



CANADIAN AGRI-FOOD TECHNOLOGY

Sowing the Seeds for Tomorrow



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Preface

The Information and Communications Technology Council (ICTC) is a not-for-profit, national centre of expertise for strengthening Canada's digital advantage in a global economy. Through trusted research, practical policy advice, and creative capacity-building programs, ICTC fosters globally competitive Canadian industries enabled by innovative and diverse digital talent. In partnership with an expansive network of industry leaders, academic partners, and policy makers from across Canada, ICTC has empowered a robust and inclusive digital economy for over 25 years.

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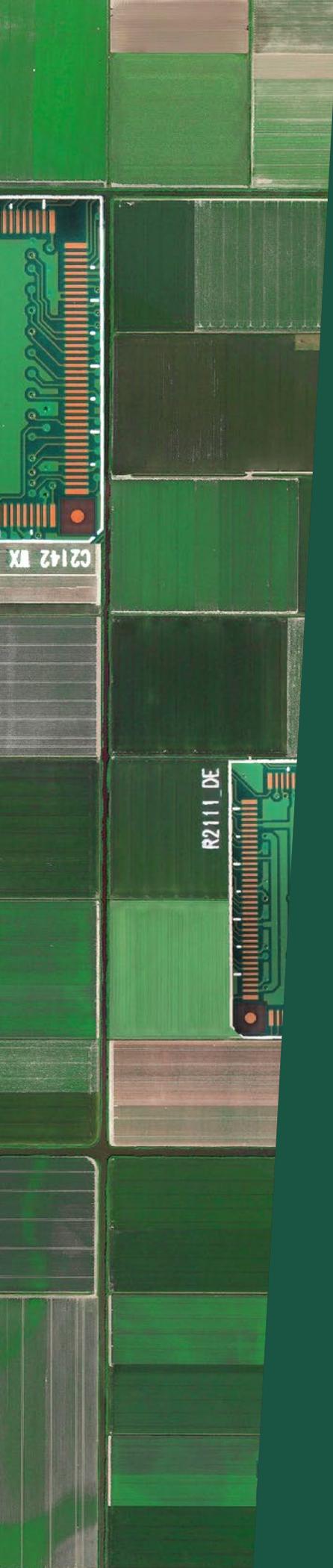
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Technology

Vertical Farming

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Executive Summary

A sustainable, competitive food and agriculture system is foundational to resilient economic growth. The UN's sustainable development goals make clear that food is tied to almost everything we do, including reducing inequality, achieving good health and well-being, responsible food consumption and production, building sustainable communities, and protecting the environment.¹ While estimates vary, food and agriculture production accounts for approximately 21% to 37% of global greenhouse gas (GHG) emissions,² 70% of freshwater use,³ and more than 50% of the world's habitable land,⁴ making agriculture a key pillar in efforts related to climate change, conservation, and biodiversity. Meanwhile, the global population is expected to reach 9.7 billion by 2050.⁵ With population growth comes greater demand for agri-food products,⁶ therefore the global food and agriculture sector will need to produce more while reducing its environmental footprint.

- 1 "The 17 Goals," 2021, United Nations Department of Economic and Social Affairs, <https://sdgs.un.org/goals>
- 2 "About 21–37% of total greenhouse gas (GHG) emissions are attributable to the food system." See: "Special Report: Special Report on Climate Change and Land: Chapter 5 Food Security," August 8, 2019, IPCC, <https://www.ipcc.ch/srcl/chapter/chapter-5/>; "Food systems account for over one-third of global greenhouse gas emissions," March 9, 2021, United Nations UN News, <https://news.un.org/en/story/2021/03/1086822>; Ritchie, H., "Food production is responsible for one-quarter of the world's greenhouse gas emissions," November 6, 2019, Our World in Data, <https://ourworldindata.org/food-ghg-emissions>
- 3 "Annual Freshwater Withdrawals, Agriculture (% of Total), 2021, Food and Agriculture Organization; AQUASTAT data; The World Bank Data, <https://data.worldbank.org/indicator/er.h2o.fwag.zs>
- 4 Ritchie, H. and Roser, M., "Land Use," September 2019, Our World in Data, <https://ourworldindata.org/land-use>
- 5 "Annual freshwater withdrawals, agriculture (% of total freshwater withdrawals)," 2017, Food and Agriculture Organization, AQUASTAT data, https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf
- 6 "To ensure food security for the predicted population of 9.6 billion people by 2050 the FAO predicts that food production must increase by at least 60 per cent to meet the demand, and a report from Tilman et al. in 2011 projected that food production must increase by 100 per cent to meet the projected food demand." See: <https://www.un.org/en/academic-impact/worlds-food-supply-made-insecure-climate-change>

Importantly, the relationship between the agri-food sector, climate change, and conservation is cyclical. The health of the global food system is intimately tied to health of the planet, as food systems rely on predictable climates, stable weather patterns, clean water, and fertile soil. Therefore agri-food not only impacts climate change and environmental degradation but is also impacted by these trends. Rising temperatures and sea levels, new precipitation patterns, and greater risk of more intense droughts, heatwaves, and natural disasters are all associated with climate change and present a significant threat to food security.⁷ Food security exists when “all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.”⁸ Food insecurity is therefore the absence of this state. Conflict, economic slowdowns, low productivity, and inefficient supply chains further impact food security by increasing the relative cost of food.⁹ For example, in 2020, amid pandemic-induced economic downturns, “the increase in the number of undernourished [people] was more than five times greater than the highest increase in undernourishment in the last two decades.”¹⁰

In addition to climate change and population growth, Canada’s agri-food sector faces “intense competitive pressures in global and domestic markets.”¹¹ Global markets increasingly demand higher quality, more secure data about food safety, including a heightened interest in food traceability across the agri-food supply chain. Governments and consumers increasingly want sustainable agri-food products like alternative proteins that meet key environmental indicators (e.g., CO₂ output and water, energy, and land use). People are learning how to grow food in new ways in urban environments, making use of vertical farms, greenhouses, and community plots. Simultaneously, there is growing interest in how to reduce food waste by keeping food fresh, longer, and using food waste as new inputs for the circular economy. Technology has a fascinating role to play in many of these market trends, but to meet these opportunities, Canada will need to prioritize agri-food innovation and digitization.

Interviewees in this study highlighted the role of precision-agriculture technologies in producing food more efficiently and more sustainably; controlled environmental agriculture, such as greenhouses and vertical farming; biotechnology; and high-tech food processing in Canada’s alternative proteins market. In terms of technology adoption, however, this study finds that while older technologies often see high rates of adoption in Canada, adoption rates for emergent technologies are often low. Further, ICTC’s survey identified six key barriers preventing agri-food tech adoption: the cost of equipment and implementation, including maintenance and operation; access to high-speed internet; low return on investment; labour shortages; technical challenges related to interoperability; and the oversupply of technologies that is not very useful to farmers.

7 Porter, J., “The World’s Food Supply is Made Insecure by Climate Change,” Accessed July 14, 2021, Food and Agriculture Organization of the United Nations, <https://www.un.org/en/academic-impact/worlds-food-supply-made-insecure-climate-change/>; “Climate change and food security: risks and responses,” 2015, Food and Agriculture Organization of the United Nations, <http://www.fao.org/3/i5188e/i5188e.pdf>

8 World Food Summit, 1996, Food and Agriculture Organization of the United Nations

9 “The State of Food Security and Nutrition in the World,” 2021, Food and Agriculture Organization of the United Nations, <http://www.fao.org/3/cb4474en/cb4474en.pdf>

10 “The State of Food Security and Nutrition in the World,” 2021, Food and Agriculture Organization of the United Nations, <http://www.fao.org/3/cb4474en/cb4474en.pdf>

11 “Agri-Food,” 2018, ISED, [https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_Agri-Food_E.pdf/\\$file/ISED_Agri-Food_E.pdf](https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_Agri-Food_E.pdf/$file/ISED_Agri-Food_E.pdf)

Focusing on labour shortages, ICTC estimates that demand in the agri-food technology industry will reach approximately 49,000 additional workers by Q4 of 2025.¹² If filled, this will bring total employment in the industry to 683,000 workers by the end of 2025.¹³ In terms of specific roles, this study finds that, while numerous roles are *relevant* to agtech, certain roles are more in demand and harder to fill than others. The agri-food system has become higher tech, with traditional tech occupations showing up as the most in demand. These roles include firmware and hardware developers, software developers, mobile app developers, web full stack developers, front-end developers, back-end developers, data scientists, business analysts, and UI/UX designers, blockchain engineers, and machine learning experts. In addition, agtech companies require a variety of interdisciplinary competencies and skills: agriculture, horticulture, and biology, engineering skills, manufacturing skills, digital skills, robotics, and data analytics.

A need for continued innovation and technology adoption is critical to help address agricultural emergencies related to climate change, respond to global population growth and growing food demand, and food insecurity. As noted by Canada's agri-food strategy council, Canada's agri-food sector is well positioned for longer-term growth; however, to meet increased food demand, Canada will need to build a 21st century talent pipeline that places a particular emphasis on digital and business skills across the agriculture and food sector.¹⁴



12 Ivus, M; Kotak, A., "Onwards and Upwards - Digital Talent Outlook 2025," Information and Communications Technology Council (ICTC), August 2021, <https://www.ictc-ctic.ca/wp-content/uploads/2021/08/digital-talent-outlook-for-2025.pdf>

13 Ivus, M; Kotak, A., "Onwards and Upwards - Digital Talent Outlook 2025," Information and Communications Technology Council (ICTC), August 2021, <https://www.ictc-ctic.ca/wp-content/uploads/2021/08/digital-talent-outlook-for-2025.pdf>

14 Canada's Economic Strategy Tables: Agri-food," Government of Canada, 2018, [https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISEDCAgri-Food_E.pdf/\\$file/ISEDCAgri-Food_E.pdf](https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISEDCAgri-Food_E.pdf/$file/ISEDCAgri-Food_E.pdf)



Introduction

Canada's agri-food system faces increasing pressure to adopt agri-food technologies: these pressures are diverse, **stemming from food insecurity, climate change, population growth, demand for sustainable food,** and other market trends. Canada is one of the more food-secure countries globally, yet no country is immune to food insecurity. In 2018, 12.7% of Canadian households were food insecure, with 8.7% of households experiencing moderate to severe food insecurity.¹⁵ These challenges are also not felt equally across demographic groups: single-parent households, low-income households, and rental households are at higher risk of food insecurity, as are individuals who identify as Black or Indigenous.¹⁶ Decades of research connect food insecurity in Canada to poor mental health outcomes,¹⁷ increased prevalence of chronic health conditions,¹⁸ and higher rates of mortality.¹⁹ Health outcomes in turn impact healthcare costs.²⁰

15 "Household food insecurity, 2017/2018," June 24, 2020, Statistics Canada, <https://www150.statcan.gc.ca/n1/pub/82-625-x/2020001/article/00001-eng.htm>

16 "Household Food Insecurity in Canada," 2021, PROOF, <https://proof.utoronto.ca/food-insecurity/>

17 Shafiee, M. et al., "Household Food Insecurity is Associated with Depressive Symptoms in the Canadian Adult Population," January 15, 2021, *Journal of Affective Disorders*, <https://doi.org/10.1016/j.jad.2020.10.057>; Jessiman-Perreault, G. and McIntyre L., "The Household Food Insecurity Gradient and Potential Reductions in Adverse Population Mental Health Outcomes in Canadian Adults," December 1, 2017, *Population Health*, <https://doi.org/10.1016/j.ssmph.2017.05.013>; Tarasuk, V. et al., "Maternal Food Insecurity Is Positively Associated with Postpartum Mental Disorders in Ontario, Canada," November 19, 2020, *The Journal of Nutrition*, <https://doi.org/10.1093/jn/nxaa240>; "Household Food Insecurity in Canada," 2021, PROOF, <https://proof.utoronto.ca/food-insecurity/>

18 Tait et al., "The Association between Food Insecurity and Incident Type 2 Diabetes in 23, 2018," <https://doi.org/10.1371/journal.pone.0195962>; "Food Security and Diabetes," February 11, 2021, *Diabetes Canada*, <https://www.diabetes.ca/advocacy---policies/our-policy-positions/food-security-and-diabetes>

19 Men et al., "Association between Household Food Insecurity and Mortality in Canada," 20, 2020, *CMAJ*, <https://doi.org/10.1503/cmaj.190385>

20 Men et al., "Food Insecurity is Associated with Higher Health Care Use and Costs Among Canadian Adults," August 2020, *Health Affairs, Health Affairs (Project Hope)* 39, no. 8 (August 2020): 1377–85, <https://doi.org/10.1377/hlthaff.2019.01637>; Tarasuk, V. et al., "Association between Household Food Insecurity and Annual Health Care Costs," October 6, 2015, *Canadian Medical Association Journal*, <https://doi.org/10.1503/cmaj.150234>

Food insecurity is a so-called “wicked problem” (one that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements), closely tied to income insecurity, affordable housing, and other socio-economic challenges. For example, food prices are a primary driver: from 2000 to 2020, the food price inflation outpaced the general inflation rate, with a “typical grocery bill” rising approximately 170%.²¹ Going forward, food prices in Canada will continue to be impacted by external shocks, including economic crises like the COVID-19 pandemic, fluctuating oil prices, and extreme weather events brought on by climate change.

In terms of climate change, within Canada, the impact on the food system is mixed. Some regions, such as the fruit growing regions in British Columbia, have been negatively impacted by climate extremes, with heat waves destroying fruit crops.²² Wildfires and wildfire smoke have also had adverse impacts on wine grapes and honeybees.²³ In the prairie regions, droughts and floods have negatively impacted crop production to the point of multiple municipalities declaring agricultural emergencies.²⁴ Looking forward, scientists expect more volatile precipitation and a greater number of hot days with temperatures above 30 degrees Celsius—possibly reaching more than 50 hot days per year late in the century.²⁵ On the other hand, climate change models also suggest that parts of the country could become more productive. Shorter winters and longer growing seasons have been observed across Canada to date, and the average growing season is expected to increase by an additional 32 days by 2100.²⁶ Barring extreme weather events and soil suitability, large parts of Canada that are currently not ideal for agriculture or have limited productivity may become more suitable for production.²⁷

Nonetheless, expanding agricultural operations into new regions generates new environmental risk, therefore agri-food experts foresee a greater need for technology to increase production from the land already in use and “reducing waste to make harvests go further.”²⁸

- 21 “Canada’s Food Price Report 11th Edition,” 2021, Dalhousie University, University of Guelph, University of Saskatchewan, and University of British Columbia, [https://cdn.dal.ca/content/dam/dalhousie/pdf/sites/agri-food/Food%20Price%20Report%202021%20-%20EN%20\(December%208\).pdf](https://cdn.dal.ca/content/dam/dalhousie/pdf/sites/agri-food/Food%20Price%20Report%202021%20-%20EN%20(December%208).pdf)
- 22 Recording breaking temperatures over a three-day period in July 2020 were so severe that they cooked significant portions of the region’s cherry, raspberry, and blueberry crops, with up to 75% of some fruits in the region becoming “too damaged to sell fresh.” Gomez, M., “B.C. heat wave ‘cooks’ fruit crops on the branch in sweltering Okanagan and Fraser valleys,” July 6, 2021, CBC News, <https://www.cbc.ca/news/canada/british-columbia/heat-fruit-crops-okanagan-fraser-valley-1.6092155>
- 23 The Canadian Press, “Wildfire smoke affecting Okanagan grapes and honey,” August, 22, 2018, CBC News, <https://www.cbc.ca/news/canada/british-columbia/wildfire-smoke-affecting-okanagan-grapes-and-honey-1.4794360>
- 24 Riley, S., “Another ‘harvest from hell’: Canada’s farmers forced to acclimatize to weird weather,” December 3, 2019, The Narwhal, <https://thenarwhal.ca/another-harvest-from-hell-canadas-farmers-forced-to-acclimatize-to-weird-weather/>; “Another Manitoba municipality declares state of agricultural disaster due to drought and heat,” July 13, 2021, CBC News, <https://www.cbc.ca/news/canada/manitoba/drought-agriculture-disaster-rm-of-armstrong-manitoba-1.6100138>
- 25 “Canada’s Changing Climate Report,” 2019, Government of Canada, https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf
- 26 “Canada’s Changing Climate Report,” 2019, Government of Canada, https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf
- 27 Hannah L. et al., “The environmental consequences of climate-driven agricultural frontiers,” February 12, 2020, PLOS ONE, <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0228305>
- 28 Chung, E., “Canada could be a huge climate change winner when it comes to farmland,” February 12, 2020, CBC News, <https://www.cbc.ca/news/science/climate-change-farming-1.5461275>

Inevitably, technology will play an important role in tackling food security and climate-related challenges. Technologically skilled labour shortages are already identified by the agri-food sector as a barrier to adopting new technology, and as the agri-food system becomes more high tech, technology adoption will drive further demand for tech-related labour and skills needs.

Canadian Agri-food Technology: Sowing the Seeds for Tomorrow assesses these challenges and other trends in Canada's agri-food sector, including trends related to agri-food tech companies and their products and services, trends in technology adoption, and labour market trends (i.e., in-demand roles and skill sets). The study used a mixed-methods research approach, which includes the following:

- A secondary literature review and analysis of secondary data acquired through web scraping
- Primary qualitative research consisting of 32 key informant interviews (KIIs) with diverse experts in the agri-food production, manufacture, and tech fields
- An industry survey of 310 agri-food technology companies, which focused on labour market needs and technology adoption

In addition, over the course of the research project, an advisory committee met to validate the research findings. Qualitative material from the interviews is referred to throughout the report. The survey findings are primarily discussed in Sections II and III. Further details about the research methodology can be found in the Appendix.

Section I of the report provides an introduction to the agri-food technology industry, beginning with key definitions and trends. The second part of Section I provides an overview of Canada's agri-food technology industry and delves into a dataset of 261 agri-food technology companies operating in Canada. It details prominent industry groups and tech verticals, in addition to trends in company size, location, and founding date. Section II presents the in-demand roles and skills in the Canadian agri-food tech ecosystem along with specific examples. Section III concludes with insights into the agri-food technology adoption landscape in Canada. It reviews technology adoption by region and discusses the key challenges to adoption.



● ○ ○ SECTION I

Agri-Food Technology Industry

Canada’s agri-food sector spans many industries, including primary agriculture, aquaculture, and food and beverage processing. Primary agriculture refers to the primary production of foodstuffs on land, including crops, horticulture, and livestock, whereas aquaculture refers to the farming of aquatic organisms in water, such as fish, crustaceans, and aquatic plants. Both agriculture and aquaculture products can also be used for purposes other than food and nutrition: for example, sheep can be farmed for their wool and hemp can be farmed to make fabric, string, bioplastics, and other industrial products.²⁹ Finally, the food and beverage processing industry consists of food service providers, food retail and wholesale, food and beverage processing, and input and service suppliers.³⁰



Figure 1: The components of Canada’s agriculture and agri-food sector.
Source: “Overview of the Canadian agriculture and agri-food sector 2018,” 2020, Government of Canada.

29 Agriculture and Agri-Food Canada tracks agricultural production for food and industrial use separately.
 30 “Overview of the Canadian agriculture and agri-food sector 2018,” November 20th, 2020, Government of Canada, <https://agr.gc.ca/eng/canadas-agriculture-sectors/sector-overviews-data-and-reports/overview-of-the-canadian-agriculture-and-agri-food-sector-2018/?id=1605883547264>

While communities across Canada rely on the agri-food sector for their food and nutrition, many Canadians also rely on the sector for work and employment. Canada’s agriculture and food sector is comprised of a complex, integrated supply chain of primary agriculture producers, input and service suppliers, food and beverage processors, retailers and wholesalers, and service providers. Together, these stakeholders generated \$143.1 billion of gross domestic product (GDP) in 2018, accounting for 7.4% of total Canadian GDP that year.³¹ The sector also employed approximately 2.3 million people in 2018, equal to 12.5% of Canadian employment (1 in 8 Canadian jobs).³² Jobs in the sector are diverse, located on farms, in processing plants, boardrooms, laboratories, and beyond.³³ In terms of growth, from 2012 to 2016, the agri-food sector grew at a faster rate than the Canadian economy generally: the agri-food sector’s GDP grew by 11% during this time period, while the Canadian economy grew only by 7.8%.³⁴

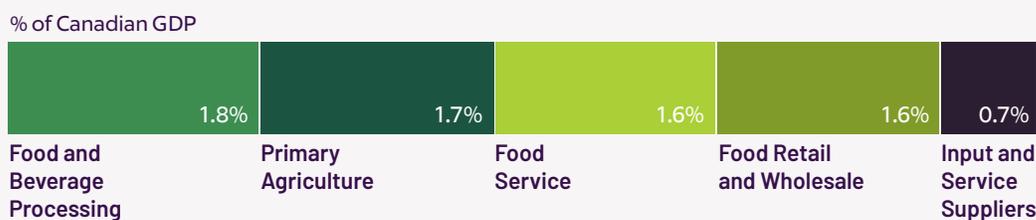


Figure 2: Within the agri-food sector, the food and beverage processing and primary agriculture industries are the largest contributors to GDP. **Data source:** “Overview of the Canadian agriculture and agri-food sector 2018”, 2020, Government of Canada.

Defining Agri-Food Technology

As with many new and emerging terms, there is no universal definition of agriculture technology, food technology, or agri-food technology. Apart from AgFunder and the Institute of Food and Agriculture—a subset of the United States Department of Agriculture—very few organizations have tried to define these terms.³⁵ Nonetheless, at a high level, **agri-food technology encompasses any advanced technology used by the agri-food sector in food production, for instance, to make food production safer, more efficient or environmentally friendly, or to create novel types of food.**

31 “Overview of the Canadian agriculture and agri-food sector 2018,” November 20th, 2020, Government of Canada, <https://agr.gc.ca/eng/canadas-agriculture-sectors/sector-overviews-data-and-reports/overview-of-the-canadian-agriculture-and-agri-food-sector-2018/?id=1605883547264>

32 “Overview of the Canadian agriculture and agri-food sector 2018,” November 20th, 2020, Government of Canada, <https://agr.gc.ca/eng/canadas-agriculture-sectors/sector-overviews-data-and-reports/overview-of-the-canadian-agriculture-and-agri-food-sector-2018/?id=1605883547264>

33 “Agriculture in Canada,” 2021, Canada Action Coalition, <https://www.canadaaction.ca/agriculture>

34 “Overview of the Canadian agriculture and agri-food sector 2018,” November 20th, 2020, Government of Canada, <https://agr.gc.ca/eng/canadas-agriculture-sectors/sector-overviews-data-and-reports/overview-of-the-canadian-agriculture-and-agri-food-sector-2018/?id=1605883547264>

35 “Agriculture Technology,” 2021, NIFA, <https://nifa.usda.gov/topic/agriculture-technology>; “AgFunder Agri-Food Tech Investing Report 2017,” 2017, AgFunder, <https://research.agfunder.com/2017/AgFunder-Agrifood-Tech-Investing-Report-2017.pdf>

The agri-food sector invokes an array of modern technologies to achieve these ends, including:

- Artificial intelligence (AI) and big data
- Sensors, broadband networks, and other internet of things (IoT) technology
- GIS, Global Positioning Systems (GPS), and aerial images
- Automated, connected, and electric vehicles and robots
- Biotechnology and bioinformatics

Given its expansive supply chain, the agri-food sector overlaps adjacent sectors, including retail, health, ICT, and manufacturing. In fact, the food and beverage processing industry is the largest manufacturing industry in Canada, accounting for 17% of all manufacturing GDP and 18% of manufacturing employment.³⁶ Past and present studies by ICTC focus on the impact of emerging technologies on retail, health, and manufacturing, and therefore it is important to clarify which areas of overlap are not included in this study. More details about how ICTC defines agri-food technology can be found in the Methodology section in the Appendix.

