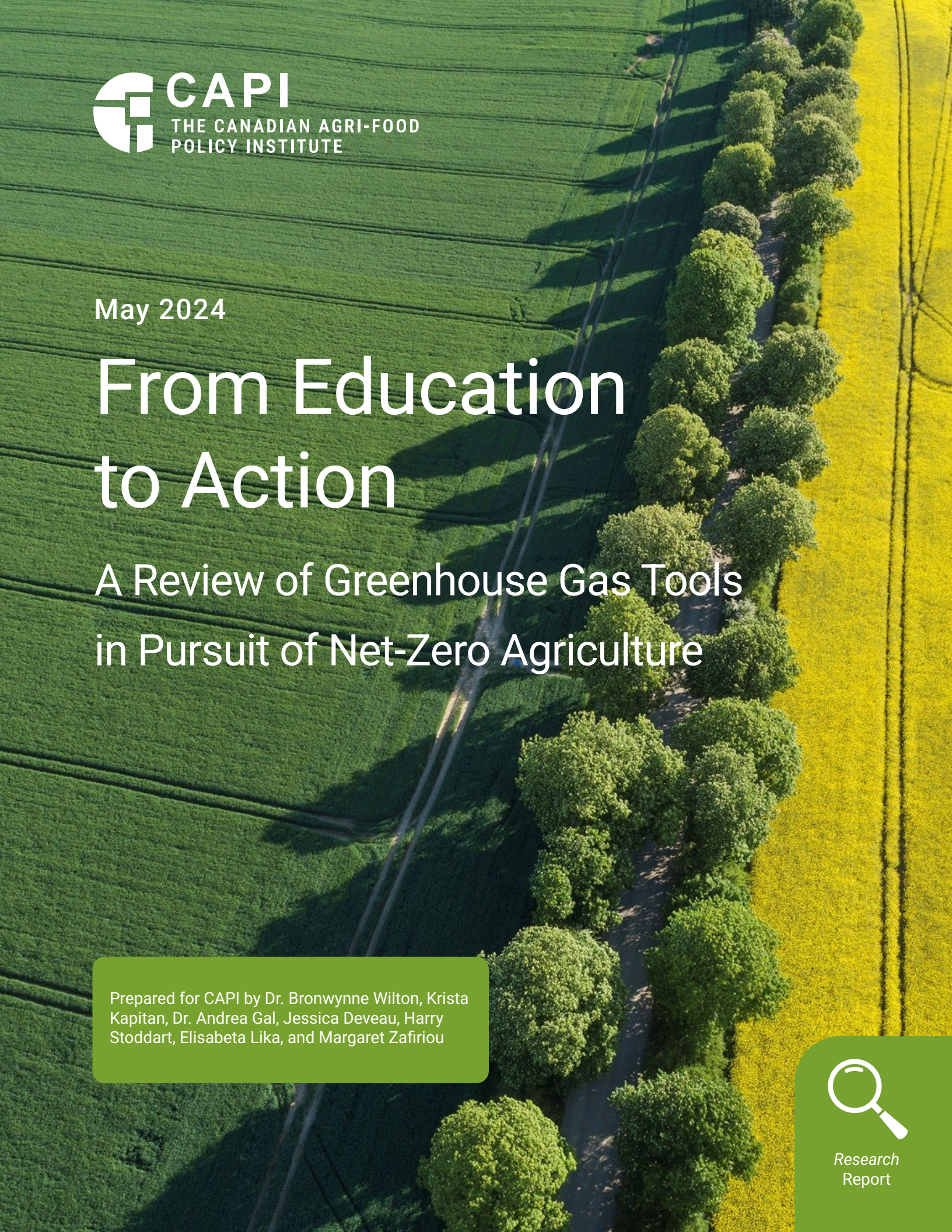

CAPI
THE CANADIAN AGRI-FOOD POLICY INSTITUTE

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From Education to Action

A Review of Greenhouse Gas Tools in Pursuit of Net-Zero Agriculture

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Research Report

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The Canadian Agri-Food Policy Institute's mission is to lead policy development, collaborate with partners and advance policy solutions within agriculture and food.

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Note from CAPI

This report explores the application and effectiveness of on-farm greenhouse gas (GHG) estimation tools as the Canadian agricultural sector strives towards net-zero emissions by 2050. The report examines selected domestic and international GHG tools, assessing their relevance and utility for the Canadian agricultural landscape.

The report identifies the significant role these tools could play in capturing accurate emissions data at the farm level, which is an important factor in shaping policies and practices for carbon reduction. The report also discusses the challenges impeding the widespread adoption of GHG tools, such as complexity, lack of regional specificity, and the barriers to accessing necessary technologies. Opportunities for public policy to encourage tool adoption through incentives, enhanced support, and clearer communication are outlined.

Additionally, recommendations are offered to enhance the effectiveness of these tools in accelerating decarbonization efforts. These recommendations include aligning tools with market and regulatory requirements, simplifying the use of the tools, enhancing farmer engagement, improving data accuracy at the farm level, and ensuring the tools are integrated into broader farm management systems. The report aims to bridge the gap between current practices and the potential for improved environmental performance in Canadian agriculture, supporting a strategic approach to achieving national net-zero targets.

Key takeaways

- It is critical to design GHG tools that are ‘fit-for-purpose’ and specifically tailored to meet the diverse needs of different farming operations across Canada. Ensuring these tools are scientifically accurate, practically relevant, and user-friendly for indicative, educational, or compliance purposes will enhance their utility for Canadian farmers.
- A significant gap exists in data accuracy, and the sector has a pressing need for tools that reflect the regional diversity of Canadian agriculture. Developing tools that account for regional specificity will improve the precision of emission tracking and support localized management strategies.
- A major barrier to the adoption of GHG tools is the absence of clear economic incentives. Aligning these tools with financial benefits could greatly enhance their attractiveness and uptake among farmers.
- Better integration of GHG tools with existing agricultural management systems is needed. This integration can reduce the operational burden on farmers and increase the practical utility of emissions data in everyday agricultural practices.
- Enhanced collaboration between the public and private sectors is essential to standardize GHG measurement approaches. Such collaboration would ensure that Canadian agricultural products remain competitive internationally, particularly as environmental sustainability becomes a more critical factor on global markets.

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1 Introduction

Agriculture is both a source of GHG emissions and a solutions provider, with the potential to mitigate its own emissions and sequester carbon from other economic sectors. As part of the federal government's goal to achieve net-zero emissions by 2050, the Canadian agricultural industry seeks to gain a clearer picture of GHG emissions at the farm level, and in agricultural processing and transportation. This data is needed to celebrate successes and identify opportunities to decrease emissions and increase carbon sequestration throughout the agri-food value chain. GHG emissions estimation tools are available for some practices and commodities, however limited uptake remains at the farm-level and the few commodities that have these tools for processing lack consistency.

This national level research is a critical missing piece for agriculture to advance effective policies, tools, programs, and metrics to accelerate decarbonization pathways to achieve net-zero emissions by 2050. The deliverables of this project will initially include a final list of public policy recommendations. These recommendations will be communicated and further discussed through a dialogue with diverse agri-food stakeholders, to increase buy-in and represent their perspectives to advance action and facilitate more rapid decarbonization.

As of 2016, the Canadian agricultural industry accounted for about 7% of the country's GHG emissions, according to Agriculture and Agri-Food Canada. This figure factors in the carbon absorbed by soils and does not include emissions associated with fossil fuel use.

This report provides the following insights:

- ✓ Context surrounding a net-zero future and what it means for Canadian farmers.
- ✓ An overview of select greenhouse gas estimation tools used in Canadian agriculture, or used internationally with applicability to Canadian agriculture.
- ✓ An assessment of the GHG tool approaches.
- ✓ Challenges and opportunities for public policy to support the adoption of GHG tools in the agriculture sector.
- ✓ Recommendations for accelerating decarbonization pathways through GHG tools in agriculture.

2 Net-zero and what it means for GHG emissions reporting in Canadian agriculture

Several factors are leading the primary agriculture sector to prioritize the reduction of GHG emissions:

Best management practices & industry-driven initiatives	The influence of government policy and programs	Private sector disclosure requirements
• Influenced by concerns over environmental stewardship and social responsibility, farmers want to identify opportunities to reduce emissions and implement BMPs to advance this work. • Farmers are also motivated by "win-win" scenarios where GHG reduction BMPs also contribute a return on investment. • Industry initiatives (e.g., value chain partnerships and commodity groups) are supporting this work.	• Policies (e.g., the Net Zero Accountability Act) and programs (e.g., On-Farm Climate Action Fund) that drive farm-level action to reduce emissions. • Funding for innovations in on-farm technologies/practices to reduce emissions (e.g., the Agricultural Methane Reduction Challenge).	• Market-based requirements and/or efforts to disclose GHG emissions. • Farmers anticipate being tasked with providing emissions estimates to enable disclosures for publicly traded food/beverage and agri-product companies.

2.1 Best management practices & industry-driven initiatives

Stakeholders across the agri-food value chain are undertaking initiatives to reduce GHG emissions and achieve net zero. For example, the Canadian Alliance for Net Zero Agri-Food (CANZA) was founded in 2023 to support pilots, projects, and scalable innovations "to remove 150 Mt of emissions from Canada's agri-food sector by 2050" (CANZA, 2023). CANZA has supported such work as "Growing a net-zero food system: An open-source framework for climate-smart agri-food products in Canada," which includes a measurement methodology for GHG accounting (Deloitte & CANZA, 2024). Farmers for Climate Solutions (FCS) is a national coalition, led by producers, to support the industry in transitioning to low-emissions, high-resilience practices. FCS collaborates with farm organizations and Indigenous partners across the country to deliver the FaRM Resilience Mentorship program to provide practical education and guidance to farmers in the areas of nitrogen management, grazing systems, and cover cropping.

Efforts are also underway at the commodity level across Canada, too (Table 1).

Table 1. Example commodity-level initiatives related to GHG emissions.

