Enteric Emissions Are Carbon-Neutral

PAUL RENAUD

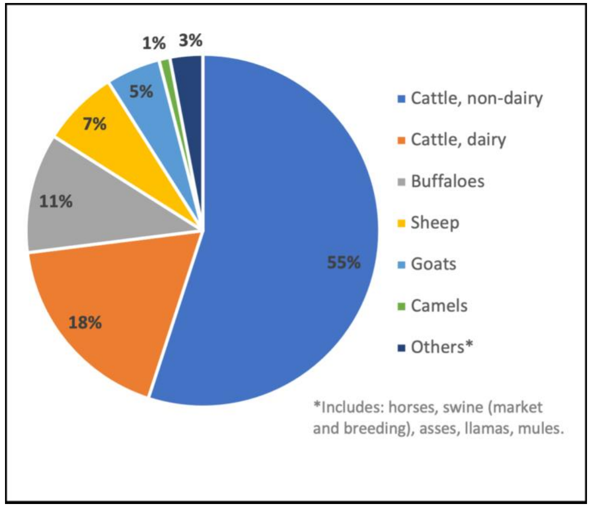
THE LANIGAN GROUP

Prioritizing the Right Things is Key to Sustainable Agriculture

- The Lanigan Group has significant experience in managing large, complex transitions in a variety of industrial sectors
  - In all cases we have found that it is important to be evidence-based so that focus can be applied to high payback initiatives
- This is NOT the case in agriculture today due to:
  - Missing critical data about existing sequestration on farms, resulting in over-focus on emissions
  - Excessive attention to emissions which are non-additive (i.e. do not impact climate change)
  - Reliance on carbon-credit based policies which simply do not work in agriculture (see “Carbon As A Cash Crop” for more info)
- The result is lost opportunity to leverage natural climate solutions on farms to actually make a difference in fighting climate change

What are Enteric Emissions?

- Enteric fermentation is a digestive process of ruminant animals (cattle, sheep, goats, buffalo, etc.) that results in the emission of methane (CH4) which is a potent GHG
  - Enteric fermentation employs anaerobic microbes to decompose and ferment food in the anima's digestive tract which are more easily absorbed.
  - Ruminant animals contain a dual stomach, the first of which contains most of the microbes, whose primary biological function is enteric fermentation of food
  - This enables ruminant animals to eat more plant based food that otherwise would not be digestible.
  - Approx 7 – 10% of the ruminant's energy intake is lost as CH4 which is expelled via belches and to a lesser extent via flatulence [FAO]
- Cattle are the main contributor to enteric emissions globally. Non-ruminant animals (pigs, horses, etc.) also employ enteric fermentation to digest food but to a lesser degree (see figure)
  - Animal age, weight, and dietary composition are the largest factors influencing enteric emissions within a species
  - In Canada 96% of enteric emissions originate from cattle (beef and dairy) [NIR 2023]
- Enteric emission of methane accounted for 30% of global methane emissions in 2011 according to the FAO and consequently is tracked in IPCC national inventory reports
  - Canada's National Inventory identifies enteric emissions as Canada's #2 source of methane emissions after oil & gas extraction [NIR 2022]



Global enteric fermentation by source, 2001-2011.
Data from FAO Statistics Division, ESS Working Paper No. 2.

Enteric Fermentation in Context of Canadian Agricultural Emissions – livestock-related emissions are 58% of all ag emissions

Canada National Inventory Report, 2023

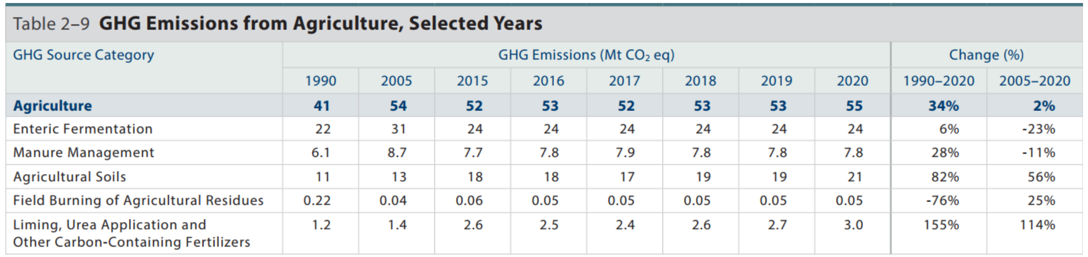
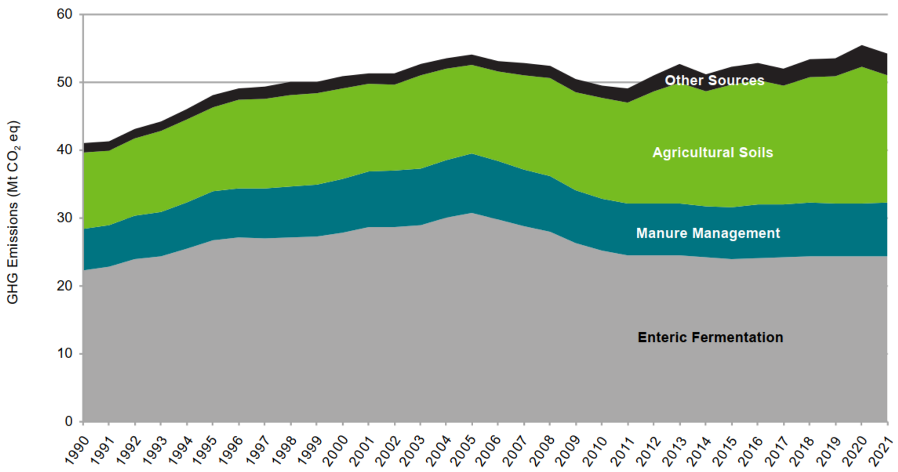


