CANADIAN AGRI-FOOD SUSTAINABILITY

Skilled Talent Needed to Meet Food Demand and Reduce Environmental Impacts

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Research by

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Preface:

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Disclaimer:

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EXECUTIVE SUMMARY

Population growth puts mounting pressure on food production; increasing climate disasters add further challenges, requiring farmers to produce more with less. Although recent years have placed greater focus on sustainability and the role of technology in agriculture, techniques like soil and water conservation and no-till production have put farmers ahead of the curve.

Many sustainability practices in the agricultural sector are already technology driven. Key examples are precision agriculture, quality control and identity preservation, cellular agriculture, and controlled environment agriculture. While these and other advancements highlight notable opportunities for the sector in terms of production and conservation, agricultural employers interviewed for this study cite labour shortages as their biggest challenge to growth and productivity.

The agricultural talent gap is partially attributed to what can be described as a fundamental shift in the agri-food labour market. Developments like farm consolidation, technology adoption and implementation, and productivity gains ultimately shrink the total volume of talent needed to support primary agricultural production. However, these same forces produce new and additional demand for talent in fields like agri-food tech, agricultural science, ag consulting, and agri-business, along with new roles and skill sets. Moreover, unlike traditional agriculture, data, agri-food science, and environmental consulting all directly inform the adoption of sustainable agricultural practices. Factoring this in, it is no surprise that one third of ag employers surveyed in this study plan to hire trades roles; another one fifth plan to hire roles in ag science and research, business and marketing, environmental consulting, digital technology, utilies, and R&D. Employers said that these roles are in demand across all seniority levels.

When it comes to critical skills, 25% of surveyed employers highlighted a need for knowledge of geography and surveying technologies (GPS, ArcGIS, Remote Sensing). Other desired skill sets include the ability to repair equipment (requiring talent with some knowledge of robotics and/or automation) and to understand, analyze, and interpret data. For the latter, employers explained that the influx of agri-food technologies and sensors has led to a demand for skilled talent that can turn data into meaningful insights that can inform decision making.

Regardless of role, sustainability knowledge and skills are essential. In fact, 65% of job postings examined in this study note a requirement for a general understanding of sustainability; a further 50% require an understanding of sustainable farming or food production, and another 30% require an understanding of environmental science. Interviewed employers echoed this reality, adding that the ability to conduct "climate risk assessments" is crucial, as is knowledge of "environmental management" and holistic "systems thinking." Moreover, it is no surprise that employers also regarded domain knowledge (for example, even a basic understanding of fields like plant science and pest management) and regulatory and legal skills as valuable. In the context of legal skills, understanding relevant regulatory mechanisms, legislation, and policy for the agri-food sector is critical.

Moreover, as workers move from entry to mid and senior levels, sustainability-related skills become more relevant and needed. They are often applied to areas like operational decision making, procurement, training and onboarding. Sustainability knowledge is also necessary to help leaders make informed decisions; that is, as new practices and technologies are developed, agricultural leaders need sustainability skills to decide which practices or tools to apply, how to train staff, how to adhere to and report on regulations, and how to monitor and evaluate the success of new practices.

Yet, despite plentiful and diverse employment opportunities, the junior talent pipeline has gaps. While nearly half of the students surveyed in this study expressed interest in pursuing a career in Canada's green economy—e.g., renewable energy production, environmental services, or sustainable agriculture—many remained unsure about pursuing this path. Nearly one-fifth of students who were not interested in green economy employment believed that they would not be able to find entry-level employment in the field. This highlights a clear disconnect between real-life labour market needs and student perceptions. In fact, many employers interviewed in this study noted challenges in filling entry-level roles. Moreover, recent research by the University of Guelph identifies a 4:1 ratio of jobs in agriculture to grads in Ontario; all indications are that demand will continue to grow in the coming years.

Skill gaps also persist to some degree. Notably, the ability to use geography and surveying technology is one of the most significant skills for entry-level roles: while a quarter of surveyed employers identified this as an in-demand skill, 70% of students surveyed noted a lack of confidence in their abilities to use these tools. Another gap is on the regulatory side: despite employers identifying talent with regulatory knowledge and skills as in-demand, many students noted a lack of knowledge in this space.

Overall, sustainability and the agriculture sector are inherently linked, and this connection will only expand as more employers adopt and implement technology. Precision agriculture, quality control and identity preservation, cellular agriculture, and controlled environment agriculture are just a few core examples. Although technology will undoubtedly help increase production, productivity, and resource sustainability, Canada's agricultural sector requires steady access to skilled talent at all levels to thrive. With employment demand far exceeding the available supply, boosting the junior talent pipeline is more important than ever. Fields like engineering, research and development, data analysis, environmental consulting, design, and business and marketing play key roles in the future of a sector that is ripe with opportunities.

INTRODUCTION

Global demand for food is growing, putting increased pressure on the environment and strengthening the need for sustainable food production. By 2050, the world's population is expected to reach 9.7 billion. To meet the 2050 food demand, the United Nations Food and Agriculture Organization estimates that global food production will need to increase by at least 60%.[1] Food system researchers have cautioned that in the absence of technical changes and dedicated mitigation measures, the environmental impacts of the food system could increase by 50% to 90%, pushing the earth beyond the planetary boundaries that define a safe operating space for humanity.[2] With the demand for food growing so quickly, it is imperative that our food and agriculture system workforce has the knowledge and skills needed to produce food sustainably.

At the same time, the agricultural sector presents diverse opportunities for decarbonization and biodiversity growth. Since the introduction of Alberta's carbon offset program in the early 2000s, conservation cropping, tillage system management, and sustainable livestock management have reduced Alberta's agricultural emissions by more than 20 million metric tons.[3] The Government of Canada introduced its own carbon offset program in June 2022[4] and is currently developing several offset protocols relevant to agriculture (e.g., soil organic carbon, livestock feed management, and improved forest management on private lands).[5] As new information becomes available and new technologies and systems are developed, a variety of technical and sustainability-related skills will be needed to facilitate their widespread adoption.

Recognizing the importance of sustainability in agriculture, this report explores the evolution of sustainability in Canada's agri-food sector, trends driving sustainability in ag, and the impact of sustainability initiatives on labour market needs. The study uses a mixed-methods research approach, including:

1 "The World's Food Supply is Made Insecure by Climate Change," 2023, *United Nations,* https://www.un.org/en/academic-impact/worlds-food-supply-made-insecure-climate-change

2 Springmann, Marco et al., "Options for keeping the food system within environmental limits," October 2018, https://www.nature.com/articles/s41586-018-0594-0

3 "Enabling agricultural emissions reduction and sustainable supply chains," January 2022, The Trade Commissioner, https://www.tradecommissioner.gc.ca/sectors-secteurs/climate_finance-financement_international/agriculture-emissions-reduction.aspx?lang=eng; Van Wyngaarden, Sarah, "Carbon Credit Systems in Alberta," 2022, *The Simpson Centre for Agricultural and Food Innovation and Public Education,* https://www.policyschool.ca/wp-content/uploads/2022/06/JSC16_CarbonCreditSystemsABAgric.Wyngaarden.June9_.pdf

4 "Canada launches Greenhouse Gas Offset Credit System to support a clean, green economy," June 2022, *Government of Canada,* https://www.canada.ca/en/environment-climate-change/news/2022/06/canada-launches-greenhouse-gas-offset-credit-system-to-support-a-clean-green-economy.html

5 "Canada's Greenhouse Gas Offset Credit System," February 2023, Government of Canada, https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system.html

- A secondary literature review and analysis of secondary data acquired through web scraping
- Primary qualitative research consisting of 26 key informant interviews (KIIs) with experts in agri-food and sustainability
- An employer survey of 67 agri-food companies
- A student survey of 312 students

In addition, over the course of the project, an advisory committee met to contribute to and validate the research findings.

Section I of the report looks at environmental sustainability in Canada's agri-food sector, including how key metrics like GHG intensity and GHG emissions have changed over time, what technologies are being adopted to make agriculture more sustainable, which actors are driving sustainability in agriculture, and what barriers exist to increasing sustainability in agriculture. Next, Section II discusses the impact of sustainability initiatives on agri-food labour market needs. It talks about how sustainability is changing the types of skills needed for traditional agricultural roles and how advances in agri-food science, technology, and data are converging with sustainability initiatives to drive demand for new types of labour in Canada's agri-food sector. Section II also identifies in-demand skills for sustainable agri-food, including seven core skill sets that are needed across the agri-food sector and occupation-specific skill sets for the top 20 most in-demand roles. Finally, Section II discusses measures needed to address agri-food labour shortages and increase attraction to the sector.

DEFINING SUSTAINABILITY IN THE CONTEXT OF AGRICULTURE

Originating in the forestry industry, the term "sustainability" was first used by ecologists and biologists to describe the idea of never harvesting more than what the forest can regenerate.[6] This idea was similarly discussed by economists concerned about population growth and resource scarcity. In 1798, Thomas Malthus published his theory on the "Principle of Population," which discusses "looming mass starvation" due to the "inability of available agricultural land to feed an expanding population."[7][8] It wasn't until the 1980s that the term gained increasing popularity at the World Commission on Environment and Development, where its chairman Gro Harlem Brundtland defined the term as "meeting the needs of the present generation without compromising the needs of future generations."[9]

[6] Kulman, Tom and Farrington, John, "What is Sustainability," 2010, MDPI, https://www.mdpi.com/2071-1050/2/11/3436
[7] Kulman, Tom and Farrington, John, "What is Sustainability," 2010, MDPI, https://www.mdpi.com/2071-1050/2/11/3436
[8] "Malthusian Theory of Population," March 2023, Vedantu, https://www.vedantu.com/physics/malthusian-theory-of-population
[9] "Our Common Future," 1987, *United Nations,* https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html

Today, sustainability is used as an all-encompassing term for practices that help meet the needs of our current society, economy, and environment without compromising the needs of future societies, economies, and environments.[10] In this case, social sustainability seeks to ensure "the continued satisfaction of basic needs—food, water, shelter—as well as higher level social and cultural necessities such as freedom, education, employment, and recreation."[11] Economic sustainability seeks to ensure "that future generations have at least the same potential economic opportunities to achieve welfare as the current generation."[12] Environmental sustainability prioritizes the "maintenance of important environmental functions, and hence the maintenance of the capacity of [nature] to provide those functions."[13]

Sustainable agricultural practices, then, include agricultural practices that enable us to feed present and future generations while also keeping within the nine planetary boundaries.[14] In addition to using profit margins to measure success, sustainable agricultural systems further prioritize environmental stewardship and social responsibility.[15]

Some key aspects of sustainable agricultural systems include:

1. Sustainable resource use
2. Reduced ecological footprint
3. Balanced long and short-term efficiency
4. Productive and ethical use of human capital
5. Efficiency-related technologies[16]

Importantly, sustainable agricultural practices come in many different forms. While regenerative and organic agriculture are two commonly used terms when discussing sustainable food production systems, many diverse practices and tools can enable some or all of the above objectives. For instance, precision agriculture, controlled environment agriculture, plant breeding, and no-till are all tools and practices that contribute to sustainable food production in valuable ways, making it important to recognize that food production does not necessarily need to be "regenerative" or "organic" to be sustainable.

[10] "Our Common Future," 1987, *United Nations,* https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html
[11] Brown, Becky et al., "Global Sustainability: Toward Definition," Environmental Management, https://www.researchgate.net/publication/226879595_Global_Sustainability_Toward_Definition
[12] Williams, Evan, "Blue print for a sustainable economy," 2001, *Wiley Online Library,* https://onlinelibrary.wiley.com/doi/10.1002/bse.299
[13] Ekins, Paul, "Environmental Sustainability," 2011, Progress in Physical Geography, https://www.researchgate.net/publication/273922812_Environmental_sustainability
[14] Springmann, Marco et al., "Options for keeping the food system within environmental limits," October 2018, https://www.nature.com/articles/s41586-018-0594-0; "Report submitted by the Special Rapporteur on the right to food, Olivier De Schutter," December 2010, UN General Assembly, https://www2.ohchr.org/english/issues/food/docs/a-hrc-16-49.pdf; "The nine planetary boundaries," 2023, *Stockholm Resilience Centre,* https://www.stockholmresilience.org/research/planetary-boundaries/the-nine-planetary-boundaries.html
[15] "Green Agriculture: foundations for biodiverse, resilient and productive agricultural systems," 2011, *Taylor and Francis Online,* https://www.tandfonline.com/doi/abs/10.1080/14735903.2011.610206
[16] "Green Agriculture: foundations for biodiverse, resilient and productive agricultural systems," 2011, *Taylor and Francis Online,* https://www.tandfonline.com/doi/abs/10.1080/14735903.2011.610206

SUSTAINABILITY IN CANADA'S AGRI-FOOD SECTOR

SECTION 1

HOW HAS SUSTAINABILITY CHANGED OVER TIME?

Globally, food and agriculture have a profound impact on the environment. It is estimated that the food and agriculture system accounts for 21% to 37% of global GHGs,[17] with crop and livestock activities accounting for 9–14% of this, land use and land-use change accounting for 5–14%, and supply chain activities accounting for 5–10%. In addition to GHGs, food and agriculture also account for 70% of freshwater use[18] and use more than 50% of the world's habitable land.[19] The food system is therefore a "major driver of climate change, changes in land use, depletion of freshwater resources, and pollution of aquatic and terrestrial ecosystems through excessive nitrogen and phosphorus inputs."[20] Moreover, it is "the primary driver of biodiversity loss," "with agriculture alone being the identified threat to 86% or 24,000 of the 28,000 species at risk of extinction."[21]

In the Canadian context, much of the adverse environmental impacts of agriculture have been associated with run-off from farms or waste mismanagement. Research shows that watersheds near primary agricultural land have higher levels of synthetic toxins (e.g., organophosphorus and organochlorides) and nutrients (e.g., ammonia, phosphorus, and nitrogen) than watersheds upstream or downstream from agricultural production sites.[22] This is especially true for wet regions with greater precipitation, like the Maritimes, Ontario, Quebec, the Red River Region of Manitoba, the Parkland region of Alberta, and the Lower Fraser River Valley region

[17] "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, 20199, IPCC, https://www.ipcc.ch/srccl/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

[18] "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

[19] Ritchie, H. and Roser, M., "Land Use," September 2019, Our World in Data, https://ourworldindata.org/land-use

[20] Springmann, Marco et al., "Options for keeping the food system within environmental limits," 2018, *Nature,* https://www.nature.com/articles/s41586-018-0594-0

[21] "Our global food system is the primary driver of biodiversity loss," Feb 2021, *UNEP,* https://www.unep.org/news-and-stories/press-release/our-global-food-system-primary-driver-biodiversity-loss

[22] Jones, A et al., "Zooplankton assemblage and body size responses to severe lake eutrophication from agricultural activities near mink farms in Nova Scotia, Canada Get access Arrow," May 2022, *Oxford Academic,* https://academic.oup.com/plankt/article-abstract/44/3/464/6584520?redirectedFrom=fulltext

in British Columbia,[23] where toxins and nutrients from agriculture have resulted in biodiversity loss and cascading ecological effects across many rivers, streams, and lakes.[24] In Lake Erie, for example, excess nutrient inputs have caused several accounts of harmful algal blooms, where cyanobacteria (algae) grows out of control, releasing toxins and reducing oxygen content, ultimately contaminating and killing fish, shellfish, amphibians, birds, and mammals.[25] Harmful algal blooms have occurred in other provinces, too, like in Nova Scotia, where mink farms disposed of waste products into nearby waterways.[26] Run-off of harmful substances from agricultural lands has also threatened the quality of drinking water and food sources (e.g., fish), tourism, and recreation. [27]

Despite health and safety risks associated with toxic agricultural inputs like pesticides, herbicides, and fungicides, the overall use of these inputs across Canada continues to increase.[28] Just between 2008 and 2010, pesticide sales across Canada increased by 13.9%. This isn't necessarily because farmers are applying pesticides and herbicides in excess. Instead, it is the result of agricultural expansion (more land being farmed) and changes in agricultural practices. For example, over the past 40 years, there has been a "shift away from livestock – cattle in particular – toward food crops, which require more inputs."[29] In addition to this, the adoption of no-till and minimal-till practices across the prairies, while positive for carbon sequestration and soil health,[30] increase reliance on pesticides.[31] Similarly, nitrogen inputs and their associated risks of contamination have increased over time in Canada.[32] Luckily, phosphorus use and its associated risks to the environment have declined in southern Ontario, helping to improve water quality in places like Lake Erie. That said, phosphorus use and contamination in other regions like Quebec and Atlantic Canada have increased.[33] Members of ICTC's advisory committee suggest that switching to biological pesticides, which are derived from natural sources like bacteria and fungi, would help reduce the environmental impacts of

[23] "Pesticides Indicator," April 2022, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/water/pesticides-indicator

[24] Rouse, JD et al., "Nitrogen pollution: an assessment of its threat to amphibian survival.," October 1999, *Environmental Health Perspectives,* https://ehp.niehs.nih.gov/doi/abs/10.1289/ehp.99107799; Parris, Kevin, "Impact of Agriculture on Water Pollution in OECD Countries: Recent Trends and Future Prospects," Feb 2011, Taylor and Francis Online, https://www.tandfonline.com/doi/full/10.1080/07900627.2010.531898; Jones, A et al., "Zooplankton assemblage and body size responses to severe lake eutrophication from agricultural activities near mink farms in Nova Scotia, Canada Get access Arrow," May 2022, Oxford Academic, https://academic.oup.com/plankt/article-abstract/44/3/464/6584520?redirectedFrom=fulltext

[25] Mohammed, Mohammed, N et al., "Understanding and managing the re-eutrophication of Lake Erie: Knowledge gaps and research priorities," December 2019, *Freshwater Perspectives and Chicago Journals,* https://www.journals.uchicago.edu/doi/abs/10.1086/705915; Allan, David J et al., "Assessing and addressing the re-eutrophication of Lake Erie: Central basin hypoxia," June 2014, *Science Direct,* https://www.sciencedirect.com/science/article/pii/S0380133014000252; https://www.jswconline.org/content/70/2/27A.short

[26] Jones, A et al., "Zooplankton assemblage and body size responses to severe lake eutrophication from agricultural activities near mink farms in Nova Scotia, Canada Get access Arrow," May 2022, *Oxford Academic,* https://academic.oup.com/plankt/article-abstract/44/3/464/6584520?redirectedFrom=fulltext

[27] Watson, Susan B et al., "The re-eutrophication of Lake Erie: Harmful algal blooms and hypoxia," June 2016, *Science Direct,* https://www.sciencedirect.com/science/article/abs/pii/S1568988315301141

[28] "Pesticides Indicator," April 2022, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/water/pesticides-indicator#b

[29] "Pesticides Indicator," April 2022, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/water/pesticides-indicator#b

[30] May, William et al., "No-Till Farming Systems in the Canadian Prairies," September 2020, *Springer,* https://doi.org/10.1007/978-3-030-46409-7_33

[31] "Pesticides Indicator," April 2022, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/water/pesticides-indicator#b

[32] Nitrogen Indicator," April 2022, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/water/nitrogen-indicator

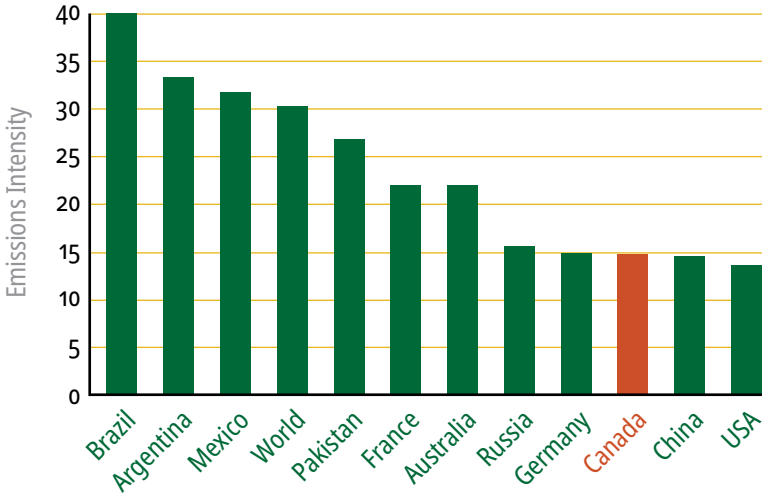
[33] "Phosphorus Indicator," April 2022, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/water/phosphorus-indicator

agriculture while increasing sustainable food production. Unfortunately, agri-food stakeholders engaged in this study explained that biopesticides are not readily available in Canada.