Commodity	Initiative
Beef	• Aims to reduce its GHG emissions from primary production by 33% by 2030 (Canadian Cattle Association, n.d.) • The industry has identified the key drivers to support the attainment of these goals
Dairy	• Dairy Farmers of Canada has committed to reaching "net-zero GHG emissions from dairy production by 2050" (Dairy Farmers of Canada, 2024) • Focused on voluntary actions at the farm level to achieve this goal and has a "Net Zero by 2050: Best Management Practices Guide to Mitigate Emissions on Dairy Farms" to assist farmers in this journey
Eggs	• Egg Farmers of Canada has committed to net-zero GHG emissions by 2050 (Egg Farmers of Canada, 2023) • National Environmental Sustainability and Technology Tool (NESTT), discussed in further detail in Section 4.0, is one resource to support egg farmers in this journey

Farmers are already implementing BMPs that reduce GHG emissions. For example, as of 2021, 31% of Canadian farms reported using no-till or zero-till seeding practices (Statistics Canada, 2022b, 2022a). Also as of 2021, Fertilizer Canada estimated that 15% of the total volume of nitrogen applied in Canada used an enhanced efficiency fertilizer product (Fertilizer Canada, 2022).

2.2 The influence of government policy and programs

Federal government policies and programs are also a driving force encouraging the move towards a net-zero future for agriculture (Table 2).

Table 2. Key federal government policies and programs supporting net-zero agriculture.

Policy/Program	Greenhouse gas emissions reduction emphasis
Canadian Net-Zero Emissions Accountability Act	• Formalized a commitment to achieve net-zero emissions by 2050 • Established the target of 40-45% reductions below 2005 levels by 2030 as Canada's enhanced National Determined Contribution (NDC)
A Healthy Environment and a Healthy Economy	• Canada's strengthened climate action plan • Presents the policies and programs that promote tangible actions towards meeting the national targets and economic and environmental progress outlined in the Net Zero Accountability Act • Includes a national target for a 30% reduction, compared to 2020 levels, in absolute levels of GHG emissions from the application of fertilizers by 2030
2030 Emissions Reduction Plan: Clean Air, Strong Economy	• Provides a roadmap for achieving, by 2030, a 40-45% reduction in GHG emissions compared to 2005 emissions
The Sustainable Canadian Agricultural Partnership (Sustainable CAP)	• A $3.5-billion, 5-year agreement (2023-2028), between the federal, provincial and territorial governments to strengthen the competitiveness, innovation, and resiliency of the agriculture, agri-food and agri-based products sector
The Agricultural Climate Solutions (ACS) program	• Has two streams: the Living Labs Initiative and the On-Farm Climate Action Fund • Supports producers in adopting management practices that can reduce emissions and increase carbon storage
The Agricultural Clean Technology (ACT) program	• Aims to scale the adoption of clean technologies (e.g., innovation in green energy and energy efficiency, precision agriculture, and bioeconomy) that are needed to enable the agricultural industry to thrive in a low-carbon economy.
The Agricultural Methane Reduction Challenge	• A competitive funding program to assist with technologies, practices, and/or processes that help to reduce enteric methane emissions from dairy and beef cattle operations

2.3 Private sector disclosure requirements

In June 2023, the International Sustainability Standards Board (ISSB) released the first two Sustainability Disclosure Standards: The *General Requirements for Disclosure of Sustainability-related Financial Information (IFRS S1)* and *Climate-related Disclosures (IFRS S2).* The documents lay out the general requirements for publicly traded entities to disclose sustainability-related financial information and for climate-related disclosures, respectively (for an overview of the current state of Scope 3 emissions reporting globally, see Appendix A).

The IFRS S2 requires companies to disclose their GHG emissions, classified as Scope 1, Scope 2, or Scope 3 emissions (Figure 1). For major food companies, Scope 3 emissions focus primarily on emissions from farm inputs. These emissions are the most difficult to calculate, given the complexity of farming systems and the diversity of farm types, regions, climate, and management practices.

Figure 1. Overview of Scope 1, 2 and 3 emissions.

Scope 1	Scope 2	Scope 3
• Emissions made directly by company activities. • Example: Emissions from machinery used in food manufacturing.	• Emissions indirectly through third-party services. • Example: Emissions associated with the energy used to heat buildings.	• Emissions from other sources that the company is indirectly responsible for through its supply chain (upstream and downstream). • Example: Emissions generated from a company's supplier of purchased goods.

The Canadian Sustainability Standards Board developed two associated exposure drafts.[1] As of March 2024, consultations were underway on amendments (Financial Reporting & Assurance Standards Canada, 2024), including:

- Voluntary reporting beginning on or after January 1, 2025.
- Mandatory reporting for Scope 3 GHG emissions as early as January 1, 2027.

Other jurisdictions have already adopted the ISSB's recommendations, and their disclosure requirements may impact Canadian companies or companies that source goods from Canada. For example, the European Union's Corporate Sustainability Reporting Directive (CSRD) will require companies to start mandatory Environmental, Sustainability and Governance (ESG) reporting in 2025. It is estimated that CSRD will impact upwards of 1,000 Canadian companies in addition to global companies operating in Canada (Marsh et al., 2023).

Agri-food companies are also setting and working towards targets for their companies, including:

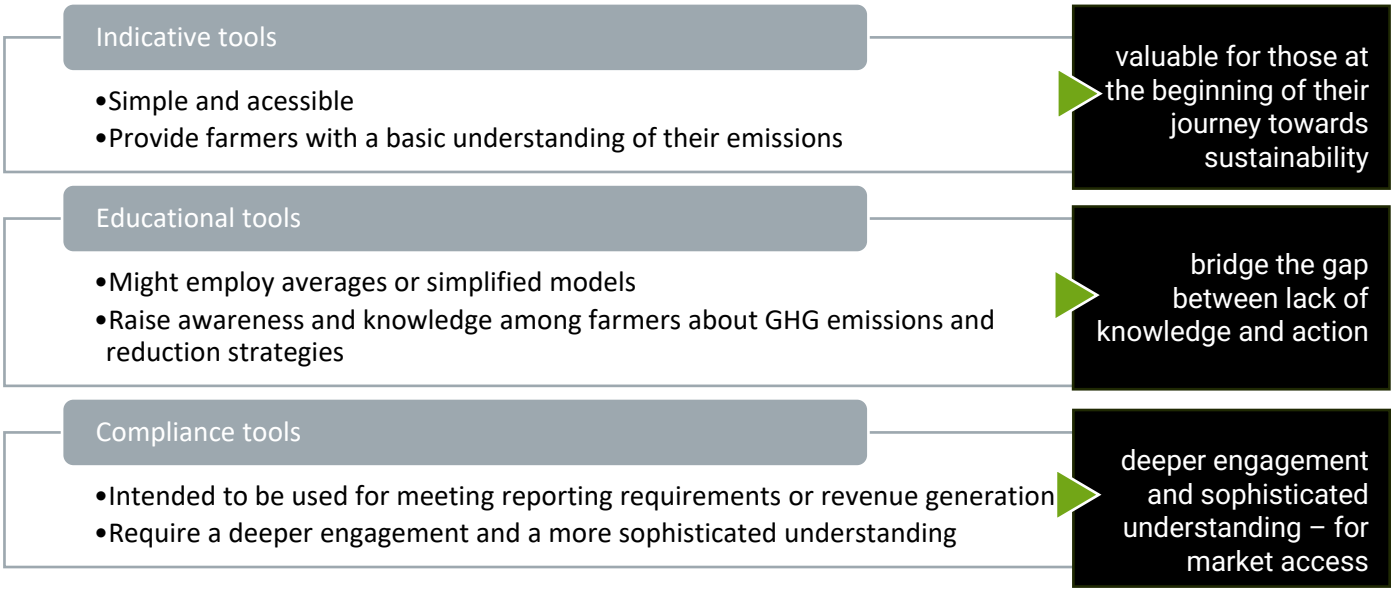
- ✓ Maple Leaf Foods has been carbon neutral since 2019, and is working to reduce its overall environmental footprint by 50% by 2025 (Maple Leaf, n.d.).
- ✓ General Mills will reduce its GHG emissions by 30% by 2030 (compared to 2020). By 2050, General Mills will achieve net zero GHG emissions across its full value chain (General Mills, 2021).
- ✓ Kraft Heinz will achieve net-zero carbon emissions by 2050, and half its current emissions by 2030 (Kraft Heinz, 2023).

[1] The exposure drafts are as follow:

- CSSB Exposure Draft – Proposed Canadian Sustainability Disclosure Standard (CSDS) 1, General Requirements for Disclosure of Sustainability-related Financial Information
- CSSB Exposure Draft – Proposed Canadian Sustainability Disclosure Standard (CSDS) 2, Climate-related Disclosures.

2.4 GHG estimation tools: An overview

Identifying and enabling opportunities for the agriculture and agri-food system to advance action and facilitate more rapid decarbonization is key. A range of tools are available in Canada to help estimate GHG emissions at the farm level. These tools can be grouped into three categories:



3 Methods

We conducted an environmental scan and literature review of tools and methodologies currently used in the sector to estimate greenhouse gas emissions (GHGs) for on-farm production. Where available, we provide insights on uptake and adoption. In total, 11 tools were assessed through this research.

Criteria for tool selection:

- ✓ Known to be used by Canadian farmers.
- ✓ Are focused on farm-level emissions estimates (i.e., estimates "end" at the farm gate).
- ✓ Select international tools that show promise for applications/relevance to Canadian agriculture.
- ✓ Select supply chain tools with farm level applicability.

Tools assessed:

- HOLOS
- AgriSuite
- CropTrak
- AgriTask
- FieldPrint Calculator
- Cool Farm Tool
- US Cropland Greenhouse Gas Calculator
- Soil Organic Carbon Reserves And Transformations in EcoSystems (S.O.C.R.A.T.E.S.)
- USDA/Colorado State University Tools
- The Ex-Ante Carbon balance tool (EX-ACT)
- Manitoba Environmental Farm Plan GHG Tool
- National Environmental Sustainability and Technology Tool (NESTT)
- Australian Greenhouse Accounting Framework (GAF) tools
- Australian Dairy Carbon Calculator (ADCC)
- Agriculture Innovation Australia Environmental Accounting Platform
- Australian Wine Carbon Calculator
- Meat and Livestock Australia Carbon Calculator
- Ruminati
- HortCarbonInfo
- Full Carbon Accounting Model (FullCAM)

A literature review was conducted to explore research related to GHG tools in the primary agriculture sector. The literature review includes peer-reviewed academic research, in addition to industry, government, and not for profit organization reports with valuable insights.