Table 2–9 **GHG Emissions from Agriculture, Selected Years**

GHG Source Category	GHG Emissions (Mt CO_2 eq)								Change (%)	
	1990	2005	2015	2016	2017	2018	2019	2020	1990–2020	2005–2020
Agriculture	**41**	**54**	**52**	**53**	**52**	**53**	**53**	**55**	**34%**	**2%**
Enteric Fermentation	22	31	24	24	24	24	24	24	6%	-23%
Manure Management	6.1	8.7	7.7	7.8	7.9	7.8	7.8	7.8	28%	-11%
Agricultural Soils	11	13	18	18	17	19	19	21	82%	56%
Field Burning of Agricultural Residues	0.22	0.04	0.06	0.05	0.05	0.05	0.05	0.05	-76%	25%
Liming, Urea Application and Other Carbon-Containing Fertilizers	1.2	1.4	2.6	2.5	2.4	2.6	2.7	3.0	155%	114%

Figure 2–18 **Trends in Canadian GHG Emissions from Agriculture Sources (1990–2021)**



Biogenic Carbon

- While any opportunity to reduce global emissions can contribute to mitigating climate change, **not all emissions are additive** to the carbon footprint of agriculture
  - Biogenic carbon is not new carbon in the atmosphere, it is carbon that is recycling in a biogenic cycle
  - In a biogenic carbon cycle, plants photosynthesize CO2 from the atmosphere to store carbon in their biomass
  - Ruminant animals consume the plants and expel some of the stored carbon as methane via enteric fermentation
  - This methane slowly decomposes back into CO2 through hydroxyl oxidation, recycling approx. half of its carbon back into carbon dioxide every decade (i.e. atmospheric CH4 has a half-life of approx. 10 years)

- Carbon footprint is the net carbon emission when emissions are offset by carbon removals via sequestration of CO2
  - Net-zero emission results in fully mitigating climate change
  - The biogenic carbon cycle has a net-zero carbon footprint on an annual carbon mole-ratio basis since the photosynthesis of CO2 occurs in the same year as the enteric fermentation and since the ratio of carbon sequestration as CO2 is greater than the emission of carbon as CH4 (examples on subsequent slides)

- The IPCC recognizes the use of bioenergy from biogenic carbon sources as having significant mitigation potential because CO2 is absorbed by growing the plants employed to produce the biofuel [IPCC 2018 AR5 Chapter 11]
  - Sequestration offsets the emissions from the use of bioenergy, hence its emissions are non-additive
  - A net reduction in global CO2 occurs when a bioenergy fuel is used to displace the use of fossil fuels
  - Long term sustainability and efficiencies in the production of fuel from bioenergy sources are important factors in the type of fuel used
    - E.G. not deforesting existing sequestration to create land area for growing a bio-fuel source
    - Preferred sources are forest & agriculture residues, organic waste, use of perennial plantations, harvesting methane from enteric fermentation and manure, etc.

How are Enteric Emissions Different than Bioenergy emissions?

- Enteric emissions are **no different** than other bioenergy emissions:
  - Enteric fermentation occurs as plant-based food is digested by livestock
  - However, carbon is sequestered via photosynthesis in the growing of that food
  - First Law of Thermodynamics states that energy cannot be created or destroyed
    - Energy out (via methane emissions) cannot exceed energy in (via daily energy intake of food)
    - It is impossible for enteric emissions to result in higher emission of carbon than the sequestration of carbon in the plants eaten

- This remains true even when we account for:
  - CH_4 having a 20x worse impact as a GHG affecting climate change
  - The molecular balance of carbon within all livestock-related emissions (e.g. manure-related methane and NO_2 emissions)
  - Livestock respiration of CO_2 not usually included as an agricultural emission
  - Differences between harvested yield and crops harvested for livestock consumption

- Enteric emissions are significantly different than methane emissions from the combustion of fossil fuels
  - Carbon emitted from burning fossil fuels is net additional carbon being added to the atmosphere because it is sourced from carbon previously stored underground for millions of years
  - Carbon added to the atmosphere faster than it is absorbed is the primary cause of climate change

Example: The Emissions of a Single Dairy Cow

- Consider a simplified case of a single 600 kg milking cow (the average weight of a dairy cow in Canada is 634 kg):
  - Requires 9,490 kg of Dry Matter Intake (DMI) per year [Nutrient Requirements of Dairy Cattle, 7th Edition, National Academic Press, 2001]
    - Which in turn requires 27,115 kg silage corn as harvested yield which leaves 630 kg of residue post-harvest (above & below ground)
    - Total biomass of corn is 27,745 kg which is 47% carbon, i.e. 13,040 kg C
    - 47,770 kg of CO2 must be photosynthesized, to accumulate 13,000 kg of Carbon

  - Produces 141 kg CH4 per year via enteric fermentation [Ominski 2007], equating to 3,525 kg CO2e
  - Net carbon sequestration after deducting enteric emissions is 9,500 kg CO2e

