A Summary Report of the Impacts of Disruptive Technologies in the Ontario Agriculture Sector

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Executive Summary

The agricultural sector in Ontario is entering an "age of disruption" (Deloitte, 2015) where advances in technology, like robotics, artificial intelligence (AI), and genetic advances, have the potential to reshape the future of work and the development of rural communities across the province. Interest in agricultural technology (AgTech) is driven by several global trends. These trends include the need to feed a growing world population, responding to the impacts of climate change while also reducing the industry's environmental footprint, food security, food safety, and traceability as well as shifting government regulations, changing consumer preferences, geopolitics inflation, supply chain issues (particularly stemming from the COVID-19 pandemic), rising input costs, and labour shortages. While there is a growing interest in understanding trends, drivers and barriers to AgTech adoption, less attention has been paid to examining how adopting these technologies might impact the future of work and rural development.

This multi-year project - funded by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) New Directions Program - was designed to understand the impacts of disruptive technology adoption, including the scope of technologies that could disrupt traditional production practices and the future of work. This report provides a summary of this research.

Technology Adoption in the Ontario Agricultural Sector

To understand the impacts of disruptive technology adoption in the Ontario agricultural sector, including the scope of technologies that could disrupt traditional production practices and the future of work, we conducted 48 in-depth interviews with 52 key informants between April 2023 and March 2024.

Supporting Technologies

- The top technologies cited by our industry experts include connected devices, remote sensing, robotics, artificial intelligence (AI), machine learning (ML), and big data and analytics.
- We also interviewed a number of ag-related technology companies; their products and services often fit within multiple supporting technology categories, with the majority being in AI/ML, robotics, remote sensing, connected devices, software & cloud computing, NextGen Farm, and big data & analytics.

Drivers for Technology Development & Adoption

- Ag industry experts highlighted a variety of drivers and some of the top responses were addressing labour challenges, increasing efficiency and production, reducing input costs, and optimizing plant and soil health.
- Ag-related technology companies highlighted similar drivers to developing their technology products and services, with the top drivers including increasing efficiency,

addressing labour challenges, increasing production, optimizing plant and soil health, reducing input cost, and enhancing and/or demonstrating environmental sustainability.

Enablers for Technology Development & Adoption

Based on interviews with ag-related technology companies, we identified enablers that allowed companies to develop and adopt specific agricultural technologies across three categories:

- **Technology-related enablers:** These included the design and adaptation of the technology for local environmental conditions or requirements, interoperability, low costs, and ease of use.

- **Organizational-related enablers:** Interviewees highlighted their close connection with, and their internal knowledge of, local agriculture systems, how they strategically targeted international markets, and how they are leading efforts to change government regulations.

- **External environment-related enablers:** Ag-related technology companies identified having a locally available supply of skilled tech labour, access to and the availability of capital, and farmers participating in technology design as critical to technology adoption and development.

Barriers for Technology Adoption

Our interviewees discussed a large number of barriers to adopting technologies. Overall, barriers to technology adoption can categorized as follows:

- Costs
- Trust
- Technology-related challenges
- Skills and training gaps
- Infrastructure constraints
- Other barriers

Barriers for Developing Technology

Ag-related technology company interviewees also identified a number of specific barriers to developing or offering their particular product or service, which can be categorized as either technology-related or external environment-related factors.

- **Technology-related barriers:** These include the associated costs and time required to develop technologies, as well as the challenges with seasonality when testing prototypes and adopting technologies.

- **External environment related barriers:** These include access to funding and capital, a lack of open source and other data, competition for talent, market size and costs of production.

Impacts on Rural Development

As part of the technology assessment, we were particularly interested in identifying impacts related to employment, skills and training, business development, and regional development.

- **Employment skills & training impacts**: Overall, interviewees discussed how adopting technologies can have several impacts on employment, which are often specific to the technology, the type of work, and even the farming operation. There was also a consensus that the impact of adopting technologies is extremely nuanced, especially with respect to overall changes in the number of jobs on a farm.

