
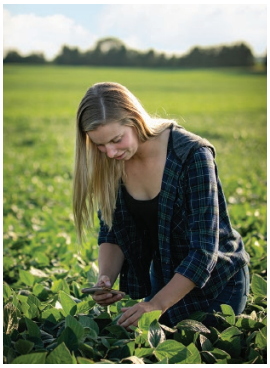


UPSTREAM EVIDENCE REPORT 2023

ARRELL FOOD INSTITUTE
AT THE UNIVERSITY of GUELPH

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About the Net-Zero Food Systems Challenge

The Net-Zero Food Systems Challenge is an experiential learning program that brought together graduate students from across Canada with thought leaders and industry decision-makers to collaboratively develop solutions for a sustainable agriculture and food system. Over the course of six months, students conducted independent research, synthesized academic and industry reports, and compared sustainability practices and commitments of food retailers in Canada and internationally. These reports summarize their findings and identify key opportunities for Canadian food retailers to enhance sustainability within the agri-food system, both upstream (production) and downstream (consumers) from their operations.

This challenge was run by Arrell Food Institute and the Ontario Agricultural College at the University of Guelph, with financial support from Loblaw Companies Limited.

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Table of Contents

Executive Summary

Food retailers work at the intersection of production and consumption; they are in a unique position to influence the environmental impact of products sold in their stores by encouraging climate-smart farming in their upstream supply chain.

However, it can be challenging for retailers to track food value chain emissions of their products through all the stages of production, post-harvest handling and storage, processing and manufacturing and distribution before arriving at grocery stores. Further, reducing product emissions may depend on other actors to adopt new practices, and measuring and incentivizing the impact of these practices can be challenging.

There are three key opportunities for food retailers to engage with climate-smart farming to support Canada's net-zero emission targets:

Measure Product and Associated Supply Chain Emissions

Retailers can capitalize on growing carbon markets by collaborating with stakeholders to develop a cost-effective measurement, reporting and verification system for soil carbon. Advancements in data technologies and accessibility will support the agri-food industry to build models with detailed carbon accounting for each product purchased from farms and sold in grocery stores.

Support Climate-Smart Farming Knowledge Transfer

Food retailers are well-positioned to serve as a hub that expedites the sharing of knowledge between farmers and enables meaningful transformation within the industry. Improving knowledge sharing networks and supporting ongoing research can promote the adoption of climate-smart practices that tap into the carbon sink potential of agricultural soils.

Mobilize and Support Incentives for Adoption and Performance

Food retailers are uniquely positioned to mobilize other stakeholders to create sustained, long-term incentives for farmers at all stages of climate-smart practice adoption.

Introduction

Canada's agriculture and agri-food system represents an integrated supply chain of primary agriculture, food and beverage processors, food retailers and wholesalers and food service providers. In 2022, agriculture and agri-food systems generated $143.8 billion (7%) of Canada's GDP and roughly $31.9 billion (24%) of that revenue was created by primary agriculture.[1] Canada's 62 million hectares of farmland provide high quality and safe food across the world. Primary agriculture, currently a source of 8-10% of Canada's greenhouse gas emissions,[2] has tremendous potential to sequester carbon, mitigate Scope 3 emissions and align with other corporate sustainability efforts – but the adoption of new agricultural practices will require support from stakeholders along the supply chain.

The Greenhouse Gas Protocol (GHG Protocol), the world's most widely used greenhouse gas accounting standards, has categorized greenhouse gas emissions into Scope 1, 2 and 3 emissions:[2]

Scope 1 – Direct emissions principally resulting from activities undertaken by the company

Scope 2 – Indirect emissions from electricity, heating, cooling, or steam that a company purchases for its own use

Scope 3 – Upstream and downstream indirect emissions that are not included in Scope 1 or 2, also known as value chain emissions

The Role of Food Retailers

Most of the greenhouse gas emissions from Canadian food retailers are Scope 3 emissions. To reduce these emissions and reach net-zero by 2050, the food value chain will need to become more transparent – prioritizing economic, social and environmental sustainability. Food retailers, the bridge between food production and consumers, can play a fundamental role in promoting business practices that support a net-zero approach across the entire food value chain. With consumer demand driving the year-round supply of goods and fresh produce through international and domestic markets, there is an opportunity for food retailers to build knowledge about every aspect of their product supply chain and its associated emissions.