Over the years, statistics like these have led many consumers to perceive agriculture as inherently unsustainable. While many negative perceptions of ag persist, evidence suggests that certain aspects of Canadian agriculture have become more sustainable over time. In 2022, Statistics Canada reported that sustainable practices are "becoming a hallmark of the agriculture industry."[34] In response to the 2020 Census of Canadian Agriculture, 64.5% of Canadian farms reported using land practice methods (compared to just 53.7% in 2016), including in-field winter grazing or feeding, rotational grazing, plowing down green crops, planting winter cover crops, and having shelterbelts or windbreaks.[35] The number of farms that reported producing organic products also increased, as has the number of farms reporting the use of renewable energy production. In 2016, 2.2% of Canadian farms reported growing produce organically, compared with 3% in 2020. Moreover, 5.2% of farms reported renewable energy production in 2016, which more than doubled by 2020 to 11.9%.

Evidence also suggests that certain aspects of Canadian agriculture are more sustainable than that of other regions around the world. For example, as shown in Figure 1, Canadian beef, milk, and egg production is more carbon efficient, emitting less carbon per kilogram of product than that of other large beef, milk, and egg producers. As will be shown later in this section, time series data also shows that the energy intensity, land intensity, and emissions intensity of agricultural production have decreased over time.

Meat of Cattle with the Bone, Fresh or Chilled



[34] "Canada's 2021 Census of Agriculture: A story about the transformation of the agriculture industry and adaptiveness of Canadian farmers," May 2022, *Statistics Canada,* https://www150.statcan.gc.ca/n1/daily-quotidien/220511/dq220511a-eng.htm
[35] "Canada's 2021 Census of Agriculture: A story about the transformation of the agriculture industry and adaptiveness of Canadian farmers," May 2022, *Statistics Canada,* https://www150.statcan.gc.ca/n1/daily-quotidien/220511/dq220511a-eng.htm

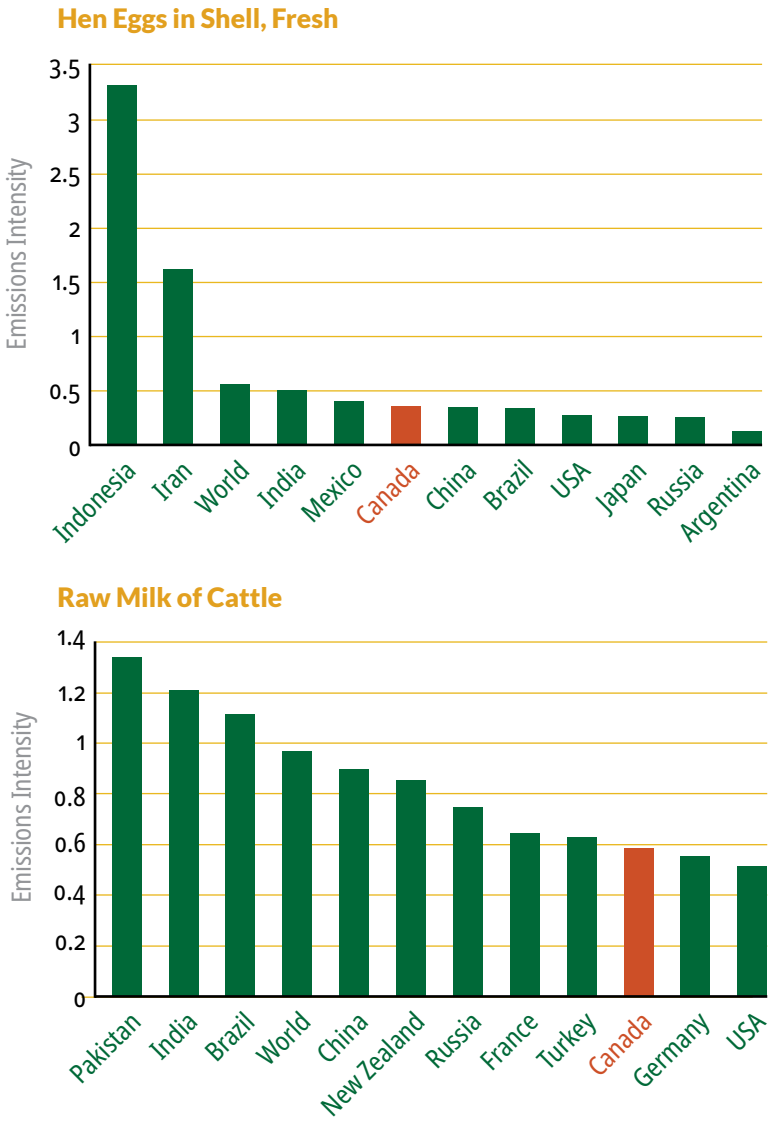


Figure 1. *The emissions intensity (kg CO2eq/kg product) of Canadian agricultural products for the year 2020 in comparison with the top producers (measured in kilotonnes of output) of this product globally. Data source: "Emissions Intensities," 2023, Food and Agriculture Organization of the United Nations, https://www.fao.org/faostat/en/#data/EI*

While constrained by external forces, like pressure to apply synthetic inputs to meet food demand, the reality is that food and agriculture producers have been practicing sustainability for some time. This sentiment was reflected by interviewees in this study, who expressed that sustainability has always been a fundamental part of agriculture and that agricultural producers are not recognized enough for their contributions to sustainability or for their work as stewards of the land. As one interviewee noted, while there may be a larger focus on sustainability practices and precision technologies in recent years, generally, farmers have been ahead of the curve on sustainability, with soil conservation, water conservation, and no-till production being prominent examples. Moreover, they noted that while the public is more interested in what farmers are doing today, sustainability has always been a foundation of agriculture.

One of the reasons why sustainability has always been a part of agriculture is because, often, what is good for the environment is good for agricultural producers—either because it helps preserve assets such as the land or because it makes economic sense. As one interviewee said, "People don't really appreciate that if the land is your livelihood and you don't take care of it, you won't have a livelihood, and you could lose it forever." Likewise, several interviewees provided examples of sustainability practices that, in addition to being good for the environment, make economic sense:

> "Every time a farmer produces the same amount of beef with a pound less [of feed], they make more money… Every time a grain farmer can just partially spray instead of spraying their whole field, they save money. Our motivation for doing [these things] is doing the right thing to some extent, but it's also very financially smart." — **SUSTAINABLE AGRI-FOOD EXPERT**

> "In addition to rising fuel and diesel prices this year, the global cost of many inputs—fertilizers especially—for agricultural crop production also increased this year, making it challenging for producers to decide what to apply. Reducing excess fertilizer application where possible is not only a cost saving but has many environmental benefits too." — **SUSTAINABLE AGRI-FOOD EXPERT**

> "Sustainability will always be important in agriculture… There's a huge economic incentive for farmers. They don't want to burn through fuel and fertilizer. Those are all expensive inputs, and they want to do everything they can to minimize their use. They don't use an excess of those because they have to pay for them. It comes out of their bottom line." — **SUSTAINABLE AGRI-FOOD EXPERT**

> "From an animal perspective, more methane will come from a cow if it's not healthy, and a healthier cow will gain more weight. Again, there's an economic reason [attached to it]." — **SUSTAINABLE AGRI-FOOD EXPERT**

While sustainability has always been a priority in Canadian agriculture, our understanding of sustainability is constantly evolving, creating a need for new information, practices, and technological solutions that can be leveraged to increase sustainability in agriculture.

TECHNOLOGY'S ROLE IN SUSTAINABLE AG

Despite evidence that farmers have been practicing sustainability for quite some time, it hasn't always been easy for farmers to understand their environmental footprint without the information and tools to do so. Each year, new scientific breakthroughs and innovations contribute to our understanding of agriculture and its links to sustainability. As one academic interviewee said, "Agriculture has always had a sustainability focus. But the issue here is that our understanding of sustainability is constantly evolving. When you think about the complexity of social ecological systems, which is where agriculture operates, it's constantly changing. And our understanding of the system is incomplete."

While our understanding of agricultural systems may still be incomplete, it has certainly grown over time. New research has allowed farmers to better understand and manage their environmental impacts. For instance, in the early and mid-1900s, applying toxic pesticides in abundance was seen as a positive because it helped increase agricultural production and addressed food insecurities.[36] It wasn't until the 1960s, when scientists such as Rachel Carson revealed the adverse environmental and human health impacts of toxic inputs, that the agricultural community began shifting their dependence on such toxins.[37] This information shift also propelled the field of pest management, whereby scientists began working to understand new management systems to control pests while reducing reliance on toxic pesticides.

As described by one of ICTC's interviewees, a similar scenario transpired for soil tillage and the development of no-till practices.

> "So, at one time, we thought it was really important to till the soil to create that nice, crumbly texture so that the plants could grow. And over the course of the last couple of decades, we've come to realize tilling is really bad for soil health. So now we are talking about minimal till, reduced till, and no-till. And that's a result of [developments in] our ecological or scientific understanding of sustainability." — **ACADEMIC EXPERT**

New information has revealed the significant benefits of no-till. Some of the most prominent environmental benefits include increased carbon sequestration, increased soil moisture, increased soil biodiversity, and reduced soil erosion.[38] As was the case in the Canadian prairies, the adoption of no-till, which began in the 1980s, has proven beneficial for economic sustainability as well. As explained by a Saskatchewan-based member of ICTC's advisory committee for this project, the adoption of no-till in the prairies was driven primarily by two factors: (1) cost savings and (2) water savings. Cost savings are the result of having to do fewer passes over a field with machinery, resulting in reduced fuel consumption.[39] Water savings comes from the preservation of crop residue from previous years to help trap snow and moisture in the soil.[40] This is particularly beneficial in the relatively dry prairies, which had lost further soil moisture due to intensive tillage practices over time. An advisory committee member explained that by coupling no-till with herbicide-tolerant crops and variable-rate fertilizer technologies, canola farmers in Western Canada have moved beyond being net zero to sequestering more carbon than they emit. Agriculture Canada's researcher, Brian McConkey, explained that the increase in soil organic carbon sequestration in the Canadian prairie accounts for 11 million tons of CO_2, reducing the nation's GHG emissions by 1.5% a year.[41]

[36] Oerke, E. C. and Dehne, H. W.,"Safeguarding production – loses in major crops and the role of crop protection, 2005, *Crop Protection and Science Direct,* https://linkinghub.elsevier.com/retrieve/pii/S0261219403002540
[37] Carson, Rachel, "Silent Spring," 1962, *Penguin Modern Classics,* London, England
[38] Baker, CJ et al., "No-tillage Seeding in Conservation Agriculture: 2nd edition," *Food and Agriculture Organization of the United Nations,* https://naldc.nal.usda.gov/download/47736/PDF
[39] May, William et al., "No-Till Farming Systems in the Canadian Prairies," September 2020, *Springer,* https://doi.org/10.1007/978-3-030-46409-7_33
[40] May, William et al., "No-Till Farming Systems in the Canadian Prairies," September 2020, *Springer,* https://doi.org/10.1007/978-3-030-46409-7_33
[41] Booker, Robin, "Canadian canola has carbon advantage," December 2015, *The Western Producer,* https://www.producer.com/news/canadian-canola-has-carbon-advantage/

The idea that technology can positively impact economic, social, and environmental sustainability was commented on by several interviewees. Many comments specifically discussed how tech could reduce the inputs needed for farming operations, resulting in environmental and economic benefits. One agri-food technology employer described this as a key aspect of their value proposition:

> "So, I think tools that make things more precise are going to be [increasingly] valuable [for sustainability]. Even things like autosteer [make a] huge difference because if you were driving on a prairie farm, you're going to have mile-long fields. And before [autosteer], when you had to steer by hand, you had overlaps [in resource allocation] … and you could essentially waste 10%. But now, with new tech, you've got a two-inch accuracy [in application], so those overlaps are gone. And so, things like GPS brought a lot of precision into ag, [showing that] you can reduce fertilizer use by 10% just by preventing overlaps." — **AGRI-FOOD TECHNOLOGY EMPLOYER**

> "Especially variable rate technology [to vary the rate of application of inputs such as fertilizers, pesticides, or seed, based on site-specific conditions rather than applying the same rate uniformly across a field] embedded in tractors and combines [is beneficial for sustainability]. And [I think] over 90% of the tractors are autosteer now.... You [can] make up the upfront cost [of the technology] because the profitability of that is massive." — **FARMER**

As shown in the following timeline, other key innovations and technological developments like plant breeding, cover cropping, and GMOs have further contributed to the evolution of sustainability in Canada's agri-food sector (Figure 2.):

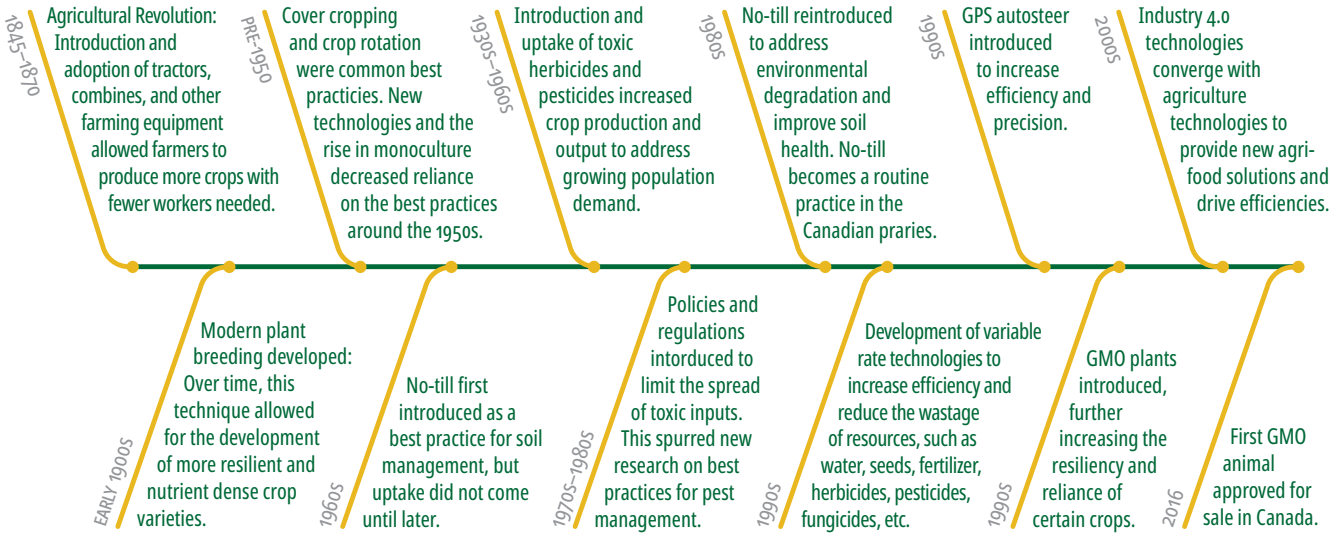


Figure 2. *Evolution of sustainability in the agri-food sector as new information and technologies were developed.*[42]

[42] Hamre & Asselstine, "Agricultural Implements Industry," 2006, The Canadian Encyclopedia, https://www.thecanadianencyclopedia.ca/en/article/agricultural-implements-industry; Kuchta, D., "What is Monocropping and Why is it Bad for the Environment?" 2021, https://www.treehugger.com/how-monocropping-harms-the-environment-5193191; Miner, J. "150 years later, agriculture in Canada has changed radically," 2017, Farmers Forum, https://farmersforum.com/150-years-later-agriculture-in-canada-has-changed-radically/; May, W. et al., "No-Till Farming Systems in the Canadian Prairies" In: Dang et al., "No-till Farming systems for Sustainable Agriculture," https://link.springer.com/chapter/10.1007/978-3-030-46409-7_33; "Saving Space and Time: The Tractor That Einstein Built," 2006, NASA Technology Transfer Program, https://spinoff.nasa.gov/Spinoff2006/er_5.html; Kumar et al., "Introduction of GPS/GNSS technology," 2021, https://reader.elsevier.com/reader/sd/pii/B9780128186176000019; Zambon et al., "Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs," 2018, https://www.mdpi.com/2227-9717/7/1/36/htm; "Genetically Modified Foods," 2015, Forsberg, Cecil, *The Canadian Encyclopedia,* https://www.thecanadianencyclopedia.ca/en/article/genetically-modified-foods

The above timeline highlights that, over the years, food science and information and communications technology have converged with agricultural innovation, leading to new sustainability practices that are technology driven. Four of these practices—precision agriculture, quality control and identify preservation, cellular agriculture, and controlled environment agriculture—were discussed extensively by interviewees. Building on interviewee remarks and academic literature, these practices are expanded upon below.

PRECISION AGRICULTURE

Precision agriculture is a farm management strategy that seeks to "take the intuition and guesswork out of farming by harnessing the power of big data."[43] 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 agricultural processes and decision making. Included in this suite of technologies are GPS, sensors, big data and AI, application programming interfaces (APIs), broadband infrastructure, and high-tech farming equipment.

Sustainability Impacts

At its core, precision agriculture is an efficiency-oriented strategy. Its goal is to make agricultural production more efficient by enabling farmers to produce more using less—less water, energy, fertilizer, pesticides, and other agricultural inputs. Because the consumption of agricultural inputs puts strain on the natural environment, practices that seek to use less of them inherently increase sustainability. Growing fields are not uniform, and different parts of a field may need more or less fertilizer or manure based on their slope, soil texture, drainage, salinity, stoniness, and soil organic matter.[44] Variable rate technology, for example, uses geographic and agricultural data to determine how much fertilizer or manure is needed at specific locations on a field.[45] By reducing fertilizer and/or manure use, variable rate technology can reduce financial costs for farmers while reducing the environmental impact of agricultural production.

Labour Impacts

Precision agriculture technologies are driving the need for technology-related skills in ag. This applies both to the development of precision agriculture solutions by agri-food technology companies and to the adoption and maintenance of solutions on the farm. On the product development side, precision agriculture companies require workers with a unique combination of agriculture and technology skills, including agronomy, soil science, crop production, software development, GIS, maths, and data science. Common roles include agronomist, precision agronomist, software developer, data scientist, data analyst, data technician, product manager,

[43] "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
[44] "Variable rate nutrient application : Should I consider it for my farm," January 2020, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/soil-and-land/soil-nutrients/variable-rate-nutrient-application-should-i-consider-it-my-farm
[45] "Variable rate nutrient application : Should I consider it for my farm," January 2020, *Agriculture and Agri-Food Canada,* https://agriculture.canada.ca/en/agricultural-production/soil-and-land/soil-nutrients/variable-rate-nutrient-application-should-i-consider-it-my-farm

sales manager, and integrated solutions consultant.[46] Agri-food producers, on the other hand, need workers who know how to use precision agriculture technologies, which may include interfacing with software programs or hardware, inputting, interpreting, and analyzing data, and troubleshooting technical problems. Here, common roles include branch manager, operations lead, production advisor, technician, mechanic, agricultural labourer, and consultant.[47]

CONTROLLED ENVIRONMENT AGRICULTURE

Controlled environment agriculture (CEA) is an indoor, technology-based approach to agricultural production where crops are grown in a modified and highly conditioned environment.[48] CEA can take many forms but most commonly includes greenhouses, vertical farms, growth chambers, hydroponics, aeroponics, and aquaponics. Using CEA technologies, agricultural producers can control things like humidity, water, CO_2, ventilation, temperature, and light, enabling them to not only overcome unfavourable climates and weather patterns but also grow produce in ideal settings at maximum efficiency and productivity. Because of this, CEA enables farmers to grow food year-round, with more regular harvests and grow in places where they were previously unable to, such as in cities, urban areas, and places without the appropriate geography, climate, or soil.

Sustainability Impacts

CEA takes place within a closed-loop growing system where there is less water loss from evaporation, and water (and nutrients) can be easily recycled. Because of this, CEA is estimated to use up to 90% less water than conventional greenhouses and up to 99% less water than open field growing.[49]

CEA is also estimated to use less land than conventional agriculture and could potentially reduce agriculture's impact on land-use change and therefore biodiversity loss. Vancouver-based Verticrop, for example, estimates that it can produce the output equivalent of a 16-acre farm using just one standard residential lot (50 by 75 feet)—using 5% of the non-CEA surface area.[50] This is because CEA prompts farmers to build upwards instead of outwards by stacking multiple growing units on top of one another.