- **Business development impacts**: Impacts identified by our interviewees included altering purchasing models, new opportunities for services and other businesses, and new markets.

- **Regional development impacts:** Interviewees highlighted include shifts in spending, attracting younger generations back to farming, infrastructure needs (i.e., rural broadband), and industry-specific policies and regulations.

Responses to Rural Development Impacts

Interviewees were asked to provide information on organizations, initiatives, or programs that have responded to the impacts. Overall, interviewees identified a range of stakeholders involved in responding to the impacts of agricultural technologies. These included: the private sector, all levels of government, postsecondary institutions and industry associations. Specific responses included:

- The AgriInnovate Program – Government of Canada
- Bioenterprise – Canada's Food & Agri-Tech Engine
- Homegrown Innovation Challenge – Weston Family Foundation
- Canadian Food Innovation Network
- Smart Farms Network – Olds College, AB
- Careers in Ag – Agricultural Manufacturers of Canada
- The Ag Robotics Working Group – Government of Ontario, OMAFRA
- Ontario Agri-Food Innovation Alliance – OMAFRA & University of Guelph
- Vineland Research & Innovation Center
- Greenhouse Technician Program – St. Clair College, ON
- Palette Skills

COVID-19 and AgTech Adoption

- Interviewees noted a number of shifts prompted by the global COVID-19 pandemic, including an increased interest in automation; an increased awareness of challenges related to labour, supply chains, and food security; challenges related to imports and supply chains; and a greater comfort with digital tools like online meeting tools while also reducing the need for in-person meetings.

Future Considerations

We asked ag industry and ag business experts about future ag-related technologies and their potential impacts on rural development. While there was a range of responses, several common themes emerged:

- Ag industry experts discussed an increase in robotics and automation, especially modular systems that offer more flexibility and weeding systems that provide better accuracy & efficiency.
- Interviewees also highlighted a growing emphasis on AI/computer vision being paired with robotics, cloud computing and IofT. Some also noted using AI-based satellite imagery analysis.
- A number of ag industry experts discussed how there is growing interest in machine learning and predictive analysis.
- With regards to future considerations for rural development, ag industry experts reinforced the observation that the impacts on employment will be nuanced. For example, adopting new technologies will lead to a "displacement of numbers" from low-skilled work to higher-skilled work.
- Looking to the future, ag industry experts discussed how labour and sustainability considerations will continue to drive decisions to adopt technologies, particularly due to shifting consumer preferences and regulations like those in Europe with regards to sustainably grown agricultural products.
- Ag-technology companies emphasized opportunities for improving environmental impact and sustainability, increasing competitiveness, and improving the lifestyle and welfare of farmers.

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1 Introduction and Context

The agricultural sector in Ontario is entering an "age of disruption" (Deloitte, 2015) where advances in technology, like robotics, artificial intelligence (AI), and genetic advances, have the potential to reshape the future of work and the development of rural communities across the province. Internationally, interest in agricultural technology (AgTech) is a growing reality with ideas such as Agriculture 4.0 (Santos Valle & Kienzle, 2020), Farmer 4.0 (RBC, 2019), and the future of agriculture (The Economist, 2016) captivating the attention of researchers, consultants, investors, and policymakers alike (see also Leader et al. 2020). At the same time, global financing for AgriFoodTech has witnessed a more than eight-fold increase from $3.1 billion in 2012 to $26.9 billion in 2022[1] (AgFunder, 2023).

While there is no agreed upon definition of AgTech, AgTech typically includes a range of technologies, including: artificial intelligence (AI) and big data; sensors, broadband networks, and other Internet of Things (IoT) technology; Geographic Information System (GIS), Global Positioning Systems (GPS), and aerial images; automated, connected, and electric vehicles and robots; and biotechnology and bioinformatics (Ivus, 2021, p. 16). Similarly, Newman (2018) identified six digital transformation trends in agriculture, including: IoT and sensors in the field; IoT and sensors in equipment; drones and crop monitoring; farming and robotics; radio frequency identification (RFID) sensors and tracking; and machine learning (ML) and analytics.