On-farm emissions contribute carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from crop and livestock production[3] – but agricultural soil is a key part of the climate solution. Canadian soils store 20% of the world's soil carbon,[4] highlighting the need to protect soil from further erosion and degradation. Canada's agricultural lands have the potential to sequester up to 38 megatons of annual greenhouse gas emissions[5] – meaning that increased adoption of agricultural best management practices is a key opportunity to enhance carbon sequestration. By increasing the adoption and use of climate-smart farming practices, food retailers can tap into the potential of our agricultural soil to act as a carbon sink. By working with producers, food retailers will not only reduce their Scope 3 emissions but will build stronger producer-retailer relationships.

What is Climate-Smart Farming?

Climate-smart farming includes farm and land management practices that build resilience against climate change, reduce greenhouse gas emissions and enhance long-term agricultural productivity.[6] Climate-smart farming practices have the potential to strengthen Canada's net-zero emission efforts through carbon sequestration and other GHG mitigation strategies. If food retailers embrace climate-smart farming principles along their value chain, it could support their adoption – further strengthening economic prosperity for producers while supporting environmental benefits and food security.

I. Opportunities for Food Retailers to Support Climate-Smart Farming in Canada

Three main opportunities offer the potential for food retailers to encourage climate-smart farming within the Canadian context.

Measure Product and Associated Supply Chain Emissions

The journey of a food product, from its origin to the grocery store shelf, has multiple stages that each contribute to its overall environmental footprint. This complex system makes it challenging to identify and quantify environmental impacts along the food value chain (see Appendix 1 for more information). End-to-end traceability in the food value chain will enhance the visibility of emissions along a product's supply chain, with the potential to impact economic profitability, social benefits and environmental impacts.

Food retailers can play a pivotal role in enhancing transparency to better assess the emissions of products throughout the supply chain. Opportunities to enhance traceability include:

- encouraging suppliers to provide emissions data and other detailed information to retailers; it may be easier to pilot this with products that have shorter food value chains and are thus easier to trace
- using labelling and marketing efforts in-store and online with consumers to enhance awareness of each product's environmental footprint
- connecting directly with local producers to support their adoption of climate-smart farming
- using technological advancements such as blockchain, RFID, QR codes and other traceability technologies to trace food from creation to consumption, including the entire lifecycle emissions for an individual product

Measuring, reporting and verifying soil carbon levels for carbon markets

Food retailers have an opportunity to capitalize on the burgeoning world of using carbon markets to sequester greenhouse gases. Agriculture currently represents a mere 1% of global carbon credits, primarily because of the absence of reliable systems for measuring, reporting and verifying the stored carbon. For example, a producer could earn up to $8-$13 in carbon credits per acre, but uncertainty in soil carbon measurement means they cannot claim the full amount. Various costs consume up to 60% of the initial credit value, with an additional 20% frequently set aside for insurance – meaning that producers typically receive a meager $2 to $4 per acre.[5]

The core challenge is the difficulty of quantifying the change in soil carbon from baseline levels due to climate-smart practices. The existing measurement, reporting and verification system for soil carbon is intricate, requiring rigorous soil analysis and process-based modeling, with the opportunity to use advanced remote sensing techniques – costly processes that are beyond the means of many producers. Carbon levels can also change over time and due to various natural processes, further complicating the measurement, reporting and verification process, and making it difficult to incentivize producers for climate-smart practices.

Canada's voluntary carbon market holds the potential to grow to a value of $4 billion by 2050.[5] To tap into this vast potential, retailers can work collaboratively with other stakeholders to develop a regional, cost-effective and scalable measurement, reporting and verification framework for soil carbon. This framework should not only quantify the environmental impact of climate-smart practices but also allow agri-food businesses to include these figures in their Scope 3 emissions records, thus aligning with their Environmental, Social and Governance (ESG) objectives. Advancements in smart sensors and artificial intelligence are opportunities to measure soil carbon levels and validate their carbon sequestration potential within the food supply chain more easily.

The Canadian Alliance for Net-Zero Agri-food (CANZA) is a network of stakeholders that recently announced its commitment towards developing and testing a system to measure, report and verify soil carbon sequestration. This group represents a strategic opportunity for food retailers to address the challenges of emissions monitoring but also position themselves as leaders in making the food supply chain more sustainable.

Support Climate-Smart Farming Knowledge Transfer

Some Canadian producers have already adopted climate-smart farming practices voluntarily, but others remain reluctant due to uncertainties such as the varying success of these practices, high initial costs, potential yield losses and long wait times to see results (see Appendix 2 for more information). Canadian food retailers have an opportunity to facilitate the transfer of knowledge amongst their supply chain partners and to encourage the adoption of climate-smart practices.