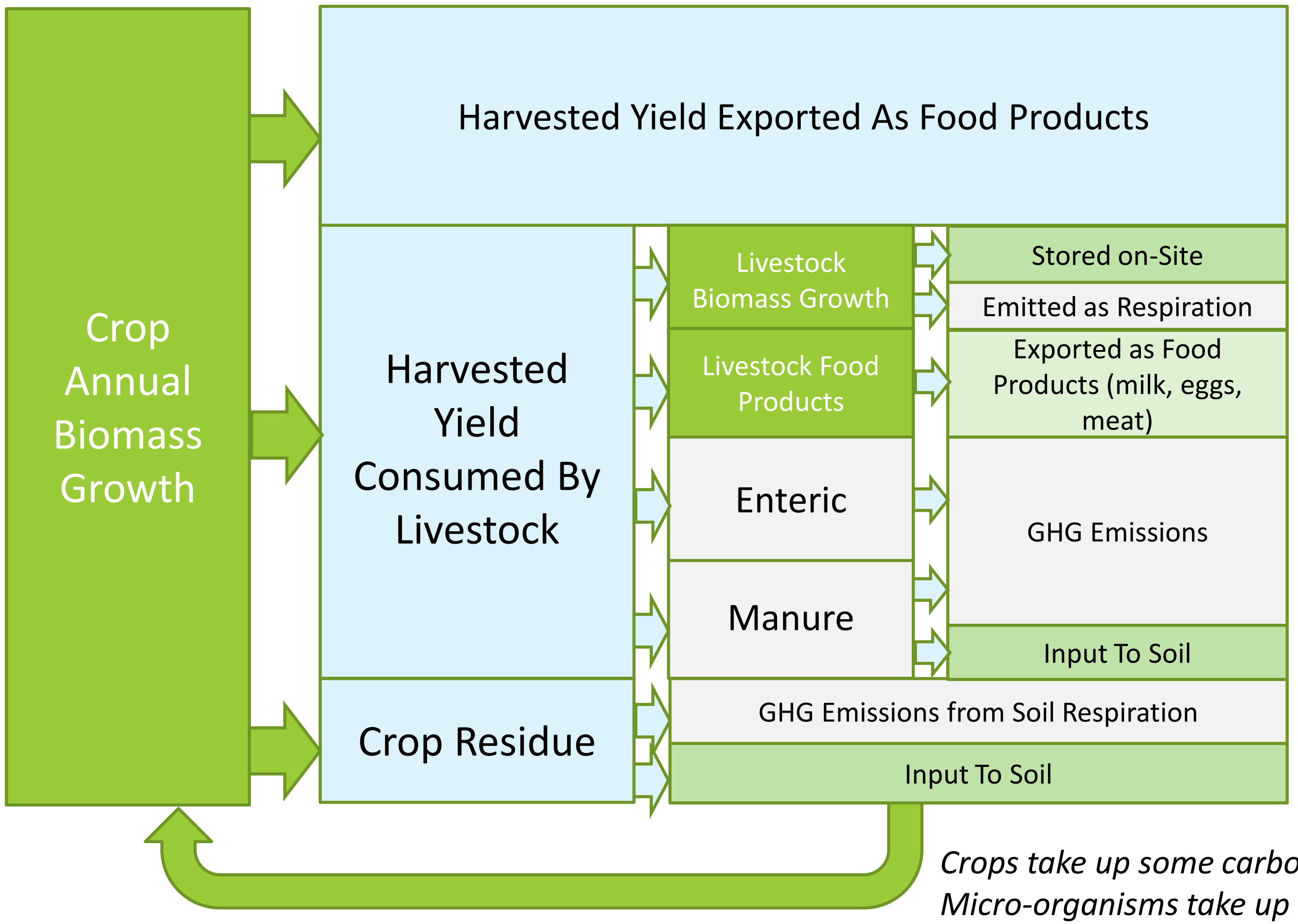
  - Produces 5.58 kg volatile solids (VS) in manure / day [IPCC factor], i.e. 2040 kg manure VS /year
  - Which volatizes to 0.02 kg CH4/kg VS [IPCC Factor] in drylot storage, or 41 kg CH4 or 1,020 kg CO2e /year
  - Net carbon sequestration after also deducting methane emitted from storage is 8,000 kg CO2e

  - Assume that the manure is also used as fertilizer, another 0.001 kg CH4 per kg VS will also be emitted (2 kg CH4, or 7.5 kg CO2e)
  - The manure contains 0.25 kg N per Kg VS [OMAFRA], for a total of 500 kg N which volatilizes as 4.5 kg N20 or 835 Kg CO2e
  - Net carbon sequestration after deducting for the use of manure as fertilizer is over 7,000 kg CO2e (i.e. 2x the level of enteric & manure emissions)

Case Study: Dairy Farm Enteric Emissions

- While the simplified case of a single dairy cow illustrates that livestock emissions are more than offset by carbon sequestration, it is a highly simplified example compared to a real farm.
- So, we modeled the entire carbon footprint of a dairy farm in Eastern Ontario:
  - 190 head of cattle
  - Growing 1500 T of crops annually to feed them (hay, soybean, corn, barley)
  - Generating 5,000 T Manure per year
- In this case study (as illustrated on the next slide):
  - A portion of the crops grown is sold for human consumption, so we account for that as a neutral carbon transfer
  - Of the amount consumed by livestock, we account for the proportion used to:
    - Sustain the cattle via respiration of CO2
    - Maintain the body weight of the herd
    - Produce milk which is exported for human consumption
    - Generate enteric emissions
    - Excrete manure
  - We also account for the decomposition of crop residue post harvest and attribute emissions from that decomposition in the same year as the harvest

Dairy Farm Case Study of Crops Grown to Sustain Livestock



Crop Annual Biomass Growth

Harvested Yield Exported As Food Products

Harvested Yield Consumed By Livestock

Livestock Biomass Growth

Stored on-Site

Emitted as Respiration

Livestock Food Products

Exported as Food Products (milk, eggs, meat)

Enteric

Manure

GHG Emissions

Input To Soil

Crop Residue

GHG Emissions from Soil Respiration

Input To Soil

No annual sequestration when number of livestock stays the same year over year, stored carbon is ultimately released when animals are slaughtered

Embedded Carbon in Harvested Farm Products
Is assumed to be released when consumed by humans

