding twenty-five years.
F. Manure application is the most stable flow of carbon from the atmosphere to soils, though sequestration from this category has decreased from -0.7 Mt in 1990 to -0.6 Mt in 2021 as the cattle herd in Ontario shrinks.

Opinions differ regarding how to *account* for soil-atmosphere carbon/CO_2 exchanges.[11] Some people advocate subtracting the tonnage of these exchanges from emissions to create a measure of "net emissions." Others, however, believe that there are good reasons *not* to do so. Drawing on extensive published science and expert opinion, the NFU has detailed why GHG emissions and soil-atmosphere exchanges (including soil carbon sequestration resulting from reduced tillage) should be kept separate when doing GHG accounting (see the NFU's 2021 submission to ECCC[12]). While soil carbon gains are *extremely* positive and contribute to ecosystem integrity, soil health, water retention, drought resilience, and climate adaptation, soil carbon gains should not be seen as offsetting, zeroing out, or otherwise erasing actual emissions, especially those from fossil fuels.

Ontario illustrates why "net emissions" are problematic. For all but one of the past thirty-one years, agricultural soils in Ontario have lost soil carbon. Any future soil carbon increases will merely be regaining what was previously lost, not offsetting the GHGs released by fossil fuel products used in agriculture or other sectors.

11 A distinction can be made between emissions *reporting* (quantifying tonnage) and emissions *accounting* (which adds in an element of interpretation or an assignment to larger categories).

12 National Farmers Union, "Submission to the Public Comment Period for the Federal Government's Draft Greenhouse Gas Offset Credit System Regulations" (Saskatoon: NFU, 2021), https://www.nfu.ca/wp-content/uploads/2021/05/Fedl-Regulations-for-Offset-Protocols-NFU-submission-May-2021-Final.pdf.

Concluding remarks

We can be certain of the following: agricultural emissions in Ontario are high and rising; livestock remain a major source of emissions; fossil fuel use is a key driver of the rise in emissions; and agricultural soils are desequestering carbon at increasing rates, primarily due to land use changes.

What is less certain are the exact emissions in most of the categories detailed above. There are significant uncertainties for many of the categories. Much work needs to be done to reduce the uncertainties. For example, NIR data on sequestration relies entirely upon modelled changes due to certain practices, and these models must be assessed against empirical data from widespread and rigorous soil sampling. Reliable data is essential as we endeavour to measure and report emissions reductions from on-farm changes—reductions that will initially be small, though very important to quantify, document, and reward.

Nonetheless, we have more than enough data and more than enough precision to move forward swiftly, energetically, and courageously to reduce agricultural emissions. Commitments by governments to cut emissions from methane, from fertilizer, and from the economy as a whole provide clear signals that we need to act now and in each coming year to reduce emissions from all agricultural categories. Our actions must address the central roles that fossil fuels currently play in agriculture.

The NFU hopes that this report and its data will guide policymakers and farmers in Ontario in this important work and, most importantly, inform the creation of sound, effective government policies and programs that can support and assist farmers as they make the needed changes to move to lower-emissions systems.

Key reports and information sources

For those interested in GHG emissions, key documents from the Government of Canada include:

- Environment and Climate Change Canada (ECCC), GHG emission data tables, https://data.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/

- ECCC, *National Inventory Report 1990–2021: Greenhouse Gas Sources and Sinks in Canada*, 2023, https://unfccc.int/documents/627833?gclid=CjwKCAjww7KmBhAyEiwA5-PUSjNOE93sC1lzH65O8nj6hyWaVyyPd0Fj_iHtL9AuJwd_taxfebPXGhoCRxQQAvD_BwE This three-part annual report is the primary source for almost all emissions values. See especially:
    - Part 1, section 2.3.3, Agriculture Sector
    - Part 1, Ch. 5, Agriculture
    - Part 1, Table 5-1, Short-and Long-Term Changes in Emissions from the Agriculture Sector
    - Part 1, Chapter 6, Land Use, Land Use Change, and Forestry

- ECCC, Canada's 8th National Communication and 5th Biennial Report, 2022, https://unfccc.int/sites/default/files/resource/Canada%20NC8%20BR5%20EN.pdf

- ECCC, Canada's Greenhouse Gas and Air Pollutant Emissions Projections 2020, https://publications.gc.ca/collections/collection_2021/eccc/En1-78-2020-eng.pdf