Canada and the Global Agri-Food Tech Industry

With such a large and diverse economic footprint in Canada, it is no surprise that investment data cites Canada as a key player in the global agri-food tech industry. According to AgFunder, in 2014, Canada ranked third in global agri-food technology deals.³⁷ Also in 2014, Canadian startup Clearpath Robotics made the Top 20 list of largest funding deals globally,³⁸ while in 2017 and 2019, three Canadian startups made Top 20 and Top 15 lists.³⁹ China, the United Kingdom (UK), Colombia, and Israel have accounted for a greater number of deals in recent years, yet Canada remains a key global player: in 2019, Canada was seventh in the total dollar value of new investment deals and sixth in the actual number of new deals (see **Figure 3**).⁴⁰ Similarly, according to Pitchbook data, 18 of the top 250 agtech investors (measured by total number of agtech deals) are Canadian.⁴¹ Put another way, Canada has the second most agtech investors after the U.S. among the top 250 investors globally.⁴²

36 "Overview of the Canadian agriculture and agri-food sector 2018," November 20th, 2020, Government of Canada, <https://agr.gc.ca/eng/canadas-agriculture-sectors/sector-overviews-data-and-reports/overview-of-the-canadian-agriculture-and-agri-food-sector-2018/?id=1605883547264>

37 "AgTech Investing Report – 2014," 2014, AgFunder, <https://agfunder.com/research/agtech-investing-report-2014/>

38 This is a global category that excludes US deals.

39 "AgFunder Agri-Food Tech Investing Report 2017," 2017, AgFunder, <https://research.agfunder.com/2017/AgFunder-Agrifood-Tech-Investing-Report-2017.pdf>; "AgFunder Agri-Food Tech Investing Report 2019," 2019, AgFunder, <https://research.agfunder.com/2019/AgFunder-Agrifood-Tech-Investing-Report-2019.pdf>

40 "Food-Agtech Investor Sentiment Report," 2019, AgFunder, <https://research.agfunder.com/food-agtech-investor-sentiment-report.pdf>

41 Pitchbook data. Accessed July 13, 2021.

42 Pitchbook data. Accessed July 13, 2021.

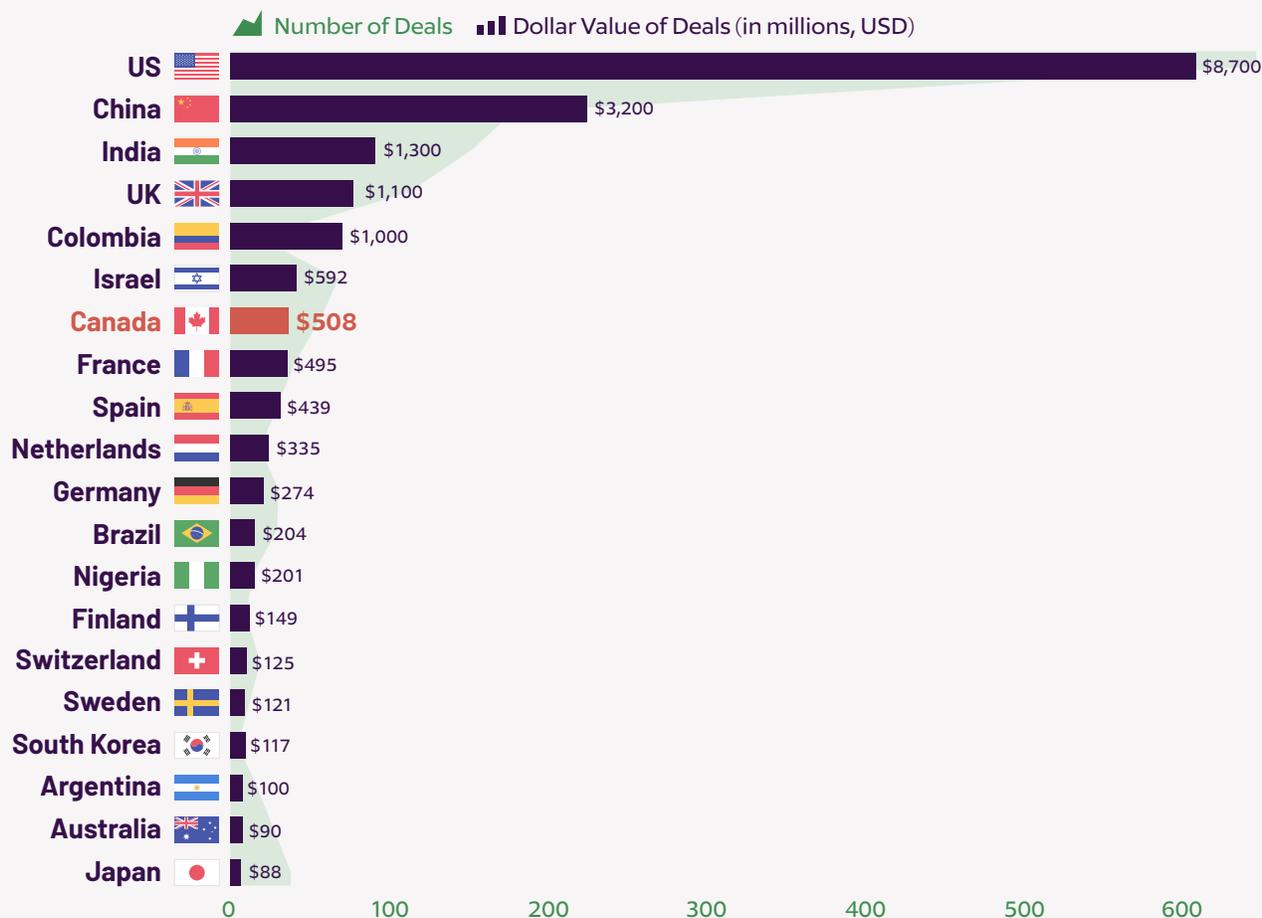


Figure 3: Annual investment value and number of investment deals by country, global.
Data source: AgFunder, 2019.⁴³

Agri-food Technology Trends

While there are numerous fascinating trends in agri-food technology, this section discusses those that emerged most often during ICTC’s key informant interviews, advisory committee meetings, and secondary literature review. This includes:

- 1 Precision agriculture
- 2 Controlled environment agriculture
- 3 Sustainable food production
- 4 Agricultural biotechnology

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“AgFunder Agri-Food Tech Investing Report 2019,” 2019” AgFunder, <https://research.agfunder.com/2019/AgFunder-Agrifood-Tech-Investing-Report-2019.pdf>

Precision Agriculture

Precision agriculture is a farm management strategy that seeks to “take the intuition and guesswork out of farming by allowing producers to harness the power of big data.”⁴⁴ It involves a suite of technologies that collect and share information about the local soil, climate, plants, and livestock and then use that data to inform agriculture processes and decision-making. Included in this suite of technologies is GPS, sensors, big data and AI, application programming interfaces (APIs), broadband connectivity, and high-tech farming equipment. In terms of benefits, precision agriculture enables increased productivity and costs savings.⁴⁵

Companies that provide precision-agriculture products and services are diverse. Some are very broad in focus, such as Alberta-based company Decisive Farming, which provides “whole-farm management solutions” that span crop production, people management, and sales and marketing. Others are narrower in focus—for instance, some precision agriculture companies focus on just fertilizer application or soil management. Similarly, precision agriculture products and services can apply to just one industry (e.g., horticulture, field crops) or product (e.g., canola, potatoes) or to multiple industries and products. Many of the companies that provide precision agriculture products and services in Canada cater to products that are either high value or widely produced, such as oilseeds, grains, and other field crops.

Some interviewees in this study brought forward data challenges related to precision agriculture solutions. For one, interviewees highlighted that precision agriculture solutions are still relatively new, and that the quality and consistency of the data that informs them have yet to be improved. Specifically, they noted that while there are many companies collecting agricultural data, there is “almost zero agreement” between companies as to what farmers should be doing to achieve certain agriculture outcomes. A second data challenge that was discussed by interviewees was that many precision agriculture solutions still require farmers to collect and/or input data manually. Considering this challenge, certain companies are currently working to better integrate their solutions with existing equipment and automate more of their data collection.

Where precision agriculture is used to guide processes like seeding, spraying, and harvesting, **high-tech farming equipment** (such as tractors, combines, or sprayers) is often involved. As agriculture technology becomes more sophisticated, so too does farming equipment: while GPS guidance, auto steer, and sectional control were once considered cutting-edge technology, today these features are considered a modern standard in farming equipment. Similarly, where precision agriculture is used to automate processes, **automated farming equipment** like automated vehicles, robots, and drones are used.

44 “Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports,” January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

45 “Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports,” January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

Interviewees in this study were excited about future developments in automated farming equipment:



We are going to see more farming equipment become autonomous. We are only at the cusp of autonomous equipment, and frankly, autonomous farm equipment is much easier to implement than autonomous vehicles generally—for example autonomous cars on the highway—because there is less risk involved.

– CEO, Precision Agriculture Company



The labour issue is becoming more and more acute. As the minimum wage goes up, the cost and availability of labor has really been a challenge, and COVID-19 has really amplified the problem.... At the same time, the technology is advancing, so it's becoming more likely that the technology will be capable of doing some of these complex tasks. So, we've got an interesting convergence: an intensifying need and a greater possibility on the technology side.

– Executive, Horticulture Company

However, interviewees noted that capacity for agricultural automation varies by commodity. For example, as is discussed further in **Section III**, automation is especially difficult to achieve in industries like horticulture where, in comparison to crop and pulse production, the products are more delicate and easier to damage.

TREND

2

Controlled Environment Agriculture

Controlled environment agriculture (CEA) is defined by the University of Arizona as “the production of plants and their products, such as vegetables and flowers, inside controlled environment structures such as greenhouses, vertical farms, and growth chambers.”⁴⁶ Similarly, Innovation Science and Economic Development Canada (ISED) defines CEA as “an indoor technology-based production system where crops are grown under a modified and highly conditioned environment” and identifies greenhouses, vertical farming, and hydroculture as the most common forms of CEA.⁴⁷

Controlled growing environments impact the agri-food industry in several important ways: first, for some time, CEA has enabled farmers to grow fruits and vegetables in ideal settings at maximum efficiency and productivity. Likewise, controlled growing environments provide shelter from unfavourable climate and weather patterns. More recently, controlled growing environments have enabled communities to grow food (or certain types of food) in places where they were previously unable to, such as cities and urban communities, colder climates, and places without the appropriate soil.

46

“UA Controlled Environmental Agriculture Centre,” 2021, The University of Arizona, <https://ceac.arizona.edu/>

47

“Enhancing automation in controlled environment agriculture farming,” January 19, 2021, Government of Canada, <https://www.ic.gc.ca/eic/site/101.nsf/eng/00125.html>

The ability to grow food in new places has several implications, including for food quality:



The main value proposition for our product is that a lot of food is bought from elsewhere and shipped up here to Canada. One problem with that is the environmental cost and another is that the products are not necessarily very good quality. It takes a long journey to get to Canada, resulting in a lot of product loss and damage. On top of that, the specific varieties that grocery stores carry are bred to be able to handle that long journey, as opposed to being bred for nutrition and flavour.

– Process Engineer Manager, CEA Company

Interviewees in this study were divided as to what extent CEA will help address food security. One interviewee noted that “as we develop the technology further, there is potential to increase the food security of our country,” however, other members of the advisory council cautioned that while CEA can enable more efficient food production in new places, the types of food (e.g., tomatoes, cucumbers, peppers, etc.) that are currently produced using CEA are not high in protein, nor diverse enough to form a complete diet. Nonetheless, CEA can help remote communities gain access to perishable food items by enabling them to grow more food locally.

A second challenge with controlled growing environments is that while they are much more efficient than traditional farms with respect to land, soil, and water use, this is not necessarily the case with their energy requirements. Interviewees highlighted the importance of using clean energy to power vertical farms and greenhouses. They also noted that many rural and remote communities in Canada that could benefit from producing more food locally rely on high-emissions energy sources like fossil fuels.

TREND

3

Sustainable Food Production



With respect to food, Canada is probably one of the most-favourably situated countries in the world, largely because of two things: clean soil and clean water, which are two key resources. At the same time, contamination and degradation are our biggest risks.

– Process Engineer Manager, CEA Company

Sustainable food production emerged as a common theme across interviews and advisory committee meetings. Interviewees discussed key drivers behind this trend, including the “push” of **government policy** and “pull” of **consumer demand**. As discussed, sustainable food and agriculture is foundational to resilient economic growth. The food and agriculture sector’s impact on the environment is significant, accounting for approximately 21% to 37% of global GHGs,⁴⁸ 70% of freshwater use,⁴⁹ and more than 50% of the world’s habitable land.⁵⁰ This makes food and agriculture instrumental in climate change, conservation, biodiversity efforts, and clean technology an important market for agri-food technology companies.

In terms of **government policy**, in 2021, the federal government committed to achieving net-zero emissions by 2050.⁵¹ As part of this policy agenda, Agriculture and Agri-Food Canada is running a \$185 million, 10-year program to “develop and implement farming practices to tackle climate change”⁵² and a \$165.7 million, seven-year program to help the agriculture sector develop and adopt transformative clean technologies.⁵³ Similarly, many foreign markets are beginning to prioritize or require green sourcing and procurement in their food systems. The European Union (EU) has also committed to achieving net-zero emissions by 2050, and through its Farm to Fork Strategy, it hopes to reduce food waste and make food production, processing, and distribution more sustainable.⁵⁴

Meanwhile, **consumer demand** for sustainable food is significant. According to a 2020 survey by the Canadian Centre for Food Integrity (CCFI), 37% of Canadians are “extremely concerned about environmental sustainability in farming,” and 36% “sought information about environmentally friendly and sustainable food production.”⁵⁵ While consumer definitions for sustainable food vary, just under 45% of Canadians believe sustainable food “has a positive impact on the environment.”⁵⁶ Moreover, the CCFI survey shows that Canadians are acting on their environmental concerns: more than 55% of Canadians actively seek out food items that use less packaging, and 47% seek out items that have a minimal environmental impact. Finally, research shows that younger Canadians aged 18 to 23 are driving increased demand for sustainable food.⁵⁷ Compared to Canadians above the age of 24, Gen-Z (ages 6–24) Canadians are “significantly more likely to seek out food items with less packaging (62%) and that have a minimal environmental impact (58%).”⁵⁸

- 48 “About 21–37% of total greenhouse gas (GHG) emissions are attributable to the food system.” See: “Special Report: Special Report on Climate Change and Land: Chapter 5 Food Security,” August 8, 2019, IPCC, <https://www.ipcc.ch/srcccl/chapter/chapter-5/>; “Food systems account for over one-third of global greenhouse gas emissions,” March 9, 2021, United Nations UN News, <https://news.un.org/en/story/2021/03/1086822>; Ritchie, H., “Food production is responsible for one-quarter of the world’s greenhouse gas emissions,” November 6, 2019, Our World in Data, <https://ourworldindata.org/food-ghg-emissions>
- 49 “Annual Freshwater Withdrawals, Agriculture (% of Total), 2021, Food and Agriculture Organization; AQUASTAT data; The World Bank Data, <https://data.worldbank.org/indicator/er.h2o.fwag.zs>
- 50 Ritchie, H. and Roser, M., “Land Use,” September 2019, Our World in Data, <https://ourworldindata.org/land-use>
- 51 “Canadian Net-Zero Emissions Accountability Act,” 2021, Open Parliament, <https://openparliament.ca/bills/43-2/C-12/>
- 52 “Agricultural Climate Solutions,” April 12, 2021, Government of Canada, <https://www.canada.ca/en/agriculture-agri-food/news/2021/03/background-agricultural-climate-solutions.html>
- 53 “A Healthy Environment and a Healthy Economy,” March 8, 2021, Government of Canada, <https://www.canada.ca/en/environment-climate-change/news/2020/12/a-healthy-environment-and-a-healthy-economy.html>
- 54 “Farm to Fork Strategy,” 2021, European Commission, https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en
- 55 “2020 Public Trust Research: trends in Trust and the Path Forward,” 2020, The Canadian Centre for Food Integrity, <https://www.foodintegrity.ca/wp-content/uploads/2020/11/ENG2020Summit-Research-HR-new.pdf>
- 56 “2020 Public Trust Research: trends in Trust and the Path Forward,” 2020, The Canadian Centre for Food Integrity, <https://www.foodintegrity.ca/wp-content/uploads/2020/11/ENG2020Summit-Research-HR-new.pdf>
- 57 “2020 Public Trust Research: trends in Trust and the Path Forward,” 2020, The Canadian Centre for Food Integrity, <https://www.foodintegrity.ca/wp-content/uploads/2020/11/ENG2020Summit-Research-HR-new.pdf>
- 58 “2020 Public Trust Research: trends in Trust and the Path Forward,” 2020, The Canadian Centre for Food Integrity, <https://www.foodintegrity.ca/wp-content/uploads/2020/11/ENG2020Summit-Research-HR-new.pdf>

Stakeholders across Canada’s agri-food industry have taken measures to reduce their environmental impact. In fact, while Canada’s agricultural output has increased over the last 20 years, the sector’s GHG emissions have remained relatively stable at approximately 60 Mt CO₂e while the carbon intensity of the sector has declined.⁵⁹ Today, the agriculture sector accounts for approximately 10% of Canada’s national GHG emissions.⁶⁰ In terms of sustainable agriculture solutions, precision agriculture technologies can help make farming more efficient and reduce carbon footprints, pesticide, and fertilizer usage.⁶¹ Meanwhile, regenerative farming practices can help increase the carbon content of soil: these include cover crops, no-till farming, increased crop rotations, and reduced chemical use.⁶²

Industry Standards

While recognizing the importance of sustainable agriculture, interviewees in this study noted that two things are needed to better support broadscale investment in sustainable agriculture solutions: greater convergence and acceptance of **industry standards** and, where needed, more accessible **identity preservation**. In discussing greater demand for sustainable food, interviewees highlighted a need to establish universally accepted standards for sustainable agriculture. They noted that, although it is possible to “measure certain attributes or impacts on the environment” such as reduced tillage, it is not certain whether those measurements would be universally accepted, nor whether they would justify calling a product “environmentally sustainable.”



We can certainly do things like reduce tillage, which results in increased carbon storage in the soils. We can also quantify that by looking at it from a gross perspective. So, en masse, we can look at how much tillage there is in the system and perform calculations on the GHG benefits of that, but does that tick the right box and make it officially environmentally sustainable?

– Public Servant, Agri-Food Sector



“The carbon side of things is a very hot topic right now—how do we show that the crops grown here are low carbon? I think that there is a huge opportunity there, but the central question is, how do we quantify that and put data behind that?”

– CEO, Precision Agriculture Company

- 59 Bilyea, Ted, et al., “Efficient Agriculture as a Greenhouse Gas Solutions Provider,” September 2019, The Canadian Agri-Food Policy Institute, https://capi-icpa.ca/wp-content/uploads/2019/09/2019-09-20-CAPI-paper-Efficient-Ag-GHG-Solutions-Provider_WEB.pdf
- 60 This measure excludes on-farm energy use and energy used in the production of fertilizer. “Greenhouse gas sources and sinks: executive summary 2021,” June 26, 2021, Government of Canada, <https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2021.html#toc5>
- 61 “Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports,” January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>
- 62 Bilyea, Ted, et al., “Efficient Agriculture as a Greenhouse Gas Solutions Provider,” September 2019, The Canadian Agri-Food Policy Institute, https://capi-icpa.ca/wp-content/uploads/2019/09/2019-09-20-CAPI-paper-Efficient-Ag-GHG-Solutions-Provider_WEB.pdf

Other interviewees highlighted that this challenge is not new: in the past, where consumers have been willing to pay a premium for certain types of food items, industries have established their own standards. As one interviewee put it, “rather than waiting for governments or other countries to set those standards, industry sets standards for themselves, and then it becomes a ‘prove me wrong’ scenario.” A short trip to the grocery store reveals the many industry-led food certifications and standards across Canada’s food system: Canada Organic,⁶³ FairTrade,⁶⁴ NONGMO,⁶⁵ Certified Halal,⁶⁶ Certified Plant Based,⁶⁷ UPcycled Certified,⁶⁸ Certified Vegan,⁶⁹ and Canadian Celiac Association Gluten-Free.⁷⁰ However, as sustainable food items are incentivized or mandated by governments—as opposed to being consumer driven—global standards will need to be established.

Identity Preservation

Interviewees also highlighted that when consumers are willing to pay an added premium for a certain type of food item, they generally want to know in no uncertain terms that the product is authentic. Similarly, some companies or industries will only use certain varieties of a product for their specific characteristics or traits. A prominent example of this type of niche market is Paterson Grain’s Wharburtons Wheat Production Program.⁷¹ Wharburtons is a baking firm based in the UK that only sources grain from producers who follow the terms of their program: in return for adhering to these terms, producers can charge an additional premium on top of the regular grain prices. In turn, producers need measures to track products throughout the supply chain. In the agri-food sector, tracking products throughout the supply chain is called **identity preservation**.

According to interviewees in this study, one of the things that is not yet clear is whether consumers will be willing to pay an extra premium for sustainably produced food:



It costs more to preserve the identity of sustainable food along the supply chain and to produce things sustainably. Right now, it is not clear whether farmers are going to be able to pass that cost along to consumers in the form of an added premium in the same way that farmers have done in the organic foods space. There is a chance that consumers will grow to expect these enhanced attributes but, at the same time, not want to spend extra on it.

– Academic Researcher, Canadian University

63 “Certified Organic,” 2020 Organic Council of Ontario, <https://www.organiccouncil.ca/organics/organic-certification/>

64 “Fairtrade International,” 2021, Fairtrade International, <https://www.fairtrade.net/>

65 “The Non-GMO Project,” 2021, <https://www.nongmoproject.org/>

66 “Halal Certification Canada,” 2021, Halal Certification Canada, <http://ifancc.org/>

67 “Driving the Industry Forward,” 2020, Plant Based Foods Association, <https://www.plantbasedfoods.org/>

68 “The Upcycled Certification Program Standard,” 2021, UpcycledFood.Org, <https://www.upcycledfood.org/the-standard>

69 “Certification – Vegan Action,” 2021, Vegan Action/Vegan Awareness Foundation, <https://vegan.org/certification/>

70 “The Gluten-Free Certification Program (GFCP),” 2021, Canadian Celiac Association, <https://www.celiac.ca/food-industry-professionals/certification-information/>

71 “IP Programs,” 2021, Paterson Grain, <https://www.patersongrain.com/for-farmers/grain-marketing/ip-programs/>

Nonetheless, interviewees noted that consumer demand will always be a moving target and importantly, where consumers are willing to pay an added premium for a specific food item, that item will need to be tracked. Concurrently, the global food system increasingly requires detailed supply chain data to satisfy food safety requirements. As technology author Xiaowei Wang writes in *Blockchain Chicken Farm and Other Stories of Tech in China's Countryside*, information about food is central to food safety: "This makes industrialized farming....an information business." Similarly, interviewees in this study said meeting consumer demand is about creating more transparency: the more data producers have and the better their records are, the easier it is to assess how they produce their crops and capture new opportunities. Today, the field of identity preservation is populated by a diverse suite of technologies: barcodes, RFID, QR codes, and other digital identity solutions; blockchain-based record management tools; and supply chain solutions that leverage IoT sensors, big data, and AI. Looking forward, interviewees were excited about expanding opportunities in this field:



The bottom line is that it costs money to preserve identity, and I think there is going to be a huge opportunity in the coming decades to deliver food products more efficiently.
 – Academic Researcher, Canadian University

Alternative Proteins

Global demand for sustainable food has given rise to numerous environmentally conscious diets. Some examples are the **organics diet**, which emphasizes eating foods produced according to strict environmental standards,⁷² the **100-mile diet**, which emphasizes eating locally grown foods, and the **flexitarian, vegetarian, vegan, and plant-based diets**, which, to varying degrees, emphasize eating foods that reduce an individual's meat and dairy consumption. The latter category of diets that seek to reduce meat and dairy consumption have given rise to a new industry: **alternative proteins**.