Emissions primarily of N2O & CH4

Sequestration net of emissions above

Emissions primarily of N2O & CO2 from both residue & fertilizer

Sequestration net of N2O & CO2 emitted above

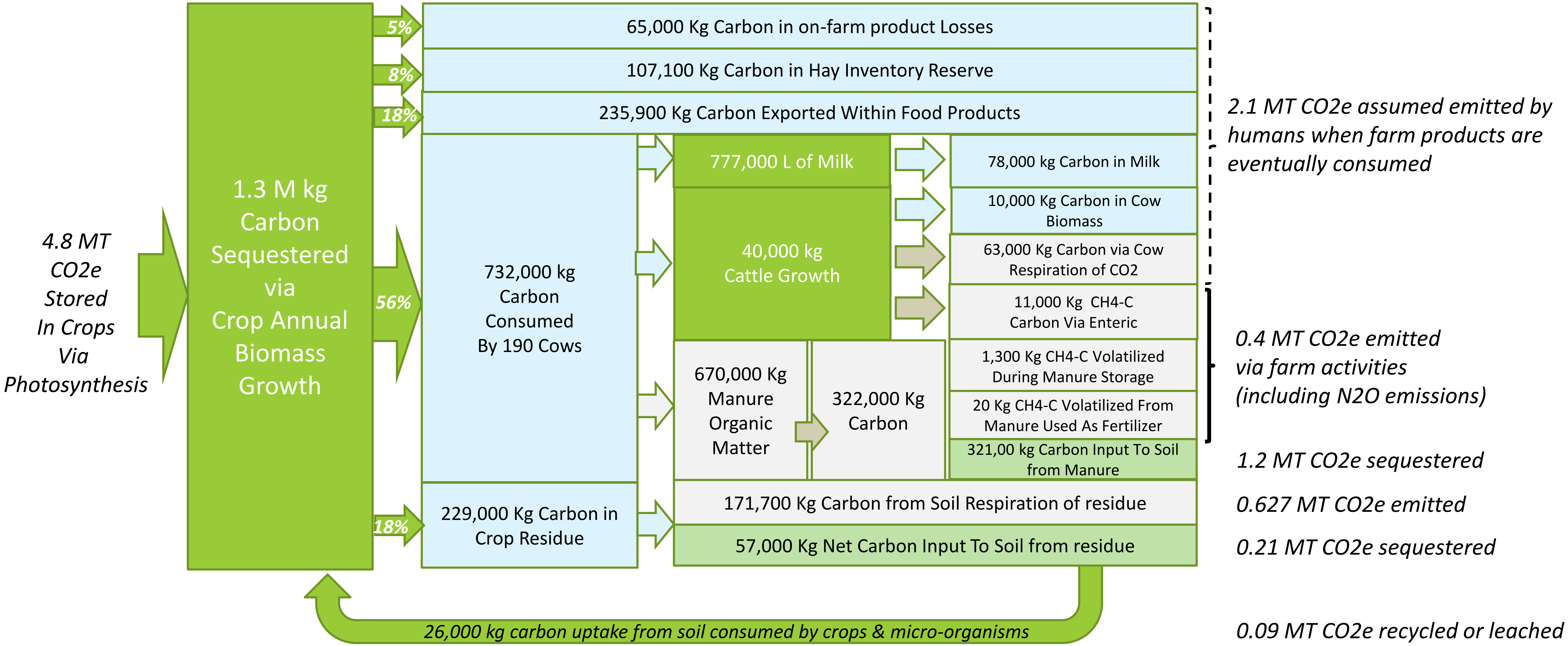
Crops take up some carbon via their roots in addition to via photosynthesis,
Micro-organisms take up carbon to grow, some carbon is leached from soil

Case Study: Dairy Farm Carbon Accounting

- Our model traces each mole of carbon on a mass balance basis from atmospheric CO2 source into plants, crops & residue, harvested crops exported as food, harvested crops consumed on-site by cattle, cattle biomass, cattle respiration of CO2, milk products, enteric and manure related emissions, and carbon input to soil
  - We were able to trace the carbon pathway to within 10% of total carbon sequestered by crops (i.e. within modelling error)
  - We accounted for molecular weight ratios from CO2 to plant carbon to CH4 and to carbon glucose / carbohydrate / sugars
  - We also included the associated emissions of N2O in manure
  - We assumed an average degree of waste in crop yield and lost milk production
  - The next slide illustrates the different carbon pathways modelled

- We also separately modelled all emissions (Scopes 1, 2, and 3) as well as other sequestration (e.g. from farm trees)
  - Even if we were to include all enteric and manure emissions, and exclude sequestration within the harvested yield, the dairy farm was still better than carbon neutral due to the sequestration of carbon by perennial plants (farm trees)
  - See Annex for details

Where Does the Carbon Sequestered in Crops Grown Go?
Case study of Ontario Dairy farm