Finally, because CEA takes place within closed, compact systems and often without the use of soil, plants grown using CEA are protected from adverse weather, pests, and weeds, thereby reducing or eliminating the need for pesticides, herbicides, fertilizers, and heavy machinery.[51]

[46] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf
[47] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf
[48] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf;
[49] Gan, Caixia et al., "Sustainability Framing of Controlled Environment Agriculture and Consumer Perceptions: A Review," 2023, *MDPI,* https://www.mdpi.com/2071-1050/15/1/304
[50] Benke, Kurt, "Future food-production systems: vertical farming and controlled-environment agriculture," May 2014, *Taylor and Francis Online,* https://www.tandfonline.com/doi/full/10.1080/15487733.2017.1394054
[51] Gan, Caixia et al., "Sustainability Framing of Controlled Environment Agriculture and Consumer Perceptions: A Review," 2023, *MDPI,* https://www.mdpi.com/2071-1050/15/1/304

Despite the purported benefits of CEA, controlled environment systems have high energy requirements when compared to conventional agriculture. Whether CEA is more sustainable than conventional agriculture should be decided on a case-by-case basis based on whether the system uses renewable or non-renewable energy, proximity to the target market, the scale of production, and to what extent existing infrastructure and buildings are repurposed.[52] In this study, two interviewees highlighted strategies they use to make CEA more sustainable, including:

- Recycle water, nutrients, and CO_2
- Use energy efficiency technologies, such as LED lights and technologies that track, analyze, and optimize energy use
- Build farms where there is a clean energy supply
- Build farms close to distribution centres and grocers to reduce transportation-based emissions
- Build relationships with local businesses to source inputs and supply food locally
- Grow produce that is normally imported from distant suppliers

Labour Impacts

CEA could profoundly impact the horticulture industry and the horticultural labour market. Because CEA enables farmers to grow year-round, with weekly as opposed to annual or biannual harvests, it reduces the seasonality of many agricultural roles.[53] It also enables agriculture to be proximate to large urban areas, giving urban populations better access to agricultural roles. Beyond this, CEA changes the types of roles that are required for horticultural production. Among other things, controlled environment systems need workers to plan and engineer growing environments and install and maintain water, ventilation, heating, and cooling systems.[54] Finally, many aspects of CEA are high-tech and/or can be automated, shifting skills requirements from traditional agricultural tasks to automation, robotics, computer science, AI, and software engineering.

[52] Gan, Caixia et al., "Sustainability Framing of Controlled Environment Agriculture and Consumer Perceptions: A Review," 2023, MDPI, https://www.mdpi.com/2071-1050/15/1/304; Vastisas, Christos, "A Systematic Literature Review on Controlled-Environment Agriculture: How Vertical Farms and Greenhouses Can Influence the Sustainability and Footprint of Urban Microclimate with Local Food Production," 2022, MDPI, https://www.mdpi.com/2073-4433/13/8/1258

[53] "AMA With Aaron Fields: What are the Benefits of Controlled Environment Agriculture?" February 2023, *Eden Green Technology,* https://www.edengreen.com/blog-collection/ama-with-aaron-fields-what-are-the-benefits-of-controlled-environment-agriculture

[54] Benke, Kurt, "Future food-production systems: vertical farming and controlled-environment agriculture," May 2014, *Taylor and Francis Online,* https://www.tandfonline.com/doi/full/10.1080/15487733.2017.1394054

CELLULAR AGRICULTURE

Over the past few decades, a variety of new "alternative protein" products have been introduced to the market, such as plant-based meat,[55] fermentation-based proteins,[56] and cellular agriculture. The last of these—cellular agriculture—was the most recently introduced, having only been approved for sale for the first time globally in Singapore in December 2020.[57]

As described in Newman and Fraser's book Dinner on Mars, there are two approaches to cellular agriculture.[58] One approach is known as tissue farming, using cultures of animal cells or "tissues"' to generate meat and dairy products that are identical to conventional meat and dairy at the cellular level.[59] The second approach is known as acellular agriculture and involves the use of yeast, fungus or bacteria and animal DNA modified in a manner that converts sugars into animal proteins, creating animal-free acellular products like casein.[60] Both processes enable the production of animal products like chicken nuggets or casein (a family of related phosphoproteins that are commonly found in mammalian milk) without raising an animal.

For Canada, cellular agriculture represents an opportunity to produce and export new agri-food products, create new companies and IP, and address challenges related to food security.[61] According to not-for-profit Ontario Genomics, by 2030, Canada's cellular agriculture industry could generate between $1.5 and $7.5 billion per year and create between 3,600 and 86,000 jobs.[62] The growth of the cellular agriculture industry in Canada will depend on developments in agri-food policies that determine when and to what extent cellular agriculture products reach Canadian food markets.

In response to a survey in 2021, 44% of Canadians indicated they had tried to consume less meat over the past year, and 77% indicated that they had purchased more alternative meat products.[63] A survey conducted in 2022 also found that 28% of Canadians had sought information about plant-based foods and meat alternatives at some point during the previous six months. Notably, younger Canadians aged 18 to 23 are driving the trend toward alternative proteins.

[55] Plant-based meat is composed of protein, fat, vitamins, minerals, and water, and is produced from plants and plant materials using high-tech food processing techniques. See: "Plant-based Meat," 2021, Good Food Institute, https://gfi.org/plant-based/

[56] Fermentation-based proteins are generated through traditional fermentation, biomass fermentation, and/or precision fermentation, which use microorganisms to change the flavour of food, produce specific ingredients, and more. See: "Fermented Meat," 2021, Good Food Institute https://gfi.org/fermentation/

[57] "Eat Just Granted World's First Regulatory Approval for Cultured Meat," December 2020, *Business Wire*, https://www.businesswire.com/news/home/20201201006251/en/Eat-Just-Granted-World%E2%80%99s-First-Regulatory-Approval-for-Cultured-Meat

[58] Newman, Leonore and Fraser, Evan, "Dinner on Mars: The technologies that will feed the red planet and transform agriculture on Earth," *EWC Press, Toronto, Canada.*

[59] "Cultivated Meat," 2021, Good Food Institute https://gfi.org/cultivated/

[60] "Cellular Agriculture Insight Report Backgrounder," 2021, *Canadian Centre for Food Integrity,* https://www.foodintegrity.ca/wp-content/uploads/2021/05/Cellular-Agriculture-Insight-Report.pdf

[61] "Cellular Agriculture: Canada's $12.5 billion opportunity in food innovation," November 2021, *Ontario Genomics,* https://www.ontariogenomics.ca/wp-content/uploads/2021/11/CELL_AG_REPORT_FULL-FINAL.pdf

[62] "Cellular Agriculture: Canada's $12.5 billion opportunity in food innovation," November 2021, *Ontario Genomics,* https://www.ontariogenomics.ca/wp-content/uploads/2021/11/CELL_AG_REPORT_FULL-FINAL.pdf

[63] "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

Research by the Canadian Centre for Food Integrity (CCFI) finds that younger Canadians are "significantly more likely" to seek out grocery stores, restaurants, and recipes that offer plant-based or meat alternatives options.[64]

While conventional meat is likely to remain the dominant form of protein in developed markets for the foreseeable future,[65] demand for alternative proteins is likely to grow, presenting a market opportunity for agri-food producers. According to estimates by the Boston Consulting Group, the alternative protein market will reach at least US$290 billion by 2035.[66]

Sustainability Impacts

While there is still a need to prove business models and assess energy use at scale, advocates for cellular agriculture maintain that it is less energy, water, and emissions intensive than conventional meat and dairy production[67] and therefore critical in reducing the environmental impacts associated with the livestock industry.[68] Global consumption of meat and dairy products has skyrocketed over the past 50 years, resulting in increased GHG emissions, freshwater withdrawals, and land use.[69] While meat and dairy are a valuable source of protein for many Canadians, research shows that meat and dairy use more land and emit more GHGs per unit of protein than plant-based proteins do.[70] With the exception of nuts, meat and dairy products also use more water.[71]

According to food system researchers, replacing conventional animal products with less intensive food types can help reduce the environmental impact of the food system. Diets with less meat and more fruits, vegetables, nuts, and legumes could reduce GHG emissions by 56% while reducing other environmental impacts (e.g., cropland use, water use, nitrogen application, and phosphorus application) by 6% to 22%.[72] The Intergovernmental Panel on Climate Change, too, notes that healthy and sustainable diets that are "high in coarse grains, pulses, fruits and vegetables, and nuts and seeds and low in energy-intensive animal-sourced and discretionary foods," which presents a major opportunity to reduce GHGs stemming from the global food system.[73]

[64] "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

[65] Ritchie, H. and Roser, M., "Meat and Dairy Production," November 2019, Our World in Data, https://ourworldindata.org/meat-production; "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

[66] Morach, Benjamin et al., "Food for Thought: The Protein Transformation," March 2021, *Boston Consulting Group,* https://www.bcg.com/en-ca/publications/2021/the-benefits-of-plant-based-meats

[67] "Cellular Agriculture: Canada's $12.5 billion opportunity in food innovation," November 2021, *Ontario Genomics*, https://www.ontariogenomics.ca/wp-content/uploads/2021/11/CELL_AG_REPORT_FULL-FINAL.pdf

[68] "Cellular Agriculture," 2023, Cellag, https://www.cellag.ca/cellagabout; "Cellular Agriculture: Canada's $12.5 billion opportunity in food innovation," November 2021, *Ontario Genomics,* https://www.ontariogenomics.ca/wp-content/uploads/2021/11/CELL_AG_REPORT_FULL-FINAL.pdf

[69] Ritchie, H. and Roser, M., "Environmental impacts of food production," June 2021, Our World in Data, https://ourworldindata.org/ environmental-impacts-of-food?country=

[70] 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." See: 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-EfficientAg-GHG-Solutions-Provider_WEB.pdf

[71] Ritchie, H. and Roser, M., "Environmental impacts of food production," June 2021, Our World in Data, https://ourworldindata.org/environmental-impacts-of-food

[72] Springmann, Marco et al., "Options for keeping the food system within environmental limits," October 2018, https://www.nature.com/articles/s41586-018-0594-0

[73] Special Report: Special Report on Climate Change and Land: Chapter 5 Food Security," August 8, 20199, *IPCC,*

Labour Impacts

The skills and knowledge required for cellular agriculture are exceptionally different from those needed for conventional ag. Cellular agriculture is a highly scientific field "broadly founded on knowledge, tools, and engineering biology methodologies."[74] Engineering biology is "a cross-sectoral platform technology built on the convergence of... genomics, proteomics, metabolomics, molecular biosciences, engineering disciplines, computing, AI, miniaturization, robotics, and automation."[75] A short visit to a cellular agriculture job board reveals the highly scientific nature of this field, featuring job titles such as research associate, research scientist, cell line development engineer, lab operations technician, science operations manager, mechatronics engineer, research and resource manager, post-doctoral bioengineer, and head of food technology.[76]

QUALITY CONTROL AND IDENTITY PRESERVATION

Quality control and identity preservation are inherent to making agriculture more sustainable. Quality control helps ensure that sustainable agricultural practices are followed and that they have the desired environmental impacts. Identity preservation, meanwhile, enables agri-food producers and manufacturers to track their productions throughout the supply chain (and, in turn, differentiate between products that were or were not produced sustainably). In this way, identity preservation helps agri-food producers meet regulatory obligations, access sustainability-oriented markets, and in some cases, pass costs onto consumers.

Agri-food businesses use many technologies to track the movement of their products, including barcodes, RFID, QR codes, geotags, and blockchain-based record management tools.[77] One Canadian company, Index Biosystems, even uses biotechnology to "imprint identify onto products": the company's "BioTags," which are made of yeast, can be mixed with or sprayed onto products to "achieve rapid source-of-origin identification without...packaging" and "verify the...sustainable production of global commodities."[78]

Sustainability Impacts

While there are many ways to preserve the identity of sustainable food products, one point of contention in industry is what metrics should be used to define something as sustainable and, in turn, what should be part of an effective quality control program.

https://www.ipcc.ch/srccl/chapter/chapter-5/

[74] "Cellular Agriculture: Canada's $12.5 billion opportunity in food innovation," November 2021, *Ontario Genomics,* https://www.ontariogenomics.ca/wp-content/uploads/2021/11/CELL_AG_REPORT_FULL-FINAL.pdf

[75] "Cellular Agriculture: Canada's $12.5 billion opportunity in food innovation," November 2021, *Ontario Genomics,* https://www.ontariogenomics.ca/wp-content/uploads/2021/11/CELL_AG_REPORT_FULL-FINAL.pdf

[76] "Latest Cellular Agriculture Jobs," 2023, JobsCellAg, https://jobs.cell.ag/; "Jobs Board," 2023, *Cellular Agriculture Australia,* https://cellularagricultureaustralia.org/jobs/

[77] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf

[78] "BioTags are microscopic barcodes made from baker's yeast that preserve the identity of products.," 2023, *Index Biosystems,* https://www.indexbiosystems.com/use-cases/food

Several interviewees brought up tensions between the need to track meaningful and scientifically relevant metrics and the temptation to use metrics that are less scientifically relevant but perhaps easier to calculate or more likely to resonate with consumers. For example, one interviewee brought up the concept of food miles, noting that, while food miles resonate well with consumers, they usually only account for the distance between the final production step and the store, glossing over other factors, such as where agriculture or processing inputs were sourced. While certain metrics are more likely to resonate than others, it is important for companies to recognize that consumers want access to meaningful data: a 2022 survey by CCFI found that just under half (42%) of Canadians are personally concerned about "greenwashing" or misleading information about the environmental soundness of a company's products.[79]

Overall, interviewees felt that existing approaches to quality control are too broad and not transparent or detailed enough. One interviewee commented that "there is much more to look at than what many companies are looking at today" and that "we can't make progress on sustainability until we're fully transparent about those things." That same interviewee brought up an example of carbon emissions, noting that "in most cases today if something has a sustainability label on it, it's probably only talking about scope one or scope two sustainability [emissions]" as opposed to "scope three emissions, which make up a far bigger percentage of everything behind food products." Similarly, another interviewee said that total life cycle assessments require "proper data and measurements" and cautioned that "we don't really have that in Canada."

According to one interviewee, "[sustainability] is not going away" and "is going to get even more detailed." They noted that "it's a digitized world we are living in: people want to know what's going on." This last interviewee provided an example of a project they worked on, where, using QR codes, consumers were given access to detailed information about food products, including what farm the ingredients were from, when the ingredients were planted and harvested, what types of fertilizers were used, and how and where the product was transported and processed. While it would be difficult to apply this type of approach to all products in the agri-food supply chain, the project provides a useful example of how detailed some approaches to sustainability can be.

Labour Impacts

Often, quality control and identity preservation data are required by regulation or used to validate environmental and social governance standards, which are increasingly required by investors, lenders, insurance providers, and grant providers. Interviewees in this study noted that the highly regulated nature of the agri-food sector makes regulatory and legal knowledge, particularly about

[79] " 2022 Public Trust Research," 2022, *Canadian Centre for Food Integrity,* https://www.foodintegrity.ca/wp-content/uploads/2022/10/2022-ENG-Public-Trust-Research-Report.pdf

environmental and food safety, an important skill. Additionally, because quality control often focuses on environmental impact, it generates demand for a variety of science and research-focused roles, including plant, soil, and animal scientists, environmental scientists, lab technicians, and more. Moreover, quality control tracking and identity preservation generate demand for workers who can interpret and analyze data. As explained by one agri-food tech employer, "Sustainability has always been there, but now you have to prove that you're doing it, and that's all related to data tracking and technology." Making use of data will require a variety of skilled workers, including data analysts and data scientists who can integrate data into agri-food technology solutions and decision makers who can incorporate data into agri-food decisions.

Conclusions on Technology and Sustainability:

Over time, global research and development have led to new technologies that can be leveraged to improve the sustainability of farming initiatives. Despite technologies providing individual solutions for agricultural and environmental problems, it is worth noting that technologies are rarely the solution in and of themselves. As stated by Newman and Fraser, "No matter what the theoretical benefits or potential benefits of a technology, technology needs to succeed in the real world and solve real-world problems."[80]

With agri-food tech being a relatively new field, it has some obstacles to overcome before it can reach its full potential. For instance, in a previous study by ICTC,[81] interviewees voiced some concern about the quality of data used in precision agriculture technologies. 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 agricultural outcomes. A second challenge discussed by interviewees was that many precision agriculture solutions still require farmers to collect and/or input data manually. These challenges have been echoed in other studies as well, further emphasizing the challenges with data interoperability and weak broadband connectivity across rural Canada.[82] [83] [84] Considering these challenges, certain agri-food tech companies are working to better integrate their solutions with existing equipment and automate more of their data collection.

[80] Newman, L., Fraser, E. (2022). Dinner on Mars: The technologies that will feed the red planet and transform agriculture on Earth. *EWC Press.* Toronto, Canada.

[81] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf

[82] Lemay, Amy et al., "GROWING AGRI-INNOVATION: Investigating the barriers and drivers to the adoption of automation and robotics in Ontario's agriculture sector," 2021, *Brock University,* https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/Brock-NCO-53-Growing-Agri-Innovation-Nov-2021.pdf

[83] Lemay, Amy et al., "Systemic Barriers and Drivers to Technology Adoption in Canada: Lessons for Agri-Innovation in Ontario from Stakeholders of Canada's Global Innovation Cluster," 2022, *Brock University and Canadian Agricultural Partnership,* https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/NCO-Policy-Brief-55-October-2022-Growing-Agri-Innovation-Lessons-from-Global-Innovation-Clusters-FINAL-WEB.pdf

[84] Lemay, Amy et al., "Systemic Barriers and Drivers to Technology Adoption in Canada: Lessons for Agri-Innovation in Ontario from Stakeholders of Canada's Global Innovation Cluster," 2022, *Brock University and Canadian Agricultural Partnership,* https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/NCO-Agri-Innovation-Final-Report-01.2023-FINAL.pdf

WHO IS DRIVING SUSTAINABLE AG?

PRIMARY AGRI-FOOD PRODUCERS

Climate change has a profound impact on the health of the global food system, which relies on predictable climates, stable weather patterns, clean water, fertile soil, and arable land. Some cascading environmental effects of climate change have included floods and droughts, and other extreme weather events like heat waves. Climate risks and extreme weather events put crop viability at risk. As explained by one interviewee, "We all planted soybeans twice this spring because as soon as the soybeans got in, it dumped rain on us for two weeks. So those soybeans did not come out of the ground, and everybody replanted. So we're looking at late soybean harvest, which then impacts the wheat that you were going to seed early in the fall… and then it impacts your rotation. Like there's a whole lot of things [that happened], and it's all just because it rained." Farmers have been forced to diversify their operations in response to these extreme weather events. This may include farmers planting a variety of crops or having a mixed operation with livestock and crops so as to not "put all their eggs in one basket." This mitigates the risk of losing an entire year's worth of earnings to one extreme weather event. Diversifying crops not only helps economically safeguard farmers but also increases soil diversity and helps naturally manage pests, which are common challenges for monocrop production. Similarly, increased costs of fertilizers, herbicides, and fuel are driving farmers to conserve resources, ultimately improving the economic and environmental sustainability of their farming operations.

CONSUMERS

Research shows that consumers care about the sustainability of their food. In response to a 2022 survey by CCFI, nearly two-thirds (60%) of Canadians indicated that they "always" or "sometimes" seek out grocery store items that use less packaging. Meanwhile, nearly half (46%) indicated that they "always" or "sometimes" seek out items that have a minimal environmental impact, even if they cost more (although price is still the primary consideration in consumer decisions).[85]

Younger Canadians are "driving attitude changes on sustainability."[86] Compared to Canadians above the age of 24, Gen Z Canadians are significantly more likely to seek out food items with less packaging and/or that have a minimal environmental impact.[87] However, whether young Canadians will be willing to pay for sustainably produced food remains yet to be seen, particularly amid rising inflation and food costs. Nonetheless, consumer demand for sustainable food is significant, driving interest in sustainable agricultural practices and new industries like alternative proteins and cellular agriculture.

[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/2022/10/2022-ENG-Public-Trust-Research-Report.pdf
[86] "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
[87] "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

DOWNSTREAM AGRI-FOOD BUSINESSES

Downstream businesses can either incentivize or constrain the ability of primary producers to adopt sustainability practices. In this study, several interviewees brought up examples of cases where downstream businesses required or were willing to pay a premium for sustainably produced products. One interviewee commented that "buyers are looking for [some kind of sustainability designation] because if I want to market my squash to Costco or Sobeys, I need to meet a certain standard before they will even look at my product." This benefits agri-businesses that can prove they are sustainable by collecting and maintaining data about carbon sequestration or other sustainability metrics. Meanwhile, verification processes may disadvantage small-scale farmers who, despite implementing sustainability practices, may not have the means to prove their sustainability and therefore risk being unable to charge a premium for their products. Still, another interviewee noted that not all businesses (e.g., wholesalers, retailers, restaurants, etc.) are willing to pay a premium for sustainably produced products and instead optimize for things like lower costs.

INVESTORS

Like consumers and downstream businesses, investors impact the use of sustainable practices in agriculture through their investment decisions. Investors increasingly want portfolios that are climate-proof (e.g., resilient to the adverse effects of climate change, government responses to climate change, and market shifts) and increasingly factor environmental, social, and governance considerations into investment decisions. These preferences put additional pressure on agri-food businesses to adopt sustainability practices and align with markets that are resilient to climate change and resulting market shifts.

GOVERNMENTS

Governments around the world are introducing new regulations and programs to both reduce the impact of agriculture on the environment and take advantage of positive opportunities within ag, such as carbon sequestration. Table 1 only outlines existing and planned initiatives by the Government of Canada, but similar programs and regulations exist in other jurisdictions around the world.