1.1 Drivers and Barriers to AgTech Adoption

Interest in agricultural technology (AgTech) is driven by several global trends. These trends include the need to feed a growing world population that is anticipated to reach 8.5 billion by 2030, and 9.7 billion by 2050 (United Nations, n.d; Fleming, 2016). In addition, the agricultural sector is struggling to respond to the impacts of climate change, like extreme weather events, while also reducing its environmental footprint (Helmer, 2023; Ramachandran et al., 2023; Fiocco et al., 2023; Ivus, 2021; Bland et al., 2023). Food security, food safety, and traceability have also generated significant concerns (Strubenhoff, 2018; Ivus et al., 2023; Philips, 2023). More recently, shifting government regulations, changing consumer preferences, geopolitics (e.g., wars), inflation, supply chain issues (particularly stemming from the COVID-19 pandemic), rising input costs, and labour shortages have further challenged the agricultural sector (Fiocco et al., 2023; Helmer 2023; Ramachandran et al., 2023; Ivus et al., 2021; Bland et al., 2023). Given these trends, Bland et al. (2023) have argued that, "the agricultural industry is under pressure" and that farmers require innovative solutions to "navigate these challenges and remain economically viable."

AgTech is often seen as part of the solution to the agricultural sector's challenges and there is a growing interest in identifying AgTech trends, drivers, and barriers (see Leader et al., 2020). A number of recent reports and studies have identified the benefits or drivers of adopting various

[1] It is worth noting that according to AgFunder, global agrifoodtech funding declined by 44% between 2021 and 2022 largely attributed to geopolitics (i.e., war), inflation, and supply chain issues (AgFunder, 2023).

technologies on farms (Helmer, 2023; Ivus et al., 2021; Wolfert et al., 2017; Lemay et al., 2021; Conteh et al., 2023), particularly for increased production and profitability. Specific benefits include improved crop yields, more efficient use of equipment, better farm management (e.g., planning harvests), more sustainable production methods, and reduced input costs and emissions (Ramachandran et al., 2023). A number of recent reports have also discussed labour shortages (exacerbated by the COVID-19 pandemic) and the increasing cost of labour as drivers of technology adoption on farms (Ramachandran et al., 2023; Helmer, 2023; Ivus et al., 2021; Conteh, 2023; Bland et al., 2023; CAHRC, 2023). Related to this is an aging farm operator population. A recent report by RBC (2023, p.1) suggests that 40 percent of farm operators in Canada are set to retire by 2033, leading to what they call the "cusp of one of the biggest labour and leadership transitions in the country's history." Technology adoption is seen as one way to attract the next generation of farmers.

Despite the benefits of technology adoption, the agricultural industry – particularly in Canada – has been slow to adopt new technologies (Ivus et al., 2021). Barriers to adoption include: the upfront costs of technology and a lack of financing (Ivus et al., 2021; Helmer, 2023; Fiocco et al., 2023; AMC, 2023); unclear return on investment (ROI) (Ivus et al., 2021; Fiocco et al., 2023); interoperability with existing systems, equipment, and products (Ivus et al., 2021; Lemay et al., 2021; Innovation, Science and Economic Development Canada, 2018); infrastructure deficits, particularly related to broadband or high-speed internet (Ivus et al., 2021; Innovation, Science and Economic Development Canada, 2018); concerns with data ownership and privacy (Ivus et al., 2021; Lassoued et al., 2023; Fiocco et al., 2023); and a lack of technology skills to implement or operate new technologies (Ivus et al., 2021; AMC, 2023).

A number of reports also highlight how farm size can be a barrier to technology adoption, with smaller farms being less likely to adopt new technologies (Ivus et al., 2021, Phillips, 2023; Helmer, 2023; Ramachandran et al., 2023). An additional barrier worth noting is the relevance of current technologies to solve real-world, on farm problems (Conteh et al., 2023). As Ivus et al. (2021, p.9) describe, there is an "oversupply of technologies that [are] not very useful to farmers."