The production and consumption of meat and dairy products has skyrocketed over the past 50 years, as have the associated GHG emissions, freshwater withdrawals, and land use.⁷³ In comparison with plant-based proteins, meat and dairy products use more land and emit more GHGs per unit of protein.⁷⁴ With the exception of nuts, meat and dairy products also use more water.⁷⁵

- 71 "Organic 101: What the USDA Organic Label Means," 2021, US Department of Agriculture, <https://www.usda.gov/media/blog/2012/03/22/organic-101-what-usda-organic-label-means/>; "Certified Organic," 2020 Organic Council of Ontario, <https://www.organiccouncil.ca/organics/organic-certification/>
- 72 Ritchie, H. and Roser, M., "Meat and Dairy Production," November 2019, Our World in Data, <https://ourworldindata.org/meat-production>
- 73 However, the GHGs associated with meat and dairy production vary by country: "AAFC research estimated that Canada was among the most efficient producers, in the bottom 90th percentile range of GHG-emissions intensity for beef production compared to global figures." Bilyea, Ted, et al., "Efficient Agriculture as a Greenhouse Gas Solutions Provider," September 2019, The Canadian Agri-Food Policy Institute, https://capi-icpa.ca/wp-content/uploads/2019/09/2019-09-20-CAPI-paper-Efficient-Ag-GHG-Solutions-Provider_WEB.pdf
- 73 Ritchie, H. and Roser, M., "Environmental impacts of food production," June 2021, Our World in Data, <https://ourworldindata.org/environmental-impacts-of-food?country=>
- 74 Ritchie, H. and Roser, M., "Environmental impacts of food production," June 2021, Our World in Data, <https://ourworldindata.org/environmental-impacts-of-food?country=>

Consuming less meat and dairy and more alternative proteins⁷⁶ can therefore have a positive impact on the environment.⁷⁷ According to the International Panel on Climate Change, consuming “healthy and sustainable diets presents major opportunities for reducing GHG emissions from food systems and improving health outcomes.”⁷⁸

The alternative protein industry, which includes **plant-based meat and dairy products**, **cultivated meat or cell-based proteins**, and **fermentation-based alternative proteins**, has emerged from these challenges in recent years. Composed of protein, fat, vitamins, minerals, and water, **plant-based meat** is produced from plants and plant materials using high-tech food processing techniques.⁷⁹ **Cultivated meat**, which at the cellular level is identical to conventional meat is produced from cells.⁸⁰ Finally, **fermentation** is long-standing process that uses microorganisms to produce alternative proteins.⁸¹

Consumers are increasingly turning to plant-based products, which are the largest source of alternative proteins. A 2021 survey by Deloitte found that 44% of surveyed consumers across Canada have tried to consume less meat in the past year.⁸² Further, 79% of surveyed consumers increased their spending on plant-based milks and other non-dairy products in 2021, while 72% have increased their purchases of alternative meat products.⁸³ Again, younger Canadians aged 18-23 are driving this trend: compared to Canadians above the age of 24, “younger Canadians are significantly more likely to say they actively seek out grocery stores, restaurants, and recipes that offer plant-based or meat alternative options.”⁸⁴

While research shows that demand for plant-based options will continue to grow, in terms of market value, meat is still the dominant form of protein.⁸⁵ Moreover, meat and dairy consumption generally increase with income and urbanization, meaning meat and dairy production is likely to increase in developing markets for the foreseeable future.⁸⁶ Nonetheless, Canada is a major exporter of lentils, dry beans, dry peas, and soy beans,⁸⁷ making the alternative proteins industry an exciting opportunity. Protein Industries Canada, which was established by the federal government in 2018, is working to “accelerate innovation and the competitiveness of the Canadian plant protein sector” and “establish Canada as a global leader in plant protein.”⁸⁸

76 McKinsey and Company define alternative proteins as “protein-rich ingredients sourced from plants insects, fungi, or through tissue culture to replace conventional animal-based sources.” See: “Alternative proteins: The race for market share is on,” August 16, 2019, McKinsey & Company, <https://www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins-the-race-for-market-share-is-on>

77 However, the carbon footprint of “meat analogues such as imitation meat (from plant products), cultured meat, and insects” versus unprocessed plant proteins is more uncertain due to differences in production, etc. See: “Special Report: Special Report on Climate Change and Land: Chapter 5 Food Security,” August 8, 2019, IPCC, <https://www.ipcc.ch/srcccl/chapter/chapter-5/>

78 “Special Report: Special Report on Climate Change and Land: Chapter 5 Food Security,” August 8, 2019, IPCC, <https://www.ipcc.ch/srcccl/chapter/chapter-5/>

79 “Plant-based Meat,” 2021, Good Food Institute, <https://gfi.org/plant-based/>

80 “Cultivated Meat,” 2021, Good Food Institute <https://gfi.org/cultivated/>

81 “Fermented Meat,” 2021, Good Food Institute <https://gfi.org/fermentation/>

82 “The future of food: a Canadian perspective; The conflicted consumer 2021 food consumer survey,” 2021, Deloitte, https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/consumer-business/ca_futureoffood_pov_en_AODA.pdf

83 “The future of food: a Canadian perspective; The conflicted consumer 2021 food consumer survey,” 2021, Deloitte, https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/consumer-business/ca_futureoffood_pov_en_AODA.pdf

84 “2020 Public Trust Research: trends in Trust and the Path Forward,” 2020, The Canadian Centre for Food Integrity, <https://www.foodintegrity.ca/wp-content/uploads/2020/11/ENG2020Summit-Research-HR-new.pdf>

85 “2020 Public Trust Research: trends in Trust and the Path Forward,” 2020, The Canadian Centre for Food Integrity, <https://www.foodintegrity.ca/wp-content/uploads/2020/11/ENG2020Summit-Research-HR-new.pdf>; “Alternative proteins: The race for market share is on,” August 16, 2019, McKinsey & Company, <https://www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins-the-race-for-market-share-is-on>

86 Ritchie, H. and Roser, M., “Meat and Dairy Production,” November 2019, Our World in Data, <https://ourworldindata.org/meat-production>

87 “Countries by Commodity,” 2021, UN Food and Agriculture Association, http://www.fao.org/faostat/en/#rankings/countries_by_commodity_exports

88 “Who We Are,” 2021, Protein Industries Canada, <https://www.proteinindustriescanada.ca/who-we-are>

TREND

4

Agricultural Biotechnology and the Bioeconomy

Canada's bioeconomy uses resources from agriculture, forestry, fishery-based biomass, and other organic waste to create bio-based products (for example, renewable alternatives to non-renewable industrial products, which are often harmful to the environment). Biotalent Canada divides the bioeconomy into four subindustries: biohealth, bioenergy, bio industrial, and agricultural biotechnology (which includes animal nutrients and supplements, livestock vaccines, and plant and animal genetics).⁸⁹

Meanwhile, agricultural biotechnology is a set of highly sophisticated techniques and tools used by scientists to understand or manipulate the genetic makeup of organisms for their use in the production or processing of agricultural goods. For example, interviewees in this study were particularly excited about the role of biotechnology in developing new plant varieties with beneficial traits (such as crops that require less water, fertilizer, or land, or are immune to certain diseases or pests). As one interviewee noted, "it is important for agriculture to be as efficient as possible in every facet to ensure food supply for the growing population." Consequently, "there are numerous challenges for plant biotechnology/plant genetics to meet." The following interviewee comments further demonstrate how biotechnology can be applied in food production and processing:



One of the areas we work in is plant biology, which is about creating a diverse range of products and enhancing the plant varieties available to growers. It is also about generating consumer insights to adequately position these products on the market. We seek to understand what consumers want so that we can breed for the consumer traits that will ultimately succeed when the product enters the market.

– Executive, Horticulture Company



Gene editing can change the properties of raw commodities, but it will also be really important in food processing—how raw commodities are processed. Gene editing holds incredible potential within the food processing industry. You can think of how we might use bacteria, yeast, and all kinds of editing techniques that directly impact the smell, flavour, and look of food, and other aspects like shelf life.

– Academic Researcher, Canadian University

These techniques have their roots far back in time and are connected to a long history of crossbreeding and selection aimed at seeking the best and most profitable varieties. Biotechnology applies to several disciplines, including genetics, biochemistry, and molecular biology.⁹⁰ A series of terms were coined to identify the various branches of biotechnology (some of which are relevant to agriculture):⁹¹

➔ **Green biotechnology** is biotechnology applied to agricultural processes, for example, the selection and domestication of plants via micropropagation, or the designing of transgenic plants to grow under specific environments in the presence (or absence) of chemicals. One hope is that green biotechnology might produce more environmentally friendly solutions than traditional industrial agriculture. An example is the engineering of a plant to express a pesticide, thereby eliminating the need for external pesticide application.

➔ **Yellow biotechnology** refers to the use of biotechnology in food production, for example in winemaking, cheesemaking, and brewing by fermentation. This also includes biotechnology-based approaches for the control of harmful insects, the characterization and utilization of active ingredients or genes of insects for research or application in agriculture and medicine, and various other approaches.

➔ **Red biotechnology** “relates to biotechnology for medical purposes, including the engineering of genetic cures, or designing organisms which create antibiotics.”⁹² In the agri-food sector, red biotechnology focuses on improving livestock health.

Finally, **bioinformatics** is an interdisciplinary field that addresses biological problems using computational techniques and makes the rapid organization as well as analysis of biological data possible.⁹³ The field may also be referred to as **computational biology** and can be defined as “conceptualizing biology in terms of molecules and then applying informatics techniques to understand and organize the information associated with these molecules, on a large scale.” Bioinformatics plays a key role in various areas, such as functional genomics, structural genomics, and proteomics, and forms a key component in the biotechnology and pharmaceutical sector.⁹⁴

Canada’s Agri-Food Technology Industry Briefly

Using Pitchbook data, ICTC compiled a dataset of 261 companies that operate in Canada’s agri-food tech industry. These companies are detailed in the sections below, including information about prominent tech verticals and business lines, location of headquarters, number of employees, and founding year.

90 “What is Biotechnology,” 2021, Norwegian University of Science and Technology, <https://www.ntnu.edu/ibt/about-us/what-is-biotechnology>

91 “Biotechnology and its impact on today’s and tomorrow’s world,” 2021, Iberdrola, <https://www.iberdrola.com/innovation/what-is-biotechnology>

92 Cutean, A. et al., “Canada’s Growth Currency Digital Talent Outlook 2023,” October 2019, ICTC, <https://www.ictc-ctic.ca/wp-content/uploads/2019/11/canada-growth-currency-2019-FINAL-ENG.pdf>

93 “Bioinformatics,” 2021, National Human Genome Research Institute, <https://www.genome.gov/genetics-glossary/Bioinformatics>

94 “Computational biology and bioinformatics,” 2021, Springer Nature Limited, <https://www.nature.com/subjects/computational-biology-and-bioinformatics>

Prominent Tech Verticals and Business Lines

Technology companies transcend traditional sector and industry categories, making it difficult to categorize startups and technology companies. For example, a fintech company providing software tools to banks could be categorized as operating in both the financial services and ICT sectors. This holds true for agriculture and food technology companies as well, which can be classified as operating in both the agri-food and ICT sectors. Similarly, industry classifications can be too broad to provide useful information about a company’s product or service lines. For example, among the list of companies, “agriculture,” “software,” and “commercial products and services” were the top three industry groups. Other approaches to classifying startups, such as the key technology verticals, can provide further insight: among the companies in the dataset, the top 10 technology verticals (in order of importance) were: AgTech, Manufacturing, CleanTech, AI and Machine Learning (ML), Robotics and Drones, Life Sciences, Mobile, FoodTech, Lifestyles of Health and Sustainability, Wellness (LOHAS), and Software as a Service (SaaS).⁹⁵

Beyond this, ICTC analyzed company descriptions to identify common themes. Ten product and service lines emerged: precision farming, controlled growing environments, crop protection and nutrition inputs, high-tech farming equipment, agricultural biotechnology, enterprise services, alternative proteins, animal farming technology, high-tech food processing, and aquaculture technology (see **Figure 4**).



Figure 4: Among the list of 261 agri-food tech companies, 10 categories of core product and service lines emerged.
Data source: Pitchbook data, ICTC Analysis. ICTC, 2021.

95 “What are industry verticals?” Pitchbook, 2021, <https://pitchbook.com/what-are-industry-verticals>

Location of Headquarters

In terms of headquarters, the companies in the dataset are primarily located in Canada (93%) and the U.S. (5%), with a handful of companies headquartered in Europe and Asia. Among companies headquartered in Canada, they are primarily located in Ontario (33%), British Columbia (18%), Alberta (17%), Quebec (11%), Saskatchewan (10%), and Manitoba (5%). **Figure 6** provides additional details about the types of companies located in each province, broken down by primary industry group.

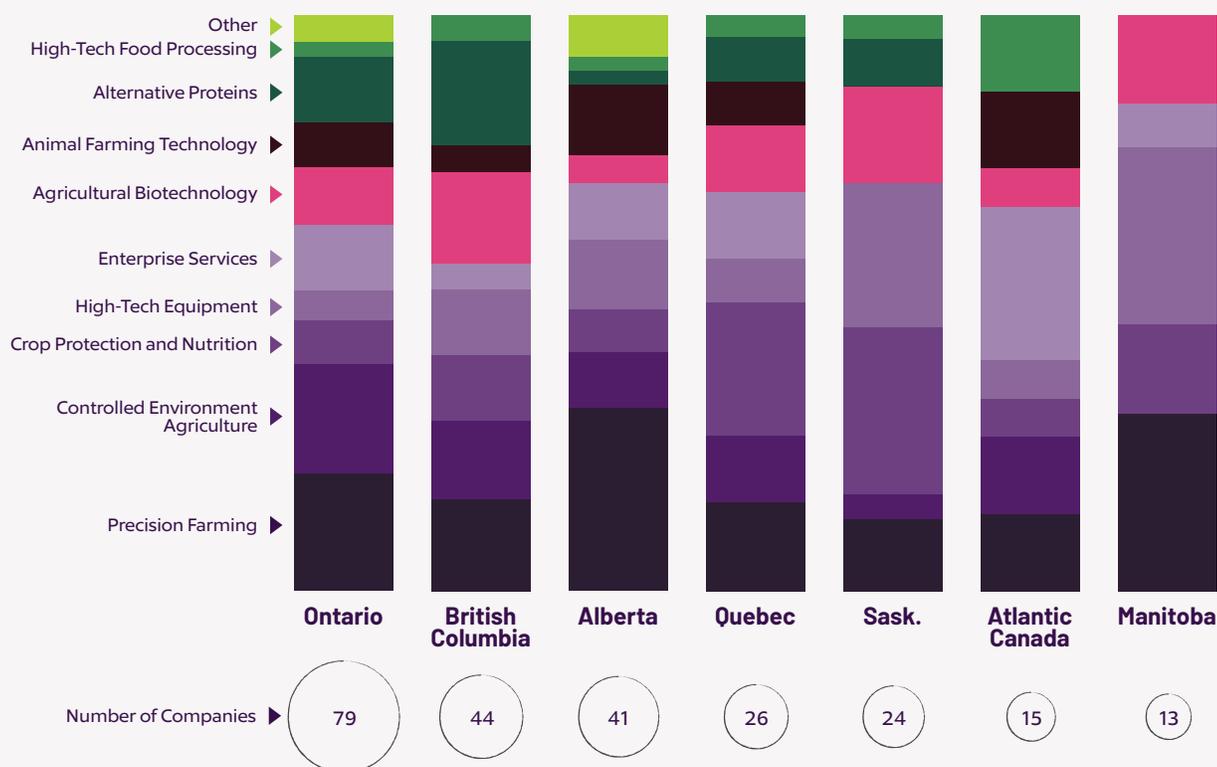


Figure 5: Agri-Food technology companies by location of headquarters (province) and industry.
Data source: Pitchbook data. ICTC, 2021.

Company Size and Founding Year

Size and founding year are useful indicators for company maturity. While small to medium sized enterprise (SME)⁹⁶ make up 99.8% of all Canadian businesses,⁹⁷ 96% of the companies in the agri-food technology dataset are SMEs (see **Figure 6** for more detail). Almost all of the companies in the dataset that are considered large enterprises (e.g., with 500 employees or more) are located in longstanding agricultural industries: agricultural biotechnology, crop protection and nutrition inputs like fertilizers and pesticides, and high-tech farm equipment. Across these three categories, the average company size is 2,123 employees.

⁹⁶ According to classification standards developed by Statistics Canada, small to medium sized enterprises are businesses with fewer than 500 employees.

⁹⁷ "Key Small Business Statistics – 2020," Industry, Science and Economic Development Canada, 2020, https://www.ic.gc.ca/eic/site/061.nsf/eng/h_03126.html

Alternatively, companies in the dataset with business lines that focus on more recently developed products and services tend to be smaller. Companies focused on precision farming, alternative proteins, controlled environment agriculture, and animal farming technologies have on average 48 to 58 employees. Finally, companies in the dataset that deliver enterprise services or perform high-tech food processing have on average 25 to 28 employees.

Similar patterns emerge with respect to company age. Companies in the dataset that cater to longstanding agricultural industries tend to be older, while those whose core business lines were more recently developed tend to be newer. On average, companies focused on agricultural biotechnology (1994), crop protection and nutrition inputs like fertilizers and pesticides (1994), and high-tech farming equipment (1996) were founded in the mid-1990s. Alternatively, the average founding date for precision farming companies in the dataset is 2008; enterprise services, 2009; alternative proteins, 2010; high-tech food processing, 2011; and controlled environment agriculture, 2011.

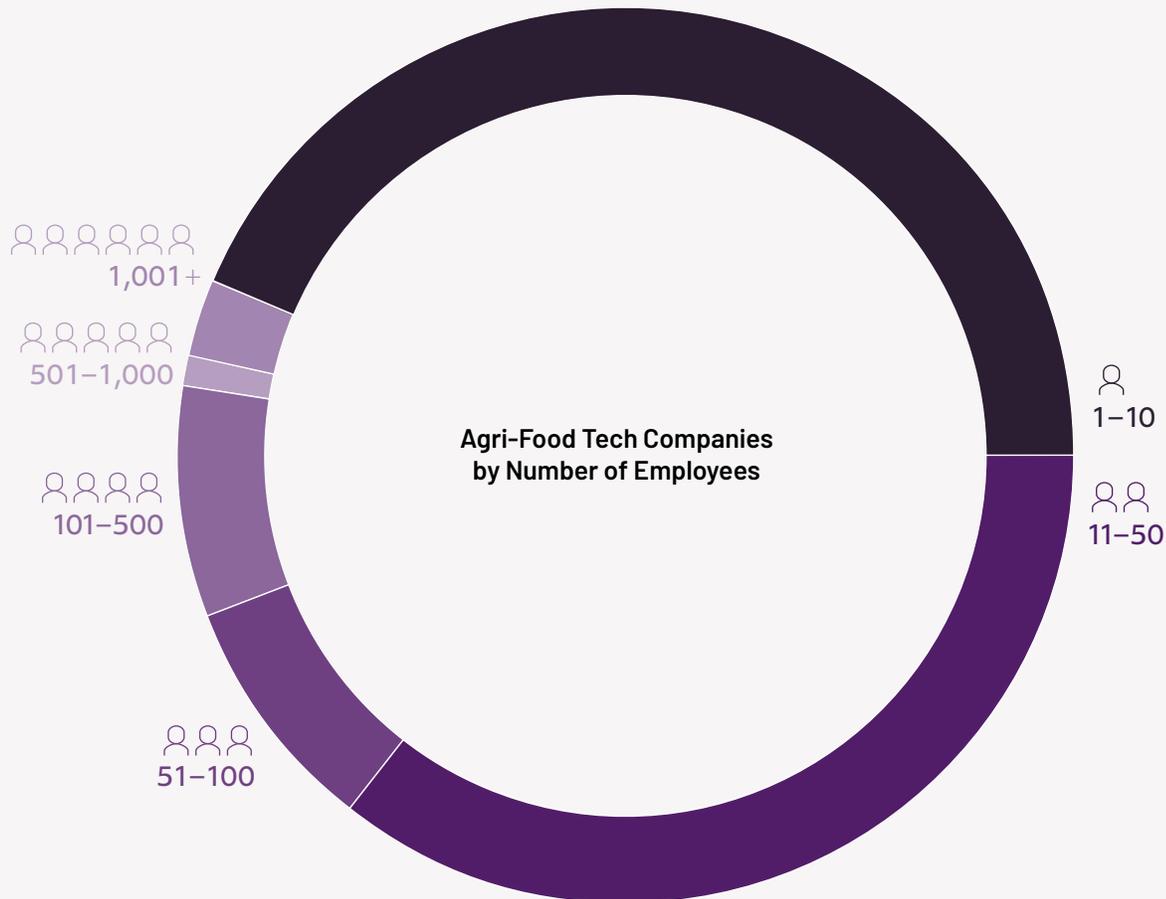


Figure 6: Agri-food technology companies by number of employees.
Data source: Pitchbook data. ICTC, 2021.



●●○ SECTION II

Agri-Food Technology Talent

With the availability of large farmlands in Canada, rising consumption levels, and increasing global demand for key food commodities, Canada's agriculture sector is well positioned for longer-term growth. Canada can seize this opportunity and boost its supply of safe, trusted, sustainable, traceable, and high-quality food products through increased adoption of cutting-edge digital technologies. However, according to Canada's Industry Strategy Table, in order to do so, Canada needs to accelerate broadband infrastructure investments to enable connectivity; increase the adoption of digital technologies that are critical to productivity improvements in the sector; incentivize digital investments across supply chains; and **build a 21st century talent pipeline with a particular emphasis on digital and business skills.**⁹⁸ Section II provides more granular insight on the labour market demand and needs of the agri-food technology industry. It begins with the labour market analysis of historical data, including ICTC's labour market forecast, Statistics Canada employment data, and job postings trends. Next, Section II takes a deeper look at the necessary roles and skill sets across the agri-food technology ecosystem, the growing impact of technology on agtech, and how talent is being drawn to the industry from technology sectors outside of agriculture.

⁹⁸ "Restart, recover, and reimagine prosperity for all Canadians," A Report from Canada's Industry Strategy Council, November 2020, [https://www.ic.gc.ca/eic/site/062.nsf/vwapj/00118a_en.pdf/\\$file/00118a_en.pdf](https://www.ic.gc.ca/eic/site/062.nsf/vwapj/00118a_en.pdf/$file/00118a_en.pdf)

Labour Market Demand

A 2019 report by the Royal Bank of Canada found that Canada's agri-food sector faces a severe skills and labour shortage, and noted the sector is moving into a "decade-long demographic crisis."⁹⁹ That same year, a forecast from Canadian Agricultural HR Council (CAHRC) cautioned that the labour gap in the agricultural sector will almost double by 2029, meaning nearly one in three jobs in this sector will go unfilled.¹⁰⁰ As the need for workers grows, rising retirements from an aging workforce and low numbers of youth pursuing an agricultural career will exacerbate the existing shortage.¹⁰¹ These trends were echoed by interviewees in this study:



I think the average age of an electrician right now in a larger processing plant is 55. The average age of a plant worker, the last I heard, was 44-48. Machinists are all now typically in their 50s. We're seeing a major decline in the workforce. It's all an older workforce.