Interviews were also conducted to understand different perspectives on the current state of GHG tool adoption, effectiveness, and their role in the journey towards net-zero emissions in agriculture. Twelve interviews were conducted with a diverse array of stakeholders, including those from the international scene, academia, government, industry, and agricultural organizations.

4 Overview of GHG tools and data sources

Tool	Commodities Covered	Data Source
Canadian Tools		
HOLOS Based on information entered for individual farms, the main purpose is to test possible ways of reducing GHG emissions and increasing soil carbon stocks by exploring the effects of different management practices.	All major Canadian grains, oilseeds, pulses, forages and some vegetable crops are included along with all major livestock species under a range of production systems.	The initial source for HOLOS methodology was the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. HOLOS V4.0 incorporates the 2019 IPCC Tier I and II refinements. HOLOS includes unique Canadian modifications which occur primarily in the estimation of soil and cropping N2O, manure management CH4, energy CO2 emissions, as well as soil and tree carbon storage and removal. The specific parameters and algorithms are derived from published scientific literature. The full documentation can be found here: HOLOS V4.0 Algorithm Documentation
AgriSuite - Greenhouse Gas Decision Support Tool Estimates greenhouse gas (GHG) emissions from crop and livestock farms in Ontario and allows users to test possible ways to reduce emissions and sequester carbon by implementing various best management practices.	Prepopulated with values for 50 Ontario grain, oilseed, and vegetable crops with the ability to create custom inputs for additional crops. The tool also includes parameters for multiple production systems for beef, chickens, chinchilla, dairy, deer/elk, ducks, emu, fox, goats, horses, mink, ostrich, rabbits, sheep, swine, turkeys, veal.	Methodology reflects IPCC guidelines. The tool is built on AAFC HOLOS with refinement incorporating Ontario-specific climate and production data, as well as the latest scientific findings on the emission reduction and carbon sequestration potential of various BMPs. The methodology document will be available eventually as a tool resource.
Manitoba Environmental Farm Plan GHG tool A GHG tool embedded into the Manitoba EFP showcases total farm emissions, by source, for seven different types of emissions. Farmers can manipulate practices to gain a better understanding of how best management practices impact their overall emissions by source. The tool includes insights	Crops (annual crop, pasture, tame and native hay), non-agricultural land (woodlands, riparian areas, wetlands and grasslands) and livestock (dairy, beef, pig, poultry, sheep, turkey) with specifications for different types of production systems.	Leverages HOLOS methodologies with specifications for Manitoba agriculture.

Tool	Commodities Covered	Data Source
about return on investment for best management practices.		
Canadian FieldPrint Calculator A farm-level measurement tool that allows growers to confidentially assess and document their environmental performance against national and regional benchmarks, using their own field data.	Alfalfa, Barley, Corn (grain), Corn (silage), Cotton, Peanuts, Potatoes, Rice, Sorghum, Soybeans, Sugar beets, Wheat (durum), Wheat (spring), Wheat (winter). The tool models soil organic carbon change in Western Canada only.	Both the greenhouse gas emissions and the soil carbon change estimates are based largely on modelling algorithms used by Agriculture and Agri-Food Canada in the HOLOS tool.
Biological Carbon Canada ESG Emission Calculator The tool is an educational instrument created by Biological Carbon Canada as part of its mission to support meaningful carbon reductions and removals to create value for farmers, ranchers and foresters.	The calculator is a printable series of tables that are sufficiently generic that they can be used for most commodities. There are also tables for land use change and energy use.	Emissions values are obtained from the 2021 ECCC IPCC Background Tables.
NESTT: National Environmental Sustainability and Technology Tool The tool allows egg farmers to undertake a sustainability assessment of their farm, benchmarking their results against other Canadian farms. With on-demand access to comparative data and the latest environmental information, egg farmers can also set informed sustainability goals and track their progress.	The tool is custom designed for the chicken egg laying enterprises on chicken egg laying farms in Canada (it does not include cropping or other enterprises that a farm may include).	The calculations are based on a Life Cycle Analysis conducted by Dr. Nathan Pelletier and his team at the University of British Columbia.
International tools with potential applicability to Canadian agriculture		
Cool Farm Tool The Cool Farm Tool is intended to help farmers choose management options that improve their environmental performance and to track and measure improvement over time.	The tool is built to generically cover all the major field crops, potatoes, rice plus beef and dairy. Other livestock species are not recommended to use the generic livestock module.	The Cool Farm Tool relies entirely on peer-reviewed empirical research, drawing from a diverse array of published data sets and IPCC methods. The results can be used as part of companies Science Based Targets Initiative (SBTi) reporting commitments. Cool Farm Tool | An online greenhouse gas, water, and biodiversity calculator

Tool	Commodities Covered	Data Source
The EX-Ante Carbon-balance Tool (EX-ACT) The suite assists decision makers to gather the evidence and the information available on the outcomes of their agrifood interventions. It helps them to quantify the amount of greenhouse gas released or sequestered from agricultural production, analyze the outcomes of activities from agrifood investments along selected agricultural value chains and assess the impact of agricultural activities on local biodiversity.	It covers the Agriculture, Forestry and Other Land Use (AFOLU) sector, coastal and inland wetlands, fisheries and aquaculture, agricultural inputs and infrastructure.	The tool is based on the IPCC methodology for GHG emissions inventories. The tool's default values are IPCC Tier 1 values but allows the user to include Tier 2 values.
USDA ARS Integrated Farm Systems Model Simulates all major farm components on a process level. The model links components of the farm to capture biological and physical processes on the farm. The model is a research and teaching tool for exploring the whole farm impact of changes in management and technology.	Dairy, beef, and crop farming systems.	The process modelling deviates from the IPCC protocol by including the CO_2 assimilated into the feedstuffs to net against the standard emissions. The approach reduces the carbon footprint of production strategies by about 25% compared to the standard IPCC modelling approach (pg. 221). Otherwise, the modelling follows IPCC guidelines.
Soil Organic Carbon Reserves And Transformations in EcoSystems **(S.O.C.R.A.T.E.S.)** SOCRATES is a model for predicting long-term changes in soil organic carbon in terrestrial ecosystems.	Crop rotations that include wheat, barley, oats, canola, grain legume, improved pasture, grass pasture, fallow	The SOCRATES model is a process-based representation of SOC dynamics in terrestrial ecosystems, which requires minimal data inputs and specifically designed to examine the impact of land use and land use change on soil carbon storage. It also contains a simple yield calculator. SOCRATES was successful in predicting SOC change at eighteen long-term non-irrigated crop, pasture and forestry trials from North America, Europe and Australasia. These trials ranged from 8 to 86 years in duration, over a wide range of climates and soil types.

Tool	Commodities Covered	Data Source
US Cropland Greenhouse Gas Calculator The calculator was created to help farmers, extension educators, agencies, policymakers, and others learn about greenhouse gas emissions from field crop agriculture to make informed decisions about crop management and environmental stewardship. The tool supported participating in a range of conservation projects by US farmers.	Grain corn, sileage corn, soybeans, wheat, oats, switchgrass	USDA emissions data derived using IPCC Tier 2 methods.
Cornell FAST-GHG ™ Calculator FAST-GHG is a greenhouse-gas calculator tool designed to give rapid, yet robust, estimates of the potential to reduce agricultural emissions.	Estimates impact of improved tillage, cover cropping and nitrogen fertilizer management on corn, wheat, and soybean production in the U.S.	Generally appears to follow IPCC Tier 2 estimate process to create regional factors based on academic literature supported findings.
FARM ES – US Dairy The FARM Program's goal is to continue showing customers and consumers that that the US dairy industry is upholding the highest standards.	Milk	Core source of data was an LCA of more than 500 US dairy farms.
COMET-Planner and COMET-Farm Created to evaluate potential carbon sequestration and greenhouse gas reductions from adopting National Resource Conservation Service (NRCS) conservation practices.	The tool is organized around specific NRCS conservation practises rather than around commodities.	USDA entity-scale greenhouse gas inventory methods.
Greenhouse Accounting Frameworks (GAF) for Australian Primary Industries A series of commodity specific spreadsheets designed to predict the magnitude and sources of GHGs emitted from a farm and a product at the farm gate. Includes Scope 1, 2, and 3 (upstream supply chain) emissions. Soil carbon	Dairy, sheep & beef, cropping, feedlot, sugar, cotton, horticulture, pork, buffalo, deer, poultry, rice	The calculations are aligned with Australia's National Greenhouse Gas Inventory methodology which is IPCC compliant.

Tool	Commodities Covered	Data Source
fluctuations are not included in the models.		
Australian Dairy Carbon Calculator (ADCC – previously known as DGAS) Excel-spreadsheet model developed to explore the implications of a range of diet, herd or feed base management options on the GHG emissions of a dairy enterprise.	Dairy	The calculations are aligned with Australia's National Greenhouse Gas Inventory methodology which is IPCC compliant.
Agricultural Innovation Australia Environmental Accounting Platform The platform is designed to provide Australian agriculture, fisheries and forestry with an accessible and standardized approach to carbon foot printing that allows for footprint calculation at a commodity, enterprise and whole of business level. The platform is designed to integrate with farm management software, agricultural service provider offerings, and agri-finance. The first stage will allow farmers, fishers and foresters (growers) to calculate their enterprise's carbon footprint across multiple commodities (the solution has just finished beta testing but hasn't been opened for general use yet).	Broad coverage of most commodities produced by Australian agriculture, fisheries and forestry.	The platform is underpinned by the GAF models which are aligned with the Australian National Greenhouse Gas Inventory reporting protocols and relevant IPCC and ISO standards.
Australian Wine Carbon Calculator This tool is designed to help grape growers and winemakers estimate their direct (Scope 1 & 2) greenhouse gas emissions.	Grapes and wine	The tool is based on the methodologies of the Australian National Greenhouse Gas Accounts (2022) and the latest global warming potentials from IPCC AR6 (2021). This calculator does not attempt to estimate offsite Scope 3 emissions (packaging, distribution, oak, etc.)
Meat and Livestock Australia Carbon Calculator This is an online version of the Sheep and Beef, and Grains Greenhouse Accounting	Beef, sheep meat, wool, grain	The calculations are aligned with Australia's National Greenhouse Gas Inventory methodology which is IPCC compliant.