Initiative	Funding Amount	Goal
Canadian Agricultural Partnership	$3 billion	Support on-farm environmental stewardship programs
Agriculture Clean Technology Program	$495.7 million	Support the development and adoption of agricultural clean technology
Agricultural Climate Solutions Fund	$855 million	Support the adoption of farming practices that tackle climate change
Carbon Offset Program	NA	Develop and incentivize the implementation of carbon protocols in ag, including those related to soil organic carbon, livestock feed management, and improved forest management
Fertilizer Emissions Reduction Target	NA	Reduce fertilizer emissions to 30% below 2020 levels by 2030
Resilient Agricultural Landscapes Program	$150 million	Support carbon sequestration, adaptation, and address other environmental co-benefits
Next Agricultural Policy Framework	NA	Put environmental considerations and climate readiness at the core of Canada's agricultural framework
Green Agricultural Plan for Canada	NA	Establish a long-term vision and approach to agri-environmental issues
Tax Credits for Investments in Clean Tech and CCUS	NA	Incentivize industry to invest in net-zero technologies, electricity generation systems, battery storage solutions, and carbon, capture, utilization, and storage solutions

Table 1. *Data source: aggregated from various Government of Canada websites.*[88]

[88] See: "Canada launches Greenhouse Gas Offset Credit System to support a clean, green economy,"2022, *Government of Canada,* https://www.canada.ca/en/environment-climate-change/news/2022/06/canada-launches-greenhouse-gas-offset-credit-system-to-support-a-clean-green-economy.html; "Canada's Greenhouse Gas Offset Credit System," 2023, *Government of Canada,* https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system.html; "Fall Economic Statement 2022," 2022, *Government of Canada*, https://www.budget.canada.ca/fes-eea/2022/report-rapport/FES-EEA-2022-en.pdf; "2030 Emissions Reduction Plan – Sector-by-sector overview," 2022, Government of Canada, https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030/sector-overview.html#sector7

BARRIERS TO SUSTAINABLE AG IN CANADA

Despite the many drivers of sustainability in ag, Canadian agri-food producers face barriers when adopting sustainable ag practices. As indicated by interviewees in this study, broadband connectivity, Canada's energy supply, and financial incentives are all confounding factors affecting agricultural sustainability.

BROADBAND INFRASTRUCTURE

Agri-food producers have long cautioned that a lack of cell phone coverage and high-speed internet impedes their ability to adopt information and communications technologies. As one interviewee stated, "Farmers need high-speed internet. Period. Full stop.... You can't run a high-tech farm if you have dial-up.... Fast, high-speed internet is so important." From an economic standpoint, inadequate telecommunications infrastructure prevents Canadian agri-food producers from adopting best practices and staying competitive in the global market. From a sustainability perspective, poor broadband connection further prevents agri-food producers from driving efficiencies in the production process, often making food production less sustainable.

COST OF ADOPTION

Interviewees indicated that the upfront cost of adopting some sustainability practices, including technology solutions, can be a barrier to adoption. They expressed the importance of having a clear business case to encourage the adoption of environmental sustainability practices in ag. While many sustainability practices yield economic benefits, such as reducing water, fertilizer, or energy consumption, others do not. As one interviewee said, "We can talk about sustainable practices, but if they're not economically viable, farmers are not going to adopt them." During the interviews, three business cases for sustainable ag emerged:

1. Practices that increase profit margins for existing revenue streams by reducing the number of inputs needed to produce the same yield
2. Practices that open new revenue streams to farmers, such as reusing agricultural waste as bioenergy or generating carbon credits
3. Practices such as organic agricultural production that consumers are willing to pay a premium for

For environmental sustainability practices where one of these business cases is not present, widespread adoption is likely to require additional incentives, such as government subsidies or other types of funding programs.

BARRIERS TO TECHNOLOGY ADOPTION

Advisory committee members commented that because sustainability is highly technology enabled, many of the barriers that prevent agri-food producers from adopting agri-food technology also prevent them from making their practices more sustainable. A 2017 study by the Innovation and Growth Policy Division of Agriculture and Agri-Food Canada identified high upfront costs, internet speeds and cellular data coverage, and lack of training or knowledgeable people as the top three barriers that prevent agri-food producers from adopting precision agriculture technologies.[89] Similarly, a 2021 study by ICTC identified the following top barriers to agri-food technology adoption:

- Cost of equipment and/or installation
- Cost of maintenance and/or operation
- Availability of equipment
- Lack of high-speed internet
- Shortage of skilled labour
- Unclear ROI and lack of awareness[90]

Participants in this study also mentioned the above barriers but further emphasized the availability of technology and regulatory challenges as core barriers that prevent technology adoption. In terms of availability, participants noted that many large agri-food technology companies based in the United States design their technology solutions with beans, corn, and other local U.S. commodities in mind. Often, technology solutions are not applicable to Canadian commodities and therefore cannot be adopted here. Even when a specific technology is applicable to the Canadian market, there is still a chance that the agri-food technology company will not want to invest the time and money that it takes to gain regulatory approval in Canada or market and distribute their products. They further emphasized the impact of lengthy or outdated regulatory processes on the adoption of highly innovative technologies, such as biological alternatives to synthetic pesticides, biotechnology, gene editing, and even drones, noting that in many cases, Canada's regulatory system is not modern enough to keep up with the pace of technology.

[89] "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
[90] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the seeds of tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf

ENERGY CONSUMPTION AND THE AVAILABILITY OF CLEAN ENERGY SOURCES

Agricultural Energy Use

Energy is used throughout the agri-food supply chain to operate machinery, power irrigation systems, heat and cool buildings, process agri-food products, and transport input and outputs to new destinations. While energy use in Canada's agriculture sector is growing, evidence shows that the sector is also becoming less *energy intensive* over time. In 2019, Canadian agriculture used less energy per dollar of GDP generated than in 2000.[91] Many strategies have helped the agriculture sector reduce its energy intensity over time:

- Replacing old power equipment with higher efficiency equipment
- Maintaining equipment properly to ensure it runs at maximum efficiency
- Changing or eliminating energy-intensive agricultural practices
- Opting for agricultural practices that result in lower overall energy consumption
- Making changes to lighting, insulation, heating, refrigeration, ventilation, irrigation systems, variable frequency drives, controllers, grain dryers, or combined heat and power.[92]

Despite these efforts, total energy use in the agriculture sector has grown, outpacing improvements to the sector's energy efficiency (See Figure 3). It is therefore important to recognize that energy efficiency can only go so far and that future improvements to agricultural sustainability will need to also reduce the *GHG intensity* of agricultural energy use.

[91] "Agriculture Sector Energy Use Analysis data," 2023, *Natural Resources Canada,* https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?

[92] "Energy management in agriculture About on-farm energy use, energy efficiency and renewable energy, and related research projects and resources," 2023, *Government of Alberta,* https://www.alberta.ca/energy-management-in-agriculture.aspx

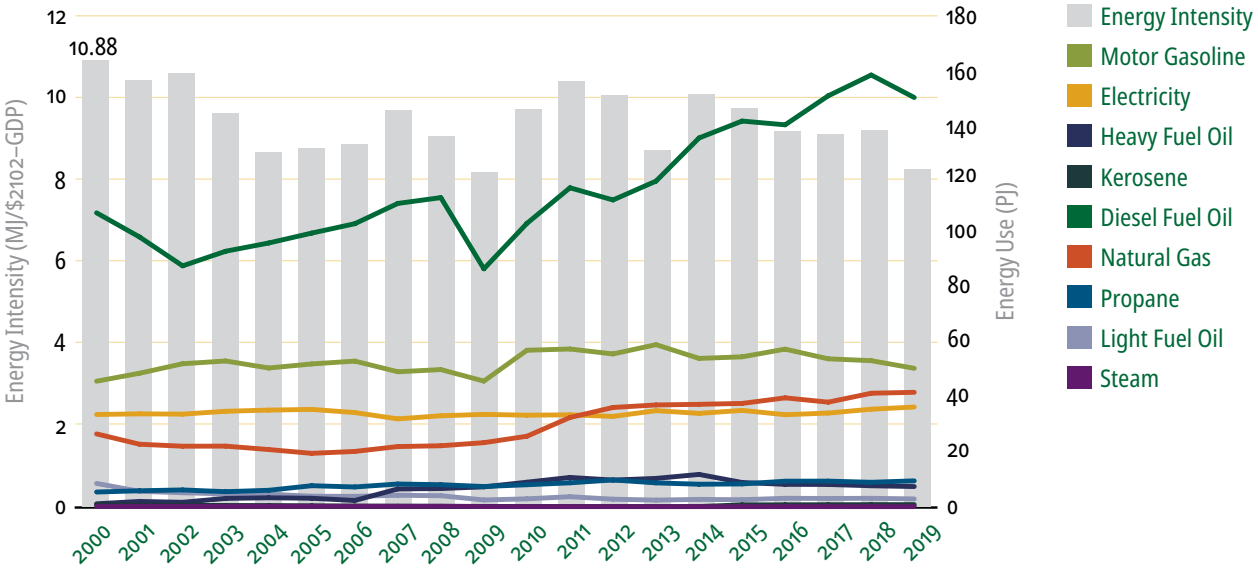


Figure 3. *Total Energy Use and Energy Intensity in Canada's Agriculture Sector from 2000 to 2019. From 2000 to 2019, Canadian agricultural energy demand increased by approximately 31%. Meanwhile, its energy intensity (e.g., the amount of energy consumed per dollar of agricultural output) fell by roughly 24%. Data Source: "Agriculture Sector Energy Use Analysis data," 2023,* Natural Resources Canada, *https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm*

GHG Intensity of Agricultural Energy Use

The GHG intensity (e.g., Mt of CO_2e emitted per unit of energy consumed) of agricultural energy use has also decreased over time. As shown by the grey bars in Figure 4, the GHG intensity of agricultural energy use fell by nearly 6% from 2000 to 2019, almost entirely (92%) due to a reduction in the GHG intensity of Canada's electricity supply (the remaining 8% was a result of minor reductions in the GHG intensity of gasoline and natural gas, which were offset by an increase in the GHG intensity of diesel fuel). And yet, despite this progress, total GHG emissions from agricultural energy use have grown by nearly a quarter (24%) since 2000.[93]

While minor improvements in the GHG intensity of gasoline and natural gas have made agriculture more sustainable, future efforts will need to focus on (1) transitioning agricultural energy use from fossil fuels to clean electricity and (2) further reducing the GHG intensity of agricultural electricity use.

[93] "Agriculture Sector GHG Emissions Base Year 2000," 2023, *Government of Canada,* https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?

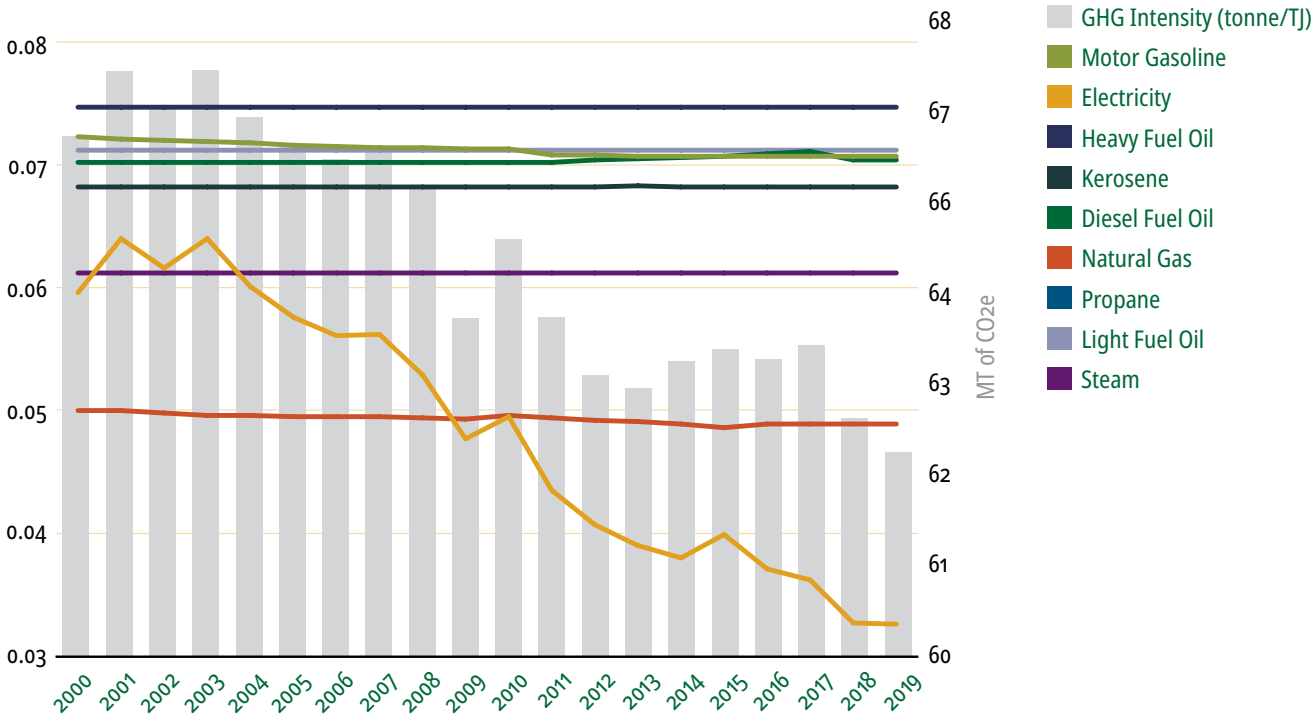


Figure 4. *The GHG Intensity of the Agriculture Sector's Energy Sources Over Time. Data Source: "Agriculture Sector GHG Emissions Base Year 2000," 2023,* Government of Canada, *https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=AN&sector=aaa&juris=oo&rn=6&page=1*

MOTIVE ENERGY USE

Motive energy use[94] is responsible for a large percentage of agriculture's energy use and emissions,[95] yet these activities are difficult to reduce (such as transportation and the use of heavy vehicles on the farm). Motive energy use accounts for 66% of agricultural energy use and 75% of GHG emissions from agricultural energy use. When you consider off-farm emissions, the impact of motive emissions is even greater. The agri-food sector has a long globalized supply chain, with regionalized infrastructure and high transportation needs. Agri-food businesses also often rely on emissions-intensive forms of transport, such as trucking, rail, shipping, and air. While agri-food businesses can optimize their supply chain by transporting goods efficiently and locating their facilities as close to processors and distribution centres as possible, interviewees cautioned that agri-food producers can only do so much to make their operations more sustainable without first reducing the environmental impact of transportation and supply chain activities more generally.

[94] Motive emissions stem from the use of motor gasoline and diesel fuel oil to produce motion or supply power to an engine. Common sources of agricultural motive emissions are transportation and the use of heavy vehicles and motorized equipment on the farm.

[95] According to the National Energy Regulatory, in 2019, motive energy use accounted for 66% of agricultural energy use and 75% of GHG emissions from agricultural energy use.

Looking Ahead

Over the past 20 years, Canadian agri-food producers have significantly reduced their energy intensity. Yet the reality is agricultural energy use continues to grow, and energy efficiency is of limited value. Whether agriculture can become more sustainable in the future will undoubtedly depend on whether Canada can (1) electrify its energy supply so that more clean and renewable electricity is used in place of carbon-intensive fuels, (2) increase the viability and availability of electric heavy-duty vehicles and machinery and enable their adoption in ag, and (3) increase the viability and availability of clean and renewable fuels, such as biodiesel, and enable their use in ag.

While many of these goals fall outside the scope of the agriculture sector, one option that is available to agri-food producers is small-scale renewable energy production. In response to the 2021 Census of Agriculture, nearly one in eight (11.9%) farms in Canada reported some form of renewable energy production.[96] This was more than double the rate of the previous census in 2016, where 5.3% of farms reported some form of renewable energy production. In both 2016 and 2021, solar energy production was the most reported form of renewable energy production. As the cost of small-scale renewable energy production decreases and as more regulatory and policy initiatives are introduced to encourage their adoption, the use of renewable energy production on farms is likely to increase. Ongoing innovations in technology, declining technology costs, and infrastructure improvements are only making it easier for farms to produce clean energy. Interviewees in this study were excited about present and future opportunities for clean energy production in agriculture, including the use of biodigesters and biomass to produce biogas and advanced biofuels.

[96] Canada's 2021 Census of Agriculture: "A story about the transformation of the agriculture industry and adaptiveness of Canadian farmers," 2022, *Statistics Canada,* https://www150.statcan.gc.ca/n1/daily-quotidien/220511/dq220511a-eng.htm

SUSTAINABLE AGRICULTURAL AND THE AGRI-FOOD LABOUR MARKET

SECTION 2

Canada is well positioned to be a global leader in sustainable food production. The Canadian agri-food sector has "abundant land and resources, access to international markets, strong research and development capacity, strong global reputation as a trusted supplier of safe, top-quality food, and strong stewards of the land."[97] Yet, Canada's ability to adopt sustainable agri-food practices will largely depend on agri-food businesses being able to access skilled talent.

AGRI-FOOD'S' CRITICAL LABOUR SHORTAGE

It is well-documented that Canada's agri-food sector is facing a critical labour shortage. In 2022, a survey by the Canadian Federation of Independent Business found that 62% of agri-businesses "found it difficult to recruit staff," 63% of agri-businesses "could not get all the staffing they needed," 80% of agri-businesses "would not advise someone to start a business because of labour shortages," and 95% of agri-business owners have "resorted to working more hours" because of the labour shortage they face.[98]

Similarly, In 2017, the Canadian Agricultural Human Resources Council (CAHRC) conducted a nationwide survey of farm operators and found that just under half (47%) of Canadian farmers are unable to hire the workers they need to fulfil minimum farm operations.[99] CAHRC estimates that the shortage of skilled labour has cost Canadian farmers $2.9 billion in earnings, equivalent to "4.7% of the industry's total value in shares."[100] While CAHRC's research focuses on primary

[97] Overview of Canada's agriculture and agri-food sector," 2022, *Government of Canada,* https://agriculture.canada.ca/en/sector/overview
[98] Overview of Canada's agriculture and agri-food sector," 2022, *Government of Canada,* https://agriculture.canada.ca/en/sector/overview
[99] "Agriculture Forecast to 2029 How Labour Challenges Will Shape the Future of Agriculture in Canada," 2021, *CAHRC,* https://cahrc-ccrha.ca/sites/default/files/2021-11/factsheet_NAT_E_web.pdf
[100] "Agriculture Forecast to 2029 How Labour Challenges Will Shape the Future of Agriculture in Canada," 2021, *CAHRC,* https://cahrc-ccrha.ca/sites/default/files/2021-11/factsheet_NAT_E_web.pdf

production, they stress that "without a thriving primary production sector, the entire agri-food value chain is at risk," including food and beverage processors, input suppliers, food distributors, retailers, wholesalers, and foodservice industries.

In 2021, ICTC published a report about Canada's agri-food tech labour market, and again, a critical labour shortage was found. In response to a survey conducted for this study, 24% of agtech companies, 17% of grain and seed producers, 28% of horticulture producers, 21% of livestock producers, and 53% of food and beverage manufacturers identified the shortage of skilled labour as a barrier to agri-food technology adoption.[101] Interviewees in that study repeatedly expressed difficulty finding technology workers, including software developers, data scientists, technicians involved in installation and maintenance, and others. These findings are further corroborated by other publications, all of which detail a severe skills and labour shortage in the food and agriculture sector.[102]

In this study, ICTC asked interviewees to discuss the most in-demand roles in the agri-food sector. In response, most interviewees stressed that all agri-food roles are in-demand. One interviewee said that "every part of agriculture is advertising for help," while another indicated that "to be candid, there's not really anything in ag that isn't in demand right now." Still, another noted that ag employers are "desperate," with many being unable to implement expansion plans simply because they do not have the labour to do so. Overall, interviewees indicated that there is "a critical labour shortage in agriculture across the board… with not one occupation or job in the industry that isn't facing a significant shortage." With the growing demand for food, the demand for agri-food workers is also likely to grow. At the same time, urbanization, Canada's aging population, and other demographic trends threaten to reduce the number of available workers, widening the labour gap.[103] Despite agricultural employers facing many challenges, such as inflation driving up input costs, employers interviewed by ICTC cited the labour shortage as the biggest challenge.