By asking (or requiring) their suppliers to adopt climate-smart practices as standard operating guidelines for their farm-to-shelf operations, food retailers can catalyze a transformation in farming practices. To enhance productivity, support adaptation to the climate crisis and mitigate further harm to the environment, various climate-smart practices can be used for both outdoor and indoor production (i.e., fields and greenhouses):

Outdoor:

- limiting soil disturbance through reduced or zero tillage
- crop diversification through cover cropping, crop rotation and intercropping
- growing perennial, rather than annual, crops to improve carbon sequestration
- integrating livestock into cropping systems, either through grazing or using the benefits of anaerobic digestion to capture methane

Indoor:

- using LED bulbs for energy-efficient lighting
- carbon dioxide enrichment for enhanced crop growth
- using innovative, soilless growing mediums

See Appendix 3 for more detailed information on climate-smart practices and their benefits and challenges.

Not all these practices can be universally applied to different production systems, and the lack of specific guidance on suitable practices for each producers' operations hinders their adoption. For instance, in the case of leafy greens production, practices like livestock integration may not be feasible for outdoor cultivation. The suitability of these practices can also vary with factors such as crop types, soil characteristics, climate conditions and the available infrastructure. Without additional support, the burden falls onto producers to tailor these climate-smart practices to their operations and set their own realistic goals/expectations.

To address this gap, there is an opportunity for food retailers to invest in research and on-farm trials dedicated to crafting the ideal climate-smart practices tailored to specific agricultural operations for their producers. By actively collaborating with research institutions, grower organizations and national research facilities, food retailers will spearhead innovation in this crucial sector.

Future of greenhouse technology

One of the promising innovations for reducing the environmental impact of agriculture is greenhouse technology; vertical farming and data-driven agriculture offer enormous opportunities for food retailers to reduce carbon emissions within their supply chain. Greenhouses offer incredible potential to shorten supply chains and localize production of crops such as leafy greens; see Appendix 4 for a detailed analysis of leafy green production in Canada.

Vertical farming

Vertical farming is a game-changer in the quest to reduce GHG emissions and bolster food production efficiency. This innovative approach maximizes space with multi-level plant arrays, cutting-edge technologies and eco-friendly features like rainwater harvesting and LED lighting. By sidestepping soil reliance and integrating green energy solutions, vertical farms drastically reduce carbon footprints.

Converting high-rise buildings into vertical farms promises year-round, high-yield output and disaster resilience. Particularly well-suited for lettuce, these farms offer lucrative returns despite initial setup costs; automation and labor optimization are key for efficient use of space. Natural lighting, when feasible, slashes energy usage and GHG emissions.

Data-driven agriculture: sensors, robotics and smart greenhouses

Crop monitoring, maintenance, weed management and harvesting can be repetitive and laborious tasks that can be optimized by data-informed, intelligent automation systems including robotics and machine learning (ML) algorithms.[7] When connected, sensors, ML algorithms and robotics work in harmony to fully optimize food production. Sensors receive information from the surrounding environment and form datasets to inform ML algorithms, then output a decision that is executed by an automation platform. Classification and regression ML models will predict, explain and proactively intervene, or suggest interventions to operators, for common agricultural problems, such as nutrient or light deficiencies and disease incidence. Together, these technologies support the autonomous growth and production of crops in smart greenhouses. Cameras, sensors, or drones collect real-time information about location, soil moisture, frequency, airflow and photosynthetic light levels to inform ML systems that will predict and optimize water, fertilizer and pesticides for a favourable growing environment with minimal waste. Although these systems might appeal to current producers, the set-up, operation and maintenance of these advanced facilities comes with high costs and technical knowledge.[7]

Already greenhouses and vertical farm technology are changing, with innovators working to utilize every cubic foot of space as efficiently as possible. Racks of plants that move autonomously through a growing chamber, tunable LED lights that allow for optimal plant growth and nutrients tailored to the plants' growth cycle and other technologies are emerging to optimize space. These systems can bring harvest-ready crops from their growth house to lean-designed harvesting and packaging stations (reducing labour costs), after which the trolleys and conveyors return to start all over again.

Mobilize and Support Incentives for Adoption and Performance

Supporting farmers through the different stages of adoption of climate-smart practices

Canadian farmers can significantly contribute to carbon sequestration and play a pivotal role in helping Canada meet its emission targets. However, they need significant and continuous support to ensure they can adapt to changing conditions and use climate-smart practices – which can be costly and challenging to implement.