Tool	Commodities Covered	Data Source
Framework tools listed above. They have been integrated to create GHG estimates at the property level as well as the emissions intensity per product produced.		
Ruminati An online emissions calculator tool designed to help farmers calculate total on-farm emissions, sequestration, and net on-farm emissions estimates broken down into Scope 1, 2 and 3.	Beef, sheep meat, wool, and grain	The tool uses the Australian National Greenhouse Gas Inventory (NGGI) equations to calculate emissions. The emissions factors for farm inputs are sourced from the 2022 National Greenhouse Accounts Factors Workbook.
HortCarbonInfo An online tool that can be used to calculate GHG emissions from most edible horticultural growing operations. The tool uses a simplified interface and Greenhouse gas emissions are calculated for electricity, fuel, fertilizer, dolomite and lime, crop residues, refrigeration leakage and on-farm waste. Other sources of greenhouse gasses exist on farms, including wastewater.	16 fruit crops and 17 vegetable crops	Emission factors are current with the 2022 National Greenhouse Accounts Factors
Full Carbon Accounting Model (FullCAM) The tool estimates the carbon stock change in ecosystems including: • above and belowground biomass • standing and decomposing debris • soil carbon resulting from land use and management activities. It is used to generate abatement estimates for vegetation methodology determinations under the Australian Carbon Credit Units Scheme.	Primarily applicability to agriculture is the carbon impacts of land use changes – either reforestation or avoided clearing of native regrowth.	Emissions data are derived from Australia's National Greenhouse Accounts.
Supply chain tools with potential applicability to Canadian agriculture		

Tool	Commodities Covered	Data Source
OPTCHAIN Carbon Tracking Optchain Carbon Tracking streamlines the carbon tracking process for consumer producing goods and food and beverage companies. It enables compliance with established reporting frameworks. It allows a business to track and monitor upstream and downstream GHG emissions in supply chains for complete visibility of all Scope 1, 2 and 3 GHG emissions, providing a detailed and accurate carbon footprint assessment and providing access to the insights needed to reduce it.	All food ingredients with a completed LCA.	LCA specific to the products being used. The LCAs are confidential information to the company producing the product. However, the LCA for Quebec Grains that was completed by the same firm that OPTEL partners with is publicly available.
CropTrak The CropTrak tool provides emissions estimates for food companies that aggregate agricultural products from multiple sources across their supply chains.	Field crops, vegetables, and fruit.	Leverages other tools such as COMET-Planner, Cool Farm Tool, FieldPrint Calculator to create aggregate GHG emissions estimates by crop and field for crop production in the supply chain of major food and beverage companies alongside estimates of yield and detailed records of production practises.
AgriTask The tool provides a comprehensive view of emissions, by region, crop and/or activity, to help guide multi-national food companies towards their reduction goals. It provides the ability to identify "hotspots," collaborate with growers to scale sustainable agriculture practices and plan additional decarbonization activities.	Field crops and horticulture.	Leverages other tools such as Cool Farm Tool for GHG estimation to create a carbon-balance dashboard.

5 Findings

5.1 Assessment of GHG tool approaches

GHG tools follow different approaches to GHG accounting. From this study and other industry research, we find several sources of data that inform GHG calculations:

- ✓ IPCC Tier I and Tier II calculations.
- ✓ Life Cycle Analysis (various sources).
- ✓ Peer-reviewed empirical research.
- ✓ Federally derived emissions estimates (e.g., Canada's National Inventory Report, USDA GHG inventory methods, Australia's National Greenhouse Gas Accounts Factors).
- ✓ Combinations of the above methodologies.

One study based in the U.K. assessed GHG tool methodologies and outputs by testing 5 different GHG tools on 7 farms to measure the variation between outputs and GHG estimates (Sykes et al., 2017). The study concluded that many of the emissions estimates on each farm varied greatly – with "a considerable amount attributable to the tools themselves." This underscores the importance of improving our understanding of the benefits and drawbacks to different tool approaches to estimating on-farm emissions, particularly when it comes to providing assurance of agricultural efforts to support a net-zero future.

Interviewees shared insights about the limitations of current GHG tools in Canadian agriculture and associated barriers to on-farm adoption (Table 3).

"Transparency [in methods] and availability of information is likely to be a key concern where [GHG] tools are sought to inform policy, and hence is a potential limiting factor in the uptake of tools by policy makers. It may also limit the extent to which users can employ the tools make informed decisions on mitigation of emissions from farming systems."

– Sykes et al., 2017

Table 3. Summary of insights from interviewees and research: Limitations of the current landscape of GHG tools in Canadian agriculture and barriers to on-farm adoption.

Current limitations and barriers	Description
Lack of regionally specific data	Tools often lack accuracy for Canadian farms and use generalized data or averages that do not fit all situations or the "nuanced realities" within the diversity of the Canadian agricultural sector, interviewees said. Interviewees highlight significant costs are associated with gathering accurate, farm-specific data, which serves as a limitation to providing regionally specific data.
Tool complexity and accessibility	Tools available often require intensive labour and advanced understanding for data input and may not be intuitive for growers. Some tools available measure "for the sake of measuring," and overloading farmers with unnecessary data could present a barrier to adoption. The accessibility of IT systems (e.g., keeping up with rapidly changing systems) and access to reliable internet has been identified as a barrier to using GHG tools (OECD, 2023). Producers are also often unaware of the tools and how they can benefit their operations.

Current limitations and barriers	Description
Whole-farm considerations	Tools that assess the entirety of a farm system's impact on GHG emissions in a comprehensive, yet user-friendly way, have largely yet to be developed. Tools should not "simplify biological processes into potentially misleading metrics." Farmers should also have the option to integrate different farm management tools to streamline the data entering process.
Lack of interoperability and transparency between tools	Different tools have varying scope and boundaries, making it difficult to compare them directly. This situation may encourage companies to "choose" tools for their supply chains, as opposed to the sector providing forward-thinking solutions that provide accurate measurement of GHG emissions.
Science takes time	Interviewees recognize that, despite ongoing research, a "significant level of uncertainty" still exists in methodologies for calculating emissions estimates, especially concerning soil carbon and nitrous oxide emissions.
Maturity of tools	Many tools are (relatively) immature. Many tools are still in their early stages of uptake, interviewees said. Quantifying the usage rates and uptakes of tools remains a challenge, particularly amongst voluntary, educational-based tools, stakeholders said.
Economic and incentive alignment (i.e., lack of clear economic incentives)	The motivation for using GHG tools is often driven by economic incentives rather than purely environmental considerations. Tools need to align more closely with financial benefits such as improved market access or eligibility for sustainability programs, to encourage wide adoption. Mechanisms that clearly articulate the economic advantages of GHG reduction efforts could significantly enhance tool uptake, interviewees suggested.
Data privacy and security concerns	Farmers' apprehensions about data privacy and the security of sensitive operational information pose a significant barrier to tool adoption. "Confusion and suspicion" about data collection if data is to be shared with regulators or organizations with unclear intentions has been identified as a barrier to participating in sustainability platforms (Buck & Palumbo-Compton, 2022). Discussions on whether farmers should be compensated for such data are also prominent. Addressing these concerns through stringent data protection measures and transparent usage policies is crucial to build trust and facilitate wider tool engagement (McIntosh, 2018).

Supply chain software companies are already releasing products to facilitate the gathering of the information that companies will be compelled to report; a Google search for "calculator for scope 3 emissions" returns 1.6 million results. Farm level GHG calculator tools will likely continue to evolve to inform the data gathering requirements necessitated by global GHG emissions reporting standards. For example, the Cool Farm Tool is commonly used in Canada. The Cool Farm Tool has been integrated into more than one supply chain software solution and has received investment from major global food and beverage companies; including companies with footprints in Canada.[2]

Canadian agri-food sector stakeholders should explore opportunities to join the Cool Farm Alliance and ensure that Canada's interests are represented.

With so many tools available to farmers and in the marketplace, this begs several questions:

- Can calculator tools used in Canadian agriculture be rooted in common methodologies that enable market-based reporting?
- Who should lead efforts to ensure tools are defensible, easy to use, and benefit farmers?
- What can we learn from other jurisdictions?

Agriculture Innovation Australia is working on developing the Environmental Accounting Platform with full API access capabilities which would allow a similar type of integration for Australian agricultural commodities (see page 23). Currently, there isn't a Canadian tool based on Canadian data with equivalent capabilities. However, models such as Canada's HOLOS tool provide promise for further exploration. Such continued exploration should include several considerations:

Fit for purpose: Each Canadian GHG tool should be designed for specific agricultural needs. For instance, certain tools might be optimized for farmer education, while others are better suited for market-based reporting. This targeted approach ensures that the tools are effective and relevant, catering specifically to the diverse requirements and sustainability goals of different farming operations.

Whole-farm approach: A national approach may enable the sector to move away from commodity-specific approaches that may duplicate efforts or use different methodologies. Ideally, farms with multiple enterprises should be enabled to measure and communicate their footprint with one tool.

Data governance: A trusted, and well governed approach to data management should be considered. Methodologies should be interoperable across other programs and channels farmers already use and trust.

Growing a net-zero food system: An open-source framework for climate-smart agri-food products in Canada

In April 2024, Deloitte and the Canadian Alliance for Net-Zero Agriculture released an open-source framework. The framework provides a unified approach to measurement, reporting, and verification (MRV) for Canadian agriculture. The aim of the framework is to "enable value-chain participants to credibly measure the emissions reductions and removals associated with climate-smart practices."

As Canadian stakeholders strive to better understand the GHG emissions from the agricultural industry and collaborate to reach net zero emissions, it will be critical to engage with existing modeling frameworks.