1.2 The Future of Work and Rural Development

While there is a growing interest in understanding trends, drivers and barriers to AgTech adoption, less attention has been paid to examining how adopting these technologies might impact the future of work and rural development. However, there is a consensus that the next generation of farm operators will require more high-tech skills (Ivus, 2023; Helmer, 2023; CAHRC, 2023; AMC, 2023). For example, according to a report by RBC (2019), the next generation of farmers are innovative, highly skilled, data-driven, and diverse. Much of the discussion on labour views technology as a means to address labour shortages and improve the quality of work on farms (RBC, 2019; CAHRC, 2023; Helmer, 2023; Ramachandran et al., 2023; Ivus et al., 2021; Conteh et al., 2023; Bland et al., 2023). Yet, there is little discussion of the impact on the number of jobs that might be created or lost due to technology adoption. However, a report by RBC (2019, p.24) does recognize that "[m]achine replacement has been

routine in agriculture" and that "[t]he challenge ahead will be to equip the workforce with the necessary digital and human skills for the tasks that remain." In addition, there is limited research on the broader rural development implications of AgTech adoption. For example, there are procurement challenges and opportunities related to technical support and services or skills training needs (RBC, 2019; RBC, 2023; CAHRC, 2023; AMC, 2023) and there is limited understanding as to whether these opportunities will be available in or near rural, agricultural regions.

1.3 Research Objectives and Approach

Given these trends, this multi-year project[2] - funded by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) New Directions Program - was designed to understand the impacts of disruptive technology adoption, including the scope of technologies that could disrupt traditional production practices and the future of work. In particular, the objectives of this research were to:

(1) Determine the nature and extent of disruptive technologies in the Ontario agri-food context;
(2) Examine how these disruptive technologies are reshaping the sector;
(3) Identify what is driving the adoption of these disruptive technologies; and
(4) Explore the impacts on rural regions and the responses by various levels of government, organizations involved in economic development and skills training, postsecondary and research institutions, industry associations, and other stakeholder organizations.

A mix-methods approach was used to meet these objectives, which included the following:

- A **knowledge synthesis** exploring historical and technological shifts in the agri-food sector; current trends, including an overview of disruptive technologies; and a discussion of the drivers, barriers, and impacts of technology adoption on farms and stakeholders in rural communities (see Leader et al., 2020).
- The creation of a **novel dataset** of 247 Canadian agricultural technology organizations to explore the national AgTech landscape (see Huneke et al., 2024).
- Qualitative research consisting of 48 **key informant interviews** with 52 key informants including agricultural industry experts, agricultural-related technology companies, and agricultural business experts to understand AgTech adoption in Ontario. Information from these interviews forms the basis of this summary report.
- A series of **AgTech case studies** exploring specific technologies and their potential impacts on rural development (see Fonseka et al., 2024a, 2024b, 2024c; Rana et al., 2024).

[2] Our project was significantly impacted by the COVID-19 pandemic and we would like to thank OMAFRA for their patience and assistance while we navigated our research through this turbulent time.

Throughout this research, an advisory committee also met to discuss our approach and provide advice on the industry, trends, case studies, and key informants.