Food retailers can mobilize and collaborate with other stakeholders in the food value chain to ensure long-term support for producers' sustainability efforts at the different stages of adoption. In early stages of adoption and implementation, producers need financial support (payment for practices/cost-share model) and technical assistance to acquire costly new technology. At the scaling and integration stage, producers need more policy support and access to large funding. Producers already sustaining adoption can be compensated by outcome-based carbon credits or they can receive additional compensation for their products.

This stage-based approach will address concerns about the sustainability of incentive programs and the possibility of long-term losses for producers. It will reward early adopters of climate-smart practices who can demonstrate the results of their practices and ensure producers (or landowners) continue climate-smart practices. To ensure the effectiveness of long-term commitments towards incentivization, the legal framework supporting incentive programs must be clear and binding, detailing responsibilities, ownership and liabilities associated with the sequestered carbon.

Incentivizing Producers for Adoption of Climate-Smart Practices

Different Stages of Adoption	Early Adoption and Implementation	Scaling and Integration	Improvement	Sustained Adoption/ Output
Recommended Support	Cost-share model to encourage initial investment and implementation	Access to funding (government and private)	Knowledge sharing platforms Support data logging infrastructure for monitoring and reporting	Carbon credit trading in carbon market Offer special prices for sustainably-produced foods as part of corporate social responsibility programs Tax credits

Effective stakeholder collaboration in ensuring long-term incentive provision

Incentivizing climate-smart farming requires stakeholders across the value chain: federal and provincial governments to provide financial incentives and education; private entities to invest in climate-smart farming; local NGOs and organizations to recognize early adopters and amplify impact (see Appendix 6 for a more detailed analysis of the role and impact of various stakeholders in incentivizing climate-smart practices). When stakeholders work in collaboration, they will help to increase the adoption of climate-smart practices, reduce emissions and move Canada closer to a net-zero future.

Other opportunities

It is essential that landowners, producers and/or those working the land are the ones to benefit substantially from incentive programs, including carbon trading. Many incentives, including carbon market gains, are often greatly reduced by carbon market traders or service providers such as soil or carbon data collection companies. While service providers should be compensated, producers must realize the full benefit of carbon markets with caps, limitations or restrictions on fees associated with measuring, validating, reporting and trading of carbon or climate credits, or any other incentive in order to incentivize their participation.

One opportunity, unrealized to date, is to incentivize the co-location of complementary industries. For example, the waste heat from one industry (i.e. power generation) might be used by another industry (i.e. greenhouses) to offset climate impacts for both. Other opportunities include using carbon dioxide emissions from a heating source to improve production in greenhouses or using digestates from wastewater treatment facilities as fertilizer. Partnerships within and between industries could revolutionize waste and carbon emissions.

Ultimately, food retailers will have to mobilize support for farmers, considering both near-term and long-term strategies to ensure the sustainability of adopted climate-smart farming practices and the permanence of sequestered carbon.

II. Near-Term Initiatives and Long-Term Strategy

Near-Term

Practices: Support the adoption of practices and key technologies that optimize soil carbon sequestration and enhance soil health. This immediate focus on practices can drive rapid improvements in carbon levels within our supply chain.

Performance: Provide financial support for the development of measurement, reporting and verification systems for GHG emissions. Buy carbon credits from farmers to offset emissions and, in parallel, offer incentives for emission reductions. This dual approach ensures that performance improvements are both tracked and rewarded.

Long-Term

Investment in real-time soil carbon measurement: Resource revolutionary approaches for continuous soil carbon measurement, such as state-of-the-art artificial intelligence and smart soil sensor technologies. These advanced tools enable real-time, precise monitoring of carbon dynamics and the evolution of sequestration progress, offering unprecedented insights into soil health and sustainability.

Collaboration and data sharing: Actively promote collaboration and data sharing across the agricultural sector, creating an open-source decision-making tool that leverages shared knowledge to determine best practices for each parcel of land based on factors such as soil type, annual precipitation, climate zone, sunlight and other variables.

Final Thoughts

Food retailers are well-positioned to play a transformative role in Canada's agri-food system. Our report highlighted key opportunities and challenges for food retailers to support Canadian farmers in the adoption of climate-smart farming. Based on their unique position in the food value chain, they can establish stronger ties with farmers and develop a network of net-zero farms throughout the country, drawn from their register of listed growers. By understanding the farming techniques currently employed by these growers, food retailers can identify opportunities to increase the adoption of climate-smart farming practices.