– Public Servant, Fisheries and Oceans Sector

Highly skilled talent is the key to the successful growth of any sector of the economy. Labour shortages of capable and skilled professionals has been identified as a key pain point impacting the ability of the agriculture sector to scale.¹⁰² With new advances in technology and growing demand for agtech professionals, the labour shortage challenge is expected to escalate.¹⁰³

ICTC released its most recent labour market outlook report, *Onwards and Upwards: Digital Talent Outlook 2025*, in August 2021.¹⁰⁴ The report highlights agri-food technology as a key innovation area for the Canadian economy and provides an employment forecast for the industry. Employment in the agri-food technology industry has grown at a faster rate than other "traditional" areas of the economy over the last 10 years, likely due to increased technology adoption. It is expected that the agri-food technology industry will continue to perform strongly as COVID-19 accelerates digitization trends.¹⁰⁵

Figure 7 shows ICTC's employment forecast for the agri-food technology industry. The industry dipped in employment in 2020, and it is expected that the industry will be on track to recover starting in the middle of 2021. Under a moderate growth scenario, demand in the agri-food technology industry will reach approximately 49,000 workers by Q4 of 2025. If filled, this will bring total employment to 683,000 workers by the end of 2025.

⁹⁹ "Farmer 4.0: How the coming skills revolution can transform agriculture," August 2019, RBC Thought Leadership, http://www.rbc.com/economics/economic-reports/pdf/other-reports/Farmer4_aug2019.pdf

¹⁰⁰ "How Labour Challenges Will Shape the Future of Agriculture: Agriculture Forecast to 2029," 2019, CAHRC-CCRHA, https://cahrc-ccrha.ca/sites/default/files/National%20Report_Final%20-%20EN%202019%20reduced%20size.pdf

¹⁰¹ "How Labour Challenges Will Shape the Future of Agriculture: Agriculture Forecast to 2029," 2019, CAHRC-CCRHA, https://cahrc-ccrha.ca/sites/default/files/National%20Report_Final%20-%20EN%202019%20reduced%20size.pdf

¹⁰² "Restart, recover, and reimagine prosperity for all Canadians," A Report from Canada's Industry Strategy Council, November 2020, [https://www.ic.gc.ca/eic/site/062.nsf/vwapj/00118a_en.pdf/\\$file/00118a_en.pdf](https://www.ic.gc.ca/eic/site/062.nsf/vwapj/00118a_en.pdf/$file/00118a_en.pdf)

¹⁰³ Duncan, E., et al., "Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities," *Journal of Rural Studies*, Volume 68, 2019, Pages 112-122, <https://www.sciencedirect.com/science/article/pii/S0743016718307769>

¹⁰⁴ Ivus, M; Kotak, A., "Onwards and Upwards - Digital Talent Outlook 2025," Information and Communications Technology Council (ICTC), August 2021, <https://www.ictc-ctic.ca/wp-content/uploads/2021/08/digital-talent-outlook-for-2025.pdf>

¹⁰⁵ Ivus, M; Kotak, A., "Onwards and Upwards - Digital Talent Outlook 2025," Information and Communications Technology Council (ICTC), August 2021, <https://www.ictc-ctic.ca/wp-content/uploads/2021/08/digital-talent-outlook-for-2025.pdf>

It is important to note that addressing this demand will involve more than just increasing the number of workers in the industry: a short visit to an agriculture-focused job board¹⁰⁶ will quickly demonstrate that agri-food work has changed profoundly over time, with many of the skills required by agricultural workers now being digital.



Figure 7: Employment in Canada's agri-food tech industry (forecast), 2021 – 2025.
Source: ICTC, 2021. **Note:** Seasonally adjusted employment.

Historical Employment Data

To analyze the growing demand for agtech specialists in detail, ICTC conducted a “mapping exercise.” Leveraging primary and secondary research findings, ICTC identified specific digital occupations relevant to the agri-food tech industry, and then linked these occupations to the National Occupational Classification (NOC) codes.¹⁰⁷

Table 1 summarizes the amalgamated digital and agri-food NOCs that were identified as having high employment growth over the last five years: the occupations (NOCs) that saw the highest employment growth, with an average annual growth rate of more than 20% were database analysts and data administrators (NOC 2172); agricultural representatives, consultants, and specialists (NOC 2123); and software engineers and designers (NOC 2173). Considering that “a fourth revolution in agricultural technology is underway, and it’s all about data,”¹⁰⁸ the importance of these roles is not surprising. This trend is further echoed by interviewees in this study:



Over the last 10 years, I've seen a huge increase in the collection of data and the rise of big data across all aspects of agriculture... You can collect all the data you want, but at the end of the day, who interprets that data? I think there's a greater need for people who can sort the data and compile it so that you can actually see the trends.
 – CEO, Precision Agriculture Company

¹⁰⁶ “Indeed: Agriculture Technology,” February 16th, 2021, Indeed, <https://ca.indeed.com/Agriculture-Technology-jobs-in-Alberta>
¹⁰⁷ “National Occupational Classification,” May 3, 2021, Gouvernement of Canada, <https://noc.esdc.gc.ca/>
¹⁰⁸ “Farmer 4.0: How the coming skills revolution can transform agriculture,” August 2019, RBC Thought Leadership, http://www.rbc.com/economics/economic-reports/pdf/other-reports/Farmer4_aug2019.pdf



We have a small team with many roles: we have software roles—someone who is looking after the development of our apps and our online presence; hardware and firmware development roles; and of course, data analysis is very important. We also have agronomy and agronomists to make sure that we aren't inventing stuff that isn't needed. So, top level, those are the roles: agronomy, hardware, and software.
 – CTO, Agri-Food Tech Company

| NOC | Occupations | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Growth Rate |
|------|--|-------|-------|-------|-------|-------|-------|-------------|
| 2172 | Database analysts and data administrators | 1,700 | 4,700 | 3,500 | 2,100 | 1,800 | 4,600 | 50.4% |
| 2123 | Agricultural representatives, consultants and specialists | 1,800 | 3,700 | 2,100 | 3,900 | 2,900 | 3,000 | 25.2% |
| 2173 | Software engineers and designers | 1,700 | 3,300 | 2,800 | 3,700 | 2,200 | 3,400 | 25.0% |
| 2233 | Industrial engineering and manufacturing technologists and technicians | 3,700 | 7,200 | 5,000 | 5,000 | 7,000 | 6,900 | 20.5% |
| 2141 | Industrial and manufacturing engineers | 3,500 | 3,200 | 2,100 | 3,100 | 2,000 | 4,200 | 15.8% |
| 2161 | Mathematicians, statisticians and actuaries | 2,000 | 3,700 | 2,300 | 3,800 | 4,700 | 1,800 | 14.9% |
| 2147 | Computer engineers (except software engineers and designers) | 1,600 | 2,100 | 2,100 | 1,800 | 1,900 | 2,500 | 10.8% |
| 2171 | Information systems analysts and consultants | 3,100 | 3,300 | 3,500 | 4,600 | 3,900 | 4,300 | 7.8% |

Table 1: Top employment growth digital occupations across the agri-food tech industry, 2015-2020.
Source: ICTC, Statistics Canada Labour Force Survey. **Note:** Average annual growth rate.

NOCs aggregate large areas of occupational activity, meaning the data presented above only partially describes the demand for the agtech professionals in the industry (and does so at a macro level). To better understand the specific roles that are in demand within these NOCs, ICTC created **Table 2**. Table 2 uses information from job postings to provide a snapshot of the top roles and hard skills for each NOC code identified in **Table 1**.

| NOC | Occupations | Top Jobs Postings | Top Hard Skills |
|------|---|---|---|
| 2233 | Industrial engineering and manufacturing technologists and technicians | Quality Control Technicians, Managers, Supervisors, Coordinators Transformation Specialists Quality Assurance Managers, Supervisors, Specialists, Assistants, Representatives, Leads Quality and Food Safety Managers Quality Directors, Managers Process Technicians Technologists Processing Technicians Data Quality Assurance Analysts Data Quality Managers | Auditing Quality Control, Management Food Safety Hazard Analysis and Critical Control Points (HACCP) Safety Assurance Corrective and Preventive Action (CAPA) Food Science Quality Management Systems Microbiology Food Manufacturing |
| 2173 | Software engineers and designers | Software Developers Application Engineers DevOps Engineers Scientific Programmers .NET Developers Service Desk Analysts Boutique Assistants UI/UX Designers Data Engineers | C# (Programming Language) .NET Framework Java (Programming Language) JavaScript (Programming Language) Git (Version Control System) Software Development Agile Methodology SQL (Programming Language) C++ (Programming Language) Python (Programming Language) |
| 2171 | Information systems analysts and consultants | Systems Analysts ERP Business Analysts Solutions Architects IT Administrators Lead Application Analysts Information Systems Analysts Systems Analyst Managers ERP Business Systems Analysts Integration Managers Enterprise Systems Analysts | Technology Solutions Enterprise Resource Planning Business Process Computer Science Agile Methodology Systems Analysis Information Management Systems Engineering SQL (Programming Language) Functional Requirement |

| NOC | Occupations | Top Jobs Postings | Top Hard Skills |
|------|--|--|---|
| 2123 | Agricultural representatives, consultants and specialists | <ul style="list-style-type: none"> Agronomists On-Site Specialists Sales Agronomists Geotechnical Managers Irrigators Field Agronomists Crop Specialists Environmental Technicians Soil Scientists Agricultural Managers, Specialists | <ul style="list-style-type: none"> Agriculture Agronomy Document Enterprise Platform Soil Science Sampling (Statistics) Crop Production Geotechnical Engineering Irrigation (Landscaping and Agriculture) Applied Research |
| 2141 | Industrial and manufacturing engineers | <ul style="list-style-type: none"> Automation Engineers Manufacturing Engineers Structural Engineers Product Development Scientists Industrial Engineers Food and Beverage Controllers Manufacturing Material Handlers Quality Assurance Automation Engineers Quality Assurance Managers Test Automation Engineers | <ul style="list-style-type: none"> Lean Manufacturing Automation Systems Engineering SolidWorks (CAD) Programmable Logic Controllers AutoCAD Quality Control Pneumatics Electronics Fabrication |
| 2172 | Database analysts and administrators | <ul style="list-style-type: none"> Data Scientists Database Administrators FSQA Managers Horticulture Specialists Crop Specialists Data Architects Data Analysts Information Services Analysts Network Administrators SQL Database Administrators | <ul style="list-style-type: none"> SQL (Programming Language) Data Analysis Computer Science Python (Programming Language) Database Administration Statistics R (Programming Language) Microsoft SQL Servers Machine Learning Microsoft Azure |

| NOC | Occupations | Top Jobs Postings | Top Hard Skills |
|------|---|--|---|
| 2147 | Computer engineers (except software engineers and designers) | <ul style="list-style-type: none"> Hardware Engineers Computer Vision Researchers Network Analysts Network Engineers Herdsmen Hardware Managers Hardware Designers Computer Vision and Machine Learning Engineers Boutique Managers Applied Researchers | <ul style="list-style-type: none"> C++ (Programming Language) Firmware Python (Programming Language) Electrical Engineering Printed Circuit Boards Design Prototyping Performance Tuning Computer Vision Capacity Planning Printed Circuit Board |
| 2161 | Mathematicians, statisticians and actuaries | <ul style="list-style-type: none"> Geotechnical Engineers Environmental Professionals Materials Engineers, Technicians Site Civil Engineers Electrical Engineers Landscapers Lead Mechanical Engineers Mechanical Engineers Agronomists Environmental Scientists/ Biologists | <ul style="list-style-type: none"> Geotechnical Engineering Civil Engineering Soil Science Environmental Engineering AutoCAD Active Server Pages (ASP) JavaScript (Programming Language) SQL (Programming Language) C# (Programming Language) Sampling (Statistics) |

Table 2: A snapshot of top job postings and In-demand hard skills.

Data Source: Emsi Data, accessed in July 2021.

Job Postings Data

Figure 8 shows the job postings trend for the eight high-growth NOCs in agriculture, forestry, fishing and hunting (NAICS 0011) in Canada. This covers the period from November 2017 to June 2021. In June 2021, there were over 123 job postings related to agtech. Among the job postings, Montreal, Toronto, Calgary, Laval, Kitchener, Quebec City, Regina, Saint John, Mississauga, and Saskatoon were the most common job locations.

In general, job posting data is a common and relevant metric for assessing the demand for certain roles. Although many interviewees reported growth in demand for digitally skilled talent over the last few years, the data below shows a relatively steady job postings trend in the 100 to 150 jobs range, with a small fluctuation in demand during 2019 and 2021. It is worth noting that many interviewees in this study rely heavily on networking, partnerships with colleges and universities, and other informal recruitment methods to obtain talent (as opposed to using online job boards and platforms). The popularity of such informal recruitment methods means that the data in **Figure 8** only partially captures the demand for digital talent and explains why the data below does not show an upward trend.



It's right now all through referrals. As we all know, it's a guy that knows a guy that knows a girl.
 – Executive, Precision Agriculture Company



Personally, I build up my network using LinkedIn. I'll go to a university like Dalhousie University or the universities on the East Coast and I'll look for the graduates in computer science or the MBA program over the last couple of years and add them add them on LinkedIn. When we do post a job, we just post it personally on our own LinkedIn accounts and get applicants that way.
 – CEO, Aquaculture Company

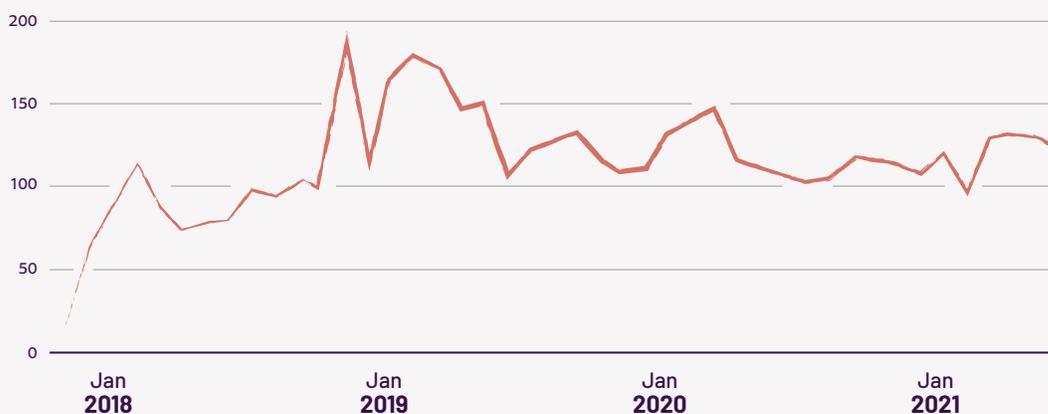


Figure 8: Job postings trend related to agtech, November 2017 – June 2021. **Source:** Emsi Data, accessed in July 2021.

Nonetheless, job postings data provides a useful way to analyze the impact of technology and its application on the agtech employment industry. For example, **Table 3** demonstrates advanced technology skill and education required through three different business-to-business domain lenses: **farm robotics, agriculture and automation,** and **precision agriculture.** The category “farm robotics” indicates a combination of production technologies combined with traditional skill sets, for example, automatic milking systems. The results for “agriculture and automation” are more explicit, identifying software developers, various automation roles, and reference to cloud-based technologies.

Finally, the data collected for “precision agriculture” shows a marked inclination to sophisticated business-side technology and higher-yield production. Interviewees in this study helped clarify why terms like precision agriculture encompass such a broad range of business activities: for example, one interviewee noted that “precision agriculture is one of the most poorly defined terms” in agriculture and “means so many different things to so many different people.” Another noted that under the broad category of precision agriculture, one can find completely different roles: a role dealing with the hardware will be “totally different” from one dealing with just the data analysis aspect.

| Search Terms | Top Jobs | Top Hard Skills |
|-----------------------------------|--|--|
| Farm Robotics | Swine Technicians Farm Workers Business Development Managers Beekeepers Manufacturing Engineers Dairy Specialists Farm Equipment Operators Farm Technicians Shippers/Receivers | Dairy Farming Automatic Milking Agriculture Automation Scripting Industrial Automation Beekeeping Sales Records Biology Business Development |
| Agriculture and Automation | Automation Specialists R Programmer developers Tax Compliance Analysts Quality Assurance Testers Conservation Technicians Robotic Process Automation Analysts IT Service Desk Leads Electricians Data Centre Network Engineers Electrical Engineering Technicians | Dairy Farming Automation Agriculture Instrumentation Programmable Logic Controllers Application Programming Interface C# Agile Methodology Auditing Microsoft Azure |
| Precision Agriculture | Production Advisors Integrated Solutions Consultants Agronomists Branch Managers Operations Leads Heavy Duty Mechanics Assistant Managers Fuel Drivers Communications Specialists | Agriculture Soil Science Crop Production Business Relationship Management Customer Relationship Management Collections Agronomy Precision Agriculture |

Table 3: Search results from targeted agtech job data analysis.

Data Source: EMSI, Accessed in July 2021.

Key Roles and Skill Sets

ICTC used a combination of research methods to identify the key roles and skillsets in the agtech industry: secondary data from online job boards and professional networking sites; and qualitative insights from the key informant interviews and advisory committee meetings.



Technical Roles in Agri-Food

According to interviewees and advisory committee members, while numerous jobs are relevant to agtech, certain jobs are more in demand and harder to fill than others. For example, various types of traditional tech occupations were identified as the most in-demand technical roles: firmware and hardware developers, software developers, mobile app developers, web full stack developers, front-end developers, back-end developers, data scientists, business analysts, and UI/UX designers. Moreover, certain tech roles were identified as being particularly hard to find: blockchain engineers, machine learning experts, data scientists, and data infrastructure engineers. ICTC survey confirmed that software developers, software engineers, full stack developers, UX/UI designers, data scientists, product managers are the most frequently hired tech occupations. When asked why these technical roles were in demand and/or hard to find, interviewees explained that “software development is a very, very competitive space,” with “a lot of aggressive hiring, big money being offered all around, and a limited supply.”

The challenges of adopting advanced technology can be seen in the emergence of the role of agricultural consultant: these individuals possess technology expertise combined with business and advanced agricultural knowledge. A scan of the labour data for this role found their top skills include C++ (object oriented programming language), *Salesforce* (cloud-based customer relationship management (CRM) software), *Kafka* (platform for handling real-time data feeds). Interviewees in this study agreed that when adopting emerging technologies, “a lot of companies will hire consultants to come in and put in a new machine—for example, one that has some autonomous capability.”

In addition to hard skills, study participants mentioned the importance of soft skills, including communication skills, knowledge of social media, teamwork, creativity, adaptability, and sales. Interviewees and AC members weighted the importance of soft skills to varying degrees:



For us, the immediate hires are software developers. The hires that come next are likely going to be more business focused: business development, sales, and marketing.

– CEO, Ag Automation Company



Communication skills are more important than tech skills... We'll look at the resume and do a basic check to make sure that [candidates] have the basic [skills], but the rest is communication. Soft skills are more important even in an AI company.

– CEO, Aquaculture Company



"The number one challenge is finding sales talent: people that can relate to the farmer, take on a consultative-type sales role on the farm, understand the farm, and talk to a farmer... We've invested significant dollars into growing our [salespeople] over two-, three-, and five-year periods to get them to a certain place because you can't just hire these people. You can hire someone from an equipment dealer that can talk to a farmer, but they won't have sold something that the farmer didn't already have a budget line item for, like tractors; and they won't have sold software or technology.

– CEO, Precision Agriculture Company

Interdisciplinary Talent

The third quotation above also highlights the importance of domain knowledge in the agri-food tech industry. Agtech talent requires a variety of interdisciplinary competencies and skills, including agriculture, horticulture, and biology, as well as engineering skills, manufacturing skills, digital skills, robotics, and data analytics. Some of these skills are acquired at school, while others are gained through work experience. The challenge is finding talent that possesses a unique blend of these interdisciplinary skills. These sentiments were also echoed by other interviewees and advisory committee members:



There are lots of people who are very good at narrow things—software design programming—but very few people understand the whole concept. Farming is extremely complex, and there are so many inputs that need to be understood. It's really hard to find people who have at least some basic understanding of farming and whatever other specialization is needed—whether software or hardware.

– CEO, Ag Enterprise Solution Company



Our CTO has a background in software, but he had to learn hardware and plant science. We had to 'up skill' him in that sense.

– CEO, Controlled Environmental Agriculture Company



One school might have really good growing techniques, but what about software and hardware? It's not a natural set of things to combine with one another: usually its engineering or horticulture in separate departments, but I think this has to come together. I'm not sure if there's a right answer for us today other than upskilling—and trying to poach talent from other places, but we can't always afford to do that.

– CEO, Precision Agriculture Company

The need for interdisciplinary talent is already impacting academic programs related to agri-food tech. While knowledge-economy roles in agri-food traditionally stem from a base education in biology and chemistry,¹⁰⁹ in recent years, advances in computer science have seen a growth in hybrid university programs, such as **computational biology** and **bioinformatics** (terms that are sometimes used interchangeably). Computational biology is a discipline that adopts methods from a wide range of mathematical and computational fields to build models for diverse types of experimental data and biological systems.¹¹⁰ Ideally, this combination of skills forms a solid basis for precision agriculture across a spectrum, from research to practical skills (specifically, being able to understand and program systems in the field, such as autonomous vehicles or sensor networks). At the same time, the practitioner has the background to understand the intricacies and nuances of the data being generated or collected.

These degree programs anticipate occupations falling under job titles such as biochemist; genetic researcher; computational biologist or bioinformaticist; precision agriculturist; and food scientist, technologist, or engineer. Although the degree curriculum is well-defined—and the job responsibilities in the industry are longstanding—these job titles have yet to appear widely on agri-food tech job boards. That said, current job postings do exhibit signs of a classic dilemma related to high tech and domain expertise, in this instance: do you teach farmers how to write software, or do you teach programmers about farming? As one interviewee noted, “no one comes with ‘ag automation’ on their resume.... You have to get people fresh out of school or retrain them from other industries.” Many job postings related to agtech read like advertisements for traditional ICT workers that are accompanied by a parenthetical “nice to have” caveat citing experience in agriculture.

Agri-Food Tech Business Domains

The challenge of finding seasoned, interdisciplinary talent is further complicated by the reality that the agri-food technology ecosystem spans so many business domains. Across this network, broad categories of occupations emerge, bridging **advanced biological research and development, agricultural systems, and sophisticated business enterprise operations**. A core backbone of agri-food tech is **biotechnology and bioscience**. Many important occupations in the industry relate to research and laboratory experimentation in areas such as genetics, horticulture, agronomy, and food science. Activities in this area include genetic experimentation and modelling; conducting measurements in the laboratory; maintaining and harvesting plots; and collecting yield data.

¹⁰⁹ “AGRICULTURAL BIOTECHNOLOGY AND FOOD SCIENCES,” 2021, University of British Columbia, <https://www.grad.ubc.ca/research/agricultural-biotechnology-food-sciences-rdf404>

¹¹⁰ “Computational Biology Department: School of Computer Science,” 2021, Carnegie Mellon University, <http://cbd.cmu.edu/about-us/what-is-computational-biology.html>; “Computational Biology,” 2019, MIT Department of Biology, <https://biology.mit.edu/faculty-and-research/areas-of-research/computational-biology/>

Two examples of the technical roles that are required by Canadian companies operating in this area are provided below. The roles were manually collected from publicly available job sites (data accessed July 2021) and each example is based on approximately five to 10 Canadian companies (many of which are startups).