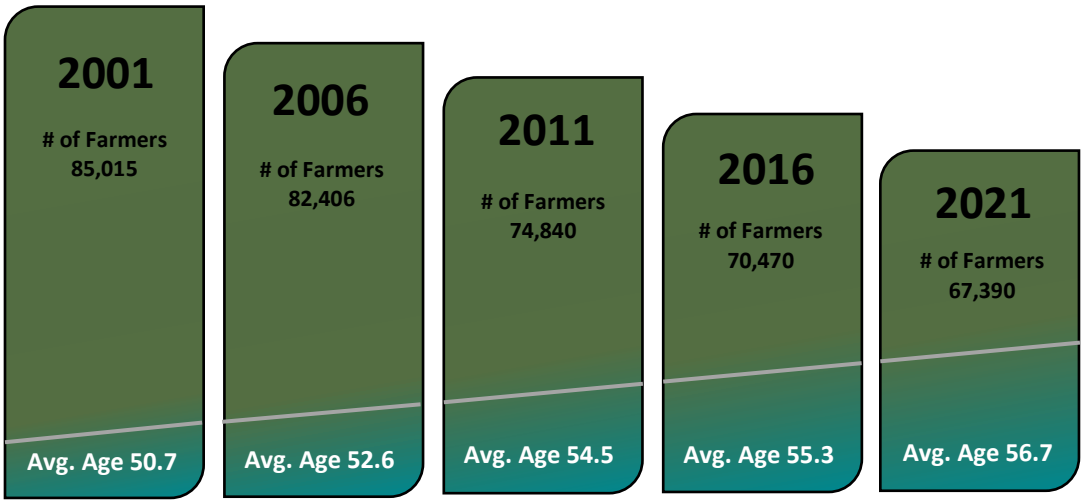
The remainder of this summary report is organized as follows. Section 2 provides a brief overview of agriculture in Ontario. Section 3 provides a summary of the main themes from the qualitative research to provide a more detailed understanding of AgTech adoption in Ontario, including technologies, drivers, barriers, and impacts. The final section outlines future considerations for the agricultural industry.

2 A Brief Overview of Agriculture & AgTech in Ontario

Within Canada, Ontario is home to over one-quarter (25.5%) of the total number of farms and 7.7% of the total farm area (Chen, 2022). This amounts to nearly 50,000 farms and roughly 11.7 million acres of farmland across the province (OFA, 2023). With regards to commodities produced in the province, according to the national 2021 Census of Agriculture, Ontario has the largest proportion of farms classified as: poultry and egg production; sheep and goat; other animal production; vegetable and melon; and greenhouse, nursery and floriculture (Chen, 2022). The province is also the national leader in acreage for soybean and corn for grain, as well as total greenhouse area. More specifically, Ontario represents over 61% of the total national greenhouse area. When compared to the previous Census of Agriculture, the total greenhouse area in the province increased from 159.8 million square feet, to 204.2 million square feet of greenhouse area (Chen, 2022).

The Ontario Federation of Agriculture (OFA, 2023) reports that almost 60% of farms in Ontario are considered small farms with less than $100,000 in revenue. The OFA also notes that the provincial agri-food sector grosses $47 billion in GDP and exports roughly $20 billion in products annually. While the Ontario agri-food sector employs over 750,000 people or approximately 10% of the provincial labour force (OFA, 2023), the 2021 census highlights an aging farm operator population. This trend is reflected in the average farm operator age, which increased from 55.3 years in 2016 to 56.7 years in 2021 while the total number of farm operators declined from 70,470 to 67,390 during that same period (see Figure 1).

Figure 1: Trends in Average Age and Total Number of Farm Operators in Ontario



Source: Created by authors based on Statistics Canada Table 32-10-0230-01

The 2021 Census of Agriculture also collected information on the use of eight different categories of technologies, including: automated guidance steering systems; GIS mapping; variable-rate input application; drones; soil sample test; slow-release fertilizer; fully-robotic milkers; and robotic greenhouse equipment. Across Canada, 50.4% of farms reported using at least one of these technologies (Chen & Jewitt, 2023). Within Ontario, over half (54.1%) of farms reported using at least one of these technologies, placing the province fourth for technology use in the country (Chen, 2022). The top three technologies with the highest use on farms in Canada, include: soil sample test (32%), automated guidance steering systems (26.8%); and slow-release fertilizer (23.4%). Another trend worth noting is that farms with higher revenues were more likely to use technology versus farms in lower revenue categories (Chen & Jewitt, 2023).