Food retailers can engage national and local experts and farmers to create a comprehensive guide to climate-smart farming techniques such as no-till methods, the use of cover crops and energy-efficient practices in controlled environment food production. They can also pioneer educational and knowledge-sharing programs, guiding farmers toward meaningful behavioral changes and promoting the widespread uptake of these climate-smart farming techniques. They can collaborate and support research and on-farm trials that focus on adapting climate-smart farming with regional considerations.

Food retailers can play a pivotal role in enhancing transparency to better assess food supply chain emissions by encouraging suppliers to provide emissions data and other detailed information. By collaborating with the government and NGOs, food retailers can help farmers access crucial funds and incentives and they can support the development of innovations such as a straightforward, scalable measurement, reporting and verification system highlights to align with national and global carbon markets and monitor progress towards net-zero.

Farmers need support through the different stages of the adoption of climate-smart farming. In an innovative move, Canadian food retailers could become the first to start purchasing not just products but also carbon credits from farms. Supporting, recognizing and financially rewarding farmers for their efforts in reducing emissions and sequestering carbon is a big step in ensuring the sustainability of adopted practices and achieving net-zero food systems in Canada.

Appendix 1 – The Challenge of Measuring Product and Food Value Chain Emissions

The journey of a food product, from its origin to the grocery store shelf, has multiple stages that each contribute to its overall environmental footprint. This complex system makes it challenging to identify and quantify environmental impacts along the food value chain. Different regions and countries have distinct production methods, regulations and energy sources that further complicate the task of monitoring emissions.

Assessing the carbon footprint of farming operations is one piece of this challenge. Agriculture contributes to greenhouse gas emissions through activities such as enteric fermentation, synthetic fertilizer use and land-use changes, but can also be a significant part of the solution with practices that sequester carbon, enhance soil health and reduce emissions. However, agricultural practices that can mitigate emissions are diverse and complex and it can be challenging to identify the best mix of practices for reduction in each situation. Understanding the effect of agricultural practices requires long-term measurement and monitoring of changes in soil carbon, which can be costly and time-consuming. Producers may not want to record and share data due to concerns such as time constraints, financial burden, resistance to change and concerns about data privacy and security.

Appendix 2 – The Challenge of Supporting Climate-Smart Farming Adoption

Currently, many producers adopt climate-smart farming practices voluntarily, but the rate and breadth of adoption remains relatively low. Reluctance often stems from uncertainties such as the varying success of these practices, high initial costs, potential yield losses and long wait times to see results. The size of a farm and its potential to sequester carbon and validate that sequestration also play a role.

However, some producers are actively using climate-smart practices, driven by personal motivations to act as stewards of the land, positive environmental views, previous experience with conservation, or the benefits they expect from improved yields. These producers often seek out information, are aware of related agri-environmental programs and might have larger farms or higher education levels. They may even engage in specific market strategies like third-party certifications. However, these motivations can vary based on location, social norms and the specific practices being considered. Factors like awareness, financial incentives, societal norms, and both internal and external influences can impact a producer's decision. Financial incentives can be a key driver in motivating farmers to adopt climate-smart farming practices. Transitioning to these practices comes with expenses, and if Canada aims to store 38 metric tons of carbon in its soil annually, it could demand up to $4 billion each year.[5] It is essential that we identify suitable financial instruments and funding sources to meet this demand. However, when producers revert to traditional methods, like returning to intensive tillage after trying no-till, this switchback can reverse any potential carbon-sequestering benefits that might have been gained over the years. As a result, it's crucial to offer additional support and incentives to encourage producers to remain committed to climate-smart practices and expand their adoption nationwide.

Appendix 3 – Benefits and Challenges of Climate-Smart Practices, Indoor and Outdoor