BIOSCIENCE COMPANY

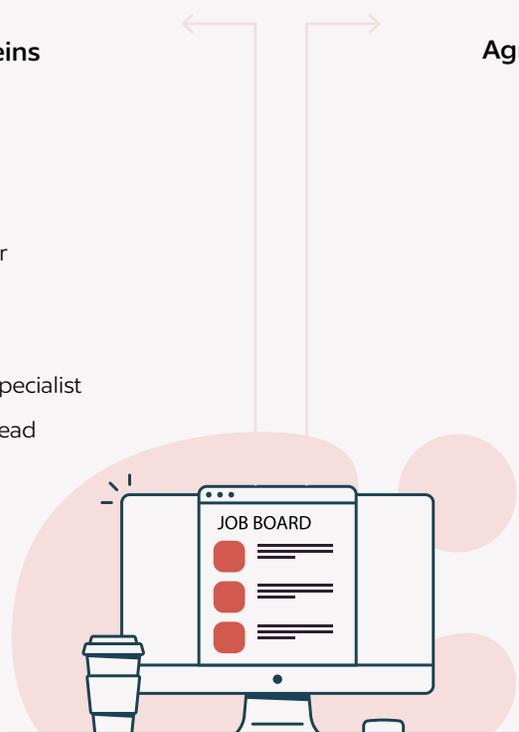
Alternative Proteins

- Chief R&D Officer
- R&D Lead
- R&D Technician
- Scientist, Researcher
- Process Engineer
- Product Manager
- Regulatory Affairs Specialist
- Quality Assurance Lead
- Quality Assurance Technician

BIOTECHNOLOGY COMPANY

Agricultural Technology

- Chief Science Officer
- Scientific Advisor
- Scientist, Researcher, Research Associate
- Process Engineer
- Quality Assurance Lead
- Quality Assurance Technician
- Geneticist, Biologist, Chemist
- Lab Technician, Technician



The categories of **agricultural systems** and **business and enterprise operations** are closely intertwined. A great number of investments by new players in the smart agriculture industry have been made in areas like IoT and sensors systems and digital supply chain management. For example, Canadian multinational company TELUS has recently begun acquiring companies in smart agriculture.¹¹¹ Job posting data show a surprising evolution in skills demand. Analysis of job data from the EMSI database for the period of 2019-2021 highlights the impact of this infusion—for example, demand for IoT and system engineering roles emerging in agricultural domains.¹¹²

In terms of occupations, **business enterprise** roles reflect sophisticated use of digital business-to-business platforms. While mostly based in software programs, these platforms can also involve the use of high-tech equipment for data inputs. The **business enterprise** category consists of supply chain analyst or managers, purchasing specialists, front-end and back-end developers, data analysts, AI or ML developers, policy and regulatory analysts, and other enterprise roles.

¹¹¹ "Creating better food outcomes," 2021, TELUS Agriculture, <https://www.telus.com/en/bc/agriculture>; "Agri-Food," 2021, TELUS Agriculture, <https://www.telus.com/en/bc/agriculture/agri-food?linktype=ge-mainnav>
¹¹² EMSI Data, Accessed July 16, 2020

Agricultural systems roles stem from farmers and horticulturists adopting high-tech equipment “on the farm” to automate tasks or gather more comprehensive data. As a result, this category includes various types of engineering-focused roles, such as systems engineers, precision agronomists, process control engineers, precision agriculture engineers, environmental engineers, and agricultural engineers. For data-gathering equipment, data analysts and data scientists may also be necessary, while equipment that requires a user-interface (e.g., a mobile or web-application) also necessitates software engineers. The quote below, sourced from the second advisory committee meeting, describes the types of roles required in a controlled environmental agriculture company:



On our team we have hardware engineers focused on mechanical, electrical, embedded systems, and software, and then on the science side we have a horticulturist and a grower that are more focused on growing. We have some folks on the sales and marketing side, and then on the supply chain side we have someone focused on sourcing hardware and knowing how to get the parts. Oh, and we have people focused on operations, industrial design, and we're now looking for people with machine learning and plant vision experience.
 – CEO, Controlled Environmental Agriculture Company

Two examples of the technical roles that are required by Canadian agricultural systems companies operating in this area are provided below. The roles were manually collected from publicly available job sites (data accessed July 2021), and each example is based on approximately five to 10 Canadian companies (many of which are startups).

AGRICULTURAL SYSTEMS COMPANY

Precision Agriculture

- Chief Technology Officer
- Senior Software Developer
- UX/UI Designer
- Full-Stack Software Developer
- Product Manager
- Quality Assurance Analyst
- Data Scientist, Analyst
- Data Technician
- Precision Agronomist

AGRICULTURAL SYSTEMS COMPANY

Controlled Environmental Agriculture

- Site Operations Lead
- Grower, Agronomist, Technician
- Quality Assurance Technician
- Engineer
(Mechanical, Electrical)
- Project Manager
- Full-Stack
Software Developer
- Project Design Lead





● ● ● SECTION III

Technology Adoption

In the late 80s and 90s, Canadian farms and agri-food manufacturing players began switching out the early electrical machines that disrupted agriculture in the second industrial revolution for new robotics and automation technologies.¹¹³ Interviewees noted that adoption of these “third wave”¹¹⁴ technologies, including automated crop harvesting techniques, auto steer, sectional control, and GPS, are now standard. In the past 10 years, however, agricultural technology adoption has shifted to cyber-physical systems with a focus on sustainability: Agriculture 4.0.¹¹⁵ Primary producers and agri-food manufacturers are now looking to adopt emerging technologies such as drones, fruit-picking robots, AI-interfaces, and smart sensors.¹¹⁶

113 Leader, J. et al., "Disruptive Technologies in the Agri-Food Sector," December 2020, University of Waterloo, https://uwaterloo.ca/disruptive-technologies-economic-development/sites/ca.disruptive-technologies-economic-development/files/uploads/files/omafra_report-final.pdf

114 Jhonattan, M. et al., "Sensing, Smart and Sustainable Technologies for Agri-Food 4.0," June 1, 2019, Computers in Industry 108, <https://doi.org/10.1016/j.compind.2019.02.002>

115 Jhonattan, M. et al., "Sensing, Smart and Sustainable Technologies for Agri-Food 4.0," June 1, 2019, Computers in Industry 108, <https://doi.org/10.1016/j.compind.2019.02.002>

116 Jhonattan, M. et al., "Sensing, Smart and Sustainable Technologies for Agri-Food 4.0," June 1, 2019, Computers in Industry 108, <https://doi.org/10.1016/j.compind.2019.02.002>

Although older, “third wave” technologies often see high rates of adoption, Canada’s adoption rates for emergent, 4.0 technologies are often low. This is partly due to their current position in the technology adoption cycle,¹¹⁷ or as one key informant called it, the “hype cycle.” Nonetheless, a recent Statistics Canada paper reports that agriculture (as well as mining, transportation, and construction) is “among the least digitally intensive sectors.”¹¹⁸ Canada’s Economic Strategy Table (a model for collaboration between industry and the federal government focused on turning Canadian economic strengths into global advantages) for the agri-food sector further reports that, “today, Canada’s agri-food sector has low rates of technology adoption compared to other countries.”¹¹⁹ 2016 Canadian Census data seems to support this trend: only 56.1% of Canadian farmers reported using computers or laptops for farm management, and other adoption rates decreased from there, with a low of 7.92% for automated environmental controls for animal housing.¹²⁰ Although adoption numbers are often low, there are significant differences in subsector adoption rates, and Statistics Canada rates “cannot account for the fact that [the agricultural sector’s] digital intensity increased tenfold [from 2000-2015].”¹²¹ In short, Canadian agri-food sector players are steadily adopting “fourth wave” technologies—but not quickly enough.

ICTC’s survey of primary producers and agricultural technology businesses across Canada also finds fourth wave technologies among the least adopted (see **Figure 9** for more detail).¹²² Across the five surveyed subsectors,¹²³ key fourth wave technologies, including drones, IoT/sensors, and AI, feature low on the adoption list. Cloud solutions, often included in Agriculture 4.0, are the exception to this trend, featuring high on the list across all sectors except horticulture.¹²⁴ Unsurprisingly, the agtech industry also demonstrates relatively high levels of adoption for AI and IoT/sensors. In contrast, computers, security software tools, and GPS have high adoption rates across most agricultural sectors.

- 117 “How to See Past the Hype and Spot Winning Agriculture Innovations,” 2021, Farm Credit Canada, <https://www.fcc-fac.ca/en/knowledge/how-to-see-past-the-hype-and-spot-winning-agriculture-innovation.html>
- 118 “Measuring Digital Intensity in the Canadian Economy,” February 24, 2021, Government of Canada, <https://www150.statcan.gc.ca/n1/pub/36-28-0001/2021002/article/00003-eng.htm>
- 119 “Agri-Food Interim Report,” 2017, ISED, [https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_Table_AF.pdf/\\$file/ISED_Table_AF.pdf](https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_Table_AF.pdf/$file/ISED_Table_AF.pdf)
- 120 Statistics Canada. Table 32-10-0446-01, Farms reporting technologies used on the operation in the year prior to the census DOI: <https://doi.org/10.25318/3210044601-eng>
- 121 “Measuring digital intensity in the Canadian economy,” February 2021, Statistics Canada, <https://www150.statcan.gc.ca/n1/pub/36-28-0001/2021002/article/00003-eng.htm>
- 122 It is important to note the limitations of ICTC’s survey: the provinces are not proportionally represented, nor are the subindustries. Indeed, Alberta and the livestock sub-industry are overrepresented. With [insert number] of total responses from subindustries including sheep, egg, beekeepers, wild blueberries, apples, and manufacturing, however, the data does form a solid base for future research. See Appendix A for more details.
- 123 See Appendix A for subsector breakdown.
- 124 Araújo, S. et al., “Characterising the Agriculture 4.0 Landscape—Emerging Trends, Challenges and Opportunities,” April 2021, Agronomy, <https://doi.org/10.3390/agronomy11040667>

Tech Adoption by Subsector



Which of the following technologies has your business or organization adopted or incorporated?



| | AgTech | Grain & Seed | Horticulture | Livestock | Manufacturing |
|---|--------|--------------|--------------|-----------|---------------|
| Digital Productivity Tools | | | | | |
| Security software tools (e.g., anti-virus, anti-spyware, anti-malware, firewalls) | 43% | 79% | 43% | 51% | 69% |
| Collaboration tools (e.g., Zoom™, Microsoft Teams™, Slack™) | 62% | 64% | 22% | 42% | 66% |
| Cloud solutions (e.g., Microsoft 365®, Google Cloud™, Dropbox™) | 62% | 29% | 14% | 34% | 69% |
| Software or databases (for purposes other than telework and online sales) | 67% | 21% | 12% | 18% | 38% |
| Digital technology to move business operations or sales online (for purposes other than teleworking or remote working) | 52% | 7% | 18% | 17% | 50% |
| Farm Management | | | | | |
| Computers/laptops and/or smartphones/tablets for farm management | 43% | 100% | 71% | 67% | 6% |
| Farm management software on any device | 52% | 57% | 24% | 43% | 9% |
| Precision | | | | | |
| GPS technology | 29% | 57% | 53% | 53% | 13% |
| Variable-rate input application (e.g., variable-rate seeders and sprayers) | 5% | 43% | 20% | 43% | 6% |
| Satellite and/or aerial imagery | 14% | 43% | 20% | 25% | 0% |
| GIS (e.g., soil quality mapping, yield mapping, NDVI mapping) | 10% | 36% | 14% | 32% | 3% |
| Connected and Autonomous vehicles (e.g., Automated guidance steering systems auto-steer on farm equipment) | 10% | 29% | 8% | 42% | 3% |
| Drones | 24% | 21% | 4% | 14% | 13% |
| Automation | | | | | |
| Automation of certain tasks (e.g., robotic milkers, robotic greenhouse equipment, automated feeding, computer algorithms for environmental controls) | 24% | 14% | 16% | 49% | 47% |
| Energy | | | | | |
| Renewable energy power generation | 5% | 0% | 6% | 16% | 0% |
| Bioenergy production (including biogas, biofuel, biomethane, biomass) | 5% | 0% | 0% | 10% | 0% |
| Gene | | | | | |
| Genetically engineered agricultural inputs (e.g., seed varieties, etc.) | 10% | 36% | 2% | 23% | 0% |
| Gene-editing technologies (e.g., to create new food stuffs) | 5% | 0% | 0% | 10% | 0% |
| Connected and Intelligent | | | | | |
| AI | 52% | 0% | 0% | 23% | 0% |
| IoT/sensors | 48% | 0% | 6% | 13% | 19% |
| Other | 10% | 0% | 12% | 4% | 13% |

Figure 9: Tech adoption by subsector. Source: ICTC survey data, 2021. Source: ICTC.

While there are some evident overall trends, ICTC's survey reveals marked differences in tech adoption between subsectors.¹²⁵ Agtech and manufacturing subsectors lead in the use of new tech to move business operations and sales online, while the three primary agriculture subsectors pull ahead on computers and laptops for farm management adoption rates. In terms of precision agricultural adoption, primary producers are again often the highest adopters because they are more likely to require the technologies in question than, for example, manufacturers. Manufacturing, on the other hand, has a high adoption rate for automation. For instance, manufacturing interviewees noted that a significant labour shortage of welders has prompted the widespread adoption of robotic welders. Finally, grain and seed producers have high rates of technology adoption for genetically engineered agricultural inputs because certain genetically engineered crops are dominant in the Canadian crop sector. In fact, genetically engineered soybeans and corn also account for 90% and 78% share of seeded crops in Canada respectively.¹²⁶



Because tech adoption depends on many factors, including sector, scale, consumer preferences, technology, topography, and the organization's location in the supply chain, varying adoption levels make sense. A recent Statistics Canada report similarly maintains that there is "considerable heterogeneity" in digital intensity between agricultural subsectors.¹²⁷ RBC's Farmer 4.0 report charts these technology adoption variations for degree of automation, categorizing industries as "frontier," "transition," and "entrenched" (see Figure 10 for more detail). Indeed, interviewees in this study made it clear that "in some subsectors it has been much easier to adopt technologies, while in other subsectors it has been a little bit slower, with adoption also varying by the type of technology."

¹²⁵ Although differences between subsectors cannot be taken as representative or statistically significant, for the most part survey findings support existing research.

¹²⁶ "Genetically modified (GM) crops in Canada," 2020, Statista, <https://www.statista.com/study/36844/genetically-modified-gm-crops-in-canada-statista-dossier/>

¹²⁷ "Measuring digital intensity in the Canadian economy," February 2021, Statistics Canada, <https://www150.statcan.gc.ca/n1/pub/36-28-0001/2021002/article/00003-eng.htm>

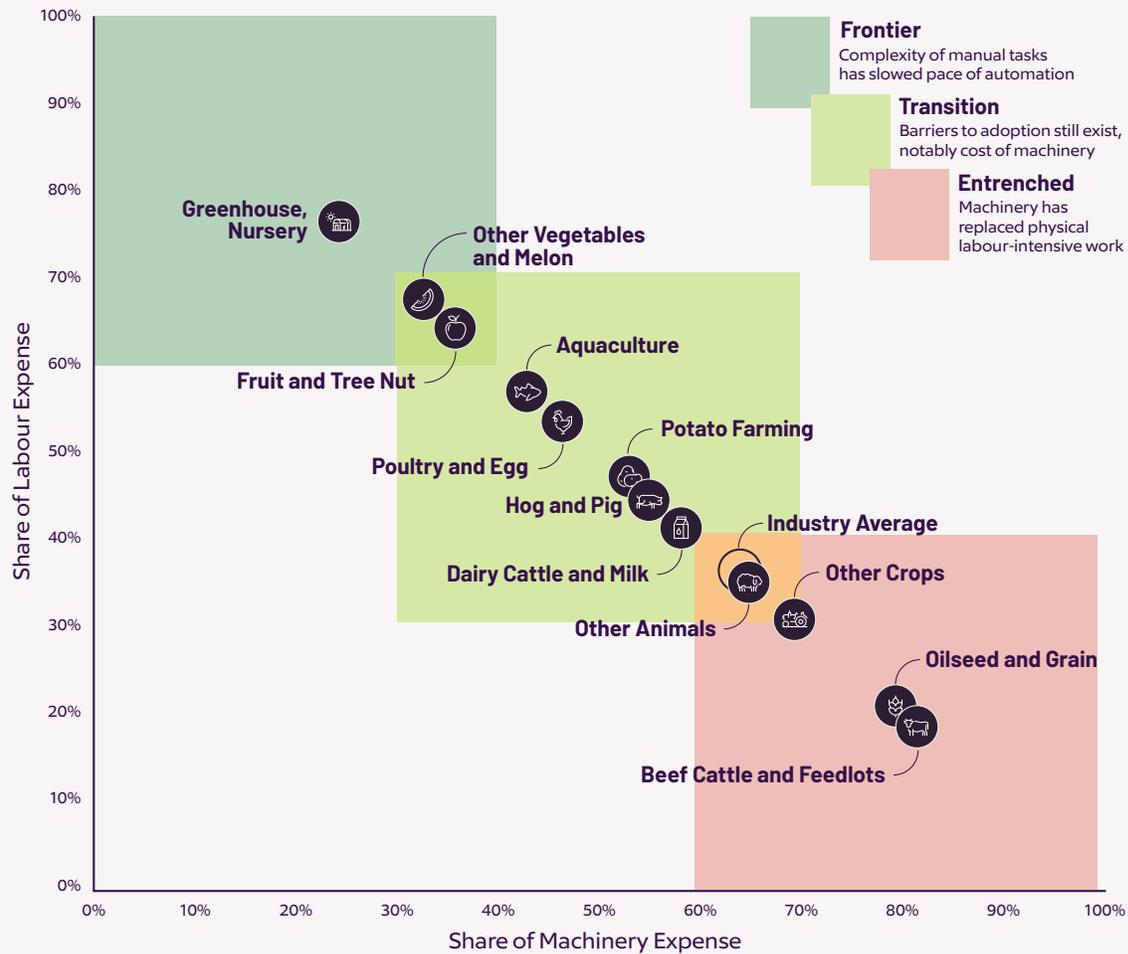


Figure 10: Relative spending on labour and machinery by subsector, 2017.

Source: RBC Thought Leadership.¹²⁸

Despite industry variations, interviewees maintained that, overall, the agriculture sector is slow to adopt, but most remain optimistic about the future. In line with Statistics Canada data, interviewees reported that “agriculture is about 10-15 years behind other sectors in technology innovation and uptake.” Another expert similarly cautioned that although “the rate of agricultural technology adoption is increasing [in Canada], it may not be at a pace that satisfies the current needs.” The majority of interviewees, however, focused on increased adoption levels in the past five years and predicted rapid growth in the future. One academic predicted that in the next 10 years, “we’re going to see an accelerating rate of technology adoption.” Another farmer and entrepreneur agreed that “the [agtech adoption] cycle is faster. It used to take 10 years, and now two years is a lifetime for some of these technologies – it’s accelerating at an incredible rate.”

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“Farmer 4.0: How the coming skills revolution can transform agriculture,” August 2019, RBC Thought Leadership, http://www.rbc.com/economics/economic-reports/pdf/other-reports/Farmer4_aug2019.pdf

The recent spike in agricultural uptake could be partly a reaction to distribution and labour problems created by COVID-19.¹²⁹ A 2021 report from the Canadian Agricultural Human Resources Council (CAHRC) found that the pandemic increased technology adoption: COVID-19 led to more adoption of technology, and in particular, online advertising, training, and interviewing are becoming more common-place.¹³⁰ An article from Farm Credit Canada similarly notes increased uptake for technologies including data-management software and online distribution platforms.¹³¹ In an interview with Alberta Farmer Express, a senior fertility specialist at CropPro Consulting, sums up the impact of the pandemic:



[The pandemic] forced a lot of our clients to use technology a little more than they were previously comfortable with. In the long run, I think that's actually going to be a good thing. Once they get used to using it, I think they're going to have a tough time going back.

ICTC's survey similarly shows high adoption levels for collaboration tools such as Zoom™, Teams™, and Slack™. This high level of adoption likely corresponds to the move to teleworking necessitated by the COVID-19 pandemic. When asked about lasting impacts of the pandemic, one key informant mused "COVID will accelerate adoption further if it follows the pattern that we are seeing everywhere else: fast forwarding trends 10 plus years in a matter of weeks or months."¹³²

It is essential that the Canadian agri-food sector continues to adopt new technologies. Agricultural subsectors that fail to adopt will quickly lose competitive advantage. Labour shortages and increasing extreme weather events make rapid technology adoption even more vital.

¹²⁹ Blair, J., "Pandemic speeding up adoption of technology," August 26, 2020, Alberta Farmer, <https://www.albertafarmexpress.ca/news/pandemic-speeding-up-adoption-of-technology/>

¹³⁰ "Understanding the Effects of COVID-19 on Canada's Agriculture Workforce," 2020, CAHRC-CCRHA, https://cahrc-ccrha.ca/sites/default/files/Impacts%20of%20COVID-19%20on%20agriculture_Final%2030Mar.pdf

¹³¹ "Understanding the Effects of COVID-19 on Canada's Agriculture Workforce," 2020, CAHRC-CCRHA, https://cahrc-ccrha.ca/sites/default/files/Impacts%20of%20COVID-19%20on%20agriculture_Final%2030Mar.pdf

¹³² Blair, J., "Pandemic speeding up adoption of technology," August 26, 2020, Alberta Farmer, <https://www.albertafarmexpress.ca/news/pandemic-speeding-up-adoption-of-technology/>



SNAPSHOT

Horticulture

Canada's horticulture sector is slow to adopt technology, yet it is one of the agricultural subsectors that needs technology the most.¹³³ A 2020 B.C. tree fruit industry report shows that while 90% of producers record pesticide and fungicide applications, only 16% keep digital records: the rest are pen and paper.¹³⁴ Remote sensing devices also have a low adoption rate of 9.1%.¹³⁵ As shown in **Figure 9**, ICTC's survey results confirm these low adoption levels both overall and for fourth wave technologies, including IoT, AI, connected and autonomous vehicles, and drones. On average, horticulture also had the highest percentage of survey respondents who noted "significant" and "extreme" difficulty finding seasonal labour. To explain the lack of labour supply, respondents mentioned difficulties paying high wages and lack of interest in harvesting. Increased automation could reduce the high cost of labour, which can represent up to 40% of total farm costs¹³⁶ and combat unstable labour supply. As one key informant noted: *"after two years of really struggling to get temporary foreign workers (TFW), sectors where you have pickers and offshore labour like horticulture will be looking really hard at robotics and anything that would free them."* As temperatures rise, labour supplies fluctuate, and extreme weather events become more commonplace, adoption becomes increasingly vital.