3 Technology Adoption in the Ontario Agricultural Sector

To understand the impacts of disruptive technology adoption in the Ontario agricultural sector, including the scope of technologies that could disrupt traditional production practices and the future of work, we conducted 48 in-depth interviews with 52 key informants between April 2023 and March 2024. We divided our interviews into four main categories, including insights from: (1) Agricultural industry experts; (2) Ag-related technology companies; and (3) Agricultural business experts (see Table 1).

Agricultural industry experts (e.g., government, industry associations, researchers and other industry experts) were asked questions about technology adoption over the *last* five years, as well as questions about technology adoption over the *next* five years. This included questions

about specific technologies, drivers to adoption, barriers to adoption and impacts on employment, education, skills, and training, business development and regional development. Ag-related technology companies (e.g., companies who have created or are selling technology products or services) were asked questions specific to their technology related product and/or service offering(s), enablers to developing the technology, barriers, and impacts on employment, education, skills, and training, business development and regional development. Similarly, agricultural business experts (e.g., individuals who are involved in on farm technology adoption) were asked questions about technology adoption, enablers to adopting the technology, barriers, and impacts on employment, education, skills, and training, business development and regional development. They were also asked questions about technology adoption over the *next* five years.[3]

Table 1: Key Informants

Category	# of Key Informants
Agricultural industry experts	22
Ag-related technology companies	24
Agricultural business experts	5

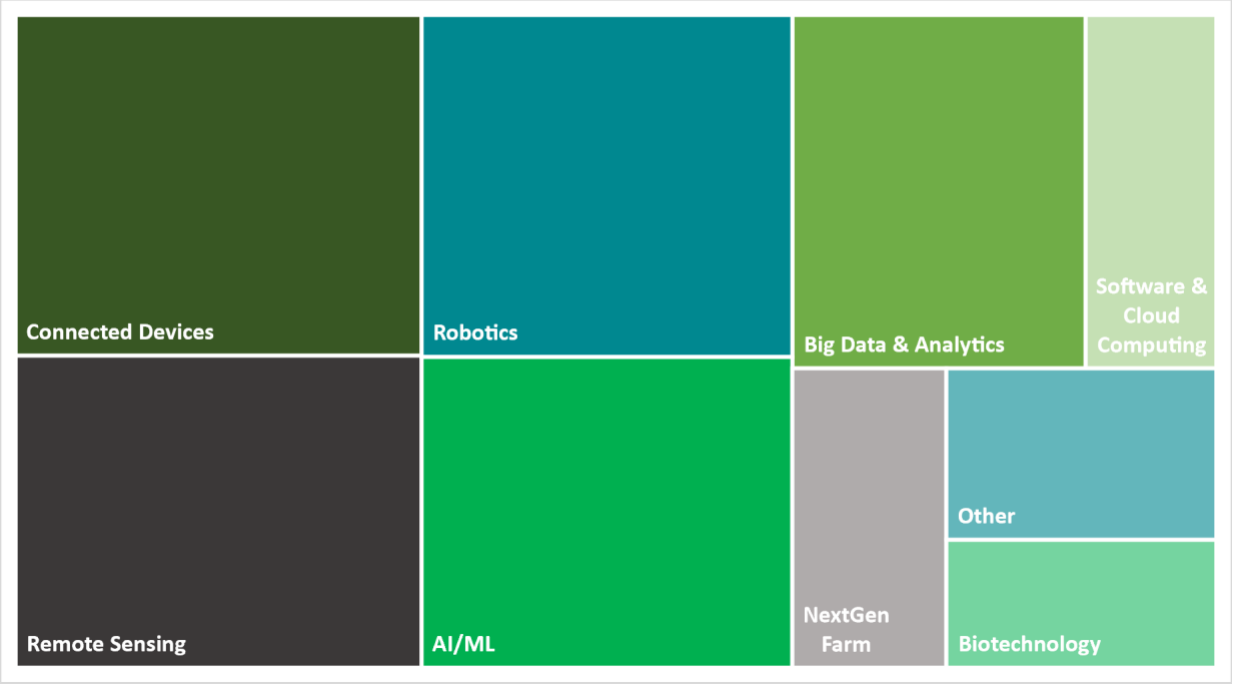
Source: Created by authors
Note: There was one additional interview that discussed a specific response to the rural development impacts