Outdoor Climate-Smart Practices

Practice	How does this practice support net-zero emission targets?
Limiting Soil Disturbance	Reduced or zero tillage minimizes the mechanical disturbance to soil from plowing, tilling and cultivation. This can lead to healthier soils with enhanced organic matter, carbon sequestration potential, biodiversity, aeration and drainage. Organic inputs (cover cropping, manure) are the key determinant in soil carbon gains rather than tillage practices;[8] downsides of reduced or no tillage can also include increases in soil nitrous oxide emissions in waterlogged conditions and weed build up.[9]
Crop Diversification	Rotating the type of crop grown on a field every year diversifies field cropping. Cover cropping is used in these diversified rotations to reduce disease and pest pressures and promote nutrient cycling. Diversification is also applied within fields where different crops are grown together through polycultures, intercropping and companion planting. Selecting the types of crops to diversify a system will depend on compatibility and desired outcomes (e.g., more nutrients or higher organic matter), but can have a multiplier effect in terms of increasing yields and reducing crop treatments. Crop diversification can be challenging for producers due to the timing of market conditions for various planned crops and seasonal weather conditions during planting seasons. Further, intercropping has demonstrable advantages for soil health, crop yield and disease resistance, however the upfront costs for advanced seeding and seed-separation equipment can be a barrier for many producers.
Perennial Cropping	Plant roots release essential compounds that fuel soil microbial communities, which help to build carbon stocks in soil. Perennial crops live for multiple years, unlike common annual crops that are grown and harvested within a single growing season. Growing perennials as winter cover crops and pastures keeps living roots in the soil for prolonged periods and improves carbon sequestration. There is a cost associated with properly maintaining perennials, including planting, fertilizing, rotation of livestock and/or harvesting hay (feed) and the potential for lost income where land might be utilized for higher value cash crops.
Livestock Integration	Livestock grazing stimulates nutrient recycling where animal wastes can act as a natural fertilizer source and contribute to soil carbon stocks. For intensive livestock operations, anaerobic digestion is a critical technology that has had minimal traction in Canada; however, it provides the opportunity to capture methane for conversion into renewable natural gas. Additionally, digestate solids can be utilized in place of synthetic fertilizers on field, thereby reducing the GHG emissions associated with their production. While grazing livestock on perennial grasslands can be relatively efficient use of land not suited for cash crops, it can prove more difficult in planted soils as it often requires a second application of perennials for livestock consumption post-harvest. For intensive livestock operations, anaerobic digesters are capital intensive and require specific technical expertise to operate, which can be a challenge in remote locations.

Appendix 3 – Benefits and Challenges of Climate-Smart Practices, Indoor and Outdoor

Indoor Climate-Smart Practices

Practice	How does this practice support net-zero emission targets?
Energy Efficient Lighting	Artificial lighting is energy- and cost-intensive for producing food all year round with standard lighting setups with high pressure sodium (HPS). Light emitting diodes (LED) are an energy-friendly alternative that can be customized to meet specific needs for a wide range of crops. The initial capital cost of switching lighting over can be a barrier, particularly where electricity costs remain low, extending the ROI.
Carbon Dioxide (CO_2) Enrichment	Enrichment is essential for indoor crop growth as their surroundings are depleted of CO_2 during photosynthesis. Current enrichment strategies can use waste CO_2 from other industries, but risk further release of emissions into the atmosphere and hazardous indoor conditions, if overapplied. Potential solutions consist of:[10] 1. Partnership between industry and agriculture – Redirecting industrial CO_2 emissions to agriculture (instead of the atmosphere) 2. Carbon capture technologies – Withdrawal and retention of CO_2 from industrial and atmospheric sources 3. Biotechnology – Modification of crops to efficiently use CO_2
Innovative Growing Media	Plants can be grown in water, air or with aquaculture through hydroponics, aeroponics or aquaponics. Common setups include hydroponics with a soilless substrate that can reduce water use and excess nutrients. Soilless substrates could be mineral, organic and synthetics (e.g., rockwool, coconut coir and polyurethane foam). These systems provide interesting benefits but require additional expertise for growers to utilize proficiently.

Appendix 4 – Leafy Greens in the Food Value Chain

The supply chain of leafy greens production in Canada involves a series of interconnected stages that ensure a consistent and fresh supply of product to consumers. Leafy greens are produced through various methods including traditional field production, greenhouse production and indoor farming techniques. Due to Canada's cold winter, field production of leafy greens is limited to the warmer months. To extend the growing season and ensure a more consistent supply of domestic leafy greens, protected culture (greenhouse, high tunnel and other controlled environment) production methods are used in Canada – mainly in Ontario, British Columbia and Quebec.[11] Lettuce production in Canada reveals a notable contrast in yield between traditional field production, with an average of 22.11 metric tons per hectare, and the highly space-efficient greenhouse production, which yields around 573 metric tons per hectare.