4.8 MT CO2e Stored In Crops Via Photosynthesis

1.3 M kg Carbon Sequestered via Crop Annual Biomass Growth

5%

65,000 Kg Carbon in on-farm product Losses

8%

107,100 Kg Carbon in Hay Inventory Reserve

18%

235,900 Kg Carbon Exported Within Food Products

56%

732,000 kg Carbon Consumed By 190 Cows

777,000 L of Milk

78,000 kg Carbon in Milk

40,000 kg Cattle Growth

10,000 Kg Carbon in Cow Biomass

63,000 Kg Carbon via Cow Respiration of CO2

2.1 MT CO2e assumed emitted by humans when farm products are eventually consumed

11,000 Kg CH4-C Carbon Via Enteric

670,000 Kg Manure Organic Matter

322,000 Kg Carbon

1,300 Kg CH4-C Volatilized During Manure Storage

20 Kg CH4-C Volatilized From Manure Used As Fertilizer

0.4 MT CO2e emitted via farm activities (including N2O emissions)

321,00 kg Carbon Input To Soil from Manure

1.2 MT CO2e sequestered

18%

229,000 Kg Carbon in Crop Residue

171,700 Kg Carbon from Soil Respiration of residue

0.627 MT CO2e emitted

57,000 Kg Net Carbon Input To Soil from residue

0.21 MT CO2e sequestered

26,000 kg carbon uptake from soil consumed by crops & micro-organisms

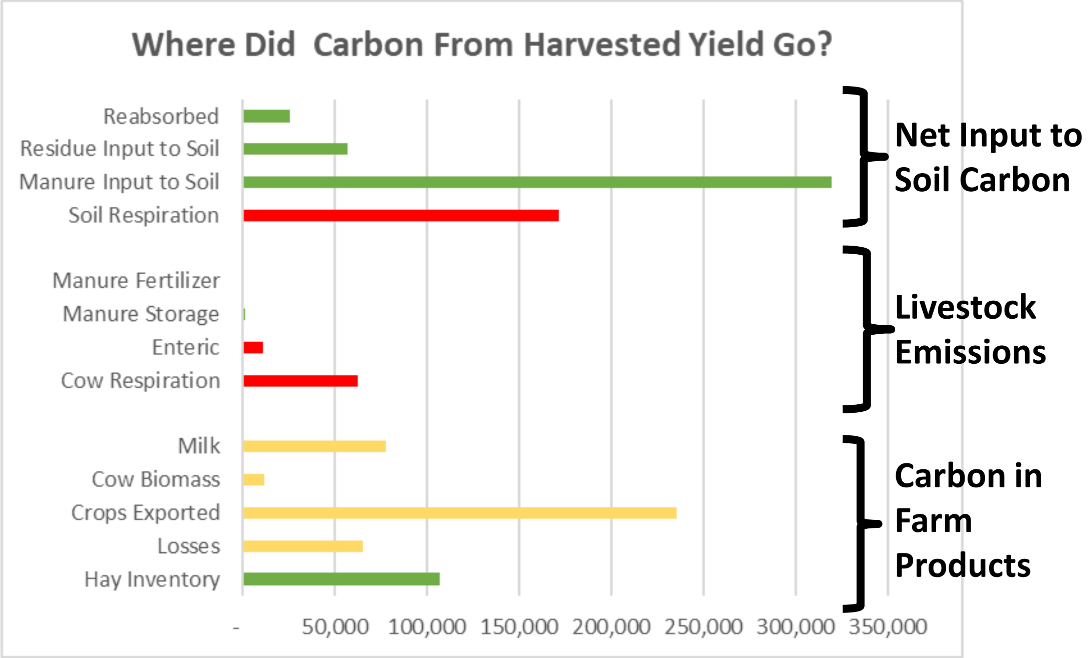
0.09 MT CO2e recycled or leached

Livestock-Related Emissions in Context of Harvested Yield

- This chart of the same data from the previous slide better illustrates the relative magnitude of where the carbon sequestered in the growing of crops ends up

- Impact of manure and enteric emissions is minor when all food for cattle is grown on-site (impact of feed supplementation is minimal)
    - Even if the dairy farm imported all food except for hay eaten by its cattle, and did not pasture its dry cows, all livestock emissions are entirely offset by sequestration of carbon in the hay grown
    - The results of this case study reveals that the farm only needs to grow 20% of the hay eaten by cattle and no other feed to break even on enteric and manure-related emissions
    - At a provincial or national scale, the exchange of livestock feed between farms enables the transfer of emissions removals (aka "insets") between farms, hence enteric and manure-related emissions are NEVER additive causes to climate change

- In other words, enteric and manure-related emissions **are no more additive than emissions from bio-fuels** because the carbon released is offset by the carbon sequestered in the process that creates the emission
    - In fact, livestock emissions are arguably better because sequestration of CO2 happens in the same year as when emissions occur from enteric fermentation



Summary of Net Sequestration in Dairy Farm Case Study

- If we eliminate the carbon transferred or stored in food, the table at the right illustrates that livestock related emissions (enteric and manure-related) are small in comparison to emissions from soil respiration that occurs in the decomposition of crop residues
- Overall, the biogenic carbon cycle is significantly carbon negative on an annual basis, sequestering over 2x more carbon than is emitted annually from livestock-related emissions

Sequesterd in Growing Crops		1,304,105	kg
Less Eliminations			
	Hay Inventory	- 107,113	
	Losses	- 65,205	
	Crops Exported	- 235,846	
	Cow Biomass	- 12,207	
	Milk	- 78,164	
	Cow Respiration	- 62,868	
Net Carbon Sequestered via Crops		742,702	kg
Emissions			
	Enteric	- 11,246	
	Manure Storage	- 1,354	
	Manure Fertilizer	- 20	
	Soil Respiration	- 171,746	
Balance	Net Sequestered	558,337	kg

The Cumulative View: What is the difference between a herd of cows and a closed power plant?

Suppose all carbon in the form of GHGs were taxed:

- A power station emits CO2 by burning fossil fuels. This CO2 is taxed while the plant operates. When it shuts down permanently, it emits no more CO2, so is no longer taxed. However, the CO2 already emitted continues to affect the climate for hundreds, or potentially, thousands of years. So, even after closing down, that power station still contributes to holding up global temperatures because of the CO2 that remains in the atmosphere.

- A herd of cows emits methane, so a farmer would be taxed for those emissions. If the herd remains the same size with the same methane emissions every year, it will maintain the same amount of additional methane in the atmosphere year on year (because annual additions are replaced by decomposition of methane and absorption of its CO2 via plants). In terms of its contribution to global warming, this is equivalent to the closed power station.

- The power station pushed up global temperatures when it was running in the past, but neither a steady herd of cattle nor a defunct power station is pushing up global temperatures in this scenario. However, under almost all proposed systems for taxing emissions that attempt to include methane, the farmer would get taxed for their herd's methane emissions every year the cows were alive, while the owner of the closed power station would not.