CANADA'S CHANGING AGRI-FOOD LABOUR MARKET

Participants in this study noted a fundamental shift in the agri-food labour market. Farm consolidation, technology adoption, and productivity gains are reducing the amount of labour needed for primary agricultural production. From 2007 to 2017, Canada's overall demand for primary agricultural labour actually declined.[104]

[101] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf

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

[103] "Agriculture Forecast to 2029 How Labour Challenges Will Shape the Future of Agriculture in Canada," 2021, *CAHRC,* https://cahrc-ccrha.ca/sites/default/files/2021-11/factsheet_NAT_E_web.pdf; https://cahrc-ccrha.ca/sites/default/files/2021-11/factsheet_NAT_E_web.pdf

[104] "Agriculture Forecast to 2029 How Labour Challenges Will Shape the Future of Agriculture in Canada," 2021, *CAHRC,* https://cahrc-ccrha.ca/sites/default/files/2021-11/factsheet_NAT_E_web.pdf

As noted by participants in this study, the same forces that are driving productivity gains in agricultural production are driving labour demand in industries adjacent to ag. Increasingly, demand for agri-food labour is generated in adjacent industries like agri-food tech, agricultural science, ag consulting, and agri-business. These industries have expanded to help producers grow food more efficiently, supported by technology development and adoption, data-informed decision making, advances in soil and plant science, and more.

The labour market data collected for this study demonstrates just how diverse agri-food roles are becoming. ICTC surveyed 67 agri-food employers across North America for this study, including 55 respondents from Canada and 12 from the United States. When asked about their hiring plans for entry-level roles over the next few years, respondents selected a diverse set of roles. While food and agriculture roles were selected by the largest percentage of respondents, one third also indicated that they planned to hire trades roles, while one fifth indicated that they planned to hire ag science and research roles, business and marketing roles, environmental consulting roles, digital technology roles, utilies roles, and R&D roles. When asked to identify entry-level roles that agri-food employers recently filled, just under one-third selected digital technology roles, likely due to the COVID-19 pandemic's impact on technology adoption over the past few years. Overall, survey responses suggest that the future of the agri-food labour market is characterized by a diversity of roles, with a strong need for science, R&D, digital technology, engineering, and environmental services talent.

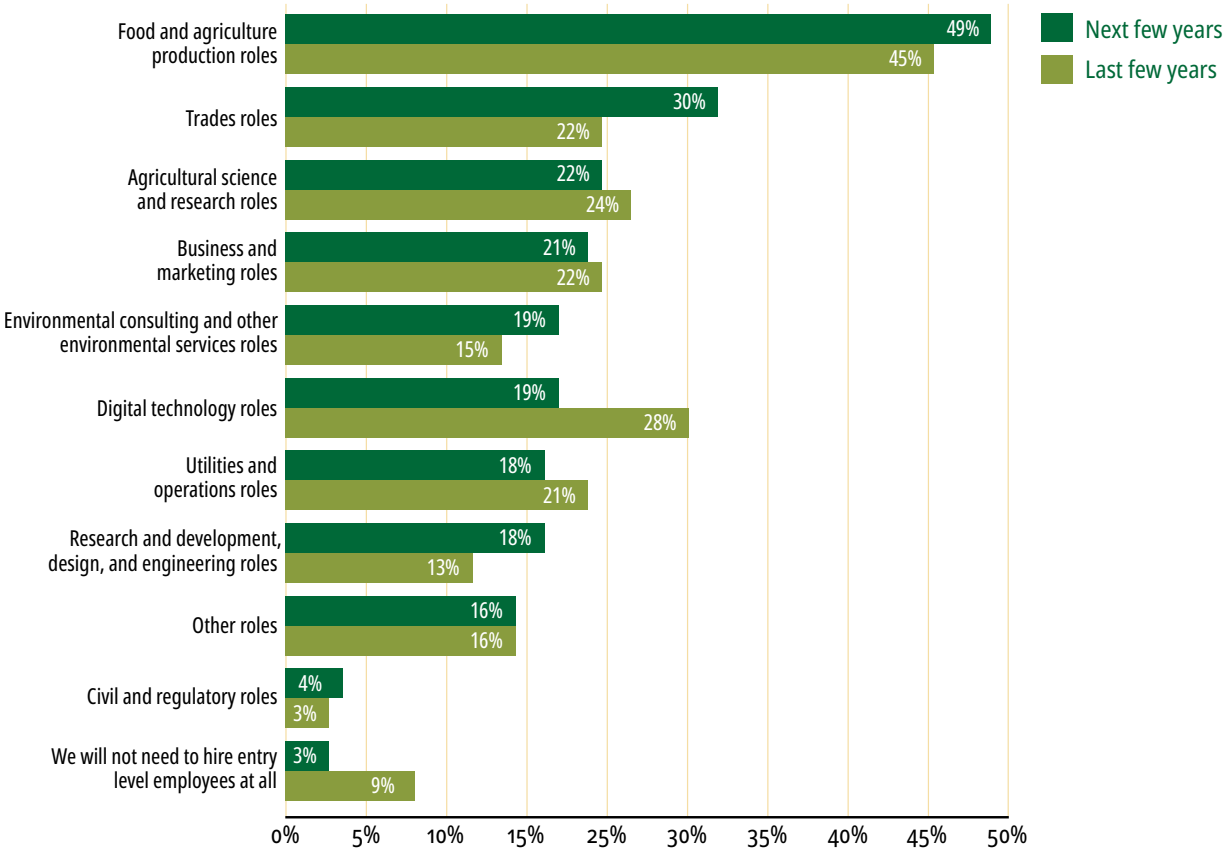


Figure 5. *Results from ICTC's agri-food employer survey (N=67).*

SUSTAINABILITY AND TRADITIONAL AGRICULTURAL ROLES

Interviewees and advisory committee members noted that demographic changes like urbanization and Canada's aging population would ensure that on-farm roles remain in demand for years to come. While this is true, the demand for these roles is not necessarily being driven by sustainability initiatives. Table 2 shows roles that were identified as in-demand but for which sustainability was not identified as a driving force.

Correspondence to Survey Categories	Roles	Seniority Level	Data Source(s)
Food and agriculture production roles	Farmworkers and General Labourers, Crop, Nursery, and Greenhouse	Entry	Interviews, Advisory Committee, O*NET
	Pesticide Handlers, Sprayers, and Applicators	Entry	O*NET
	Growers	Entry to senior	Web Scraping, Interviews
	Horticulturists	Entry to senior	Web Scraping, ECO Canada
	Ranch Managers	Mid to senior	Interviews
Business and marketing roles	Grain Marketers	Entry to senior	Interviews
	Grain Buyers	Entry to senior	Interviews
	Sales Reps	Entry to senior	Web Scraping, Interviews
	Customer Service Representatives	Entry to senior	Web Scraping
	Agricultural Economists	Mid to senior	Interviews
	Farm Liaison	Mid to senior	Interviews
Other roles	Warehouse Workers	Entry	Web Scraping
	Manufacturing Roles	Entry	Interviews

Table 2. *Roles for which sustainability was not identified as a driving force for demand. Various data sources.*

Sustainability initiatives are likely to impact the skills needed for these roles. Indeed, many of these roles already incorporate skills related to sustainable agriculture. As discussed by interviewees in this study, "farmers have been practicing sustainability for ages," and so many agricultural roles already feature best management practices grounded in sustainability. For growers, these practices may include water conservation, no-till farming, or minimizing and optimizing the use of fertilizers, pesticides, and herbicides. For ranchers, these practices may include specific breeding practices or the use of specific types of food.

As workers climb to seniority level, sustainability-related skills become more related to operational decision making, procurement, training and onboarding, and other mid to senior-level tasks. Undoubtedly, these mid to senior-level workers will be crucial in driving the adoption of sustainable agricultural practices. As more is learned about sustainability in agriculture and as new practices are developed, supervisor and management-level workers will need to stay informed, decide what practices to apply within their farms, train their staff on new practices, adhere to and report on regulations, and monitor and evaluate the success of new practices. Mid to senior-level workers involved in decision making and planning tasks are predicted to have a greater relationship with sustainability than entry-level or labour roles.

The incorporation of sustainability-related skills in traditional agriculture roles will likely become more pronounced as government policies, industry standards, and consumer demand drive a more enhanced focus on sustainability in agriculture. For now, the extent to which sustainability is integrated into traditional agriculture roles is primarily dependent upon farming operations: for example, farmworkers and general labourers working on organic or regenerative farms will have higher linkages to sustainability than those working on operations not grounded in sustainability. Similarly, the degree to which business and marketing professionals need sustainability-related skills will depend on whom they work for: business and marketing employees who work for agri-businesses focused on sustainability, such as organic input companies or some precision agriculture companies, will have higher linkages to sustainability. Those working for large input companies or selling toxic amendments will meanwhile have lower linkages to sustainability.

Overall, while specific skill sets for traditional agricultural roles are predicted to evolve in response to sustainability initiatives, the demand for these roles is not expected to be influenced directly by sustainability initiatives. Increasing demand for these roles is instead driven by demographic changes, chronic labour shortages, and the expansion of agricultural production to meet international food demand.[105]

SUSTAINABILITY AND THE FUTURE OF CANADA'S AGRI-FOOD LABOUR MARKET

Unlike traditional agricultural roles, the demand for roles related to technology adoption, data, agri-food science, and environmental consulting is directly tied to the adoption of sustainable agricultural practices. Advances in agri-food science, technology, and data are converging with sustainability initiatives to drive demand for this type of talent in Canada's agri-food sector. Table 3 demonstrates how diverse today's agri-food labour market is, incorporating a vast number of disciplines and skill sets. As demonstrated in Table 3, many of these roles can be entry, mid, or senior level: for example, one could progress through their career

[105] Hodson, Richard, "Food Security," April 2017, *Nature,* https://www.nature.com/articles/544S5a

from a junior food scientist to a food scientist to a senior food scientist. Others, such as engineering roles, consultant or manager roles, and skilled trades roles, require several years of direct industry experience before workers are fully trained and/or certified.

Correspondence to Survey Categories	Roles	Seniority Level	Data Source(s)
Food and agriculture production roles	Agricultural Equipment Operators	Entry to senior	Interviews, AC, O*NET
	Agricultural Equipment Technicians	Entry to senior	Web Scraping, Interviews
	[General] Equipment Technicians	Entry to senior	Web Scraping
	[General] Service Technicians	Entry to senior	Web Scraping
	Facility operator	Entry to senior	Interviews
Agricultural science and research roles	Food Science Technicians	Entry to senior	ONET
	Lab Technician	Entry to senior	Interviews, Advisory Committee
	Plant Scientist	Entry to senior	ONET
	Soil Scientist	Entry to senior	ONET, Interviews, ECO Canada
	Animal scientist	Entry to senior	ONET
	Microbiologist	Entry to senior	Web Scraping, ECO Canada
	Plant Breeders	Entry to senior	Interviews
	Biochemist	Entry to senior	Advisory Committee
	Agrologist	Entry to senior	Web Scraping, ECO Canada
	Agronomist	Entry to senior	Web Scraping, Interviews, ECO Canada, Advisory Committee
	Agriculture Specialist	Mid to senior	Web Scraping
	Certified Crop Advisor	Mid to senior	Interviews

Correspondence to Survey Categories	Roles	Seniority Level	Data Source(s)
Digital technology roles	Data Entry Clerk	Entry	Advisory Committee
	Precision Agriculture Technician	Entry	ONET, Interviews
	Field/ Agricultural Technician	Entry	KIIs, ONET, ECO Canada
	Automation Technician	Entry	Interviews
	GIS Technician	Entry	Web Scraping
	Variable Rate Technologist	Entry	Interviews
	Remote Sensing Technologist	Entry	ONET, ECO Canada
	Drone Pilot / Operator	Entry	Advisory Committee
	Roboticist	Entry to senior	Advisory Committee
	Programmers	Entry to senior	Advisory Committee
	Software Developer	Entry to senior	Advisory Committee
	Full Stack Developer	Entry to senior	Web Scraping
	Data Scientist	Entry to senior	Web Scraping, Interviews, Advisory Committee, ECO Canada
	Data Analyst	Entry to senior	Web Scraping, Interviews, Advisory Committee
Skilled trades roles	Building technicians, such as HVAC	Entry to senior	Interviews
	Electrician	Mid to senior	Web Scraping
	Heavy-Duty mechanic	Mid to senior	Interviews
	Millwright	Mid to senior	Interviews
Environmental consulting and other environmental services roles	Environmental Monitoring Technician	Entry	ECO Canada
	Sustainability Specialist	Mid to senior	ECO Canada
	Sustainability Consultant	Mid to senior	Interviews, ECO Canada
	Environmental Manager	Mid to senior	ECO Canada
Research and development, design, and engineering roles	Process Engineer	Mid to senior	Web Scraping, Interviews
	Project Engineer	Mid to senior	Web Scraping, Interviews
	Machine Learning Engineer	Mid to senior	Advisory Committee
	Machine Vision Engineer	Mid to senior	Advisory Committee
	Software Engineer	Mid to senior	Advisory Committee
	Data Engineer	Mid to senior	Advisory Committee
	Mechatronics Engineers	Mid to senior	Advisory Committee

Table 3. *Roles whereby demand is directly impacted by sustainability initiatives. Various data sources.*

Digital technology and engineering roles account for a large portion of the roles listed above, including software developers, data scientists, remote sensing technologists, precision agriculture technologists, and automation technicians, all of which are relatively new to the agri-food sector. As discussed by interviewees in this study, many sustainable agricultural practices are highly dependent on technology adoption and are therefore driving large-scale demand for technology and engineering roles. Once adopted on the farm, new devices and equipment need to be serviced and maintained, generating further demand for agricultural equipment operators and technicians. As summarized by one interviewee,

"In terms of future jobs in sustainable agriculture, you're going to see more robotics, and you're going to see the continued focus on data and efficiency… and let's face it, the tractor or combine will break down, whether it's self-driven or not. As you bring more electronics and more complicated devices to the farm, it's not going to be so easy for the farmer [to fix], and instead, a technician will be needed."

It is well-known that specific agri-food technologies are not applicable to all commodities and that the pace of technology adoption varies substantially by industry.[106] Understandably, these differences will impact what roles are needed in specific industries. In this study, for example, interviewees noted stronger demand for variable rate technologists in the prairie provinces, where variable rate technologies have been adopted at a broad scale to increase the efficiency and sustainability of seeding, irrigation, and fertilizer and pesticide application.[107] Similarly, Ontario has seen widespread adoption of controlled environment agriculture, driving demand for building technicians and facility operators.

Sustainable agricultural practices, particularly those that are technology enabled, are highly related to data. Data is vital to improving and optimizing agri-food processes for economic, environmental, and social sustainability, including soil nutrient data, geospatial data, climatic data, and genetic data. Participants in this study stressed that many sustainable agri-food practices require workers who can collect, analyze, and interpret data, as such a variety of data-related roles have emerged and will continue to grow in importance. As expressed by one interviewee,

"Data analytics is massive. We never have enough numbers. They never come fast enough, and they're never up to date or delivered in a timely fashion that is useful. Data will continue to be a big player in agriculture moving forward…. We'll need people to collect it, analyze it, and make something productive with it. Data will be essential to the growth of the sector and the ability to have a sustainable future."

While increased reliance on data will surely lead to growth in data analyst and data science roles, it will also lead to growth in agricultural science and research

[106] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf

[107] Laforge, Julia et al., "Farming the Future: Agriculture and climate change on the Canadian Prairies," 2021, IISD, https://www.iisd.org/system/files/2021-11/farming-future-agriculture-climate-change-canadian-prairies.pdf; Nicol, Lorraine and Nicol, Christopher J, "Adoption of precision agriculture to reduce inputs, enhance sustainability and increase food production: A study of southern Alberta, Canada," 2018, *WIT Transactions on Ecology and the Environment*, https://www.researchgate.net/publication/329460208_Adoption_of_precision_agriculture_to_reduce_inputs_enhance_sustainabiltiy_and_increase_food_production_A_study_of_southern_Alberta_Canada

roles, including lab technician roles, many of which are linked to food processing, food science, and food safety. The importance of these roles in ensuring food safety and sustainability was stressed by one interviewee who works in controlled environment agriculture:

> "Food science and food safety are crucial to us. We have our own lab in-house, and we have our own technicians. So, all our products get tested with a statistically relevant sample to make sure they don't have any pathogens before they're released to the market. The products sit in our warehouse for a day while these test results are processed. We also test all of the inputs—the water, the substrate, the peat, and the seeds. They each get tested on a rotation. I want to say it's 15 times a day. That part of our business is massive. We have lab technicians that run the lab, and then we have food safety people who are more process oriented."
>
> — **AGRI-FOOD EMPLOYER, CONTROLLED ENVIRONMENT AGRICULTURE**

LOOKING ABROAD: HOW DOES THE UNITED STATES COMPARE?

Labour market data from the United States Department of Labour suggests that similar labour market trends are occurring in the United States agri-food sector. While traditional agricultural roles, such as farmworkers and labourers, and farmers, ranchers, and other agricultural managers, account for the largest number of projected job openings in the agricultural sector from 2021 to 2031, these roles are growing at a slower rate than roles related to agri-food technology or agricultural science.

Figure 6 shows that the demand for farmworkers and labourers is growing at a slower than average rate, while the labour force for farmers, ranchers, and other agricultural managers is in decline. Comparatively, demand for precision agriculture technicians, agriculture technicians, food science technicians, remote sensing scientists and technologists, soil and plant scientists, and animal scientists is growing. Of these roles, agricultural equipment operators and animal scientists are growing at rates "much faster than average," while agricultural technicians, precision agriculture technicians, and food science technicians are growing at a "faster than average" rate.

As is the case in Canada, it is likely that these trends are being driven by a combination of industry consolidation and the adoption of efficiency-oriented technologies, automation, and robotics. Moreover, increasing demand for technical and scientific roles is likely being driven by the increased adoption of agri-food tech and the increased need for sustainability-related skills on farms.

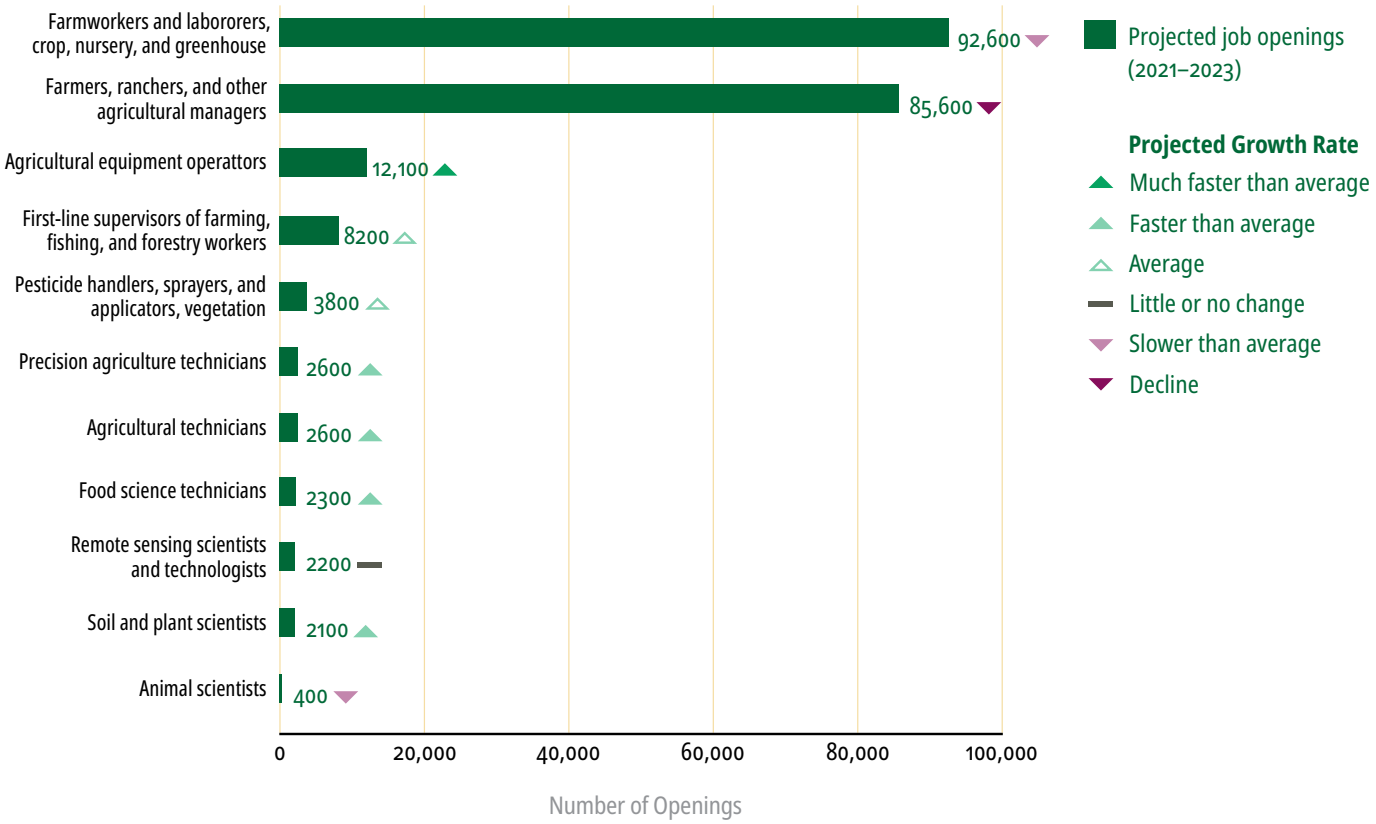


Figure 7. *Projected job openings in the United States for agricultural roles from 2021–2031. Data source: ONET labour market data.*

OUTSOURCING SUSTAINABILITY ROLES: EXTENSION SERVICES

For small to medium sized agri-businesses, it can be more affordable to outsource sustainability expertise as opposed to hiring for these roles internally. As such, some agri-businesses will outsource sustainability-related tasks to consulting firms and agricultural advisory boards or councils. Agri-businesses will typically outsource work to specialists who can offer insights and guidance on environmental matters. Some commonly outsourced roles include certified crop advisors, agronomists, agrologists, biologists, sustainability consultants, sustainability specialists, environmental monitors, and environmental educators from advisory boards.