[2] A full list of partners and members involved in the Cool Farm Tool can be found at: https://coolfarm.org/members-partners/

Public sector approaches: The case of Australia's greenhouse accounting frameworks and environmental accounting platform

The Greenhouse Accounting Frameworks are a series of commodity specific spreadsheets designed to predict the magnitude and sources of GHGs emitted from a farm and a product at the farm gate. The frameworks include methods for Scope 1, 2, and 3 (upstream supply chain) emissions calculations.[3]

The calculations are aligned with Australia's National Greenhouse Gas Inventory methodology which is IPCC compliant.

From the Greenhouse Accounting Frameworks, Agricultural Innovation Australia is developing an Environmental Accounting Platform to enable the sector to tap into an accessible and standardized carbon foot printing tool.

Australia's approach to develop a single source of the national picture of methodologies is a model worthy of exploration in Canada:

"Our whole of agriculture, fisheries and forestry approach is designed to help Australia avoid the fragmentation, duplication and inconsistencies seen in other markets that have a proliferation of carbon calculators."

- Develop single-source methodologies for calculating scope 1, 2 and 3 emissions for agriculture.
- Ensure the methodologies are defensible and compliant with global approaches (i.e., IPPC, ISO compliance).
- Enable whole-farm GHG tools that align with the goals of the organization (e.g., BMP practice education adoption/education, or market-based reporting) and that integrate with trusted channels farmers already use and trust.

Success factors

- ✓ The platform is pre-competitive and will integrate with existing channels.
- ✓ A whole-farm approach to ensure farms with multiple enterprises are able to benefit.
- ✓ Data, intellectual property, and governance will be maintained by a not-for-profit organization.
- ✓ A Technical Advisory Panel advises on emerging research and possible updates to the platform.

[3] Soil carbon fluctuations are not included in the models.

5.2 Public policy: Challenges and opportunities ahead

Overcoming limitations in GHG tools and barriers to farm-level adoption

Although statistics are not available to formally quantify uptake of all GHG tools in Canada, industry representatives acknowledge that farmer use of GHG tools remains relatively low. For example, an estimated approximately 20% of Canadian egg farmers use the National Environmental Sustainability and Technology Tool ("NESTT").[4] The limitations of on-farm tools (see Section 5.1) hinder widespread adoption by farmers.

Government, researchers, and industry all have roles to play in helping to overcome these limitations and barriers, and to encourage farmers to use these tools (Table 4).

Table 4. Strategies for overcoming limitations in GHG tools and barriers to farm level adoption.

Limitations and barriers addressed	Strategy category/policy intervention type	Examples/strategic solutions	Role of government, researchers, and industry
• Lack of clear economic incentives • Tool complexity and accessibility (e.g., labour intensive to use and perceived complexity) • Lack of regionally specific data	Enhanced financial incentives and technical assistance	**Financial incentives:** Provide subsidies or cost-share funding for adopting best management practices identified through GHG tools. Provide funding for researchers to collect, analyze, and incorporate more regionally specific data into existing tools. **Technical assistance:** Offer free consultations or support services for tool setup and use.	**Government:** Offer funding and support services to both researchers developing/refining the tools and farmers using the tools. **Researchers:** Develop and simplify tool interfaces. Ensure the tool is accessible for non-specialists. Identify and address gaps in regionally specific data. **Industry:** Encourage adoption by offering incentives or supports for reduced GHG emissions in supply chains.
• Tool complexity and accessibility (e.g., lack of training opportunities, lack of awareness)	Educational programs	**Training programs:** Create workshops for farmers to learn about the tools, and how to use them. Partner with agricultural organizations and commodity groups to reach their members. **Awareness campaigns:** Run campaigns highlighting the benefits of GHG reduction and tool usage. Highlight opportunities for increased	**Government:** Fund and promote educational initiatives. **Researchers:** Provide the scientific basis for training content. Ensure this content is plain language and accessible. **Industry:** Support awareness campaigns and offer training for farmers.

[4] An interviewee associated with the NESTT project shared this estimate.

Limitations and barriers addressed	Strategy category/policy intervention type	Examples/strategic solutions	Role of government, researchers, and industry
		return on investment and improved labour efficiencies.	
• Data privacy and security concerns	Data privacy protections	**Data protection guidelines:** Develop and implement strict data privacy standards. **Transparent policies:** Clearly communicate how data will be used and protected. For example, consider Ag Data Transparent certification.	**Government:** Enforce data protection laws and standards. **Researchers:** Ensure research and tools adhere to privacy standards. **Industry:** Respect data privacy in all dealings with farmers. Clearly communicate data privacy policies.
• Whole-farm considerations	Tool simplification and accessibility	**Tool development:** Enhance tools to be more intuitive and capable of handling whole-farm assessments. **User-friendly design:** Simplify user interfaces and reduce the need for specialized training.	**Government:** Support the development of simplified tools. **Researchers:** Focus on user-centric design principles in tool development. Ensure tools are accessible to non-specialist audiences. Identify opportunities to streamline data entry through optional/voluntary integrations with existing farm management systems. Build in these integrations as possible. **Industry:** Provide feedback on tool practicality and integration into farm management systems.
• Lack of market-driven demand	Market-driven demand	**Market incentives:** Develop premium pricing or certification for low-emission products. **Supply chain integration:** Encourage food processors and retailers to preferentially source from farms using GHG tools.	**Government:** Facilitate market conditions that reward sustainable practices. **Researchers:** Provide evidence linking sustainable practices with market benefits. **Industry:** Offer incentives for verified low-emission products. Offer programs to support farmers in adopting BMPs that reduce their GHG emissions.

Limitations and barriers addressed	Strategy category/policy intervention type	Examples/strategic solutions	Role of government, researchers, and industry
• Lack of interoperability and transparency between tools • Science takes time • Maturity of tools	Working group formation and framework development	**Working group:** Develop a national working group for stakeholders involved in developing and refining GHG tools to reach a consensus on a standardized methodology.[5] Develop an overarching communications strategy, emphasizing the potential return on investment (ROI) from the use of these tools.	**Government:** Support the formation of the working group. **Researchers:** Collaborate to develop a standardized methodology for GHG tools. **Industry:** Participate in working group discussions to share insights into industry need related to GHG tools. Help to promote the ROI from GHG tools. Explore and leverage opportunities for integration/interoperability between different farm management systems to streamline the data entry process for GHG tools.

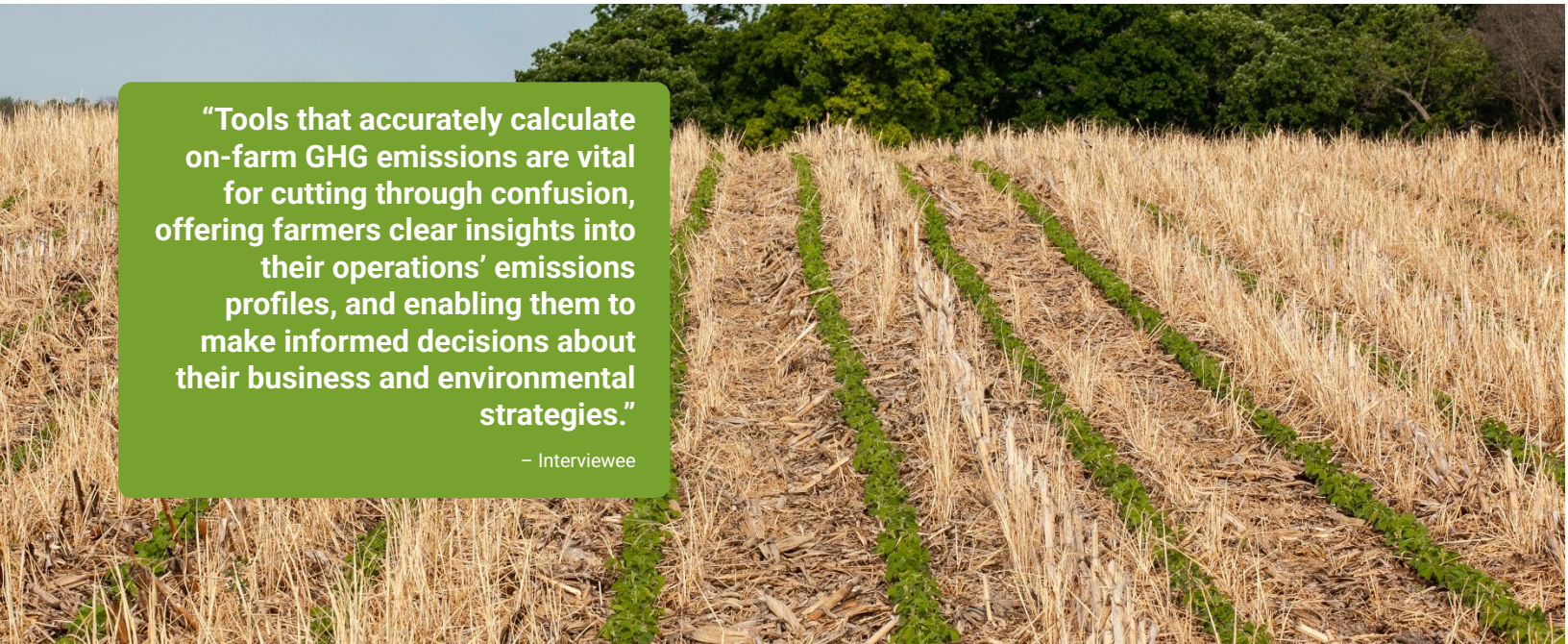
[5] This example is inspired by a recommendation for more international collaboration on GHG tools. See Wilton Consulting Group. (2024). "EU-CANADA CETA Agriculture Dialogue Sustainability Workshops Stakeholders' Conference Potential Paths Forward."

The future of GHG tools

Building on strategies to enhance the adoption of GHG tools, it is important to next turn the attention to their future evolution. It is clear from the interviews that enhancements are critically needed to ensure these tools become integral components of farm management systems. Farmers and industry experts alike have voiced specific areas for improvement to make these tools more effective and widely adopted. Addressing these needs will not only increase tool usability but also bolster their role in achieving sustainable agricultural practices.