In ICTC's survey of wild blueberries producers in Nova Scotia, the most selected response to barriers to profitability and yield consistency was extreme weather. New technologies could help mitigate these impacts. For example, apple growers could turn to Integrated Pest Management technologies to reduce the risk of crop damage stemming from invasive species, including the codling moth. On this front, Canadian companies like Semios offer smart mating disruption technologies and automated camera traps.¹³⁷

¹³³ "The 2020-2021 Innovation Report," 2021, Vineland Research and Innovation Centre, <https://www.vinelandresearch.com/wp-content/uploads/2020/11/Innovation-Report-2020-21-Web.pdf>

¹³⁴ Cartier, L. and Lembke, S., "The British Columbia Tree Fruit Industry: Preparing for Precision Agriculture and Climate Change," Okanagan College, <http://dx.doi.org/10.13140/RG.2.2.12018.53448>

¹³⁵ Cartier, L. and Lembke, S., "The British Columbia Tree Fruit Industry: Preparing for Precision Agriculture and Climate Change," Okanagan College, <http://dx.doi.org/10.13140/RG.2.2.12018.53448>

¹³⁶ Rotz, S. et al., "Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities," May 2019, Elsevier Journal of Rural Studies, <https://doi.org/10.1016/j.jrurstud.2019.01.023>

¹³⁷ "Insect Pest Management," 2021, Semios, <https://semios.com/solutions/insect-pest-management/>

Automation and robotics can help alleviate the labour issues – both cost and availability – restricting the growth of Canada’s horticulture sector.¹³⁸ Indeed, according to Vineland’s Innovation Report 2020-2021, horticulture is “the most labour-intensive agricultural sector and the one where automation technologies could make the most dramatic difference.”¹³⁹ For instance, harvesting makes up approximately 20% of the human labour needed to produce cucumbers, which in Canada “translates into approximately \$27 million spent annually on cucumber harvesting alone.”¹⁴⁰ The greenhouse cucumber harvesting robot under development at Vineland could help reduce this financial burden and horticulture’s dependency on human labour. The robot currently has a success rate of just under 90%, with a picking time of under 14 seconds per cucumber.¹⁴¹ Although impressive, the robot still falls behind the human average of one cucumber per second.¹⁴² Vineland predicts that this promising technology will reach farmers in the next 10 years.

Similar to Vineland’s robot, many horticultural technologies are not yet ready for commercial use. Key informants noted a pattern of tech deficiencies:



There are not a lot of technologies in the [horticulture] market—for automation especially. Most of the technologies [that are available] are in the early stages of development, so there’s no catalogue of equipment for growers to consult and purchase what they need. A lot of this stuff hasn’t even been developed yet.

– Executive, Horticulture Company



If you think about a peach, which needs to be picked off a tree, that tree lives in the orchard for 20 or more years, meaning peaches have to be picked without damaging the tree. On top of that, it’s a very soft fruit. It can’t be blemished, and it has to look good on the grocery store shelf at the end. Handling a product like that is very different from a lot of other agricultural commodities, meaning when we try to automate the processes, it’s a lot more complicated. There’s a lot of opportunity to apply technologies like automation and vision systems to horticulture because of where the sector is currently—relying mostly on human labour.

– Executive, Horticulture Company

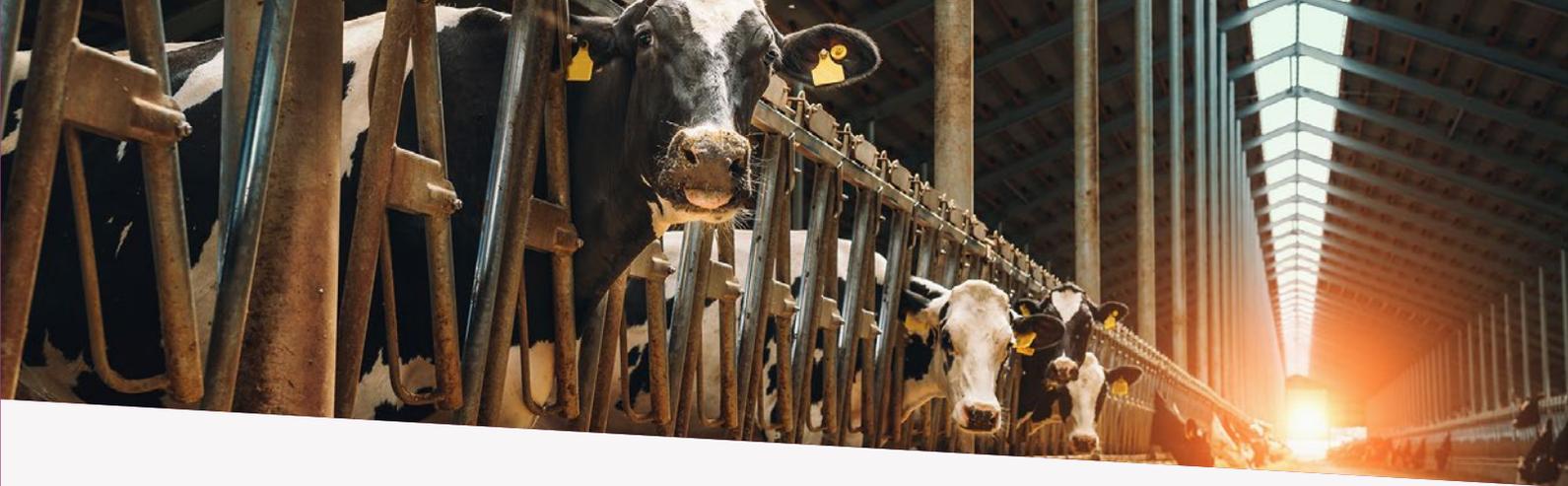
138 “The 2020-2021 Innovation Report,” 2021, Vineland Research and Innovation Centre, <https://www.vinelandresearch.com/wp-content/uploads/2020/11/Innovation-Report-2020-21-Web.pdf>

139 “The 2020-2021 Innovation Report,” 2021, Vineland Research and Innovation Centre, <https://www.vinelandresearch.com/wp-content/uploads/2020/11/Innovation-Report-2020-21-Web.pdf>

140 “An automated workforce to harvest Canada’s greenhouse cucumbers,” November 2019, Produce Grower, <https://www.producegrower.com/article/production-an-automated-workforce-to-harvest-canadas-greenhouse-cucumbers/>

141 Guillen, S, “Vineland Converts Husky UGV into Cucumber Harvester to Boost Commercial Greenhouses,” July 2021, Clear Path Robotics, <https://clearpathrobotics.com/blog/2021/07/vineland-research-and-innovation-centre-converts-husky-ugv-into-cucumber-harvester-to-boost-commercial-greenhouses/>

142 Guillen, S, “Vineland Converts Husky UGV into Cucumber Harvester to Boost Commercial Greenhouses,” July 2021, Clear Path Robotics, <https://clearpathrobotics.com/blog/2021/07/vineland-research-and-innovation-centre-converts-husky-ugv-into-cucumber-harvester-to-boost-commercial-greenhouses/>



SNAPSHOT

Livestock

Canada's livestock sector leads robotics adoption. Automated environmental controls for animal housing, robotic milking, and synchronization of ovulation with timed AI are a few of the key technologies improving the efficacy of poultry, dairy, beef, sheep, egg, and other Canadian livestock subsectors. In fact, the Canadian dairy, livestock, and feedlot subsectors boast high rates of technology adoption for cow milking and feed-pushing robots compared to international counterparts—even surpassing the U.S.¹⁴³ Data from the 2016 Agriculture Census supports this picture of dairy and livestock at the forefront of innovation adoption. In 2015, 53.3% of pig and hog producers used automated animal feeding and 43.3% of egg and poultry producers used automated animal housing controls. Preliminary results from a 2021 survey of agricultural automation and robotics are also promising: 44% of surveyed livestock producers adopted automation and robotics (compared to 36% of crop producers).¹⁴⁴ Additionally, just under three-quarters of surveyed dairy producers, adopted dairy robotics.¹⁴⁵ ICTC survey data paints a similar picture: livestock producers used the most automation. Almost half of the survey respondents had automated certain tasks. Further, several interviewees in this study pointed to livestock as a leading subsector in the adoption of various technologies:



If you look at some of the supply managed commodities, like dairy as an example, you will see a much higher rate of robotic milking adoption.

– Academic Professor, Canadian University

On the other hand, one interviewee informed ICTC that cheese and wine producers in Quebec often choose not to adopt technology so they can market their products as artisanal.

143 Jelinski, M et al., "Factors Associated with the Adoption of Technologies by the Canadian Dairy Industry," October 2020, The Canadian Veterinary Journal 61, no. 10: 1065–72

144 Lemay, M. et al., "Preliminary Findings of a Provincial Survey on the Adoption of Automation & Robotics Technologies in Ontario's Agriculture Sector," May 2021, Brock University, <https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/BROCK-NCO-Working-Paper-WEB-FINAL.pdf>

145 Lemay, M. et al., "Preliminary Findings of a Provincial Survey on the Adoption of Automation & Robotics Technologies in Ontario's Agriculture Sector," May 2021, Brock University, <https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/BROCK-NCO-Working-Paper-WEB-FINAL.pdf>

Barriers to Adoption

Innovative technologies are being developed for use across the supply chain, yet many barriers prevent agri-food producers and manufacturers from adopting these technologies. A recent study conducted by the Innovation and Growth Policy Division of Agriculture and Agri-Food Canada looked at the adoption of precision agriculture technologies in Canada and found that the top three barriers to adoption were: overall cost of high initial investment, internet speeds and cellular data coverage, and lack of training or knowledgeable people.¹⁴⁶ ICTC's survey also identifies the cost of equipment, implementation, maintenance, and operation as key barriers preventing agri-food tech adoption across subindustries (see **Figure 11**). As with technology adoption, barriers vary by subsector. For example, ICTC survey findings show availability of equipment impacts agtech and manufacturing more than primary producers. Key informants note this gap is due to supply chain, production, and logistics issues aggravated by COVID-19. Key barriers are discussed below.

Barriers to Tech Adoption, by Subsector



Which barriers does your organization face when adopting new technologies or automation?



| | AgTech | Grain & Seed | Horticulture | Livestock | Manufacturing |
|---|--------|--------------|--------------|-----------|---------------|
| Cost | | | | | |
| Cost of equipment and/or installation | 71% | 75% | 59% | 65% | 74% |
| Cost of maintenance and/or operation | 43% | 58% | 20% | 39% | 41% |
| Availability | | | | | |
| Availability of equipment | 33% | 25% | 20% | 15% | 24% |
| Infrastructure | | | | | |
| Lack of high-speed internet | 24% | 67% | 39% | 38% | 26% |
| Lack of energy infrastructure | 5% | 33% | 9% | 13% | 3% |
| Labour | | | | | |
| Shortage of skilled labour to implement and operate | 24% | 17% | 38% | 21% | 53% |
| Business | | | | | |
| Lack of awareness | 29% | 17% | 9% | 23% | 18% |
| Unclear ROI | 38% | 25% | 23% | 30% | 38% |
| Unclear implementation strategies | 24% | 8% | 7% | 17% | 3% |
| Regulations | | | | | |
| Regulatory barriers | 5% | 58% | 4% | 19% | 0% |
| Poor interoperability | 5% | 33% | 23% | 19% | 12% |
| Other | | | | | |
| Not necessary | 10% | 8% | 21% | 16% | 9% |
| No barriers | 10% | 0% | 13% | 1% | 15% |

Figure 11: Barriers to tech adoption by subsector. **Source:** ICTC survey data, 2021.

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"Hitting the Target: Benefits and Barriers to Precision Agriculture in Canada," July 2017, Government of Canada, http://www.r2b2project.ca/wp-content/uploads/2018/05/AAFC-Summary-of-PA-Survey-Results-July_2017.pdf

Cost and Financing

Farms with more money are more likely to adopt emerging technologies. There are high-cost requirements to adopting new tech, making it difficult for companies to keep up with the latest industry innovations. Buying used equipment is an option for older equipment, however, specialized crops and emerging technologies are often not available in the second-hand market.¹⁴⁷ As noted earlier, survey respondents across all subsectors identified cost as the primary barrier to adoption. As one key informant explained:



When they're a new customer and they haven't already bought technology like what we're providing, there's no budget line item. So, we're asking them to add a line item, which means that, from their view, they're adding a cost—that's certainly one of the major barriers on the farm.

— CEO, Precision Farming Company

Equipment and other technology costs vary per crop and farm size, but interviewees confirmed that most equipment investments have high initial costs.¹⁴⁸ Small to medium farms that generate lower profit are less likely to adopt new tech. For instance, Agriculture and Agri-Food Canada data shows that “precision agriculture technology is tailored to farms above 500 acres in size, so for farms below that acreage, or with an annual income below \$75,000, the rate of adoption of these technologies declines significantly.”¹⁴⁹ Another report on precision agriculture from the BC government, further notes that variable-rate, GPS, and GIS technologies are “most applicable” to large acreage grain and oilseed farms.¹⁵⁰ Interviewees from various subsectors agreed that scale matters:



There are differences in adoption rates based on scale. If you're farming 100 acres in Ontario, it's going to be harder to invest in automated GPS or precision agriculture technologies, whereas if you're farming 5000 acres on the prairies, it starts to make more sense.

— Academic Professor, Canadian University



I don't think we're getting to the next level of technology adoption and digitalization quite yet, and that's probably due to a number of factors. But I think it's because our firms are typically smaller here.

— Public Servant, Fisheries and Oceans Sector

¹⁴⁷ Krymowski, J., “The true financial cost of modern farming,” October 8, 2019, AGDaily, <https://www.agdaily.com/insights/true-financial-cost-modern-farming/>

¹⁴⁸ Krymowski, J., “The true financial cost of modern farming,” October 8, 2019, AGDaily, <https://www.agdaily.com/insights/true-financial-cost-modern-farming/>

¹⁴⁹ “Scaling Down Precision Agriculture,” December 17, 2018, Government of Canada, <https://www.ic.gc.ca/eic/site/101.nsf/eng/00040.html>

¹⁵⁰ “Bc-Precision-Agriculture-Technologies-for-Nutrient-Management-Final-Report.Pdf,” accessed July 14, 2021, <https://delphi.ca/wp-content/uploads/2019/09/bc-precision-agriculture-technologies-for-nutrient-management-final-report.pdf>

One notable exception to the purchasing power argument, is agricultural robots. While some small-scale producers have adopted robots, these machines are not yet widely adopted at the commercial operations level.¹⁵¹ Here, again, research shows that initial costs prevent larger-scale producers from adopting new robots instead of paying relatively inexpensive wages.^{152,153}

Financially supporting small and low revenue generating farms is key to increasing technology adoption. As one interviewee highlighted: "small businesses need some help with technology adoption, but they don't have the money and the facilities for this new function, new ability, new capacity." Accordingly, the Parliamentary Agriculture and Agri-Food Committee¹⁵⁴ and the Agri-Food Economic Strategy Table¹⁵⁵ have both recommended that the government encourage and support the purchase of high-tech equipment by Canadian agriculture and agri-food businesses. For example, the Agriculture and Agri-Food Committee recommended amending tax legislation to create an expedited tax deduction for the purchase of high-tech farm equipment. In 2021, a temporary, but more comprehensive tax deduction for certain high-tech farm equipment was introduced for farmers through the 2021 federal budget.¹⁵⁶ Another example of a programming to mitigate cost barriers is Ontario's cost-share program. Introduced in April 2021, this program provides \$22 million to help agricultural businesses adopt new technologies.¹⁵⁷

High Speed Internet

Internet access is a well-known barrier to technology adoption in rural areas throughout Canada. While there is limited data available regarding broadband access on farms, various witnesses before the Parliamentary Agriculture and Agri-Food Committee noted that internet access in rural areas is a key challenge for farmers that want to adopt internet or cloud-dependent tech, such as precision agriculture tools and IoT technologies.¹⁵⁸ The Canadian Federation of Agriculture similarly reports that a "significant portion" of farmers do not have access to broadband internet, and those that do often have unreliable and expensive connections.¹⁵⁹ In fact, consultations for Canada's Rural Economic Development Strategy, heard worrying accounts of "farming operations trying to access global markets with fax machines."¹⁶⁰

151 Pederson, S. et al., "Robotic Seeding: Economic Perspectives," November 16, 2017, Springer Precision Agriculture: Technology and Economic Perspectives, https://doi.org/10.1007/978-3-319-68715-5_8

152 Relf-Eckstein, J. et al., "Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming," December 2019, Elsevier NJAS - Wageningen Journal of Life Sciences, <https://doi.org/10.1016/j.njas.2019.100307>

153 Pederson, S. et al., "Robotic Seeding: Economic Perspectives," November 16, 2017, Springer Precision Agriculture: Technology and Economic Perspectives, https://doi.org/10.1007/978-3-319-68715-5_8

154 "Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports," January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

155 "Agri-Food," 2018, ISED, [https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_C_Agri-Food_E.pdf/\\$file/ISED_C_Agri-Food_E.pdf](https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_C_Agri-Food_E.pdf/$file/ISED_C_Agri-Food_E.pdf)

156 "The 2021 Federal Budget Highlights for the Agriculture Sector," April 22, 2021, MNP, <https://www.mnp.ca/en/insights/directory/the-2021-federal-budget-highlights-for-the-agriculture-sector>

157 Ontario Ministry of Agriculture, Food and Rural Affairs, "Ontario announces \$22M cost-share program to adopt technology in agricultural sector," April 21, 2021, Greenhouse Canada, <https://www.greenhousecanada.com/ontario-launches-22m-cost-share-program-to-adopt-technology-in-agricultural-sector/>

158 "Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports," January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

159 "Expanding and Improving Rural Broadband Access," 2021, CFA, <https://www.cfa-fca.ca/issues/expanding-and-improving-rural-broadband-access/>

160 "High-Speed Access for All: Canada's Connectivity Strategy," July 16, 2019, ISED, https://www.ic.gc.ca/eic/site/139.nsf/eng/h_00002.html

Over a third of ICTC's survey respondents identify lack of high-speed internet as a barrier to adoption. Grain and seed producers have the highest rate, with two-thirds of respondents selecting lack of high-speed internet as a barrier. Agtech (24%) and manufacturing (26%) companies are the least affected by this barrier. This is because agtech operations are often located in urban centres; however, manufacturers are based both in rural and urban areas. Key informants noted the majority of Canadian agricultural manufacturers based in rural areas face barriers to high-speed internet access. Survey respondents in manufacturing, however, were predominantly in urban areas. Across several primary agriculture industries, key informants identified connectivity as a barrier:



One of the biggest challenges is internet access. In rural Nova Scotia, there are fish plants that have no internet capacity.

– Public Servant, Fisheries and Oceans Sector



One factor that impacts regional adoption is the availability of real broadband. Many technologies need access to a good internet connection to be able to work effectively. In parts of rural Canada, there are pockets where rural broadband is quite weak...deploying a technology that relies on high-speed internet becomes challenging.

– Public Servant, Agri-Food Sector

The pandemic further exacerbated these connectivity issues as farmers across Canada struggled to maintain connections with retailers, suppliers, and consumers. While some producers are adopting new digital solutions, such as Zoom calls with agronomists and digital farmer's markets, others are falling behind due to unstable and slow internet connections.¹⁶¹ Moreover, in-person trade shows, which often introduce producers to new technologies, shifted to online platforms, making them less accessible to their primary audience.¹⁶²

To tackle these issues, stakeholders have advocated for the need to expand broadband infrastructure spending programs to target farms without broadband. The Parliamentary Agriculture and Agri-Food Committee also recommended that "to improve access to broadband internet in rural farming communities,"¹⁶³ the federal government set aside \$2 billion to connect small homes and small businesses to broadband in underserved communities as part of their three-year Canadian Infrastructure Bank Growth Plan.¹⁶⁴

¹⁶¹ Bakx, K., "Zoom calls and online shopping: Life on Canadian farms in 2020," October 9, 2020, CBC News, <https://www.cbc.ca/news/business/ag-digital-tools-covid-1.5755738>; Rezanoff, M., "A Canadian Agriculture Broadband Strategy," October 2020, CAAR, <https://caar.org/the-communicator/october-2020/1292-a-canadian-agriculture-broadband-strategy>

¹⁶² Rezanoff, M., "A Canadian Agriculture Broadband Strategy," October 2020, CAAR, <https://caar.org/the-communicator/october-2020/1292-a-canadian-agriculture-broadband-strategy>

¹⁶³ "Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports," January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

¹⁶⁴ "Prime Minister announces infrastructure plan to create jobs and grow the economy," October 2020, <https://cib-bic.ca/en/the-canada-infrastructure-bank-announces-a-plan-to-create-jobs-and-grow-the-economy/>

Additionally, the federal government's Budget 2021 announced an extra \$1 billion over six years for the Universal Broadband Fund, supporting speedier expansion of broadband projects across rural Canada.¹⁶⁵ Other companies mitigate connectivity issues by developing high-tech farming equipment that can work at slower internet speeds.¹⁶⁶

Return on Investment

For producers to adopt, agricultural technology companies need data to prove their technology's worth. With emerging technologies, there is often limited data on reduced input costs or increased yields, and thereby uncertainty on investment (ROI).¹⁶⁷ In a case study of DOT™, for example, researchers found it difficult to quantify potential benefits to individual producers of a field robot with self-monitoring, analysis, and reporting capabilities because farm operator data is only reported in aggregate by Statistics Canada.¹⁶⁸ Researchers noted that "information is not cross-referenced to a piece of equipment, operation, or task, and the actual cost savings to farmers will vary based on farm size, wage rate, and type of farm operation."¹⁶⁹ Yet difficulties predicting ROI also persist in certain precision agriculture technologies that have been available since the early 2000s (see Interoperability for more on data-sharing).¹⁷⁰ Even when relevant data is available, producers often distrust the numbers.¹⁷¹ About 30% of respondents to ICTC's survey across survey subindustries identified ROI as a barrier. Interviewees and AC members also emphasized that ROI is a primary barrier to technology adoption across all industries. One interviewee reported the following:



Farmers don't have enough information available to them to do a cost-benefit analysis and decide whether new tech will be worth it. Part of it is that the data doesn't exist for some products yet; part of it is that farmers' growing contexts are different, and there are so many variables involved; and part of it is that it's too complicated to be able to predict.

– Academic Researcher, Canadian University

¹⁶⁵ "Universal Broadband Fund," April 2021, Innovation, Science and Economic Development Canada, https://www.ic.gc.ca/eic/site/139.nsf/eng/h_00006.html

¹⁶⁶ "Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports," January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

¹⁶⁷ Relf-Eckstein, J. et al., "Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming," December 2019, Elsevier NJAS - Wageningen Journal of Life Sciences, <https://doi.org/10.1016/j.njas.2019.100307>

¹⁶⁸ Relf-Eckstein, J., "CREATING AN INNOVATION OPPORTUNITY SPACE FOR BROADACRE SMART FARMING: A CASE STUDY OF AUTONOMOUS FARM EQUIPMENT," May 2020, University of Saskatchewan, <https://harvest.usask.ca/bitstream/handle/10388/12884/RELF-ECKSTEIN-THESIS-2020.pdf>; Relf-Eckstein, J. et al., "Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming," December 2019, Elsevier NJAS - Wageningen Journal of Life Sciences, <https://doi.org/10.1016/j.njas.2019.100307>

¹⁶⁹ Relf-Eckstein, J. et al., "Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming," December 2019, Elsevier NJAS - Wageningen Journal of Life Sciences, <https://doi.org/10.1016/j.njas.2019.100307>

¹⁷⁰ Relf-Eckstein, J. et al., "Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming," December 2019, Elsevier NJAS - Wageningen Journal of Life Sciences, <https://doi.org/10.1016/j.njas.2019.100307>

¹⁷¹ One study on barriers to precision agriculture adoption in Ontario found that "producers [lack] confidence in the agronomic recommendations made based on the data generated by site-specific data." See: Mitchell, S. et al., "Adoption barriers for precision agriculture technologies in Canadian crop production," December 8, 2020, Canadian Journal of Plant Science, <https://doi.org/10.1139/cjps-2020-0234>



I always like to think about it from this perspective: if you're a farmer, you have 30 tries. You have the chance to grow 30 crops in your career, so, it's a pretty big deal if one doesn't work out that well. There needs to be a lot of trust between the farm and any company they're working with, especially when that company is going to make a lot of changes on their farm. These relationships take time to establish and build, so time isn't always on our side. It's a one- or two-year sales cycle from the point when our sales team gets there.