Beginning in 1913, the Agricultural Instruction Act helped build capacity for agricultural extension services, which disseminated knowledge to farmers across Canada.[108] When the federal government did away with this act, agricultural

[108] Keesing, Paul Brunton, "A study of provincial agricultural extension services in Canada: 1952-1961," *UBC,* https://open.library.ubc.ca/soa/cIRcle/collections/ubctheses/831/items/1.0104630

extension services became the responsibility of each province. Canadian provinces began staffing extension officers in each county. They worked directly with farmers to mobilize information on new technologies, research, and best practices.[109] These services helped farmers stay up to date with state-of-the-art information and adapt to regulatory and environmental changes. In the mid-1990s, agricultural policy shifted to focus more heavily on self-reliance and international competitiveness and reduced government financial support for extension services.[110] While provincial agriculture extension services still exist, the programs are now less robust. In response, private sector extension services have experienced growth across Canada.

As explained by ICTC interviewees, some private services focus on economic supports, while others focus more on agronomic and environmental sustainability supports. Economic supports may include a farm management specialist who works with farmers, helping with business risk management, loans, financing, and succession planning. On the agronomic side, farmers may seek expertise from agronomists or agrologists who can provide insights into best practices for crop protection and soil health.

When looking for practical guidance on crop protection, farmers can seek out expertise from certified crop advisors. Certified crop advisors belong to a professional association known as the American Society of Agronomy and require formal education in agronomy, practical experience, and must pass two comprehensive exams.[111] Further, to keep their certification, certified crop advisors must continue ongoing education each year so they can properly inform farmers of the latest agronomic information. As explained by one interviewee, these individuals work to "make sure that regardless of the environmental or climatic conditions of a growing season, they [the farmers] are able to get a good yield." Without the ability to rely on the government extension services, the demand for certified crop advisors has grown over time. According to one interviewee, "There are about 2000 of them [certified crop advisors] across the country."

In addition to agronomic advice, agri-businesses may also outsource expertise from sustainability consultants and specialists, as well as environmental monitors and educators. Some of the tasks taken on by these individuals include conducting life cycle analyses, carbon accounting, helping farmers align operations with updated regulatory and legal changes or helping farmers assess the environmental risks of their operations. Farmers may also seek out advice from sustainability and environmental professionals indirectly by reviewing tools and public-facing reports. Furthermore, certain advisory boards offer training and resources to help farmers conduct their own environmental assessments.

[109] Keesing, Paul Brunton, "A study of provincial agricultural extension services in Canada: 1952-1961," *UBC,* https://open.library.ubc.ca/soa/cIRcle/collections/ubctheses/831/items/1.0104630
[110] Skogstad, Grace, "Agriculture and Food Policy," 2014, *The Canadian Encyclopedia,* https://www.thecanadianencyclopedia.ca/en/article/agriculture-and-food-policy
[111] "Steps to Verification," 2023, *Certified Crop Advisor,* https://www.certifiedcropadviser.org/become-certified/steps-to-certification

An example of this would be the Environmental Farm Plan, led by provincial governments across the country.[112]

Given how busy farmers are, it can be challenging to stay up to date on current information and technologies. Having extension services and consultancies can help farmers make sound economic, environmental, and social decisions, and the demand for these services will continue to be strong in the coming years. Unfortunately, the privatization of extension services may disadvantage small-scale agri-businesses, which may be at an economic disadvantage to access private services.[113] Therefore, private extension services should be seen as supplementary to public extension services, not a replacement.

[112] "Helping farmers identify and assess environmental risks, 2023, NSEFP, https://nsefp.ca/; "Alberta Environmental Farm Plan," 2023, Alberta EFP, https://www.albertaefp.com/; "Canada-Ontario Environmental Farm Plan (EFP)," 2022, *Government of Ontario,* https://www.ontario.ca/page/canada-ontario-environmental-farm-plan-efp

[113] Labarthe, Pierre and Laurent, Catherine, "Privatization of agricultural extension services in the EU: Toward a lack of adequate knowledge for small-scale farms?" 2013, https://www.sciencedirect.com/science/article/abs/pii/S0306919212001054

IN-DEMAND SKILLS

There are a diversity of in-demand roles within the agri-food sector. While the desired skills and competencies differ from job to job, a generalized outlook on skill sets provides insights into common skill sets desired by many agri-food employers. In this section, we look at the general skill sets identified as important by key informant interviewees, survey respondents, and advisory committee members. In the following section, we hone in on the specific skill sets that are needed for the 20 most in-demand sustainable agriculture-related roles. Notably, many of the required skill sets are directly related to sustainability, such as environmental impact assessments or soil testing, while others are more general and related to operational tasks.

CORE SKILLS FOR SUSTAINABLE AGRI-FOOD

Participants in this study (key informant interviewees, survey respondents, and advisory committee members) provided insights into the core skills and competencies that are generally required for sustainable agri-food practices. While the skills needed for specific occupations vary (and these are outlined in the next section), seven general skills are outlined below.

SOFT SKILLS

Soft skills are critical to all agri-food roles. In fact, many interviewees in this study placed a higher degree of importance on soft skills than technical skills. From their perspective, technical skills are easier for employees to improve or learn on the job when workers already have strong soft skills like work ethic, interest, and teachability. Overall, the soft skills discussed by interviewees in this study are quite similar to the web scraped human skills that will be listed below for the top 20 roles. Employers noted that they seek candidates with strong communication, teamwork, and problem-solving abilities, as well as candidates who have an innovative mindset and a strong work ethic and who are trustworthy, empathetic, and patient. Notably, soft skills are highly important for business and marketing roles, which require the ability to build strategic partnerships, communicate well, and develop trust.

> "You need to be able to write an email that gets to the point. Farmers are working 14-hour days all summer. You can't send them an email that's two pages long."
> — **AGRICULTURAL RECRUITER**

> "We're always after people that can work well in teams, that can communicate well. I don't think those things [skills] have really changed [over time]. And they're probably more important than the technical skills. You know, technical skills are important, but if they can't work with the team, work within your culture, then it's just not going to work." — **AGRI-FOOD TECHNOLOGY EMPLOYER**

MULTIDISCIPLINARY SKILLS

Given the complexity of agricultural systems, it is unsurprising that the ideal agri-food candidate is someone with multidisciplinary knowledge of agriculture, business, technology, and sustainability. Individuals who have at least a general understanding of all facets of the industry are able to make connections and identify solutions that may have otherwise been challenging to understand without multidisciplinary knowledge. For example, an agricultural technology developer will be able to create a more marketable solution if they understand the practicalities and limitations of farming.[114] Likewise, an agronomist working on crop protection will benefit from a strong understanding of the agroecosystem, including the soil systems and the climatic systems that the crops are built upon. While it is important to have specialists in certain domains of agriculture, these specialists should not work in siloes and should instead work to understand the complexity of agricultural systems.

AGRI-FOOD DOMAIN KNOWLEDGE

There is a strong need for workers with an understanding of the agri-food sector. While specific requirements vary by role, interviewees noted a demand for workers who understand animal husbandry, plant science, genetics and plant breeding, agronomy, and trends in the agri-food market. Employers discussed that it can be easy to find people with strong technical skills or strong business skills, but it is much harder to find someone who can pair those skills with a strong understanding of agriculture and food. In terms of specific knowledge areas, ICTC's employer survey found that general agronomy skills like plant science and best management practices for protecting plants from pests, diseases, and weeds were in demand. Interviewees meanwhile noted that for business and marketing roles, the strongest candidates will have a comprehensive understanding of Canada's agri-food sector and farming. As explained by one interviewee, "There is a need for people who can communicate and connect with farmers on a local level." This interviewee provided the example of merchant advisors, noting that "the most in-demand ones" can talk to farmers and merchants about things like the grain and ethanol supply chain or how specific products can be used on the farm.

[114] Lemay, Amy et al., "Systemic Barriers and Drivers to Technology Adoption in Canada: Lessons for Agri-Innovation in Ontario from Stakeholders of Canada's Global Innovation Cluster," 2022, *Brock University and Canadian Agricultural Partnership,* https://brocku.ca/niagara-community-observatory/wp-content/uploads/sites/117/NCO-Policy-Brief-55-October-2022-Growing-Agri-Innovation-Lessons-from-Global-Innovation-Clusters-FINAL-WEB.pdf

ICTC advisory committee members also stressed the need for people skilled in animal husbandry. This was echoed by a sheep farmer interviewed by ICTC, who said it was nearly impossible to find people with the knowledge and practical experience needed to work on their farm. This interviewee specifically mentioned understanding animal behaviour, animal science, and how animals interact with the environment as being high-demand skill sets.

ENVIRONMENTAL KNOWLEDGE

According to ICTC's employer survey, the top two most in-demand environmental skill sets are the ability to carry out awareness programs and present on environmental matters and the ability to collect, analyze, and interpret agricultural samples and data for environmental purposes. Interviewees, too, discussed these skill sets, however, they more broadly referred to them as the ability to conduct "climate risk assessments" and a knowledge of "environmental management." Otherwise, general environmental literacy was cited as important, as was "systems thinking" (e.g., thinking about things as holistic systems, such as soil systems, water systems, and nutrient systems). Notably, the ability to adopt a "systems perspective" and understanding the real-world complexities of agricultural practices and their interaction with society were considered important skill sets in other studies.[115]

Regulatory and legal skills were also mentioned by employers as being in high demand internally. As expressed by one employer, many candidates want to work in sustainability because they "want to help the world and help the planet" but lack a practical understanding of agri-food's regulatory environment. According to interviewees, the regulatory and legal knowledge required for agri-food is expansive and can include an understanding of how carbon credits are generated, approved, and sold, what is needed for new technology or innovation to become approved for market use, and what regulations oversee agri-food inputs, production, and processing. As one interviewee, a former farmer, explained, the regulatory and legal skills gap is large and is a result of the complex nature of agriculture. They added that "the regulatory and legal side [of agriculture] is really important and [is] really hard to find good candidates [for].... There's a ton of due diligence that needs to be done... and it really does take a long time to learn and understand."

While general environmental knowledge is important for all roles, not all agri-food businesses need to hire employees with technical environmental skill sets, such as the ability to collect, analyze, and interpret data or the ability to conduct environmental risk assessments. Indeed, some interviewees indicated that they outsource these types of tasks to environmental consulting firms or conservation agencies, while others mentioned these as being important for internal employees to possess.

[115] Sorensen, Laura Brandt et al., "What Skills Do Agricultural Professionals Need in the Transition toward a Sustainable Agriculture? A Qualitative Literature Review,"2021, *MDPI,* https://www.mdpi.com/2071-1050/13/24/13556

SCIENTIFIC RESEARCH SKILLS

The agri-food sector increasingly involves science and research roles, including animal, plant, and soil scientists, food science and lab technicians, biochemists, biologists, geneticists, and more. Across roles, lab and research best practices were identified as being in demand, such as a strong understanding of the general scientific process, the ability to implement objective, sound methods and procedures, and the ability to attain scientific results. In response to ICTC's employer survey, 23% of agri-food employers ranked an understanding of soil science as being in demand. Interviewees, too, expressed that skills related to plant science and crop protection are vital, however, some interviewees placed a stronger emphasis on soil science, given that climatic stressors such as extreme temperatures and weather events will become more common. Demand for scientific research skills looks different in other areas such as biotech, controlled environment agriculture, or agri-food processing operations. These operations instead require talent with a good understanding of laboratory settings, laboratory best practices, biochemistry, bioinformatics, genetics, and plant breeding. As explained by one interviewee from the canola industry, there is growing demand for plant breeders who have strong laboratory and biotech expertise, and often "plant breeding is a difficult space to try and fill." Moreover, they explained that a lot of biotech tools used in plant breeding now to make cell cultures, tissue cultures, and biotech tools are not just important for roles in cellular agriculture but for conventional plant breeding as well.

DIGITAL SKILLS

When asked to rank the top digital skills required for their business, 25% of surveyed agri-food employers listed competencies in geography and surveying technologies (GPS, ArcGIS, Remote Sensing) as the most important. Geospatial skills also were cited by ICTC interviewees as being high in demand, with several interviewees citing the ability to operate drones as a related skill set. One interviewee, an agri-food employer, elaborated on how difficult it can be to find talent with these skills, noting "a big gap in agriculture right now for engineers who understand farming and have geospatial skills like GIS." They added that while geospatial skills are "the core of pretty much every kind of solution in farming."

The ability to understand, analyze, and interpret data was also cited by interviewees as being in-demand. Employers explained that there has been an influx of agri-food technologies and sensors, all of which produce data, and that skilled individuals are needed to turn this data into meaningful information that can inform agri-food decision making. As explained by one interviewee, "Instruments [are] good at collecting data and doing their job, but what we don't have as much of is the interpretation of that data and the practical use of that data to improve a farmer's sustainability outcomes… that's certainly going to be an area of emerging importance going forward." Interpreting and analyzing data are also important for supply chain traceability and life cycle analysis reports, both of which are used to validate environmental and social governance standards. Increasingly, environmental and social governance standards are required by investors, lenders, insurance providers, and grant providers. As explained by one agri-food tech

employer, "Sustainability has always been there, but now you have to prove that you're doing it, and that's all related to data tracking and technology." Making use of data will require a variety of skilled data scientists and analysts with an understanding of programming languages like Python, JavaScript, Java, and SQL. In response to ICTC's survey, 12% of employers identified programming languages as in demand, and programming languages were similarly identified as in demand through ICTC's web scraping techniques. In addition to an increased need for core data science and data analyst roles, widespread technology adoption means that all roles will increasingly require data-related skills.

Finally, operations and maintenance roles will increasingly require the ability to operate and maintain agricultural technologies and equipment. In response to ICTC's survey, 16% of employers identified the ability to maintain and improve instruments, equipment, facilities, components, products, or systems as an in-demand skill, while 16% of employers identified the ability to recommend and implement changes or repairs as in-demand. These tasks will require diverse individuals that understand agricultural technologies and have general experience in engineering, mechanics, electronics, robotics, and automation. Based on ICTC's employer survey, it is also important for those working closely with equipment to possess strong operational skills, such as adhering to safety practices and procedures and complying with industry regulations.

BUSINESS AND MANAGEMENT SKILLS

Interviewees noted a strong need for candidates with business and management skills. While soft/human skills make up a core part of business and management roles, interviewees further identified technical skills and competencies that are required on the business and management side of agriculture. This may include conducting market analyses or financial analyses to better manage an agri-business or to calculate the costs and benefits of specific agri-food practices. Furthermore, many business and management roles require an understanding of customer relations software, with 21% of agri-business employers reporting a need for employees that understand Excel, Visio, and Salesforce. Given the diversity of skills required by business and management professionals, one interviewee referred to them as "generalists," with competencies in agriculture, technology, business, and strong interpersonal abilities.

OCCUPATION-SPECIFIC IN-DEMAND SKILLS

The below section expands on the general skills needed for sustainable agri-food practices by providing a list of in-demand skills for specific agri-food roles. ICTC used job postings data to identify the top 20 most in-demand roles needed to implement sustainable agri-food practices in Canada's agri-food sector, as well as the most in-demand technical and human skills for these roles. While the below data represents an aggregation of multiple job postings, the skills needed for an actual role may vary depending on the size and subsector of the hiring company. For instance, the skills required by a service technician on an organic farm would differ from one working in a controlled-environment agriculture facility or agri-food processor.

Grower

In-Demand Role

Top Technical Skills and Competencies

- Agriculture Diploma/Degree
- Diploma/Degree
- Health and Safety Regulations
- Climate Change Mitigation
- Organic Farming
- Excel
- Sustainable Agriculture
- Sustainability Best Practices
- Microsoft Office
- Plant Science
- Environmental Science

Top Soft Skills

- General Communication
- Leadership
- Planning
- Time Management
- Creativity
- Responsibility
- Teamwork
- Working Independently
- Written Communication
- Resilience

Sales Representative

In-Demand Role

Top Technical Skills and Competencies

- CRM
- Sustainability Best Practices
- Excel
- Renewable Agriculture
- Business Development
- Sustainable Agriculture
- Microsoft Office
- Precision Agriculture
- Certified Crop Advisor (CCA)
- Industry Knowledge
- Salesforce

Top Soft Skills

- General Communication
- Working Independently
- Time Management
- Active Listening
- Design Thinking
- Leadership
- Written Communication
- Negotiation
- Flexibility
- Planning

Service Technician

In-Demand Role

Top Technical Skills and Competencies

- Repair Agricultural Equipment
- Sustainable Agriculture
- Health and Safety Regulations
- Wind Technician Certification
- Heavy Equipment Technician Certification
- Driver's License
- Troubleshoot Wind Turbines
- Sustainability Best Practices
- Wind Turbine Installation and Maintenance

Top Soft Skills

- General Communication
- Working Independently
- Design Thinking
- Positive Attitude
- Flexibility
- Written Communication
- Problem Solving
- Teamwork
- Leadership
- Time Management

Agronomist

In-Demand Role

Top Technical Skills and Competencies

- Crop Production Industry Knowledge
- Agricultural Sales
- Certified Crop Advisor (CCA)
- Excel
- Soil Testing
- Plant Science Degree
- Sustainability Best Practices
- Sustainable Agriculture
- Environmental Regulations
- Environmental Remediation

Top Soft Skills

- General Communication
- Planning
- Time Management
- Problem Solving
- Decision Making
- Flexibility
- Working Independently
- Leadership
- Teamwork
- Responsibility

Electrician

In-Demand Role

Top Technical Skills and Competencies

- Repair AC/DC Motors
- Troubleshoot Equipment
- Programmable Logic Controllers (PLCs)
- First Aid
- Journeyman Electrician
- Workplace Hazardous Materials Information System (WHMIS)
- Driver's License
- Renewable Energy Equipment Maintenance
- Sustainability Best Practices
- Good Manufacturing Practice (GMP)

Top Soft Skills

- General Communication
- Working Independently
- Design Thinking
- Leadership
- Problem Solving
- Planning
- Creativity
- Time Management
- Positive Attitude
- Teamwork

Customer Service Representative

In-Demand Role

Top Technical Skills and Competencies

- Excel
- Microsoft Office
- Certified Crop Advisor (CCA)
- Sustainability Best Practice
- SAP
- Inside Sales
- Biomass Energy Production
- Microsoft Dynamics
- Microsoft Windows
- Sustainable Agriculture

Top Soft Skills

- General Communication
- Responsibility
- Positive Attitude
- Design Thinking
- Problem Solving
- Building Relationships
- Guiding Others
- Planning
- Time Management

Equipment Technician

In-Demand Role

Top Technical Skills and Competencies

- Heavy Equipment Technician Certification
- Repair Agricultural Equipment
- Service Hydraulics
- Red Seal Certification
- Journeyman
- Driver's Licence
- Troubleshoot Equipment
- Certified Journeyperson
- Renewable Energy
- Sustainability Best Practices

Top Soft Skills

- General Communication
- Problem Solving
- Working Independently
- Time Management
- Leadership
- Positive Attitude
- Planning
- Oral Communication
- Written Communication
- Design Thinking

Agricultural Equipment Technician

In-Demand Role

Top Technical Skills and Competencies

- Agriculture
- Repair Agricultural Equipment
- Hydraulic Systems
- Troubleshoot Equipment
- Journeyperson
- Repair Diesel Engines
- Driver's License
- Heavy Equipment Technician Certification
- Agricultural Equipment Technician Red Seal Certificate
- Workplace Hazardous Materials Information System (WHMIS)

Top Soft Skills

- General Communication
- Problem Solving
- Oral Communication
- Working Independently
- Time Management
- Positive Attitude
- Active Listening
- Flexibility
- Planning
- Ability To Learn

Agrologist

In-Demand Role

Top Technical Skills and Competencies

- Invasive Plants
- Sustainable Agriculture
- Soil Health
- Regenerative Agriculture
- Environmental Science
- Soil Science
- Sustainability Best Practices
- Ecology
- Environmental Protection
- Plant Science Degree