Adapted from: [Cain M. 2018]: A new way to assess 'global warming potential' of short-lived pollutants. Carbon Brief Ltd; 2018.
https://www.carbonbrief.org/guest-post-a-new-way-to-assess-global-warming-potential-of-short-lived-pollutants

Summary of Findings

- Enteric emission reduction is important because any emission reduction is beneficial in mitigating climate change
  - As the second largest source of methane emissions in Canada, reducing enteric emissions presents a significant mitigation opportunity
  - However, *enteric emissions are no different than any other bioenergy emission* and are *non-additive to the problem of climate change* even if they are not mitigated

- We demonstrated this via a simplified calculation for a single dairy cow that shows that 2x the enteric emissions are sequestered in the same year that they occur

- We provided a detailed case study that shows the disposition of carbon via crops consumed by livestock from an average sized, operating dairy farm in Eastern Ontario
  - Soil respiration emissions from decomposition of crop residue are greater than enteric emissions from livestock
  - Manure-related emissions are negligible compared to other emissions
  - More carbon is input to soil than is emitted from livestock-related emissions
  - Exported farm products consumed ultimately by humans & livestock off-farm are a larger disposition of carbon than enteric emissions

Key Takeaways

1. Our analysis shows that, contrary to popular myth, livestock emissions do NOT contribute to climate change because every gram of carbon in those emissions has been offset by the carbon sequestered in the plants eaten by those animals. I.E. they are net-zero because of the biogenic recycling of carbon each year.
2. Even on a cumulative basis, considering that methane has higher impact as a GHG than CO2 on short-term global warming (which is why a ratio of 20x is used to convert methane into CO2 equivalent), enteric emissions do not contribute to long-term climate impact because they break down into CO2 over a decade and this CO2 is reabsorbed into the plants grown to feed livestock (and by other perennials such as pasture and trees).
3. Livestock emissions are actually better than net-zero because our analysis shows that 2x the ratio of sequestration to emissions occurs in practice. For example, when manure is used as fertilizer only a portion of the solids contributes to emissions, the majority is input to soil for longer term storage.
4. The current national inventory of GHG report (NIR) shows that livestock related emissions are over half of all agriculture-related emissions, so this implies that Canadian ag as a whole is already has a carbon neutral footprint. The actual carbon footprint of Canadian agriculture will be the subject of a future presentation.
5. Although Canadian enteric and manure-related emissions may appear large, they do not impact global warming and should not be prioritized over higher impact initiatives such as:
    - Reducing the use of fossil fuels and synthetic fertilizer that actually contribute to non-biogenic GHG in the atmosphere
    - Significantly increasing on-farm sequestration of CO2 via proven agroforestry methods instead of subsidizing unproven carbon capture methods during fossil fuel extraction and processing

Related Research

- [Liu, S., Proudman, J., Mitloehner F.M. 2021] Rethinking methane from animal agriculture, CABI Agriculture & Bioscience, (2021) 2:22 https://doi.org/10.1186/s43170-021-00041-y
  - Concurs that enteric emissions are biogenic and non-additive. Further observes that enteric emissions have fallen in the USA over the past 5 years due to improvements in livestock productivity.

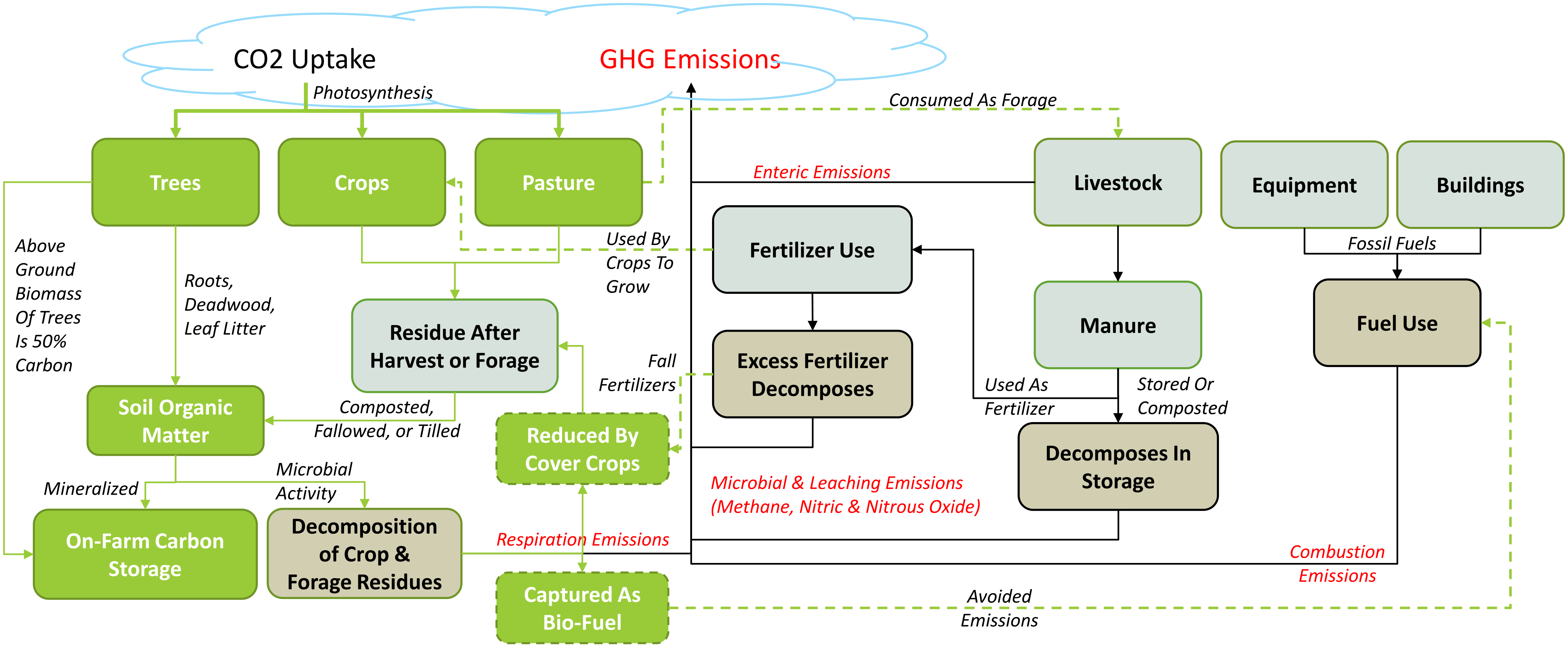
- [Allen MR. 2021] Short-lived promise? The science and policy of cumulative and short-lived climate pollutants. Oxford Martin Policy Paper; 2015. http://www.oxfordmartin.ox.ac.uk/downloads/briefings/Short_Lived_Promise.pdf.
  - Argues that it is better to prioritize early reductions in peak CO2 & N2O over short lived climate pollutants (SLCP) such as CH4, black carbon aerosols & HFCs because early SLCP mitigation will have very little impact on eventual peak warming due primarily to CO2