Greenhouse cultivation provides an ideal setting with a regulated environment (temperature, humidity, light) and protection from external elements – but comes with its own set of costs – labour, building, maintenance and operation costs and their associated greenhouse gas emissions. While greenhouse lettuce production offers impressive yields, field production also has unique advantages, especially in terms of carbon sequestration. If management practices focus on improving soil health, field production provides an opportunity to sequester carbon in the soil, which is not typically possible in greenhouses. Both methods have their own merits and drawbacks, contributing to the resilience of the agricultural sector and ensuring a dependable food supply.

While production methods play a crucial role in ensuring resilience of the food chain, the origin of the product is equally pivotal. In 2021, Canada imported a substantial volume of lettuce – 253,074 metric tons from the United States for a total value of CAD 553,129,000. This import volume is significantly greater, approximately 3.5 times, than total national field production.[12] This reliance on external sources, particularly from California, means our product supply may face procurement challenges – which means that it is especially important to diversify production methods and relocate leafy green production in Canada. By investing in Canadian leafy green production, food retailers have the opportunity to enhance supply chain resilience, offer fresher and more sustainable products, support local communities, reduce transport costs, and build stronger connections with consumers who prioritize local and sustainable options. This aligns with the evolving landscape of consumer preferences and contributes to a more robust, adaptable and responsive food supply chain.

Canadian Lettuce Production, 2021[11,12]

Metric	Field	% of Canadian Field Vegetable Crop (rank)	Greenhouse	% of Canadian Greenhouse Vegetable Crop (rank)
Planted Area	3,420 ha	3.2% (10th)	33.52 ha	1.7% (4th)
Production Volume	75,612 metric tons	3.3% (7th)	19,221 metric tons	2.7% (4th)
Farm Gate Value	CAD 84,967,000	6.0% (6th)	CAD 65,255,000	3.3% (4th)
Export Volume	39,473 metric tons	6.1% (5th)	-	-
Export Value	CAD 70,059,000	9.2% (2nd)	-	-
Import Volume	267,154 metric tons	13.5% (1st)	64 metric tons	0.0% (4th)
Import value	CAD 559,200,000	15.5% (1st)	CAD 386,000	0.1% (4th)

Appendix 5 – The Challenge of Incentives for Adoption and Performance

Incentives can be a key driver in producer adoption of climate-smart farming practices. Transitioning to these practices can be expensive – costing up to $4 billion per year to store 38 metric tons of carbon in Canada's soil. Incentive programs have conventionally involved a variety of stakeholders (public and/or private), financial sources and payment modes for producers who prioritize the conservation, sustainable management and restoration of agricultural ecosystems. Over the years, these efforts have been outlined through successive initiatives: the Agricultural Policy Framework (2003-2008), Growing Forward 1 (2008-2013), Growing Forward 2 (2013-2018), the Canadian Agricultural Partnership (2018-2023) and the Sustainable Canadian Agricultural Partnership (2023-2028). Every five years, Agriculture and Agri-Food Canada forms agreements with provinces, encompassing environmental programs like the Canadian Agricultural Partnership and the On-Farm Climate Action Fund. Private sectors and community groups have also made significant contributions towards the incentivization of sustainable practices. For instance, ALUS Canada partners with local organizations and communities to provide financial incentives to farmers and ranchers for ecological goods and services like carbon capture and sequestration, biodiversity, cleaner air and water, and flood and drought mitigation. Recently, Loblaw, Maple Leaf, RBC, Nutrien and BCG, with support from Smart Prosperity Institute and Arrell Food Institute established a national alliance called "Canadian Alliance for Net-Zero Agri-food (CANZA)" with the goal of mobilizing investment, projects, policies and market incentives to remove 150 metric tons of emission from Canada's agri-food sector by 2050.

These commitments from both government and private bodies have led to notable ecological, economic and social successes in Canada: the amount of carbon dioxide sequestered in Canada's farmlands has increased; improved incentive characteristics (such as increased funding and interest), carbon market growth and the emergence of new schemes like

crowdfunding have contributed to economic success; and there has been an increasing level of involvement from producers and improved partnerships among stakeholders.

There are still key challenges that limit the effectiveness of incentives. Stakeholders may not know what activities should be incentivized and what incentive or combination of incentives is a best fit, as evident in many model (trial) incentive programs that did not result in long-term projects. Some agri-environmental initiatives focus solely on education and capacity-building, while incentive-based programs tend to follow three different models:

1. Pay for Practice, where funding is linked to the actual implementation of conservation practices

2. Enhanced Pay for Practice, which includes significant educational and capacity-building components alongside financial incentives

3. Pay for Performance, a newer approach which rewards producers based on tangible environmental outcomes from their practices. This has shown great promise in producing the right environmental goals and targets, and the verification-based metrics mean that the carbon sequestered can be traded in the carbon market to offset emissions.