Top Soft Skills

- Planning
- Negotiation
- Leadership
- General Communication
- Responsibility
- Design Thinking
- Resilience
- Creativity
- Guiding Others
- Time Management

Warehouse Worker

In-Demand Role

Top Technical Skills and Competencies

- Warehouse Operations
- Lift Truck Operation
- Food Safety Regulations
- Sustainability Best Practices
- Hazard Analysis Critical Control Points (HACCP)
- Mobile Equipment Certification
- Material-Handling Equipment (MHE) Operation

Top Soft Skills

- Working Independently
- General Communication
- Positive Attitude
- Planning
- Responsibility
- Teamwork
- Ability To Learn
- Leadership
- Time Management

Process Engineer

In-Demand Role

Top Technical Skills and Competencies

- Data Analysis
- Process Engineering
- AutoCAD
- Sustainable Production
- Chemical Engineering
- Mechanical Engineering
- Project Management
- Excel
- Research
- SolidWorks

Top Soft Skills

- Design Thinking
- Written Communication
- Problem Solving
- General Communication
- Planning
- Leadership
- Teamwork
- Time Management
- Decision Making
- Working Independently

Project Engineer

In-Demand Role

Top Technical Skills and Competencies

- Project Management
- Excel
- P. Eng. Designation
- SQL
- SolidWorks
- Clean Energy Generation Technologies (nuclear, hydroelectric, biomass and solar)
- Microsoft Office
- Primavera
- Sustainability Best Practices
- Environmental Science Degree

Top Soft Skills

- Design
- Planning
- General Communication
- Responsibility
- Leadership
- Time Management
- Positive Attitude
- Written Communication
- Teamwork
- Creativity

Agriculture Specialist

In-Demand Role

Top Technical Skills and Competencies

- Agriculture Diploma/Degree
- Agricultural Business Management
- Precision Agriculture
- Microsoft Office
- GPS
- Digital Agriculture
- Sustainability Best Practices
- Sustainable Agriculture
- Telematics
- Precision Land Management

Top Soft Skills

- Flexibility
- Planning
- Leadership
- Communication
- Decision Making
- Responsibility
- Working Independently
- Active Listening
- Critical Thinking
- Problem Solving

Full Stack Developer

In-Demand Role

Top Technical Skills and Competencies

- SQL
- JavaScript
- Python
- C#
- AWS (Amazon Web Services)
- Docker
- Azure
- TypeScript
- APIs
- Vue

Top Soft Skills

- Design Thinking
- General Communication
- Decision Making
- Written Communication
- Leadership
- Time Management
- Flexibility
- Working Independently
- Problem Solving
- Teamwork

Data Scientist

In-Demand Role

Top Technical Skills and Competencies

- Python
- SQL
- Remote Sensing
- Machine Learning
- AWS
- SAS (Statistical Software Suite)
- Big Data
- Sustainable Agriculture
- Sustainability Best Practices
- SkyWatch Satellite Agricultural Data

Top Soft Skills

- General Communication
- Design Thinking
- Working Independently
- Resilience
- Planning
- Creativity
- Leadership
- Flexibility
- Time Management
- Problem Solving

Data Analyst

In-Demand Role

Top Technical Skills and Competencies

- SQL
- Python
- Agriculture
- Sustainable Agriculture
- Operations
- Excel
- Access
- Data Analytics
- GIS
- Environmental Science

Top Soft Skills

- General Communication
- Planning
- Design
- Leadership
- Problem Solving
- Teamwork
- Responsibility
- Active Listening
- Guiding Others
- Written Communication

Horticulturist

In-Demand Role

Top Technical Skills and Competencies

- Environmental Remediation
- Red Seal Certification
- Environmental Science
- Horticulture
- Occupational First Aid
- Cultivating Maintenance
- Pruning
- Fertilizing Plants
- Sustainable Horticulture
- Ecological Remediation

Top Soft Skills

- Planning
- Design Thinking
- Positive Attitude
- General Communication
- Working Independently
- Resilience

Environmental Monitor

In-Demand Role

Top Technical Skills and Competencies

- Environmental Science
- Ecology
- Hazard Analysis and Critical Control Points (HACCP)
- Environmental Protection Plans (EPPs)
- Environmental Auditing
- Workplace Hazardous Materials Information
- System (WHMIS)
- Climate Change Mitigation
- Sustainability Best Practices
- Environmental Score Cards
- Environmental Compliance

Top Soft Skills

- Working Independently
- Problem Resolution
- General Communication
- Leadership
- Planning

Microbiologist

In-Demand Role

Top Technical Skills and Competencies

- Research
- Microsoft Office
- Ecology
- Food Science
- Microbial Ecology
- Environmental Monitoring
- Food Microbiology
- Adaptability Planning
- Good Laboratory Practice (GLP)
- Sustainable Agriculture

Top Soft Skills

- Planning
- General Communication
- Responsibility
- Design Thinking
- Creativity
- Written Communication
- Teamwork
- Positive Attitude
- Decision Making
- Problem Solving

GIS Technician

In-Demand Role

Top Technical Skills and Competencies

- GIS
- Python
- SQL
- Access
- ArcGIS
- AutoCad
- Natural Resource Management
- Partnership for Water Sustainability
- ArcMap
- Sustainability Best Practices

Top Soft Skills

- Planning
- Design Thinking
- Written Communication

Job Postings Trends

Technical Skills

The above data demonstrates how diverse the technical skills needed for sustainable agri-food practices are. Several in-demand skills relate directly to the principles of environmental sustainability: many roles (65% of job postings) require a general understanding of sustainability. Further, 50% of job postings require an understanding of sustainable farming or food production, while 30% of job postings require an understanding of environmental science. Roles focused more heavily on digital technologies, like data scientists and analysts, have less focus on sustainability and are more heavily focused on computing and programming skills, including programming languages like Python, Structured Query Languages (SQL), Amazon Web Services (AWS), and Statistical Software Suite (SAS).

Human Skills

When looking at in-demand human skills, the need for strong communication was mentioned across all job postings. This includes oral and written communication. Both forms of communication are crucial in several facets of the agri-food sector, including business relations and sales, environmental knowledge dissemination, and internal productivity. Other key human skills include teamwork, responsibility, leadership, problem solving, and planning. Many of these human or "soft" skills were echoed by ICTC interviewees and are expanded on in the following section.

STUDENT PERSPECTIVES ON AGRI-FOOD CAREER PATHWAYS AND SKILLS

To understand how students feel about agri-food career pathways and in-demand skills, ICTC surveyed 312 post-secondary students in programs related to the agri-food sector. Survey respondents were primarily enrolled in programs related to environmental sustainability, energy, engineering, digital technologies, and agriculture. When asked about their immediate career plans, 33% of students stated they hoped to find entry-level employment, while 27% stated they planned to pursue further education. Nealy half (43%) of students expressed interest in pursuing a career in Canada's green economy, such as in renewable energy production, environmental services, or sustainable agriculture or food production.

Among students who were not interested in pursuing a career in the green economy, nearly one-fifth (17.5%) indicated that they were not interested in pursuing a career in the green economy because they did not think they would be able to find entry-level employment. This is surprising given that there is no shortage of entry-level agri-food roles. In fact, employers interviewed by ICTC stressed that they had a hard time filling entry-level roles. According to a recent study published by the University of Guelph's Ontario Agricultural College, there are currently four job openings for every graduate of their program.[116] While demand for these students is already high, at least in Ontario, demand for entry-level talent is expected to increase further in the years to come. In response to a survey conducted by the University of Guelph, 44% of food employers and 56% of agriculture employers anticipate higher levels of hiring over the next five years.[117]

[116] "Planning for Tomorrow 2.0 Summary Report, 2017," 2017, *Synthesis Agri-Food Network*, https://www.uoguelph.ca/oac/sites/uoguelph.ca.oac/files/Planning%20for%20Tomorrow%202.0%20Executive%20Summary_AODAFinal.pdf
[117] "Planning for Tomorrow 2.0 Summary Report, 2017," 2017, *Synthesis Agri-Food Network,* https://www.uoguelph.ca/oac/sites/uoguelph.ca.oac/files/Planning%20for%20Tomorrow%202.0%20Executive%20Summary_AODAFinal.pdf

Students were also asked to report their familiarity with technology-related skills and core environmental topics.

In terms of technology-related skills, students reported the highest degree of confidence in their ability to use operating systems software, like Linux, Windows, and Bash, followed by business management and customer relations software, and then programming languages like Python, Java Script, Java, and SQL. These skill sets were similarly listed by agri-food employers as important skill sets, with 12% of employers stating that understanding programming is the most important technology-related skill set and 10% of employers stating that understanding operating systems software is the most important software skill set. Students felt the least confident in their understanding of machine learning methods and their ability to operate cloud/server infrastructure tools. While some interviewees mentioned these as being important skill sets, few employers surveyed by ICTC ranked them as the most important. Notably, the ability to use geography and surveying technology was identified as the largest digital skills gap: while a quarter of surveyed agri-food employers identified this as an in-demand skill, 70% of students indicated that they are not at all confident or not so confident in their ability to use these tools.

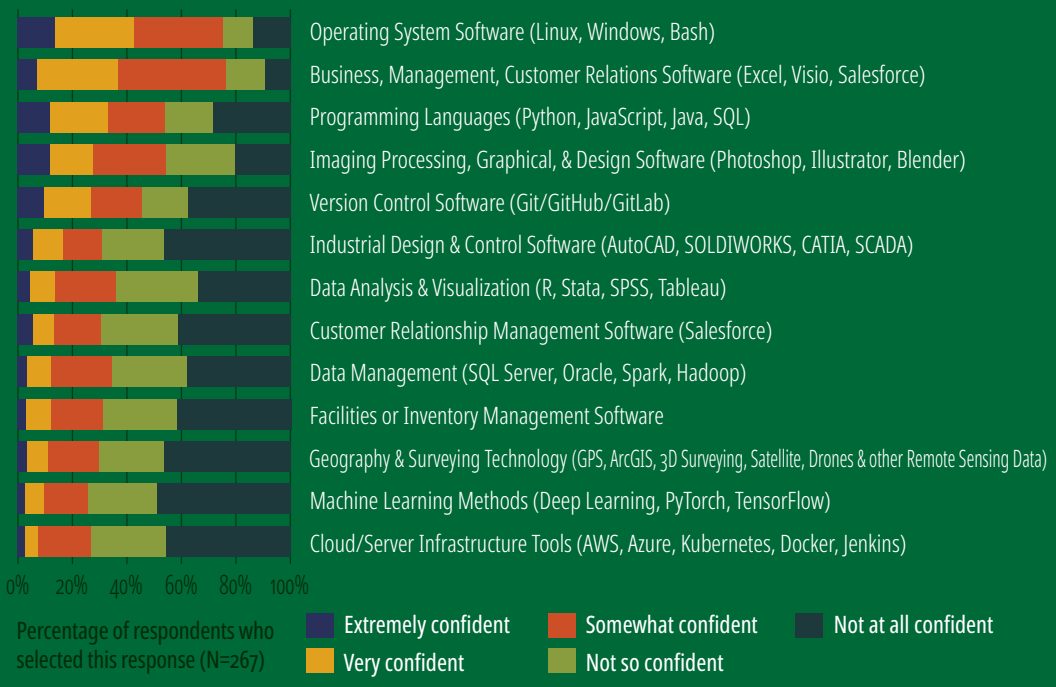


Figure 8. *Student familiarity with technology-related skills. Distribution of survey responses to the question, "How confident are you in your ability to use the following tools?"*

Core Environmental Knowledge

ICTC also asked students to assess their familiarity with a list of core environmental topics. These topics were adapted from ECO Canada's list of core knowledge areas for environmental workers, which was published in 2016.[118] ECO Canada is a Canadian labour market research organization that conducts labour market research on Canada's environmental sector.

As seen in Figure 9, students were overall more confident in their knowledge of general environmental literacy than they were in their technology-related skills. Nearly all respondents indicated that they were "somewhat," "very," or "extremely confident" in their understanding of how human activities impact the environment and the value of protecting, conserving, and restoring natural resources. Meanwhile, approximately 80% of respondents indicated they were confident in their knowledge of global environmental trends, concerns, and challenges, the impact of the environment on public health, specific problems like biodiversity or climate change, environmental concerns among the public, and human responses to environmental concerns.

Respondents indicated that they were less confident in more technical environmental knowledge areas, such as how different environmental disciplines are connected, environmental science, technology, and terminology, environmental management systems, environmental legislation and agreements, and Canadian environmental business practices.

Approximately two-thirds of respondents indicated that they were "not so confident" or "not at all confident" in their understanding of environmental legislation and agreements and Canadian environmental business practices. While employers interviewed by ICTC stressed the importance of general environmental literacy, they also emphasized the large skills gap related to the regulatory and legal side of sustainability. The legal and regulatory skills gap mentioned by employers is apparent among surveyed post-secondary students, implying that post-secondary education institutions will need to increase their capacity to educate students on the practical, business, and legal intricacies of environmental sustainability.

[118] "Competencies for Environmental Professionals in Canada," 2016, *ECO Canada,* https://info.eco.ca/acton/attachment/42902/f-65f916cd-d7be-432b-9bce-6f8bcbb92dce/1/-/-/-/-/NOS-for-Environmental-Professionals-ECO-Canada.pdf

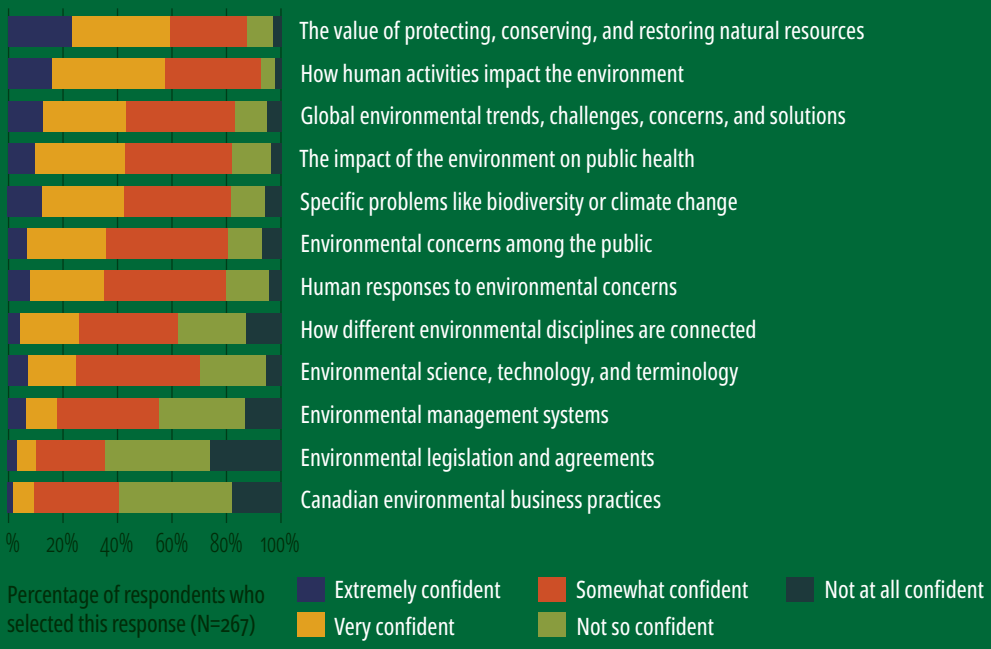


Figure 9. *Student familiarity with environmental topics. Distribution of survey responses to the question, "How familiar are you with the following environmental topics?"*

ADDRESSING LABOUR MARKET CHALLENGES AND INCREASING ATTRACTION TO THE SECTOR

To close the agri-food labour gap, specific challenges must first be addressed, including the seasonal nature of agriculture-food, the physical nature of agriculture-food, the negative perceptions of agriculture-food, and rural talent attraction. Below we explore these concepts further, break down negative perceptions of working in agri-food, and detail the value of working in the sector.

Seasonal Nature of Agri-Food

It is true that some aspects of agriculture, like primary production, are seasonal in nature. Notably, primary production of crops is quite seasonal, with the demand for labour increasing in the warmer months of the year to plant, maintain, and harvest crops. On the other hand, primary production roles tend to be less intensive and require fewer hired staff in the winter. ICTC interviewees described that the seasonal nature of primary production can lead to less structured schedules and burnout during the busy season:

"It's hard work and long hours seasonally. There is a downside.... and I think burnout is really high in the industry."

— AGRICULTURAL RECRUITER AND RANCHER

"It's still a very seasonal business. For example, our two hired staff work on the farm the normal seasonal hours, which could be 60-80 hours per week. That's what is required to get the crop in or harvested, and then we have to give them a lot of downtime in the winter – just feeding cattle maybe two to three hours a day. So that's the nature of it. It's hard to structure. You have to work with Mother Nature, not necessarily the time clock." **— CANADIAN FARMER**

The seasonal nature of agriculture isn't going away, but innovation in automation and robotics is working to alleviate some of the repetitive tasks required by primary production workers, such as planting, applying inputs, pest control, harvesting, quality control, and packaging.[119] As noted in a recent report by ICTC, the labour shortage in the horticulture sector is likely to accelerate the adoption of such technologies.[120] The adoption of such technologies will reduce the seasonal pressures of agriculture while also positively contributing to the quality of life of agricultural workers and increasing operational environmental sustainability.

Physical Nature of Agriculture

Other employers interviewed by ICTC explained that the physical nature of agriculture can be a "turn-off," with many people no longer willing to do hands-on manual labour. As a representative from an agricultural NGO explained, "General labour jobs are probably the hardest to fill because it's more manual labour." Like the challenge of seasonality, the physical challenge with agriculture is most prominent in primary production, such as horticulture. For instance, an individual who works as a master grower told ICTC, "You must be willing to do physical labour. It's very hands-on work." Another farmer interviewed by ICTC described the prominence of physical labour in animal husbandry jobs such as working with sheep or cattle.

While agriculture will always have some physical aspects, technology adoption is similarly expected to alleviate the physicality of agriculture and create labour savings.[121] With increased agricultural technology on farms, general labourers will have safer working conditions and less physical strain.[122] Furthermore, agtech will reduce repetitive tasks and will increase "value-add" tasks, such as managing and maintaining technology, measuring environmental metrics, and making data-informed farming decisions.[123] [124] This shift was discussed by several interviewees:

[119] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf
[120] Ivus, Maryna et al., "Canadian Agri-Food Technology: Sowing the Seeds for Tomorrow," 2021, *ICTC,* https://www.digitalthinktankictc.com/ictc-admin/resources/admin/canadian-agrifood-tech-2021.pdf
[121] Rodenburg, Jack, "Robotic milking: Technology, farm design, and effects on work flow," 2017, *Science Direct,* https://www.sciencedirect.com/science/article/pii/S0022030217306495#bib7; Bijl, R et al., "The Profitability of Automatic Milking on Dutch Dairy Farms," 2007, Science Direct, https://reader.elsevier.com/reader/sd/pii/S0022030207726255
[122] Marinoudi, Vasso et al., "Robotics and labour in agriculture. A context consideration," 2019, *Science Direct,* https://www.sciencedirect.com/science/article/abs/pii/S1537511019303617
[123] George, A Shaji and George, A Hovan, "The transformation of the agriculture sector and market due to the fourth industrial revolution (4.0)," 2020, *STRAD,* DOI:10.5281/zenodo.6657942
[124] Marinoudi, Vasso et al., "Robotics and labour in agriculture. A context consideration," 2019, *Science Direct,* https://www.sciencedirect.com/science/article/abs/pii/S1537511019303617

"[With the adoption of agtech] there's going to be a lot less physical labour on farms in the future, trending toward none. Instead, more agricultural jobs will require an understanding of digital technology." **— FOOD SYSTEMS ACADEMIC**

"We're replacing the manual labour with robotics and automation. We'll need people to operate those machines, and they'll need advanced digital skills to do that." **— AGRI-FOOD INNOVATION ACADEMIC**

"A lot of specialized industries are adopting technology to replace the labour force that they can't get or keep. So, we're seeing a lot of movement to automation, especially in the greenhouse industry, like vegetables where there's packaging." **— AGRICULTURAL NGO**

"In the future, I certainly see a lot of reduction in manpower. Jobs [will be] filled by automation and robotic systems." **— AGRI-FOOD TECHNOLOGY EMPLOYER**

While the physicality of agriculture is expected to become less of an issue with increased agtech adoption, it is unlikely that the physical nature of agriculture will be eliminated altogether. Agricultural employers therefore encourage this career choice to people who enjoy working outside and being physically connected to the land. As explained by one employer, "Agriculture is a lot of fun, [especially] if you like dirt."