These tools should:

- ✓ **Become integrated with existing farm management tools** to streamline data collection and analysis, reduce the time and effort required by farmers to engage with these tools. Tools must evolve to automatically pull data from various farm activities, thereby streamlining the process of GHG calculation.
- ✓ **Be user friendly and accessible** (i.e., easy for producers to understand and use without in-depth technical knowledge about GHG emissions – this may include the development of mobile apps, improved user interfaces, etc.).
- ✓ **Provide actionable insights** (e.g., identify practices that will both reduce GHG emissions and increase profitability and/or improve operational efficiency).
- ✓ **Be continuously updated** to reflect the latest scientific findings and evolving agricultural management practices across Canada, ensuring accuracy and relevancy.
- ✓ **Incorporate regionally specific and accurate data** to reflect variation across Canada. This adaptation will improve the accuracy of GHG calculations and make the tools more applicable to the varied environmental conditions and farming practices across the country.
- ✓ **Have a robust framework to ensure data protection and privacy** (e.g., Ag Data Transparent certification). Transparent policies on data usage and security can address farmers' concerns and encourage broader tool adoption.
- ✓ **Be regularly refined** based on input from users (i.e., farmers), as well as researchers. Tools should be adaptable, with mechanisms for users to suggest improvements, ensuring they evolve in ways that directly address the users' needs and preferences.



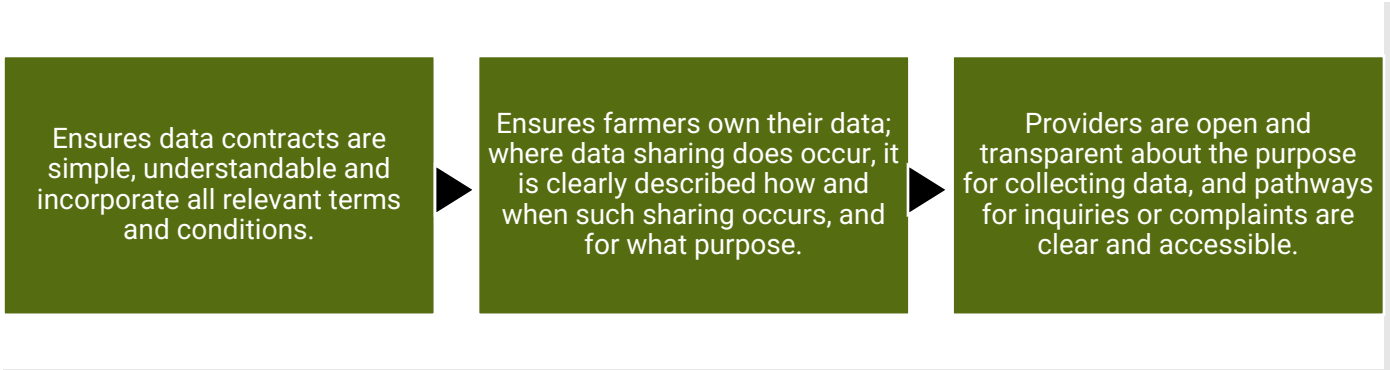
"Tools that accurately calculate on-farm GHG emissions are vital for cutting through confusion, offering farmers clear insights into their operations' emissions profiles, and enabling them to make informed decisions about their business and environmental strategies."

– Interviewee

Showcase: AgExpert's integration with Holos

Farm Credit Canada's AgExpert is a farm management software. Producers can use AgExpert Accounting for financial recordkeeping, and AgExpert Field for records related to field inventory, crop rotations, and cost of production. AgExpert is also Ag Data Transparent certified, which means that farmers continue to own their data and it is safe. Farmers also control who they share their data with.

Ag Data Transparent Certification



Increasingly, AgExpert offers integration with other tools and solutions to streamline recordkeeping and to help producers make better decisions. As of this spring, one such integration is with Holos. The process for estimating their farm's carbon sequestration is streamlined, as the tool leverages the production data farmers have already entered into AgExpert. Farmers can access carbon sequestration estimates at both the field and full-crop scale. In the longer term, AgExpert aims to integrate the capability for farmers to estimate both nitrous oxide and methane emissions.

By integrating Holos into AgExpert, Farm Credit Canada offers a GHG tool that is:

- ✓ Accessible
- ✓ Low touch
- ✓ User friendly
- ✓ Voluntary (i.e., AgExpert users can opt in or out)

Farmers' data related to carbon sequestration also remains private, and the data never leaves the AgExpert platform.

Knowledge mobilization

Knowledge mobilization is another crucial tool to help overcome the barriers of a lack of awareness of GHG tools, as well as training of how to use these tools. To help ensure the success of such knowledge mobilization efforts, it is crucial that a diversity of delivery agents is involved, including:

- Public (e.g., Agriculture and Agri-Food Canada, provincial and territorial agricultural ministries).
- Non-government (e.g., producer organizations and commodity boards).
- Private extension and advisory service providers (e.g., input suppliers).

What is knowledge mobilization?

"The essential objective is to allow research knowledge to flow both within the academic world, and between academic researchers and the wider community. By moving research knowledge into society, knowledge mobilization increases its intellectual, economic, social and cultural impact."

– SSHRC 2014 definition, as cited in Cooper et al. (2018)

Typically, public agricultural extension and advisory services (AEAS) providers take more of a top-down approach (Klerkx, 2020). For example, these service providers could:

- Develop and promote factsheets about how to use the tools.
- Ensure subject-matter specialists in call centres (e.g., the Ontario Ministry of Agriculture, Food, & Rural Affairs' Agricultural Information Contact Centre) have a familiarity with these tools.
- Offer training to agronomists, Professional Agrologists, and Certified Crop Advisors to familiarize them with the tools and the benefits they could offer farmers.

Private AEAS actors and producer organizations can often take a more proactive approach to meeting industry extension needs. For example, if demand grows, these service providers could:

- Host workshops focused on enabling farmers to use these tools.
- Work directly with farmers to help them use the tools and develop action plans to adopt new BMPs to reduce their carbon footprints.

This knowledge exchange must be multidirectional. Farmers should have an opportunity to learn from AEAS providers and one another. Knowledge mobilization activities and events should be designed to create settings where farmers can exchange knowledge (Knook et al., 2023), as farmers often take cues from their peers (Stackhouse et al., 2022). For example, in a workshop setting, farmers can discuss how they have adapted BMPs to suit local conditions.

Farmers should also have opportunities to share their knowledge with the researchers developing the tools, as well as the service providers, to ensure the tools, educational materials, and promotional strategies are regularly refined to best meet the needs of users.

Provision of accurate data

To this point in their development, GHG tools have been focused on farmer education and highlighting the differences between management practises to encourage adoption of practises that lower emissions. This use continues to be important. However, with ESG reporting standards now existing for GHG emissions, a secondary use of these tools is emerging that has the potential to impact the competitive position of Canadian exports. That is, the aggregation of supply chain GHG emissions for global food and beverage companies.

Globally, farm level GHG emission calculator tools have been built with a variety of objectives and foci. For example, tools have been constructed to support payments under specific government programs,[6] educate farmers on the benefits of implementing specific management practises,[7] to support specific commodities,[8] or to provide whole farm estimates.[9] The differences in use cases result in differences in data requirements and differences in outputs. However, tools that support sustainability reporting will be required to follow standardized methodologies.[10]

Tools are being built to facilitate reporting at a global scale, but companies headquartered in the US, Europe, and Asia, may adopt approaches that don't give visibility to Canadian commodities' advantages and regional variation across Canada.

"Countries need more robust measurement, reporting and verification (MRV) systems for agricultural greenhouse gas emissions to accurately reflect their national circumstances and transparently demonstrate mitigation.

Tools and resources to help countries tailor MRV to their production systems and policy priorities are critical." – Global Research Alliance on Agricultural Greenhouse Gases (2018)

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[6] For example, The EX-Ante Carbon-balance Tool (EX-ACT) and the Colorado State/USDA tools
[7] For example, HOLOS, AgriSuite GHG Decision Support Tool, US Cropland GHG Calculator, the Australian GAF tools
[8] For example, NESTT, Dairy Farm ES, the Australian Wine Carbon Calculator
[9] For example, HOLOS, AgriSuite GHG Decision Support Tool, AIA Environmental Accounting Platform
[10] For example, companies subject to the EU's Corporate Sustainability Reporting Directive (CSRD) are required to follow the European Sustainability Reporting Standards (ESRS).

Canada's vast geography and varied soil types, topography, and climate influence wide variations in the carbon intensity of commodities produced (Table 5). Such variable influencing factors should be accounted for in emissions accounting. However, the methods used to estimate the emissions may not necessarily accurately capture the differences. For example, the FAO reports Canada's carbon intensity for pork and beef production systems as an average for North America (Appendix B).

Table 5. Examples of variation in production intensity of various commodities across Canada.