Another key question with incentive programs is how to ensure the permanence of carbon sequestered. Many current incentive programs are time-specific (within five to ten years), leaving uncertainty about whether the incented practices are sustainable. This challenge must be addressed by all stakeholders in the food value chain; food retailers, specifically, are well positioned to act as a link between stakeholders to harness opportunities and ensure Canada's agriculture system meets its net-zero target.

Appendix 6 – Effective Stakeholder Collaboration to Incentivize Climate-Smart Farming

Enabling Factors	Support Mechanisms	Desired Outcomes	Monitoring and Verification	Broader Impact
Federal Government's Increased Funding	Provision of context-specific climate-smart guidelines and financial incentives	Increase in adoption of climate-smart practices	Standardized measurement and reporting, in alignment with global carbon market norms	Generation of agricultural carbon credits benefiting farmers
Cost-Effective Provincial Funding for Climate-Smart Farming	Equipping farmers with education, training and decision-making tools	Sustained implementation of climate-smart farming practices	Creation of a regional agricultural carbon sequestration inventory with set baselines and targets	Enhanced agricultural yield with minimized emissions
Direct Private Sector Investment in Climate-Smart Farming	Establish partnerships, prioritize climate-smart sourcing, provide financial incentives and offer training to farmers	Ensure consistent climate-smart farming, align brand with net-zero and improve supply chain sustainability	Engage third-party audits and maintain transparent reporting on climate-smart initiatives	Decreased corporate (Scope 3) carbon emissions
Collaborative Efforts of NGOs, Government and the Private Sector	Recognizing early adopters and fostering knowledge sharing	Improvement in the effectiveness of climate-smart farming	Localized tracking and verification methods	Progress towards Canada's net-zero emission goal

[1] Agriculture and Agri-Food Canada (2022). Overview of Canada's agriculture and agri-food sector. https://agriculture.canada.ca/en/sector/overview

[2] Greenhouse Gas Protocol. (n.d.). GHG Protocol. https://ghgprotocol.org

[3] Agriculture and Agri-Food Canada (2023). Greenhouse gas emissions and agriculture. https://agriculture.canada.ca/en/environment/greenhouse-gases

[4] Sothe, C., Gonsamo, A., Arabian, J., Kurz, W. A., Finkelstein, S. A., & Snider, J. (2022). Large Soil Carbon Storage in Terrestrial Ecosystems of Canada. Global Biogeochemical Cycles, 36(2), e2021GB007213. https://doi.org/10.1029/2021GB007213

[5] RBC Economics & Thought Leadership (2022). Fertile ground: How soil carbon can be a cash crop for the climate age. https://thoughtleadership.rbc.com/wp-content/uploads/Ag-Capital-PDF.pdf

[6] Food and Agriculture Organization of the United Nations (2023). Overview: Climate-Smart Agriculture.

[7] Usigbe, M.J., Asem-Hiablie, S., Uyeh, D.D. et al. Enhancing resilience in agricultural production systems with AI-based technologies. Environ Dev Sustain (2023). https://doi.org/10.1007/s10668-023-03588-0

[8] Mary, B., Clivot, H., Blaszczyk, N., Labreuche, J.,& Ferchaud, F. (2020). Soil carbon storage and mineralization rates are affected by carbon inputs rather than physical disturbance: Evidence from a 47-year tillage experiment. Agriculture, Ecosystems. Environment, 299, 106972. https://doi.org/10.1016/j.agee.2020.106972

[9] Cusworth G.,& Garnett, T. (2023). What is regenerative agriculture? TABLE Explainer. TABLE, University of Oxford, Swedish University of Agricultural Sciences and Wageningen University and Research. https://doi.org/10.56661/2d7b8d1c

[10] Wang, A., Lv, J., Wang, J., Shi, K. (2022). CO2 enrichment in greenhouse production: Towards a sustainable approach. Frontiers in Plant Science, 13. https://doi.org/10.3389/fpls.2022.1029901

[11] Agriculture and Agri-Food Canada. (2021). Statistical Overview of the Canadian Greenhouse and Vegetable and Mushroom Industry.

[12] Agriculture and Agri-Food Canada. (2021). Statistical Overview of the Canadian Field Vegetable Industry.