Negative Perceptions of Agriculture

ICTC interviewees explained that societal perceptions of the agriculture sector being "dirty," "very physical in nature," "for uneducated people," and "low paying" are preventing the sector from closing its labour gap. Similar perceptions of agriculture having "low wages and limited career prospects" is common across many OECD countries—contributing to international labour shortages across the agri-food sector.[125] This is, in part, the result of an increasingly urbanized society, with most of the world's population living in cities and employed in sectors other than agriculture.[126] This has created a disconnection from food systems and has reduced broader societal agricultural literacy.[127] Similarly, ICTC interviewees explained that the negative bias toward agriculture careers is especially pronounced in urban areas. Reflecting on their personal experiences, one interviewee explained: "In the 8os, when I was younger, I wanted to farm. [But] when you grow up in the 8os and you tell your parents you want to farm, and you live in town, that doesn't go. It's because farming was not a good business to get into. It was not and is still not considered a particularly progressive or desirable industry."

[125] Ryan, Michael, "OECD Food, Agriculture and Fisheries Papers," 2023, *OECD,* https://www.oecd-ilibrary.org/agriculture-and-food/labour-and-skills-shortages-in-the-agro-food-sector_ed758aab-en
[126] Birkenholz , Robert et al., "A Pilot Study: Assessment of Agricultural Literacy Among College Students," 1994, *JSTOR,* https://www.jstor.org/stable/43764991
[127] Birkenholz , Robert et al., "A Pilot Study: Assessment of Agricultural Literacy Among College Students," 1994, *JSTOR,* https://www.jstor.org/stable/43764991; Wachenheim, C and Lesch, W, "Public Views on Family and Corporate Farms," 2002, Journal of Agricultural and Food Information, https://www.semanticscholar.org/paper/Public-Views-on-Family-and-Corporate-Farms-Wachenheim-Lesch/96f8148a6a295e06f70a47ed59d2a373ea68b5d4

Negative perceptions of the agricultural sector have reinforced an urban versus rural skills divide.[128] The phenomenon of the "urban-rural skills divide" was discussed by several interviewees as being the result of cultural differences in upbringing between rural and urban youth. For instance, youth growing up in rural communities are more likely to be exposed to agriculture and have a better understanding of the industry. Comparatively, urban youth are less likely to be exposed to agriculture. This lack of exposure is compounded by a lack of agricultural education in primary and secondary school systems. As most urban youth are not exposed to agriculture, they (1) lack experience and skills foundational to the sector and (2) are less likely to consider a career in the sector. This is even true for students and early career professionals who have an interest in environmental sustainability and agriculture. As one interviewee explained, "The younger generations that do care about the environment and sustainability, in a lot of cases, don't have an understanding of agriculture. [It's because of] the disconnection caused by urbanization. So, I think that's probably the harder piece to fill." With fewer youth exposed to agriculture at a young age, fewer youth pursue agriculture as a career.

Rural Talent Attraction

In Canada and around the world, a combined movement of urbanization, economic development, and digitalization has hollowed out rural communities. In 2021, nearly three-quarters of Canadians lived in one of Canada's larger urban centres, such as Toronto, Vancouver, or Montreal.[129] The number of communities in Canada that are classified as "urban" is growing due to changes in population density, and urban areas also account for the majority of Canada's population growth. According to Statistics Canada, large urban centres with a population of 100,000 people or more accounted for most of Canada's population growth from 2016 to 2020.[130] These trends are partly attributable to immigration patterns, whereby newcomers are more likely to move to Canada's larger cities than smaller ones, and partly because many rural youths move from rural to urban areas in pursuit of specific post-secondary education programs, job opportunities, or lifestyle changes.

Together, the above trends are limiting the number of workers who live in rural areas and are familiar with rural industries like agri-food. Increasingly, it is evident that the agri-food sector can no longer rely solely on a labour force stemming from rural areas. To address labour shortages, urban talent will be critical, however, attracting urban youth to the sector will require breaking down negative stereotypes and perceptions of agriculture, as well as increasing agricultural education at the primary and secondary levels. It will also require a concerted effort to both retain rural youth in rural communities and attract newcomers and young

[128] Frick, Martin et al., "Rural and Urban Adult Knowledge and Perceptions of Agriculture," 1995, *Journal of Agricultural Education,* 10.5032/jae.1995.02044
[129] "Canada's large urban centres continue to grow and spread," 2022, *Statistica Canada,* https://www150.statcan.gc.ca/n1/daily-quotidien/220209/dq220209b-eng.htm
[130] "Canada's large urban centres continue to grow and spread," 2022, *Statistica Canada,* https://www150.statcan.gc.ca/n1/daily-quotidien/220209/dq220209b-eng.htm

adults who grew up in urban areas to rural areas. On the latter point, this study's advisory committee members cautioned that it is important for communities to look at talent attraction holistically. Workers consider a range of factors beyond pay, job satisfaction, and career trajectory when choosing which positions to apply for and where to live, and the list of amenities that workers want and require is ever growing. Today, this list includes things like broadband availability, community amenities and events, up-to-date primary and secondary curriculums, engaging extra-curricular programs, and services to help newcomers become established in Canada.

Attracting Talent to Agri-Food Sector

Agriculture is a complex industry with a variety of roles that need to be filled. ICTC interviewees expressed that to attract skilled talent to the sector, more needs to be done to spread knowledge on the sector and its opportunities. Notably, one agronomist interviewed by ICTC said, "I just think it [agriculture] is a great topic. And I think the more we spread positive knowledge and information, it's just going to help more people to take up agriculture. I think it's a career path that a lot of people overlook, or they just think, 'Oh, this is dirty, there's no growth in potential here.' But we all know how important it is. We need food to survive. And I think if we try to make it more admirable and give it the credit that it deserves, then I think we'll have a lot more young people and future generations pursuing agriculture."

To help showcase the benefits of working in the agricultural sector, interviewees discussed what attracted them to agriculture and why they feel working in agriculture has value. As described by interviewees, key benefits of working in agriculture include:

- Competitive pay and income
- Diversity of career opportunities
- Innovative atmosphere
- Opportunity for lifelong learning
- Supportive culture
- Opportunity to help address food insecurities
- Opportunity to heal the planet through sustainability initiatives

All interviewees had a strong passion for the agriculture sector and saw it as being a sector in which Canadians can have prosperous careers. Some of the above points are elaborated on in the following quotes:

> "The reliance on STEM in agriculture is huge now. You may never see a farm and be involved in agriculture [you could work from home in a digital role]. You could do just about anything [any job] in agriculture. It's a sector that has fruitful career opportunities. There's lots to do and lots to learn." **— AGRICULTURAL NGO**

> "A modern farm is different than what the perception is. It's not like the 1960s, with a guy on a tractor. It's not always dirty and dusty. The reality is the modern farm works with high-tech machinery, like a $1.2 million combine that is leveraging numerous data systems like GPS technologies. There is complex genetics. You use variable rate technology to pinpoint sprays.... You know, at the end of the day, you're feeding the world, right? So, it is a much different world than what a lot of people think. It's also a world that, quite honestly, needs highly skilled people, and it's a world that, quite honestly, pays quite well and does not have a $1,000,000 price tag for a house." **— AGRICULTURAL COLLEGE**

> "It's never boring. It's absolutely never boring. And there are a lot of opportunities." **— ANIMAL HUSBANDRY EXPERT**

> "Farmers are some of the nicest people in the world... and [agriculture] is not quite as cutthroat as some other industries." **— AGRICULTURAL RECRUITER**

> "At the core of sustainability, our food system is one of the biggest opportunities that we have to help heal the planet." **— AGRI-FOOD TECHNOLOGY EMPLOYER**

> "You eat three meals a day, and it comes from a farm, whether it's a grain farm, a cattle farm, a dairy farm, or livestock. [Working in agriculture], you are contributing to the growth of food for your country and for the world because we are a massive exporter as well." **— AGRI-FOOD TECHNOLOGY EMPLOYER**

POLICIES, PROGRAMS, AND PARADIGM SHIFTS NEEDED TO ADDRESS AGRI-FOOD LABOUR SHORTAGES

To meet labour needs, a number of policies, programs, and paradigm shifts will need to take root. Broadly speaking, this includes exposing youth to agriculture, better aligning post-secondary teachings with industry needs, and increasing experiential learning opportunities. Paired with community buy-in and positive perceptions of agriculture, the initiatives below will help address rural-urban skills divides, keep up with the pace of technology and environmental sustainability trends, and increase skilled agri-food talent.

A contributing factor to the agri-food labour shortage is the lack of exposure Canadian youth have to agriculture and food systems. As noted in the above section, this is particularly true for urban communities, where children rarely visit a garden or see where their food comes from. This lack of exposure is partly responsible for an urban-rural skills divide. To address this divide, youth across all communities need exposure to agriculture. Interviewees in this study emphasized that exposure to agriculture should start in primary schools and continue through secondary schools. Some interviewees explained that introducing primary school students to ag could be as simple as involving students in a community gardening initiative or taking field trips to local farms. At the secondary level, giving students the option to take an agricultural, urban farming, or controlled environment agriculture course may further drive interest in the sector. One agronomist interviewed in this study explained the value of taking an agricultural course in high school and described some of the course objectives, including using computer software to develop a virtual farm:

> "We had a virtual farm… and we got to decide what animals we might raise or crops that we might grow. And [by this], we got some exposure looking at like what type of inputs that you need, and what would it cost to raise those animals or grow those crops. So, it gave you a little bit of a financial perspective as to how to make a sustainable [agriculture] system." **— AGRONOMIST**

Across Canada, some organizations are working to help increase agricultural literacy among youth. Notably, Ag in the Classroom Canada is working to do this for students across every grade level in Canada.[131] Ag in the Classroom provides resources, tools, and services for teachers to help integrate agriculture into curriculums, with hopes of inspiring future agricultural leaders. Similarly, Explore Ag Digital,[132] a program funded in part by Protein Industries Canada and led by Enterprise Machine Intelligence and Learning Initiative (EMILI), Actua, and Ag in the Classroom, helps enhance secondary student knowledge of digital agriculture. Further, ICTC interviewees highlighted that 4-H Canada offers a strong agricultural foundation for youth.[133] While these programs are helping introduce Canadian youth to agriculture, they are primarily administered in rural regions. To fully address the urban-rural skills divide in agriculture, widespread adoption of these kinds of programs will be needed – especially in urban areas. Adopting these programs may require shifts in education policy, recognizing agriculture as an important subject area of study. Additionally, given the increasing importance of urban farming and controlled environment agriculture to Canada's food system, students now have more opportunities than before to engage with farming early on, even while remaining within urban areas.

[131] "Agriculture in the Classroom," 2023, *AITC Canada,* https://aitc-canada.ca/en-ca/
[132] "Exploring Digital Ag Project," 2023,*AITC Canada,* https://www.agricultureforlife.ca/explore-digital-ag
[133] "Learn to do by doing," 2023, *Canadian 4-H Council,* https://4-h-canada.ca/

Addressing the agri-food labour shortage extends beyond grade school. Post-secondary education institutions also have a large role to play. Agri-food stakeholders interviewed in this study expressed that Canadian Universities are quite traditional in their agricultural teachings and have not evolved in response to shifts in the agri-food sector. To help increase the applicability of agricultural programs, post-secondary curriculum developers should work to ensure their students possess the in-demand skill sets outlined in this report. Additionally, education institutions should work with industry to ensure alignment between educational and industry goals.

Additionally, interviewees in this study described post-secondary institutions as being siloed, with a lack of integration between faculties and departments. Given the multidisciplinary nature of agriculture, it would be beneficial to break down these siloes and increase cross-pollination between departments. This could include teaching engineering students about agricultural technologies, including agricultural business cases in business administration programs, or teaching agricultural students the principles of ecology. ICTC advisory committee members also stressed that, given the need for geospatial skills in agriculture, geography departments should increase their integration with agricultural departments.

Further, interviewees noted the need for more specified programs and courses like animal husbandry, agricultural engineering, or soil science. One interviewee said it is challenging to find entry-level talent with a background in soil science because many Canadian agricultural programs receive financial and other support from crop-input companies and, as a result, focus more heavily on crop science and protection than they do on soil science. Similarly, one interviewee expressed that it is nearly impossible to find people with animal husbandry skills, stating that there are limited university programs that provide students with the diverse skill sets needed to pursue careers in livestock.

To help ensure students have the practical skills required for the agri-food sector, experiential learning will also be needed. This can be done via Co-Op or internship programs, which help students gain applied knowledge while also exposing them to the diversity of career opportunities they will be presented with upon graduation. Agri-food employers suggested that colleges, especially those focused specifically on agriculture, have more experiential learning components and therefore better prepare students for industry.

Altogether, education will be key to ensuring that the agri-food sector has a strong labour force. Agri-food education must start at a young age, in primary and secondary schools, and continue through post-secondary education. To ensure youth are exposed to agriculture, the education system may need to undergo a paradigm shift, whereby agriculture is increasingly valued and is seen as an important subject area to be covered in curriculums. Such a paradigm shift may also require a positive reframing of the agri-food sector, especially in urban areas.

CONCLUSION

With the world's population expected to reach 9.7 billion by 2050,[134] the demand for food is greater than ever before. At the same time, policies, regulations, and consumers are putting pressure on the agri-food sector to help mitigate climate change and reduce environmental degradation. As such, the agri-food sector is forced to increase food production while decreasing its environmental footprint.

Addressing food insecurities while mitigating climate change is quite a feat. Luckily, ICTC finds that Canadian farmers have been practicing sustainability for years. This is because the land represents a farmer's livelihood. Because farmers rely on the land, they have had to protect it to ensure productivity for years to come. While farming is deeply rooted in sustainability, new innovations and research have allowed farmers to increase the sustainability of their operations to a higher degree. The adoption of new technologies has and will continue to help farmers produce more with less, which ultimately contributes to environmental, social, and economic sustainability.

While new technologies are helping to increase sustainability in agriculture, a skilled labour force is still needed. This is because technologies do not replace labour altogether. Instead, technologies can be leveraged to help reduce repetitive tasks and increase value-added work. Unfortunately, Canada's agri-food sector is facing a critical labour shortage, with many parts of the agricultural value chain struggling to fill important roles. This labour shortage is driven by demographic challenges and negative perceptions of agriculture being "low paying" and "dirty," driving talent away. ICTC interviewees contradict negative perceptions of agriculture, saying that there are many fruitful and meaningful career paths in the agri-food sector. Interviewees repeatedly explained that pursuing a career that helps feed the world and address climate change is extremely meaningful and wished more people would feel the same way.

This study found that there are many career opportunities to choose from in the agri-food sector. Some of these roles are more traditional to the agri-food sector and include primary production roles, skilled trades roles, and business and marketing roles. While an understanding of sustainability is increasingly important for these roles, the labour demand for traditional agriculture roles is not directly influenced by the emergence of sustainability initiatives. Instead, the demand for

[134] "Growing at a slower pace, world population is expected to reach 9.7 billion in 2050 and could peak at nearly 11 billion around 2100," 2019, *United Nations,* https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html

agricultural science and research roles, digital technology roles, and environmental service roles are directly influenced by sustainability initiatives. This is in part due to the interconnectedness between environmental sustainability and technology in agriculture. Of these roles, supervisor and managerial-level roles have the highest linkages to sustainability, as they are the decision makers determining to what extent environmental sustainability practices are implemented.

Core in-demand skill sets for the agri-food sector include soft skills, multidisciplinary skills, agri-food domain knowledge, environmental knowledge, scientific research skills, digital skills, and business and management skills. An understanding of sustainability is critical to ensuring sustainability is integrated into Canada's food production processes, and as such, the need for an understanding of environmental sustainability is continually growing. As precision agriculture, controlled environment agriculture, cellular agriculture, and quality control and identity preservation technologies continue to take root in agriculture, the demand for people who can design, understand, operate, and maintain technology systems is growing. Employers explained that these technologies are increasing the information (data) produced, and in response, there is a growing demand for agri-food talent who can understand, analyze, and interpret robust datasets. Further to this, agri-food employers stressed the demand for business skills, including sales, marketing, and strategic partnership development. While sustainability, technical, and business skills are in-demand, employers explained that being able to marry those skill sets with an understanding of agriculture is vital. Additionally, agri-food employers placed a great deal of importance on soft skills like communication, work ethic, teamwork, and problem solving. Given the complexity of agricultural systems, it has been identified that the strongest agri-food candidates are those who have multidisciplinary experiences and can understand the sustainability, technical, and agricultural aspects of agri-business.

To become a leader in agri-food sustainability and global food production, key agri-food stakeholders, education institutions, and policymakers must work together. Policymakers will be key in ensuring the agri-food sector has the technologies, tools, and resources to facilitate sustainability practices in agriculture. These policies will need to ensure that environmental sustainability practices are realistic and economically feasible for farmers to integrate. Further, becoming a leader in sustainable food production will require a strong labour force. For this to be possible, youth (especially in urban areas) must be exposed to agriculture at a young age. Findings from this study suggest that this should start in primary and secondary schools. Further to this, post-secondary education institutions must work with industry to ensure their teachings align with the progressive industry agriculture has become. If able to accelerate policies that enable sustainability while also addressing agri-food labour shortages, Canada will be able to progress as a global leader in sustainable food production.

APPENDIX: RESEARCH METHODOLOGY AND STUDY LIMITATIONS

RESEARCH METHODOLOGY

SECONDARY SOURCES

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 provided information to help further validate the findings in the report. The initial literature review helped identify interviewees, advisory committee participation, and form a methodology for the quantitative portion of the research.

Web Scraping

ICTC's data science team used web scraping and machine learning techniques to web scrape jobs and skills-related data from online job posting sites. The scraped data was parsed and analyzed to assess the most in-demand jobs and skills related to sustainability in Canada's agri-food sector. While job postings provide valuable data for jobs and skills analysis, it is worth noting that web-scraped data may not be reflective of all in-demand roles due to sectoral differences in how job opportunities are shared and how employers find suitable candidates. For example, trades and union roles tend to be posted in-house and are typically not publicly available.

PRIMARY RESEARCH METHODOLOGY

Key Informant Interviews

ICTC conducted 26 key informant interviews with diverse experts on sustainability in Canada's agri-food sector. Interviews were conducted from August to December 2022. Interviewees held influential positions within their organizations, including that of farmer, business owner, CEO, and others. The interview questions were tailored to collect information about the interviewee's experiences within their companies and within the agri-food sector, such as their opinions about sustainability practices and trends in Canadian agri-food and the impact of sustainability on Canada's agri-food labour market. The interviewees were coded in NVIVO using a combined inductive and deductive approach.

Employer Survey

ICTC contracted a vendor to conduct a survey of 67 agri-food employers located in North America: 55 employers were located in Canada, while 12 were in the United States. The survey was conducted in August 2022. To be included in the survey, respondents had to, at the time of responding, (1) be working to make the agri-food sector more sustainable (they were provided with a series of qualifying prompts) and (2) be involved in or be familiar with their companies hiring and skills assessment processes. Respondents were asked about their recent entry-level hiring activity, entry-level hiring plans for the next few years, training and education preferences, and entry-level skills needs.

In developing the survey questions, ICTC utilized data from O*NET OnLine, which is hosted by the Occupational Information Network and the United States Department of Labour, Employment, and Training. In addition to this, ICTC utilized ECO Canada's list of core knowledge areas for environmental workers, published in 2016.[135] The employer survey questions were aligned with the questions posed in the student survey in order to allow for comparability between the survey responses.

Student Survey

ICTC conducted an in-house survey of 312 students across Canada who are registered in post-secondary and college programs relevant to sustainable agri-food. To deliver the survey, ICTC partnered with a number of college and university faculties and departments across Canada, in addition to utilizing its own repositories of student contacts. Students were asked about their plans for future employment and education, which industries they want to work in and why, and how comfortable they are with a variety of sustainable agri-food skill sets.

In developing the survey questions, ICTC utilized data from O*NET OnLine, which is hosted by the Occupational Information Network and the United States Department of Labour, Employment, and Training. In addition to this, ICTC utilized ECO Canada's list of core knowledge areas for environmental workers, published in 2016.[136] The student survey questions were aligned with the questions posed in the employer survey to allow for comparability between the survey responses.

LIMITATIONS OF RESEARCH

While efforts were made to mitigate potential biases, there are certain limitations that may be inevitably embedded in this study. While ICTC made a concerted effort to speak with a diverse range of sustainable agri-food 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 26 interviews, a sample that is too small to be considered representative of the entire industry. Similarly, while ICTC made a concerted effort to reach a comprehensive survey sample, there may be inherent biases in the data provided by survey

[135] "Competencies for Environmental Professionals in Canada," August 2016, *ECO Canada,* https://info.eco.ca/acton/attachment/42902/f-65f916cd-d7be-432b-9bce-6f8bcbb92dce/1/-/-/-/-/NOS-for-Environmental-Professionals-ECO-Canada.pdf
[136] "Competencies for Environmental Professionals in Canada," August 2016, *ECO Canada,* https://info.eco.ca/acton/attachment/42902/f-65f916cd-d7be-432b-9bce-6f8bcbb92dce/1/-/-/-/-/NOS-for-Environmental-Professionals-ECO-Canada.pdf

respondents.