Commodity	Examples of variation in intensity of production across Canada
Barley	Carbon intensity may range from less than 0.25kg CO2eq/kg DM to over 1.0 kg CO2eq/kg DM across Canada. In some provinces, the highest intensity areas can produce emissions that are over double or triple the lowest intensity regions (Desjardins et al., 2020). This variation can carry over into livestock production depending on the source of feedgrains used in livestock rations.
Winter wheat	The GHG emission (excluding soil organic carbon changes (SOCC)) may range from 0.27 t CO2e/t output to 0.67 t CO2e/t output across Canada (Pearson & Dyer, 2023).
Oats	The GHG emission (excluding SOCC) may range from 0.31 t CO2e/t output to 0.91 t CO2e/t output across Canada.*
Dry beans	The GHG emission (excluding SOCC) may range from 0.31 t CO2e/t output to 0.49 t CO2e/t output across Canada.*
Soybeans	The GHG emission (excluding SOCC) may range from 0.17 t CO2e/t output to 0.24 t CO2e/t output across Canada.*
Grain corn	The GHG emission (excluding SOCC) may range from 0.30 t CO2e/t output to 0.34 t CO2e/t output across Canada.*

* Source: Fertilizer Canada. (2020). *4R Nutrient Stewardship Grower Adoption across Canada: A summary of the fertilizer use survey conducted from 2014 to 2021.* https://fertilizercanada.ca/wp-content/uploads/2022/08/SPARK-FERTILIZER-USE-IN-CANADA-REPORT-2022-VF_08_04_2022.pdf

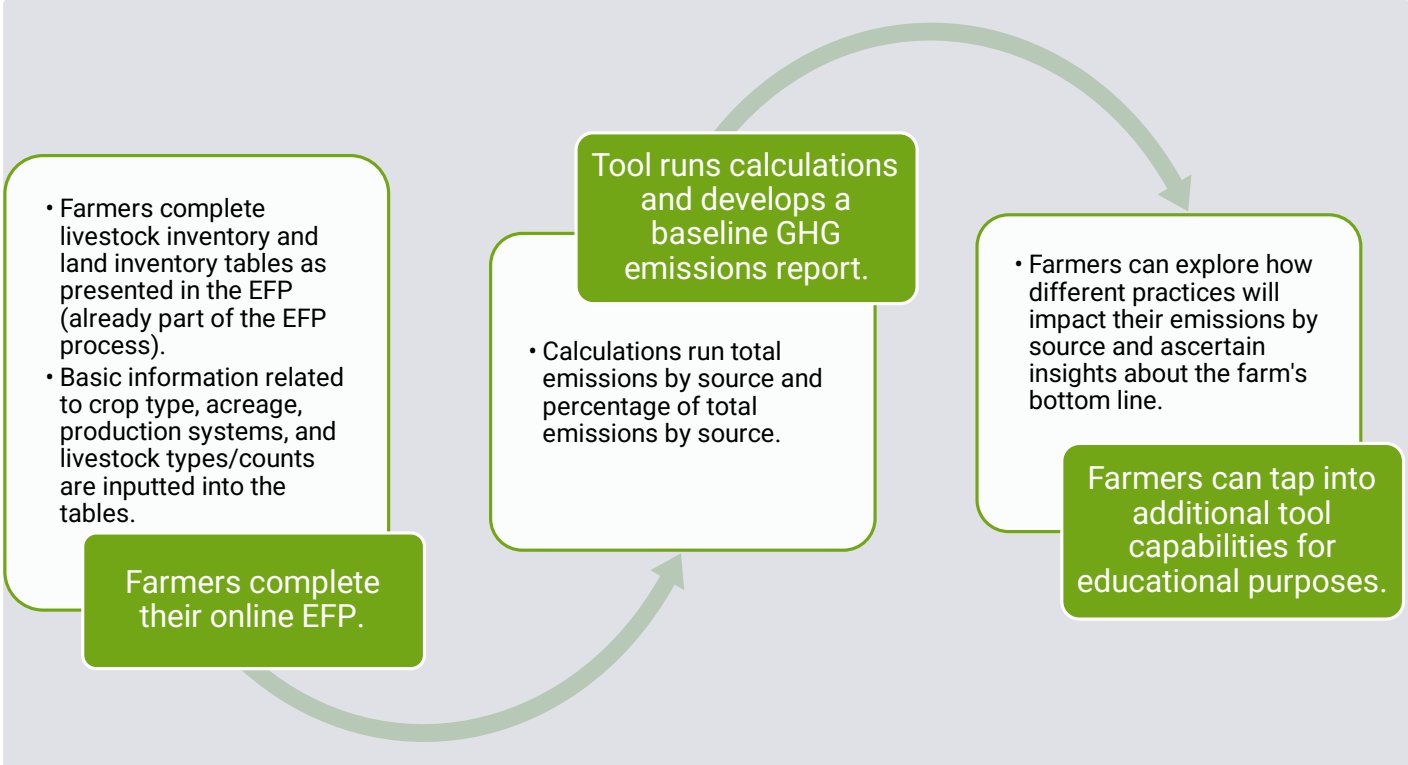
Over the last 30 years, Canadian farmers have evolved their management practices that impact soil health, and ultimately, soil carbon fluxes (Appendix C). These changes have translated into substantial differences in the carbon intensity of Canadian crops over time. This also underscores the need for an ongoing process to update the GHG emissions calculators to ensure they reflect current management practices across Canadian agriculture.

Showcase: Manitoba Environmental Farm Plan's Voluntary Greenhouse Gas Tool

Manitoba is developing a Greenhouse Gas Emissions Tool (GHG Tool). The tool will show farmers an estimate of their on-farm emissions by source. The GHG Tool will provide estimates for seven different types of farm emissions:

(1) Soil nitrous oxide
(2) Carbon dioxide from fossil fuel consumption
(3) Enteric methane
(4) Manure methane
(5) Indirect manure nitrous oxide emissions from ammonia volatilization
(6) Carbon dioxide from carbon-containing fertilizers
(7) Nitrogen fertilizer manufacturing

How does the GHG Tool work?



Emissions calculations are based on software and formulae derived from Agriculture and Agri-Food Canada's (AAFC) HOLOS Tool. The collaboration between Manitoba EFP stakeholders and AAFC enabled:

- ✓ Increased uptake of HOLOS methodologies derived by AAFC researchers, with specifications made for regional realities in Manitoba.
- ✓ The simplification and streamlining of the HOLOS methodologies into the EFP program for farmer use.
- ✓ Broader education around BMPs to reduce GHG emissions using simple pathways in existing programming.

To facilitate consistency between tools, policy makers can provide a common source of calculations (a "single source of the truth") that are presented in different ways to meet the needs of various users. This is the vision of Australia's Greenhouse Accounting Frameworks and resulting Environmental Accounting Platform (see page 23).

It would be in Canadian agriculture's best interest to ensure that tools accurately reflect the GHG emissions of Canadian commodities and up-to-date management practices.

Canadian agriculture stakeholders should also continue to monitor the supply chain software space to identify emerging trends and solutions and proactively ensure Canadian agriculture is accurately represented in the datasets being used. Ultimately, this market will move beyond the use of farm level calculators based on academic modelling to data derived from supply chain LCAs. As Canadian agriculture invests in this space, it would be prudent to adopt a process that takes the LCA approach so that the industry is well positioned for the future evolution of data requirements.

Canadian public policy should play a leading role in advocating for standards for the calculations that apply uniformly and in a way that allows the regional differences of Canada to be accurately reflected.

Each region in Canada is unique and specific opportunities for emissions reductions will vary by location. As such, direct comparisons of emissions between regions for the purpose of "weighing" sustainability should be avoided. However, these regional differences should be understood to enable accurate estimations of emissions reductions across Canadian farms; this information is necessary for accurate and scientifically sound Scope 3 reporting. Ultimately, such leadership will ensure emissions measures for Canadian agricultural products are accurate.

6 Conclusions and recommendations

Farmers' perspectives on net-zero goals and the vast array of GHG calculation tools available for the Canadian agricultural industry play an important role in shaping the path towards sustainability. The challenge is twofold. On one side, some farmers currently do not see the immediate value in targeting net-zero emissions or understanding their GHG footprints. Often, this situation is because the connection to potential benefits, such as access to carbon markets or economic incentives, remains unclear. This situation underscores the urgent need for more effective communication that clearly articulates the benefits of GHG tools and how they can support both financial and environmental goals for farmers.

"GHG tools' effectiveness depends on their ability to reflect the nuanced realities of individual farms, which can vary widely across regions, management practices, and production systems. Without high-quality, farm-specific data, tools risk providing generic insights that may not translate into actionable or effective strategies for all farmers."

– Interviewee

On the other side of the spectrum, those farmers who are interested in leveraging GHG tools to enhance their sustainability efforts encounter a cluttered landscape with many options, making it hard to choose the right tool. This situation is where the "fit-for-purpose" concept becomes vital. Not all tools are universally applicable or beneficial across the diverse spectrum of farming operations. Each type of tool serves a distinct role, catering to the specific needs and capacities of different farmers. This nuanced approach is not just about ensuring that tools are available, but also about ensuring they are meaningful and effective for their intended users.

The government's role in ensuring Canadian agricultural emissions estimates are accurate is critical; especially for tools that have implications beyond farm management, such as participation in carbon credits or for scope 3 emissions reporting. Standardizing data sources and methodologies can ensure that the outputs of these tools are recognized and defensible, both domestically and internationally, strengthening existing markets and facilitating farmers' access to new markets.

Beyond the availability and functionality of these tools lies a deeper challenge: educating farmers of the tools' value and relevance. Both government and industry must invest in clear communication about the role of these tools. Rather than focusing on the grand scheme of net-zero ambitions, the communications must address the immediate context of farmers' operations and economic interests. This involves demystifying the tools, highlighting their benefits, and showcasing how they fit into the broader picture of agricultural sustainability and profitability.

Collaboration among tool developers is equally important to avoid duplication of efforts and ensure that resources are directed towards creating tools that genuinely meet the needs of farmers. By working together, developers can ensure that tools are not just technically and methodologically sound, but also aligned with the practical realities and challenges of modern farming.

We propose two key roles for public policy to support the uptake of tools and increase buy-in to advance action and facilitate more rapid decarbonization: the provision of accurate data and identifying and overcoming barriers to adopting GHG tools.

6.1 Providing accurate data

(1) Federal partners at AAFC should explore opportunities to align HOLOS methodologies with global emissions reporting frameworks to enhance the value to farmers, drawing on inspiration from Australia's approach. Federal partners at AAFC should continue to update the HOLOS tool with current, regionally accurate information and make it available for calculating Scope 3 emissions in food and beverage supply chains.
(2) National agricultural sector stakeholders, including government and industry representatives, should convene a leadership group to develop a roadmap to ensure Canadian agriculture has a co-ordinated and efficient plan to communicate the data needed for emissions reporting. The leadership group should also support initiatives to encourage the uptake of GHG calculator tools to enable farmers to adopt BMPs.
(3) Commodity organizations, in collaboration with public policy stakeholders and academia, should continue to conduct LCA analysis of GHG emissions from Canadian agri-food commodities to have industry-wide data available to purchasers of Canadian commodities.
(4) Canada's National Index on Agri-Food Performance should continue to identify opportunities to ensure aggregated, outcomes-based primary production data is rooted in accurate measurements of the realities of Canadian agriculture.

6.2 Encouraging the adoption of GHG tools

Encouraging the farm-level adoption of GHG tools requires a collaborative effort between government, industry (commodity and agricultural organizations), the value chain, and researchers.