– CEO, Precision Agriculture Company

Preliminary results from a 2021 survey on agricultural automation and robotics further validate these findings: 34% percent of producers that did not adopt agricultural technologies, and 45% of producers that did, indicated that insufficient ROI was a major barrier to technology adoption.¹⁷² Additionally, interviewees in this study stressed that unclear ROI can result from market uncertainties in addition to technology uncertainties. Consumer preferences, which impact the tech market, can change quickly, meaning technologies that are profitable one year can potentially be problematic the next. As one key informant put it:



Sometimes the market is slow in development or not transparent in what it wants. For example, it might be unclear if the market really wants and is willing to pay for higher-premium products like organic, or for other things like environmentally friendly food products, non-GMO, etc.

– Academic Researcher, Canadian University

Since ROI depends on the effectiveness of the technology, based on the location, farm scale, and other factors, local examples of implementation and impact can encourage producers to adopt. In fact, a 2021 survey found that 80% of producers adopting technologies purchased “off the shelf” and approximately 60% of purchases took place within 100km of their farm: these purchasing trends point to producers valuing “proven technology that has been fully commercialized, scaled, and is readily available through their local retail market.”¹⁷³ Initiatives such as Olds College’s “Smart Farm” and Agriculture and Agri-Food Canada’s “Living Labs” help bridge the gap between research and implementation by testing emerging technologies “in the context and scale in which they will be adopted: on local farms under real agricultural production conditions.”¹⁷⁴

¹⁷² Lemay, M. et al., “Preliminary Findings of a Provincial Survey on the Adoption of Automation & Robotics Technologies in Ontario’s Agriculture Sector,” May 2021, Brock University, <https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/BROCK-NCO-Working-Paper-WEB-FINAL.pdf>

¹⁷³ Lemay, M. et al., “Preliminary Findings of a Provincial Survey on the Adoption of Automation & Robotics Technologies in Ontario’s Agriculture Sector,” May 2021, Brock University, <https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/BROCK-NCO-Working-Paper-WEB-FINAL.pdf>

¹⁷⁴ “About the Living Laboratories Initiative,” February 25, 2021, Government of Canada, <https://agriculture.canada.ca/en/scientific-collaboration-and-research-agriculture/living-laboratories-initiative/about-living-laboratories-initiative>

In 2020, Olds College’s Smart Farm helped validate a number of technologies for Albertan farmers, including cattle facial recognition for lameness detection and the cost effectiveness of optical spraying for western Canada.¹⁷⁵ Interviewees supported these findings, noting that local testing would positively impact their adoption tendencies:



A lot of these technologies assume that a farm is made up of square fields, that sort of thing... We have a lot of weirdly-shaped fields and I’m not entirely sure if the technology would work properly. Seeing it work for someone nearby is the best way to know if it fits for you, too.

– Co-Owner, Canadian Farm

Labour Shortages

Producers need easy and affordable access to digitally skilled implementation, support, and maintenance workers to improve technology adoption. The labour shortage addressed in **Section II**, however, means that primary producers are often left without local tech support. Witnesses before the Parliamentary Agriculture and Agri-Food Committee highlighted that in Canada, there are shortages in the talent required to design, build, and service high-tech equipment.¹⁷⁶ Moreover, the technology that producers adopt to address manual labour shortages, can in turn create new labour gaps, hampering technology adoption. As the Executive Director of the CHARC cautions, automation can help reduce manual labour, but “you have to then train the workforce; you have to adapt to those new production techniques and technology, and in order to maintain those systems, you need different skills moving forward.”¹⁷⁷ In ICTC’s survey, across the subindustries an approximately 30% selected shortage of skilled labour as a barrier to technology adoption. Just over half of agricultural manufacturing subsector respondents and 38% of horticulture respondents identified lack of labour as a barrier. One primary producer interviewed by ICTC echoed these findings:



With a big project like implementing [data-management software], you’re going to need a lot of setup and help. It wouldn’t be easy to get somebody out to the farm to help set up and babysit us through the process. That was an instance where lack of labour was a factor in us not adopting the new technology.

– Co-Owner, Canadian Farm

¹⁷⁵ “Smart Farm 2021 Impact Report,” 2021, Olds College, <https://www.oldscollege.ca/Assets/external/about-us/smart-farm/2021/Smart%20Farm%20Impact%20Report.pdf>

¹⁷⁶ “Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports,” January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

¹⁷⁷ Relf-Eckstein, J. et al., “Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming,” December 2019, Elsevier NJAS - Wageningen Journal of Life Sciences, <https://doi.org/10.1016/j.njas.2019.100307>

Lack of researchers, developers, and knowledge workers can further slow primary producer adoption. A report by the Agricultural Institute of Canada warns that “skilled labour shortages in primary agriculture over the last 10 years have an impact on all stages of the innovation continuum, particularly research dissemination activities that promote farm-level adoption of innovation.”¹⁷⁸ Without knowledge transfer and educational outreach, producers are less likely to learn about and understand relevant applications of emerging technologies, which in turn reduces adoption levels.¹⁷⁹ This gap between research and producers can reduce the usefulness of the resulting tech to farmers, further limiting adoption (see Progress in Tech for more information).¹⁸⁰ Accordingly, experts recommend incentives for young Canadians to develop varied agricultural technology skill sets and a focus on research dissemination. For example, one advisory committee member noted:



There are multiple layers to the challenge of attracting the right talent—sourcing talent from other places, but also training our Canadian workforce. I think the biggest challenge is that it's not just one thing, it's multidisciplinary.
 – CEO, Precision Agriculture Company

Two industry experts similarly stressed the importance of multidisciplinary learning in a recent Policy Options article, recommending fluency for future farmers in STEM disciplines, business, and scientific knowledge.¹⁸¹ In May 2021, the federal government made a commitment to developing this workforce by funding 2,000 youth jobs in agriculture through the Youth Employment and Skills program.¹⁸² Innovative educational programs, such as Lakeland College’s degree in Agricultural Technology, will also help bridge the supply gap.¹⁸³ As noted in Canada’s Economic Strategy Table: “to compete, the sector will need a workforce with the right skills to succeed in an automated, digitalized future.”¹⁸⁴

Interoperability

Efforts to adopt new technologies come with a myriad of technical challenges related to interoperability¹⁸⁵: proprietary software constraints, difficult or non-existent APIs (application programming interfaces), legislation over the right to repair personal equipment, and the general lack of integration between brands.

- 178 “An Overview of the Canadian Agricultural Innovation System,” 2017, Agricultural Institute of Canada, https://aic.ca/pdf/AIC20170825_DC_CFI_Contextpiece_Short_version_FINAL_11.2.pdf
- 179 “An Overview of the Canadian Agricultural Innovation System,” 2017, Agricultural Institute of Canada, https://aic.ca/pdf/AIC20170825_DC_CFI_Contextpiece_Short_version_FINAL_11.2.pdf
- 180 “An Overview of the Canadian Agricultural Innovation System,” 2017, Agricultural Institute of Canada, https://aic.ca/pdf/AIC20170825_DC_CFI_Contextpiece_Short_version_FINAL_11.2.pdf
- 181 E. Fraser, L. Newman, “Enabling the Digital Agricultural Revolution” Policy Options, 2021, <https://policyoptions.irpp.org/magazines/april-2021/enabling-the-digital-agricultural-revolution/>
- 182 “Minister Bibeau launches program to create 2,000 youth jobs in the agriculture sector,” May 6, 2021, Government of Canada, <https://www.canada.ca/en/agriculture-agri-food/news/2021/05/minister-bibeau-launches-program-to-create-2000-youth-jobs-in-the-agriculture-sector.html>
- 183 “Lakeland College Launches Canada’s First Degree in Agriculture Technology” Realagriculture, 2021, <https://www.realagriculture.com/2021/01/lakeland-college-launches-canadas-first-degree-in-agriculture-technology/>
- 184 “Agri-Food Interim Report,” 2017, ISED, [https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_Table_AF.pdf/\\$file/ISED_Table_AF.pdf](https://www.ic.gc.ca/eic/site/098.nsf/vwapj/ISED_Table_AF.pdf/$file/ISED_Table_AF.pdf)
- 185 Interoperability is the ability to interchangeably share, or exchange data between various devices or systems without interference in a way that produces efficiencies or greater knowledge in a particular area.

While considerations are placed on the value of creating “heterogeneous sources of information” to help understand and process emerging and diverse data streams, safety concerns continue to mount.¹⁸⁶ In the United States, security concerns prompt controlled area networks and Binary Unit Systems (BUS) to standardize physical connections between electronic devices, limiting outside communication opportunities where vulnerabilities may be present.¹⁸⁷ Globally, the International Standards Organization (ISO) developed ISOBUS 11787-1995, which provides an “Agricultural Data Interchange Syntax,” and ISO 11783-1:2017, which is a worldwide serial and data network communication protocol that enables direct data communication between tractors, devices, and farm management software.¹⁸⁸ Despite best efforts, the effectiveness of ISO is fairly limited, given that it remains a voluntary, and not a compulsory industry standard.

The growing popularity of open source software has also been seen to alleviate interoperability challenges. For example, the Ag Data Application Programming Toolkit (ADAPT) is designed to help farmers transfer data from their preferred API into different original equipment manufacturer (OEM) systems.¹⁸⁹ While widespread open source initiatives gain traction internationally, Canada faces challenges moving toward inclusive technology practices, such as comprehensive “right-to-repair” legislation. Often linked to consumer equipment, such as smartphones, a lack of comprehensive right-to-repair policies in Canada has had negative implications in the agricultural industry, most notably with respect to operating costs.¹⁹⁰ Repairs are seen as a financially lucrative business opportunity, encouraging manufacturers to monopolize their product lines and actively discourage right-to-repair legislation. Similar challenges exist in the EU, where “software technological protection” measures (TPM’s) inhibit the ability of agricultural producers to repair or maintain their digital products.¹⁹¹ This can lead to inflated costs, limited availability, and hindered supply timelines.¹⁹²

- 186** Pang, L. et al., “Data-source interoperability service for heterogeneous information integration in ubiquitous enterprises,” 2015, *Advanced Engineering Informatics*: Volume 29, Issue 3, <https://www.sciencedirect.com/science/article/pii/S1474034615000531>
- 187** Fountas, S. et al., “Farm machinery management information system,” 2015,
- 188** *Computers and Electronics in Agriculture*: Volume 110, <https://www.sciencedirect.com/science/article/abs/pii/S0168169914002932>
- 189** Relf-Eckstein, J. et al., “Farming Reimagined: A case study of autonomous farm equipment and creating an innovation opportunity space for broadacre smart farming,” December 2019, Elsevier NJAS - Wageningen Journal of Life Sciences, <https://doi.org/10.1016/j.njas.2019.100307>
- 190** Several multinational corporations within the European Union leverage ADAPT’s open-source framework, including OEM’s owned by CNH industrial – an Italian multinational, headquartered in Basildon, UK. Likewise, ADAPT is present in North American, leveraged by American interests such as the AGCO Corp., an agricultural machinery manufacturer based in Duluth, Georgia. See: Beers, G. and Hecker, E., “Seamless Interoperability Between Farm Machines and Software is a Step Closer,” 2018, *Internet of Food*, <https://www.iof2020.eu/latest/press/2018/03/seamless-interoperability-between-farm-machines-and-software>
- 191** Rosborough, A., “Canada Needs Right-to-Repair Legislation,” 2021, *Policy Options*, <https://policyoptions.irpp.org/magazines/may-2021/canada-needs-right-to-repair-legislation/>
- 192** Rosborough, A., “Unscrewing the Future: The Right to Repair and the Circumvention of Software TPM’s in the EU,” 2020, *VLEX – Journal of Intellectual Property, Information Technology and E-Commerce Law*: Volume 11 – 1, <https://international.vlex.com/vid/unscrewing-the-future-the-847039058>
- 193** Ibid.

TPMs were also raised by expert witnesses during the 2018-2019 parliamentary review of the Copyright Act, where stakeholders from the IoT technology community testified that “TPMs are too restrictive and prohibit legitimate non-infringing activities.”¹⁹³ In June 2019, the concerned parliamentary committee called on the government to consider policy measures that would address these challenges,¹⁹⁴ and in July 2021, the government launched a public consultation.¹⁹⁵

Progress in Tech

A final, quite simple challenge in adopting new tech is that not all tech is *useful* to farmers. Some agri-food tech companies try to solve problems that farmers do not necessarily have. Alternatively, they solve problems the wrong way, creating more challenges for farmers. For example, speaking about his open source software for autonomous tractors, Brian Tischler notes that while incredibly “innovative and cool,” the app hasn’t really improved productivity on the farm, and it hasn’t allowed him to relax because he still has to monitor it.¹⁹⁶ He continues to say that “it’s a lot harder than we think to apply technology to farming in a way that truly helps farmers.”¹⁹⁷ Interviewees in this study similarly noted that technological difficulties, including poor user experience, can hamper adoption:



One of the major challenges is on the equipment side... the ease and functionality of the latest iPad is just not there, and most of the monitors are not that user friendly. This has resulted in barriers to adoption—especially for larger farms which have operators that are non-family members or non-owners of the farm. A farmer’s main concern is not having downtime, and the monitor becomes something of a roadblock to them adopting tech because it creates a risk of having to deal with tech instead of being in the field.

– CEO, Precision Agriculture Company



There are challenges with technology ...and meat processing because of the different sizes of meat—particularly beef. We saw this during COVID. We have a fairly labour-intensive processing sector because the technology hasn’t adapted to varying sized carcasses.

– Academic Professor, Canadian University

- 193 “Consultation on a Modern Copyright Framework for Artificial Intelligence and the Internet of Things,” July 16, 2021, Government of Canada, <https://www.ic.gc.ca/eic/site/693.nsf/eng/00317.html>
- 194 “Statutory Review of the Copyright Act: Report of the Standing Committee on Industry, Science and Technology, 42nd Parliament,” June 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/INDU/report-16/>
- 195 “Consultation on a Modern Copyright Framework for Artificial Intelligence and the Internet of Things,” July 16, 2021, Government of Canada, <https://www.ic.gc.ca/eic/site/693.nsf/eng/00317.html>
- 196 Powell, N., “Canada seen poised to lead world in food production if we can seize “fourth agricultural revolution,” August 28, 2019, Financial Post, <https://financialpost.com/commodities/agriculture/fourth-agricultural-revolution-will-depend-on-technology-and-skills-rbc-study>
- 197 Powell, N., “Canada seen poised to lead world in food production if we can seize “fourth agricultural revolution,” August 28, 2019, Financial Post, <https://financialpost.com/commodities/agriculture/fourth-agricultural-revolution-will-depend-on-technology-and-skills-rbc-study>

While some of ICTC's survey respondents voiced their frustrations with tech, particularly in the horticulture sector, most responses were predominantly positive. For instance, when asked how newly implemented technologies impacted their operations, ICTC survey responses from Canada's grain and seed sectors were positive, indicating a strong correlation between increased field efficiencies and lowered GHG emissions. Larger crop yields and increased cost savings were also noted. Research shows that producer satisfaction with agricultural technology varies by technology type, but generally correlates with performance and clear ROI.¹⁹⁸ In other words, if it works well and there is proof, farmers will adopt the technology.

Looking forward, it will be important to integrate more and earlier feedback from primary producers into technology development through initiatives like Living Farms, which may increase the usefulness and user experience of new technologies (see Return on Investment for more information). Similarly, interviewees noted that "early partnerships between companies and progressive producers—like autonomous tractors partnering with producers on the cutting edge—pave the way for more accessible uptake." More input from farmers earlier in the process can help increase adoption.

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Lemay, M. et al., "Preliminary Findings of a Provincial Survey on the Adoption of Automation & Robotics Technologies in Ontario's Agriculture Sector," May 2021, Brock University, <https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/BROCK-NCO-Working-Paper-WEB-FINAL.pdf>

Adoption Drivers

Climate Crisis

Canada's agricultural sector faces a litany of issues stemming from a worsening global climate crisis. A 2019 study from Environment and Climate Change Canada reports that Canada is warming two times faster than the global average,¹⁹⁹ and analysts forecast a mix of higher temperatures, shorter winters, frequent wildfires, freezing rain, and the thawing of permafrost.²⁰⁰ Canada's northern regions are warming faster than the rest of the country, impacting resource development and conservation efforts.²⁰¹ A need for continued innovation and technology adoption becomes critical as businesses shift their focus toward the reduction of GHGs caused by farming activities. Additionally, industry has begun looking toward technology to help mitigate the fluctuating impacts of climate change related to production and food processing.

Early OECD (2011) recommendations identified a series of benchmarks to adopt and implement innovative technologies to address climate concerns. Particularly, they stressed the need for strong domestic and international policy that could inspire confidence for widespread private investment.²⁰² Importance was placed on implementing flexible measures that help avoid "locking in" technologies that may one-day become inefficient. Likewise, emphasis was placed on balancing "technology-neutral" policies that help diversify tools centred on sustainability.²⁰³ A 2018 roundtable report published by the OECD continues this exploration. This report identifies how innovations that leverage AI and nanomaterials promise low-emission solutions for the future, assuming investment is prioritized.²⁰⁴ The report indicates that projections for global tech adoption to fight climate change are optimistic, with over 4 billion (USD) dollars for clean energy innovation initiatives being added since 2015.²⁰⁵ This includes over 40 international research partnerships now dedicated to climate innovation.

- 199 "Canada's Climate Change Report," 2019, Environment and Climate Change Canada, <https://www.deslibris.ca/ID/10100227>
- 200 Schnitter R. and Berry, P., "The Climate Change, Food Security and Human Health Nexus in Canada: A Framework to Protect Population Health," July 2019, International Journal of Environmental Research and Public Health 16, no. 14, <https://doi.org/10.3390/ijerph16142531>; "Climate Change and Land," August 7, 2019, IPCC, https://www.ipcc.ch/site/assets/uploads/2019/08/Edited-SPM_Approved_Microsite_FINAL.pdf; "Climate Change and Land," August 7, 2019, IPCC, https://www.ipcc.ch/site/assets/uploads/2019/08/Edited-SPM_Approved_Microsite_FINAL.pdf.
- 201 Bush, L., Lemmen, D., "Canada's Changing Climate Report," Government of Canada, 2019, https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf
- 202 "Promoting Technological Innovation to Address Climate Change," OECD, 2011 <https://www.oecd.org/env/cc/49076220.pdf>
- 203 Ibid
- 204 Cervantes, M. et al., "Accelerating the development and diffusion of low-emissions innovations," 2018, OECD: Round Table on Sustainable Development, <https://www.oecd.org/sd-roundtable/papersandpublications/Accelerating%20the%20development%20and%20diffusion%20of%20low-emissions%20innovations.pdf>
- 205 Ibid.

A 2019 review of climate change, food security, and human health in Canada breaks down climate change impacts into four relevant categories.

1

Food Production: As climate change continues, an extension of Canada's viable growing season could positively impact Canadian food producers. Likewise, a longer outdoor feeding season for livestock could increase young animal survival rates.²⁰⁶ However, the risks to food production outweigh the benefits. An increase in climate disruptions on Canada's food production processes will bring with it an increase in droughts in British Columbia and the Prairies, as well as an increase in invasive species and disease risks.²⁰⁷

2

Food Processing: The predicted outcomes of climate change impacts on food processing in Canada includes an unstable supply of viable resources, disrupted processing operation inputs, and processing facility damage.²⁰⁸

3

Food Distribution: Climate change is resulting in increased transportation interruptions. For example, Manitoba's northern communities are "[experiencing] supply shortages of healthy food products due to warming conditions, resulting in deteriorating ice roads."²⁰⁹ Rural and remote communities that face difficulties producing and storing food are particularly vulnerable to climate-related food insecurity. The Government of Canada reports that transportation infrastructure and public transport systems in urban areas are also particularly vulnerable.²¹⁰

4

Food Preparation and Consumption: Climate change can affect "diet composition and diversity."²¹¹ In a (2019) FNFNES survey, First Nations, Inuit, and Métis adults noted that climate change impacts the access and supply of traditional foods.²¹² Recent studies have also reported climate-related changes in Caribou supply and distribution across Canada.^{213,214}

- 206 "Agriculture and Climate Change," 2021, Prairie Climate Centre, <https://climateatlas.ca/agriculture-and-climate-change/>; "Climate Scenarios for Agriculture," May 25, 2012, Government of Canada, <https://www.agr.gc.ca/eng/agriculture-and-the-environment/agricultural-practices/climate-change-and-agriculture/climate-scenarios-for-agriculture/?id=1329321981630>
- 207 Warren, F. and Lemmen, D., "Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation," 2014, Government of Canada, https://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2014/internet/w14-26-U-E.html/collections/collection_2014/rncan-nrcan/M174-2-2014-eng.pdf
- 208 Schnitter R. and Berry, P., "The Climate Change, Food Security and Human Health Nexus in Canada: A Framework to Protect Population Health," July 2019, International Journal of Environmental Research and Public Health 16, no. 14, <https://doi.org/10.3390/ijerph16142531>
- 209 Schnitter R. and Berry, P., "The Climate Change, Food Security and Human Health Nexus in Canada: A Framework to Protect Population Health," July 2019, International Journal of Environmental Research and Public Health 16, no. 14, <https://doi.org/10.3390/ijerph16142531>
- 210 Palko, K. et al., "Climate Risks and Adaptation Practices for the Canadian Transportation Sector 2016," 2017, Transport Canada, http://publications.gc.ca/collections/collection_2017/tc/T42-12-2017-eng.pdf.
- 211 Schnitter R. and Berry, P., "The Climate Change, Food Security and Human Health Nexus in Canada: A Framework to Protect Population Health," July 2019, International Journal of Environmental Research and Public Health 16, no. 14, <https://doi.org/10.3390/ijerph16142531>
- 212 Chan, L. et al., "FNFNES Final Report for Eight Assembly of First Nations Regions," November 2019, Assembly of First Nations, University of Ottawa, University of Montreal, https://www.fnfnes.ca/docs/FNFNES_draft_technical_report_Nov_2_2019.pdf
- 213 "Climate Change Driving Indigenous Food Insecurity in Canada: Report," October 21, 2020, The Narwhal, <https://thenarwhal.ca/climate-change-indigenous-food-insecurity-report/>.
- 214 Warren, F. and Lemmen, D., "Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation," 2014, Government of Canada, https://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2014/internet/w14-26-U-E.html/collections/collection_2014/rncan-nrcan/M174-2-2014-eng.pdf

A 2020 report from the Government of British Columbia also identifies that climate change presents a significant risk to the security of fruit and vegetable supply chains. British Columbia currently imports an estimate \$7.3 billion dollars of food internationally, with approximately \$2 billion from California alone, which is experiencing its own climate-related challenges such as drought and forest fires.²¹⁵ Although little research is currently available, one thing is clear: “the pattern of international trade flows in agricultural products may look extremely different... because of the effects of climate change.”

From a technology adoption perspective, the federal government recently announced a \$165.7 million dollar investment into their “Agricultural Clean Technology Program.” This program is set to provide agri-businesses and farmers with access to funding to help ease the financial burden of adopting of clean technologies while lowering their GHG emissions.²¹⁷ The funding is geared to move businesses toward a lower-carbon footprint, focusing on priority areas such as green energy, energy efficiency, precision agriculture, and the bioeconomy.²¹⁸ While operating through two streams, an “Adoption Stream” looks to support the adoption of new technologies with a focus on reducing GHG emissions. The “Research and Innovation Stream” looks to support the investment into research, pre-market innovation, and the demonstration and commercialization of clean technologies.²¹⁹

Global Population Growth

According to a medium-variant projection from the 2019 UN report on World Population Prospects, the global population increases to 9.7 billion by 2050.²²⁰ Population growth will vary significantly by region, resulting in food security challenges that will need to be addressed, and spurring a great need for technology adoption to help provide more secure supply chains. For example, Sub-Saharan Africa is projected to account for more than half of this growth and already faces challenges that threaten human health, such as food and water security and climate-challenges.²²¹ Compared to a 2000-2002 baseline, global undernourishment is predicted to increase globally, as shown in **Figure 12**.