- [Badr, O., Probert, S.D., O'Callaghan, P.W., 1992] Sinks for atmospheric methane, Applied Energy, Vol 41, Issue 2, 1992, pp 137-147 https://doi.org/10.1016/0306-2619(92)90041-9
  - Identifies several natural sinks in the methane to CO2 cycle

- [EPA, 1995] Greenhouse gas biogenic sources. In: Fifth edition compilation of air pollutant emissions factors, vol. 1. Raleigh: EPA; 1995. https://www3.epa.gov/ttn/chief/ap42/ch14/index.html.
  - Classifies enteric emissions as biogenic carbon

Annex

Visualizing Farm-Level Carbon Footprint Dynamics
(excluding changes in land-use and indirect emissions)



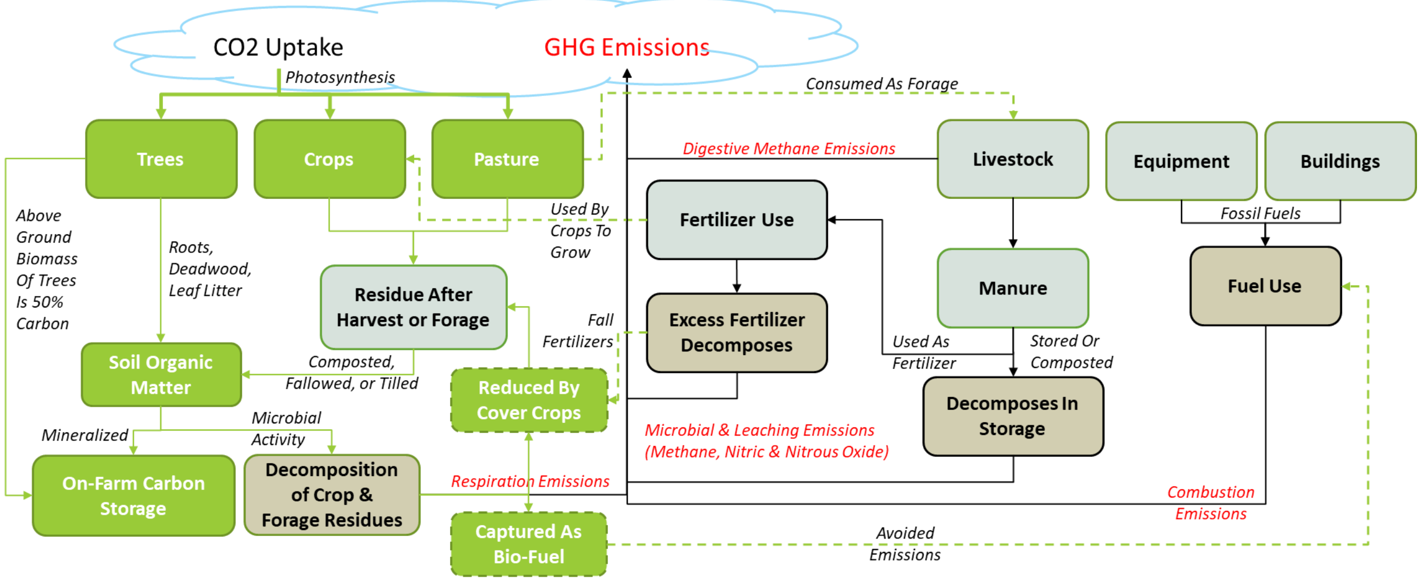
Comprehensive Farm-Level Carbon Footprint Modeling of Those Dynamics

Sequestration

- Models gains/losses In IPCC-defined carbon pools:
    - Above Ground Biomass
    - Below Ground Biomass
    - Soil Organic Carbon
    - Organic Litter & Deadwood
- Includes trees, crops, grasses

Emissions

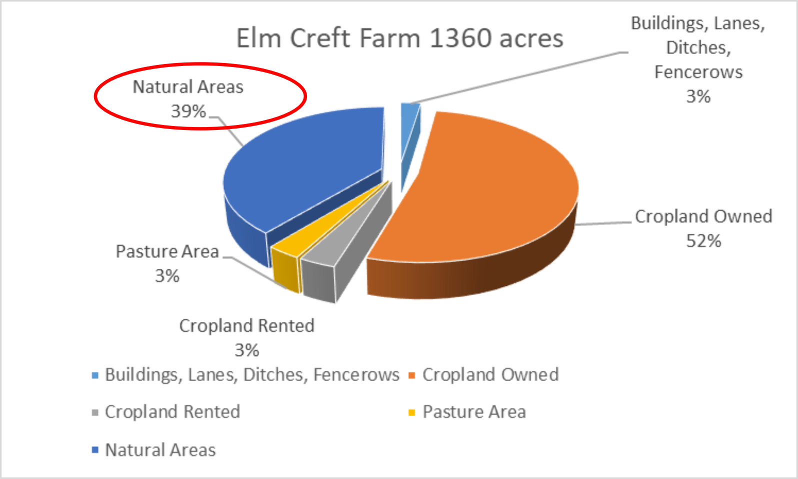
- Models all 3 Scopes (ISO 16047)
- Direct Emissions
    - Crops & Livestock
    - Fuel & Fertilizer use
- Indirect Emissions
    - Electrical use
    - Upstream
        - Fuel extraction & processing
        - Input chemical manufacturing
        - Feed & other input deliveries
    - Downstream
        - Transport Harvest to Market
        - Export of manure and other by-products to other farms



The carbon content in harvested crops is not considered to be a carbon pool because it is either consumed or wasted, ultimately releasing any stored carbon in the process.