(1) Support the refinement of "fit-for-purpose" tools, grounded in a shared methodology and dataset, that best support the different use cases (i.e., indicative, educational, or compliance).
(2) Explore opportunities to link educational GHG tools as part of eligibility for funding through government programs such as the On-Farm Climate Action Fund.
(3) Leverage public and private incentives to support the implementation of best management practices identified via approved GHG tools to reduce emissions. For example, incorporate user-friendly tools into existing extension services, like the Environmental Farm Plan.
(4) Increase the availability of extension services and other advisors (e.g., agronomists, Professional Agrologists, Certified Crop Advisors, farm management professionals, government call centre staff, etc.) who can help farmers use and implement GHG tools.

Ultimately, through a "fit-for-purpose" approach to GHG tools, aligned with strategic policy support and a concerted effort in education, communication, and standardization, the agricultural sector can increase the adoption and use of GHG calculation tools. They can serve as effective instruments to contribute to the attainment of national and global net-zero goals.

7 Appendices

Appendix A. Scope 3 reporting regulations by jurisdiction.
Table 6. Current Scope 3 reporting regulations by Jurisdiction.

Regulation/Standard	Region	Type of Company	Timeline
Corporate Sustainability Reporting Directive (CSRD)	EU	Large/mid-sized companies and SMEs; both EU-based companies and non-EU companies with significant activity in the EU.	Implemented January 2023. Phased-in reporting from 2025-2028, starting with PIEs.
Corporate Sustainability Due Diligence Directive (CSDDD)– Proposed	EU (Proposed)	Large EU-based companies and large non-EU companies within CSDDD scope. SMEs not yet affected.	Adopted by the European Commission in February 2022 and likely to come into effect in 2025.
Climate Corporate Data Accountability Act (California SB 253)	California	Private and public companies operating in CA with >$1B in revenue.	Signed into law by state governor in October 2023. Proposed phased-in reporting from 2026-2030.
International Sustainability Standards Board (ISSB) Standards	Global	Any company as specified by country.	Currently for voluntary use. Officially effective January 2024 with phased-in approach for Scope 3.
	UK	Most economically significant UK companies.	ISSB Standards already mandated in UK companies' 2023 Annual Reports.
	Australia (Proposed)	Adoption for large, medium, and small companies.	Phased-in approach to begin based on company size from 2024 – 2027.
	Canada (Proposed)	TBD	TBD – Canadian Securities Administration determining whether/how to adopt ISSB.

Adapted from: Aligned Incentives. (2023). *Navigating mandatory Scope 3 emissions reporting in the EU, US, and beyond.* https://alignedincentives.com/mandatory-scope-3-emissions-reporting-eu-us-uk-international/

Appendix B. Carbon emissions intensity of beef and pork by country.

Geography§	Cattle herd size, 2020[1]	Emissions intensity (kg CO2e/kg product beef), 2015[3]	Net exporter rank, beef, 2021[2]	Swine / pig herd size, 2020[1]	Emissions intensity (kg CO2e/kg product pork), 2015[3]	Net exporter rank, pork, 2021[2]
1. Brazil	152,705,209	58.97 (C&S.Am.*)	1st	10,281,058	5.36 (C&S.Am.)	4th
2. India	97,241,178	105.63 (S. Asia)	-	1,770,422	10.09 (S.Asia)	-
3. USA	93,793,300	17.42 (N.Am.)	-	19,328,000	4.95 (N.Am.)	2nd
4. China	39,733,748	52.74 (E. Asia)	-	103,043,069	6.59 (E.Asia)	-
5. Argentina	38,122,559	58.97 (C&S.Am.*)	4th	1,344,240	5.36 (C&S.Am.)	-
6. Ethiopia	35,145,888	106.97 (SSA*)	-	7,283	6.66 (SSA*)	-
7. Mexico	24,947,446	58.97 (C&S.Am.*)	10th	4,697,001	5.36 (C&S.Am.)	-
8. Pakistan	24,812,000	105.63 (S. Asia)	-	-	10.09 (S.Asia)	-
9. Australia	21,152,914	27.37 (Oceania)	2nd	564,512	7.89 (Oceania)	-
10. Colombia	19,771,683	58.97 (C&S.Am.*)	-	1,677,667	5.36 (C&S.Am.)	-
11. Chad	16,118,605	106.97 (SSA*)	-	22,312	6.66 (SSA*)	-
12. France	16,010,325	24.09 (W.Eur.)	-	3,434,250	4.97 (W.Eur.)	9th
13. Sudan	15,878,633	46.25 (WANA*)	-	-	6.57 (WANA*)	-
14. Tanzania	14,167,525	106.97 (SSA*)	-	104,177	6.66 (SSA*)	-
15. Türkiye	12,575,837	46.25 (WANA*)	-	198	6.57 (WANA*)	-
16. Myanmar	12,275,771	52.74 (E. Asia)	-	4,798,160	6.59 (E.Asia)	-
17. Bangladesh	12,195,500	52.74 (E. Asia)	-	-	6.59 (E.Asia)	-
18. Venezuela	11,367,456	58.97 (C&S.Am.*)	-	750,037	5.36 (C&S.Am.)	-
19. Indonesia	11,353,415	52.74 (E. Asia)	-	2,267,473	6.59 (E.Asia)	-
20. Canada	11,265,000	17.42 (N.Am.)	8th	3,492,500	4.95 (N.Am.)	5th
21. New Zealand	9,074,509	27.37 (Oceania)	3rd	58,633	7.89 (Oceania)	-
22. Spain	5,972,787	24.09 (W.Eur.)	-	8,199,018	4.97 (W.Eur.)	1st
23. Ireland	5,876,496	24.09 (W.Eur.)	9th	419,643	4.97 (W.Eur.)	-
24. Netherlands	3,321,900	24.09 (W.Eur.)	-	2,885,250	4.97 (W.Eur.)	7th
25. Denmark	1,350,000	24.09 (W.Eur.)	-	3,347,750	4.97 (W.Eur.)	3rd

*Acronyms and abbreviations
C&S.Am.: Central and South America
SSA: Sub-Saharan Africa
WANA: West Asia and Northern Africa

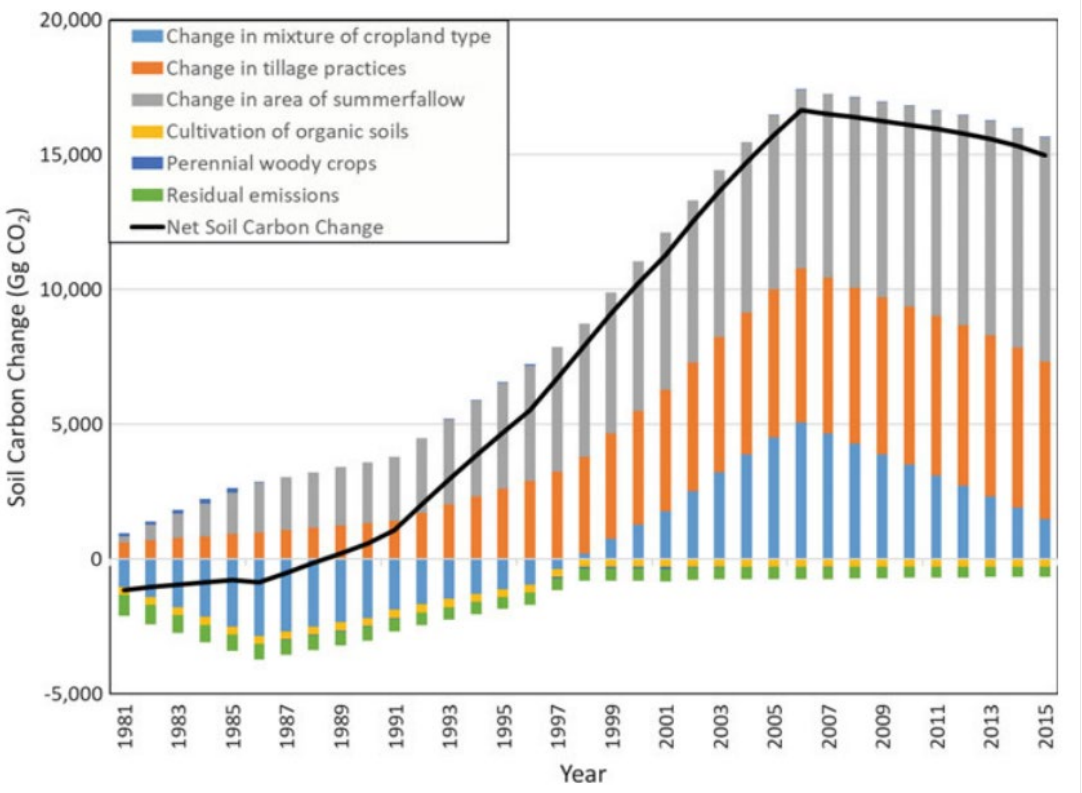
§Regions defined according to GLEAM.

Data sources:
(1) (FAOSTAT, 2020b). *Livestock patterns.* https://www.fao.org/faostat/en/#data/EK
(2) (FAOSTAT, 2021). *Crops and livestock products*. https://www.fao.org/faostat/en/#data/TCL (calculations performed internally)
(3) (FAO, 2022). FAO. (2022). *GLEAM v3 Dashboard [2015 data]. In: Shiny Apps.* Global Livestock Environmental Assessment Model. https://foodandagricultureorganization.shinyapps.io/GLEAMV3_Public/

Reprinted from: Mussell, A., Poirier, A., & Zafiriou, M. (2023). *Animal Agriculture in Canada and its Regions: A White Paper on Livestock.* Canadian Agri-Food Policy Institute.

Appendix C. Soil carbon change in agricultural soils in Canada.

Figure 2. Soil Carbon Change in Agricultural Soils in Canada 1981-2015 due to management practice changes.



Reprinted from: Desjardins, R. L., Worth, D. E., Dyer, J. A., Vergé, X. P. C., & McConkey, B. G. (2020). The Carbon Footprints of Agricultural Products in Canada. [Page 11]. In S. S. Muthu (Ed.), *Carbon Footprints: Case Studies from the Building, Household, and Agricultural Sectors*.

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