- 215 “The Future of B.C.’s Food System,” 2020, Government of British Columbia, <https://engage.gov.bc.ca/app/uploads/sites/121/2020/01/FSTF-Report-2020-The-Future-of-Food.pdf>; Kim, S., “Canada’s scientists conclude that human-induced climate change had a strong impact on forest fires in British Columbia,” 2019, Government of Canada, <https://www.canada.ca/en/environment-climate-change/news/2019/01/canadas-scientists-conclude-that-human-induced-climate-change-had-a-strong-impact-on-forest-fires-in-british-columbia.html>
- 216 Gouel, C. and Laborde, D., “THE CRUCIAL ROLE OF INTERNATIONAL TRADE IN ADAPTATION TO CLIMATE CHANGE,” November 2018, National Bureau of Economic Research, <https://doi.org/10.3386/w25221>
- 217 Anderson, O., “Helping farmers and agri-businesses adopt clean technologies to reduce emissions and enhance competitiveness,” 2021, Government of Canada, <https://www.canada.ca/en/agriculture-agri-food/news/2021/06/helping-farmers-and-agri-businesses-adopt-clean-technologies-to-reduce-emissions-and-enhance-competitiveness.html>
- 218 Anderson, O., “Helping farmers and agri-businesses adopt clean technologies to reduce emissions and enhance competitiveness,” 2021, Government of Canada, <https://www.canada.ca/en/agriculture-agri-food/news/2021/06/helping-farmers-and-agri-businesses-adopt-clean-technologies-to-reduce-emissions-and-enhance-competitiveness.html>
- 219 Anderson, O., “Helping farmers and agri-businesses adopt clean technologies to reduce emissions and enhance competitiveness,” 2021, Government of Canada, <https://www.canada.ca/en/agriculture-agri-food/news/2021/06/helping-farmers-and-agri-businesses-adopt-clean-technologies-to-reduce-emissions-and-enhance-competitiveness.html>
- 220 Although prior forecasts have overestimated population growth, there is a strong (95%) belief that the world population will land between 9.4-10.1 billion by the targeted date. See: “2019 Revision of World Population Prospects,” 2019, United Nations, <https://population.un.org/wpp/>
- 221 “Climate Change Is an Increasing Threat to Africa,” October 27, 2020, UN Climate Change News, <https://unfccc.int/news/climate-change-is-an-increasing-threat-to-africa>



Figure 12: Mean global undernourishment prevalence in future scenarios compared to 2000-2002 baseline.²²²
Source: United Nations.

In some scenarios, population growth is forecasted at a lower rate in several high-income countries. In Canada, due in large part to immigration efforts, Statistics Canada projects a population increase from 37.1 million people in 2018 to approximately 70 million in 2068 (high-growth scenario).²²³ As discussed in the section above, climate change could allow for higher crop yields in Canada. One study, however, found that **Europe, Australasia, US, and Canada all experience a decrease in food insecurity in certain scenarios:** in short, “countries with a projected decrease in population growth had higher food security, while those with a projected rapid population growth tended to experience the worst impacts on food security.”²²⁴ Interestingly, witnesses who came before the Parliament of Canada’s Agriculture and Agri-Food Committee for its study on the agri-food sector highlighted that **globally, population growth means “opportunities for Canada, which produces far more agriculture and agri-food products than it consumes.”**²²⁵

Issues stemming from global population growth are not standalone and are recognized as being one of several contributing factors toward technology adoption. As Kathleen Mogelgaard, a consultant on population dynamics and climate change for the University of Maryland notes:



*Population growth...is a very complicated, multifaceted [issue.] Population issues certainly are an important dimension of how society will unfold, how society will be able to cope with the climate crisis...but it's not a silver bullet, and it's certainly not the main cause of climate change.... It is [however] an important piece of the puzzle.*²²⁶

²²³ Molotoks, A. et al., “Impacts of Land Use, Population, and Climate Change on Global Food Security,” November 5, 2020, Food and Energy Security Volume 10, Issue 1 e261, <https://doi.org/10.1002/fes3.261>

²²⁴ “Population Projections for Canada (2018 to 2068), Provinces and Territories (2018 to 2043),” September 17, 2019, Government of Canada: Statistics Canada, <https://www150.statcan.gc.ca/n1/pub/91-520-x/91-520-x2019001-eng.htm>

²²⁵ Molotoks, A. et al., “Impacts of Land Use, Population, and Climate Change on Global Food Security,” November 5, 2020, Food and Energy Security Volume 10, Issue 1 e261, <https://doi.org/10.1002/fes3.261>

²²⁶ “Advancements of technology and research in the agriculture and agri-food sector that can support Canadian exports,” January 2019, House of Commons, <https://www.ourcommons.ca/DocumentViewer/en/42-1/AGRI/report-15/page-69>

²²⁷ N. Mortillaro, “Is Population Control the Answer to Fixing Climate Change?” 2019, CBC News: Science, <https://www.cbc.ca/news/science/population-climate-change-1.5331133>

To address growing concerns, technology adoption and innovative practices can aid low-impact food production systems at scale. Technologies and practices related to soil organic matter and erosion control, improved cropland and livestock maintenance, and genetic improvements for heat and drought tolerance can support a dramatic global scale-up.²²⁷ With these changes come a series of strongly recommended social modifications as well, as demand-side adaptations are also required. As is discussed in Section I, behaviours such as adopting sustainable diets and reducing food loss and waste aid in decreasing the land required to maintain current needs, ultimately producing fewer opportunities for food system vulnerabilities.²²⁸

Food Insecurity

In places such as northern Canada, growing food security issues are a daily concern. In large part due to climate conditions and a strong dependency on seasonal road infrastructure and general accessibility, food insecurity impacts nearly 70% of Nunavut's population.²²⁹ Likewise, in northern Manitoba, more than 60% of on-reserve Indigenous households face growing food security challenges.²³⁰ Entailing health and well-being considerations, food security has become an "unprecedented public health issue" in Canada.²³¹ Technology, such as controlled environmental agriculture, have allowed some northern communities to produce food in cold climates while helping regulate food supply chains, however, concerns remain.¹³² Issues such as startup costs, profit projections, environmental impacts, trialability and reversibility were highlighted alongside the vulnerability of using complex technology.²³³

In other regions such as British Columbia, issues of food security have spurred government action, providing financial aid to businesses looking to adopt emerging technologies. Provincial and federal governments have begun funding the adoption of traceability technologies, tracking movement of food from production and processing to distribution. The acquired data aids in better monitoring the distances that food is required to travel for emissions purposes, while aiding in the reduction of foodborne illness. In Nova Scotia, issues of food security have had direct implications on the livelihoods of independent food producers, forcing some to pivot and redirect their production efforts (i.e., shifting from pork to berry production.) This pivot, however, brought with it opportunities to leverage technology to monitor plant nutrition, waste, and atmospheric controls when responding to fluctuating temperature changes and wind conditions.²³⁵

- 227 "Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security and Greenhouse Gas Fluxes in Terrestrial Ecosystems" 2019, IPCC, <https://www.ipcc.ch/srcll/chapter/chapter-5/>
- 228 "Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security and Greenhouse Gas Fluxes in Terrestrial Ecosystems" 2019, IPCC, <https://www.ipcc.ch/srcll/chapter/chapter-5/>
- 229 "Affordable Food in The North" Food Secure Canada," 2019, <https://foodsecurecanada.org/resources-news/news-media/we-want-affordable-food-north>
- 230 "Affordable Food in The North" Food Secure Canada," 2019, <https://foodsecurecanada.org/resources-news/news-media/we-want-affordable-food-north>
- 231 "Affordable Food in The North" Food Secure Canada," 2019, <https://foodsecurecanada.org/resources-news/news-media/we-want-affordable-food-north>
- 232 Natcher, D. et al., "Assessing the Constraints to the Adoption of Containerized Agriculture in Northern Canada" May 2021, *Frontiers in Sustainable Food System: Volume 5*, <https://www.frontiersin.org/articles/10.3389/fsufs.2021.643366/full>
- 233 Natcher, D. et al., "Assessing the Constraints to the Adoption of Containerized Agriculture in Northern Canada" May 2021, *Frontiers in Sustainable Food System: Volume 5*, <https://www.frontiersin.org/articles/10.3389/fsufs.2021.643366/full>
- 234 Comeau, J., "New Technology Strengthens Food Security, Safety," 2021, Government of Canada,, <https://www.canada.ca/en/agriculture-agri-food/news/2021/02/new-technology-strengthens-food-security-safety.html>
- 235 Gorman, M., "New Government Fund Aims to Help Grow High-Tech Agriculture," 2021, CBC News, <https://www.cbc.ca/news/canada/nova-scotia/farming-food-agriculture-government-funding-1.5959201>

COVID-19 also presented a series of food security challenges as concerns mounted regarding the volatility of Canada's fragile food supply system. Guelph University's Dr. Evan Fraser, Director of the Arrell Food Institute and co-chair of the research study *Growing Stronger: Aiming for Resilience in our Canadian Food System*, cites an industry executive saying that "the [food supply system in Canada] bent, but didn't break, but it came close to breaking on a couple of key points."²³⁶ While acknowledging the importance of grocery store workers, delivery drivers, and food processing and production labourers, other concerns were raised: travel bans limited the availability of temporary foreign workers and caused acute labour shortages; surplus organic waste was caused by a lack of demand in the food and beverage industry; and long-term closures occurred in meat-producing facilities due to COVID-19 outbreaks.²³⁷

Dr. Fraser and Dr. Lenore Newman, who is Canada Research Chair: Food Security and Environment, University of The Fraser Valley, however, note that widespread technology adoption may hold the key to providing a greener and more resilient food security system. Three technologies were highlighted, including vertical farming, precision agriculture, and cellular agriculture (covered in more detail in **Section I**).²³⁸ While implementing technology, it is important to observe regional circumstances, climates, and accessibility, and consider whether it does not aggravate existing food security issues.²³⁹ Technologies that address regional food security not only hold the potential to increase agricultural outputs but also address transportation challenges. From a regional production perspective, new ways of growing (e.g., urban farming,²⁴⁰ vertical farming,²⁴¹ pod farming, etc.) could enable food production in historically challenging locations, both rural and urban. For example, the City of Vancouver created a local food strategy to increase local urban food production. It included initiatives like increased use of backyard chickens, community gardens, and farmer's markets.²⁴²

²³⁶ Kelly, L., "Pandemic Offers Change to 'Reimagine' Food System," 2021, Northern Ontario Business, <https://www.northernontariobusiness.com/industry-news/agriculture/pandemic-offers-chance-to-reimagine-food-system-3536203>

²³⁷ Kelly, L., "Pandemic Offers Change to 'Reimagine' Food System," 2021, Northern Ontario Business, <https://www.northernontariobusiness.com/industry-news/agriculture/pandemic-offers-chance-to-reimagine-food-system-3536203>

²³⁸ Fraser, E. and Newman, L., "Three Technologies Poised to Change Food and the Planet," 2021, University of Guelph, <https://news.uoguelph.ca/2021/02/three-technologies-poised-to-change-food-and-the-planet/>

²³⁹ Anderson, M., "Timothy A. Wise: Eating Tomorrow: Agribusiness, Small Farmers and the Battle for the Future of Food," September 1, 2020, *Agriculture and Human Values* 37, no. 3: 923–24, <https://doi.org/10.1007/s10460-020-10024-w>

²⁴⁰ "Local Food," 2021, The City of Vancouver, <https://vancouver.ca/green-vancouver/local-food.aspx#food-progress>

²⁴¹ "Estimated market value of vertical farming in Canada from 2014 to 2025, by technology type," February 2018, Statista, <https://www.statista.com/statistics/801438/market-value-of-vertical-farming-in-canada-by-technology/>

²⁴² "Local Food," 2021, The City of Vancouver, <https://vancouver.ca/green-vancouver/local-food.aspx#food-progress>



Conclusion

Climate change and environmental degradation are inherently tied to food. Reducing agricultural GHG emissions, freshwater consumption, and land use while responding to increased demand for food in domestic and international communities is a difficult task. At the same time, COVID-19 has highlighted the nature of our delicate food supply system, displaying how prolonged or slowed productivity levels and economic downturns can threaten our way of life. Price volatility and inflation are progressing without a sense of immediate reprieve. Likewise, it is clear that Canada's food stability remains deeply susceptible to external factors such as extreme weather conditions, fluctuating costs of oil and gas, and health-related emergencies.

Amid Canada's shifting social and environmental circumstances is a degree of opportunity: confronting these challenges while achieving food security is fertile ground for innovation. In response, companies operating across Canada are employing clean tech, AI and ML, robotics and drones, software, and life sciences technologies to deliver diverse agri-food tech products and services. As a result, technologies like precision agriculture, controlled environmental agriculture, sustainable food production, and agricultural biotechnology are reshaping domestic and international food systems.

New and emerging skill sets are now sought after in smaller rural communities while new roles and responsibilities are being created in new segments of the agri-food industry—all of which underscores the growing prominence of technology. This report overviews Canada's agri-food technology industry and provides a clearer picture of the challenges and opportunities that lie ahead. By considering and adequately planning for in-demand roles and specialized skills, Canada's agriculture sector can realize the competitive advantage that technology can impart on food security, the economy, and the mitigation of climate change. As the motivations for greater tech adoption grow, so do the opportunities for Canada to find greater efficiencies, establish new production practices, and position itself as an integral player in the global response to food production.

Methodology

Secondary Sources

Company-Level Data

ICTC curated a list of companies in the Canadian agri-food technology industry using Pitchbook. Companies were included if they operated in the agtech, foodtech, and restaurant tech verticals and had an office or headquarters located in Canada. The initial search results were vetted for inaccurate data, and inactive companies were removed. Similarly, companies were removed from the initial search results if they did not fall within this study's definition of agri-food tech companies (see Defining Agri-Food Technology below for more information).

Defining Agri-Food Technology

Given its expansive supply chain, the agri-food sector overlaps adjacent sectors, including retail, health, and manufacturing. In fact, the food and beverage processing industry is the largest manufacturing industry in Canada, accounting for 17% of all manufacturing GDP and 18% of manufacturing employment.²⁴³ Past and present studies by ICTC focus on the impact of emerging technologies in retail, health, and manufacturing, and therefore it is important to clarify which areas of overlap are not included in this study. The following criteria were used to refine the list of agri-food tech companies in Canada:

-  Technology companies that serve the food retail and food service industries are considered retail technologies and therefore excluded from this study: these are sometimes referred to as "food retail technology" or "restaurant technology"
-  Biotechnology companies are excluded from this study if they are primarily aimed at the healthcare sector, however, those focused on livestock animal health are included
-  The only high-tech food processing companies that are included in this study are those focused on novel food production or high-tech food processing techniques, such as those used in the production of alternative proteins and plant-based foods (e.g., gas chromatography, high-performance liquid chromatography, protein extraction and isolation, extrusion science)
-  Technology companies that serve manufacturing plants that prepare and package agri-food products

Company-Level Data

ICTC used a combination of web scraping techniques and proprietary secondary data to identify key roles and skills in the agri-food tech industry. Sources used for web scraping included publicly available information from job aggregation websites, professional networking sites, and EMSI.

Existing Literature

The qualitative and quantitative portions of this project were supported by a thorough review of available literature. The literature review helped shape research methods and questions and provide information to help further validate findings in the report. The initial literature review helped identify interviewees, advisory committee participations, and form a methodology for the quantitative portion of the research.

Primary Research Methodology

Existing Literature

The agri-food technology survey was targeted to primary producers, industry experts, and manufacturers across Canada, and responses included those from individual with higher-level decision-making within their organizations, such as owners/founders, CEOs, executives, and managing directors. ICTC received 310 responses from sectors including wheat, barley, eggs, sheep, and bees. Questions ranged from in-demand roles and skills to technology adoption trends, to the impacts of COVID-19 on operations.

| Sector | Subsector | Provinces and Territories | Respondent # |
|----------------|-----------------------|---------------------------|--------------|
| AgTech | Various | Alberta | 104 |
| AgTech | Various | British Columbia | 28 |
| Grain and Seed | Crops General | Manitoba | 61 |
| Grain and Seed | Wheat and Barley | New Brunswick | 0 |
| Grain and Seed | Grain | Newfoundland and Labrador | 0 |
| Horticulture | Beekeepers | Northwest Territories | 0 |
| Horticulture | Beekeepers | Nova Scotia | 38 |
| Horticulture | Wild Blueberries | Nunavut | 0 |
| Horticulture | Horticulture | Ontario | 17 |
| Horticulture | Tree Fruit | Prince Edward Island | 8 |
| Horticulture | Produce | Quebec | 27 |
| Horticulture | Apples | Saskatchewan | 27 |
| Horticulture | Beekeepers | Yukon | 0 |
| Livestock | Eggs | | |
| Livestock | Sheep | Total | 310 |
| Livestock | Forage and Grasslands | | |
| Livestock | Sheep | | |
| Manufacturing | Various | | |

Table 4: Subindustry representation in survey.

Table 5: Provincial and territorial representation in survey.

Key Informant Interviews

ICTC conducted 32 key informant interviews with diverse expertise in the agri-food producing, manufacturing, and tech fields. Interviews were conducted from January to June 2021. Interviewees held influential positions within their organizations, including founders, CEOs, professors, directors, and owners. These interviews were tailored to collect information on general organization questions, trends in argi-food technology in Canada, labour, and talent.

| Sector | Number | Province | Number |
|----------|--------|------------------|--------|
| Private | 15 | Alberta | 2 |
| Academic | 8 | British Columbia | 1 |
| Public | 7 | Manitoba | 4 |
| Civil | 2 | Nova Scotia | 6 |
| | | Ontario | 11 |
| | | Quebec | 3 |
| | | Saskatchewan | 5 |

Table 6: Sectoral representation in key informant interviews.

Table 7: Provincial representation in key informant interviews.

Advisory Committee

ICTC hosted three advisory committee meetings of eight industry stakeholders. The data was presented with interactive activities on Miro and Jamboard. The advisory committee members met three times during the duration of the project, meetings occurred in March, June, and August 2021. Advisory committee participants also held influential positions such as CTO, CEO, Professors, and Scientific Directors (in startups, large organizations, civil, academic, private, and healthcare sectors).

| Sector | Number | Province | Number |
|----------|--------|------------------|--------|
| Private | 6 | Alberta | 2 |
| Academic | 2 | British Columbia | 2 |
| | | Ontario | 1 |
| | | Quebec | 1 |
| | | Saskatchewan | 2 |

Table 8: Sectoral representation in advisory committee.

Table 9: Table 9: Provincial representation in advisory committee.

Forecast Methodology

ICTC uses monthly Statistics Canada Labour Force Survey (LFS) data, split by NAICs and NOCs, to forecast employment levels for the various sectors under consideration in its Outlook reports.²⁴⁴ These monthly data series are adjusted for seasonality using the X-13ARIMA-SEATS Seasonal Adjustment Program.²⁴⁵ In addition, several macroeconomic and financial data series from Statistics Canada and the Bank of Canada are used for analysis. These include data on output,²⁴⁶ prices,²⁴⁷ labour market conditions,²⁴⁸ financial variables,²⁴⁹ and other macroeconomic variables such as investment,²⁵⁰ household savings,²⁵¹ and retail sales.²⁵²

Vector Autoregressive (VAR) models are used to perform the forecasting. VAR is a stochastic process model used to capture the linear interdependencies among multiple time series. In a VAR model, each variable has an equation explaining its evolution as a function of its own lagged values, the lagged values of other endogenous and exogenous variables, and the error term. VAR models do not require an understanding of the causal relationship between the variables within the model, merely the knowledge that the variables are interrelated. Model specification (variables, lags) are chosen based on minimization of the Schwarz-Bayesian and Hannan-Quinn Information Criteria (SBC & HQC).

Vector Autoregressive (VAR) models are used to perform the forecasting. VAR is a stochastic process model used to capture the linear interdependencies among multiple time series. In a VAR model, each variable has an equation explaining its evolution as a function of its own lagged values, the lagged values of other endogenous and exogenous variables, and the error term.

- 244 Alexandra Cutean et al., "Canada's Growth Currency: Digital Talend Outlook 2023," 2020, ICTC; Ivus, Kotak, and McLaughlin, 2021, ICTC, "The Digital-Led New Normal: Revised Labour Market Outlook for 2022"
- 245 CSRM US Census Bureau - Brian C. Monsell, "US Census Bureau - X-13ARIMA-SEATS Seasonal Adjustment Program - Version 1.1 Download Page, PC Version," accessed 29 June 2021, https://www.census.gov/srd/www/x13as/x13down_pc.html
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- 247 Statistics Canada, "Consumer Price Index (CPI) Statistics, Measures of Core Inflation and Other Related Statistics - Bank of Canada Definitions," 22 December 2016, <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810025601>; Statistics Canada, "Gross Domestic Product Price Indexes, Quarterly," 1 October 2012, <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610010601>; Statistics Canada, "Fisher Commodity Price Index, United States Dollar Terms, Bank of Canada, Monthly," 18 June 2021, <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1010013201>
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VAR models do not require an understanding of the causal relationship between the variables within the model, merely the knowledge that the variables are interrelated. Model specification (variables, lags) are chosen based on minimization of the Schwarz-Bayesian and Hannan-Quinn Information Criteria (SBC & HQC).

The employment forecast for the sector is a function of assumptions regarding the trend in the aggregate unemployment rate and other macroeconomic variables. The unemployment rate projections are based on forward-looking expectations at the level of the aggregate economy, supplemented by findings from ICTC's national survey of Canada's digital economy. Unemployment rate projections enter exogenously into the VAR models to predict output (GDP) and employment trends. Other variables like inflation, interest rates, stock indices, commodity prices, and wages sometimes enter the model depending on whether they optimize the information criteria.

Limitations

While efforts were made to mitigate potential biases, there are certain limitations that may be inevitably embedded in this study.

Measuring "Size" of Agri-Tech and Food-Tech Innovation Industry

To define the agri-tech and food-tech innovation industry in this report, ICTC utilized a combination of secondary and primary research to estimate the size of the industry in Canada. While ICTC will continue to track this data over time, it is possible that the overall size of this industry may be smaller or larger than the initial estimates. This limitation applies to the agri-food tech company dataset curated using Pitchbook data, the job postings data curated using EMSI and web scraping techniques, and the Statistics Canada labour force data.

Qualitative Insights

While ICTC made a concerted effort to speak with a diverse range of agri-food tech stakeholders, the trends identified through key informant interviews and advisory committee meetings should be interpreted only as the experiences of those interviewed. In total, ICTC conducted 31 interviews, a sample that is too small to be considered representative of the entire industry.

Survey

While ICTC presented the survey by industry average based on key informant and advisory committee input, since neither industry nor provinces and territories are represented proportionally, the survey results should not be taken as representative or statistically significant. Trends and findings observed in the report, particularly variations between subindustries, could be biased toward the overrepresented industries (e.g., sheep and eggs) as well as provinces (e.g., Alberta) (see Figure 13 and Figure 14 for more detail). Moreover, by focusing only on horticulture, livestock, and grain and seed, ICTC's survey does not represent other key agricultural subsectors. These results have significant limitations but still provide a solid basis for future research.