Although this is not true for crops consumed by livestock (as previously demonstrated) we excluded sequestration of carbon in harvested crops in the whole farm analysis shown on the next slide.

Elm Creft Farm, Perth Ont



Farm Activity

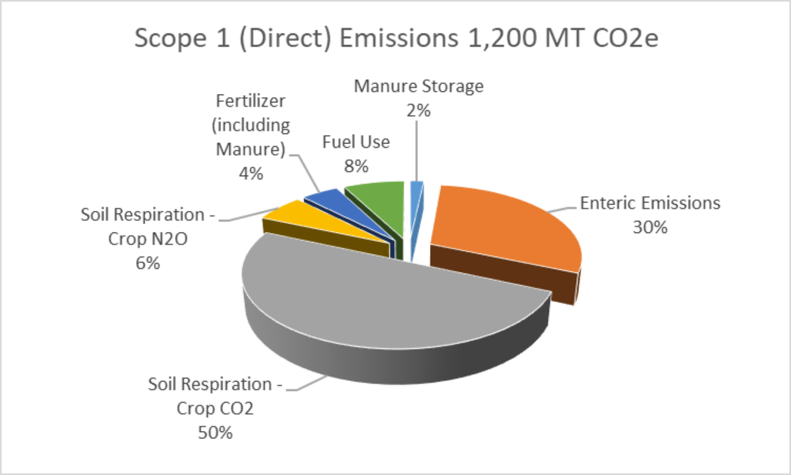
Carbon Negative Dairy Farm

Livestock

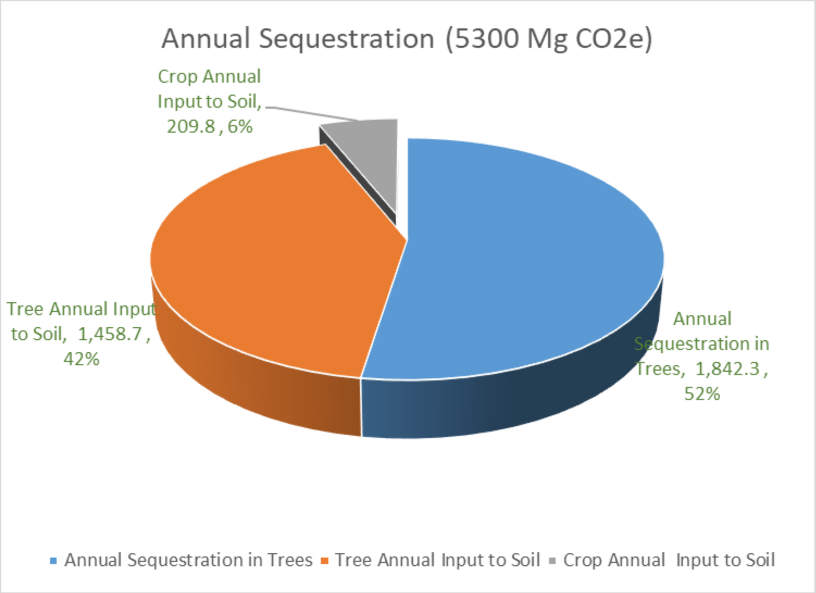
- 190 Dairy Cattle
- 776,728 L Milk Produced
- 5,050 T Manure Nutrients

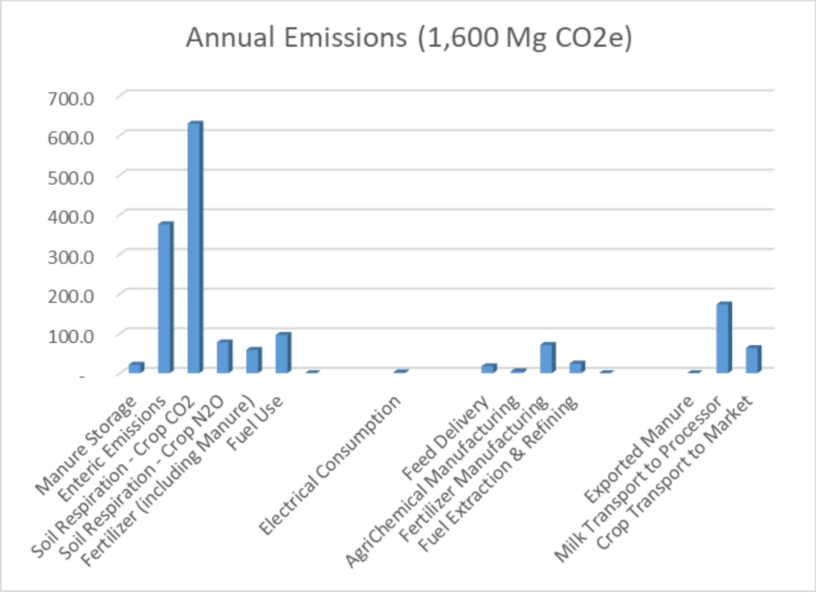
Crop Yields

- 1,753 T Hay
- 714 T Corn – Grain
- 322 T Corn - Silage
- 100 T Barley
- 172 T Soybeans



Carbon Footprint is Significantly Carbon-Negative





Scope 1
85%

Scope 2
0.2%

Scope 3
14%