3.1 Supporting Technologies

We asked our ag industry experts about the top three technologies being adopted over the last five years in the Ontario agriculture sector. We categorized their responses into the supporting technologies identified in our quantitative analysis (see Table 2 for a detailed description; see also Huneke et al. 2024). More specifically, the top technologies cited by our industry experts include connected devices, remote sensing, robotics, AI/ML, and big data and analytics (see Figure 2). It is worth nothing that technologies within all categories were discussed by interviewees. In addition, interviews mentioned several other technologies related to mechanization, grain dryers, and biodigesters.

[3] Our approach to this research was inspired by the Remote Controlled Mining Project, which includes technology assessment (see Grunwald, 2014; Russell, Vanclay & Aslin, 2010), key informant interviews, and comparative case studies to draw lessons for both theory and practice. This research was also inspired by the technology assessment approach outlined by Franks and Cohen (2012) and McNab and Garcia-Vasquez (2011) and adapted by Hall (2018; 2020) to identify the social impacts of technology with added emphasis on the spatial impacts and unique place-based responses. The structure of the interview guides was also inspired by the approach by Rowles (2021) which examined technology transitions.

Figure 2: Top Supporting Technologies – Ag Industry Experts



Note: For illustrative purposes only
Source: Created by authors

Table 2: Description of Supporting Technologies

Technology	Description
Software & Cloud Services	Software platforms for farm management, yield mapping, monitoring, or analyzing historical data (not predictive)
Connected Devices	Devices or equipment connected over WiFi or Bluetooth to transmit data on/driven by machinery operation or processing functions (may involve sensors)
Remote Sensing	Monitoring/observational sensing (e.g. soil moisture monitoring, livestock monitoring, monitoring/observation using drones)
Biotechnology	Gene editing, GMO, molecular-level input delivery mechanisms
AI/ML	Automation functions enabled by software using artificial intelligence or machine learning models (e.g. computer vision)
NextGen Farm (CEA)	Controlled environment agriculture (CEA) management technologies for greenhouses or indoor/vertical farming, including lighting, climate control, heating, irrigation, and input application
Robotics	Automated or semi-automated robotic equipment, including in field farming, livestock production, and controlled environments (e.g. weeding, seeding, pruning, harvesting, milking)
Big Data & Analytics	Data platforms that process large data sets and/or integrate data from multiple sources (weather, farm equipment, etc.) to produce insights or predictive algorithms (if/then predictions)
Other	All other technologies (e.g. mechanization)

Source: Created by authors

Within connected devices, ag industry experts discussed specific technologies like GPS navigation and auto-steer. For example, Ag Industry Expert 1, explained how "*Because the tractor basically you set it and program it, it goes to the end of the field, turns itself around and comes back the other way. And with the proper distancing between that trip going one way and the next trip coming back*." Similarly, within remote sensing, a number of the industry experts detailed how drones are being used to provide information for spraying and harvesting. A number of industry experts also discussed specific robotics like robotic milking systems and, as Ag Industry Expert 12 further explained, "*[…] all the associated automation around the dairy farm*." Industry experts also provided more information on how big data and analytics are creating new management systems for operating farms. More specifically, Ag Industry Expert 6, noted *"[…] you can now have barn management systems that are linked to the internet that are remotely accessible and that are monitoring everything from sort of like internal temperatures and feed amounts and just the ability for a farmer now wherever they are to monitor exactly what's happening in their barn […]"*

It is worth noting that ag industry experts also discussed how farmers are integrating renewable energy into their operations. For example, Ag Industry Expert 14 noted:

> *And then thirdly, would be on-farm energy generation...combine power systems, co-generation units. Because they can really do sort of a quad generation model where they'll bring the natural gas fossil fuels to produce the electricity to run their lights. But they'll also have a system to recapture the CO2 and feed it into the crop, to push them to optimize photosynthesis while storing the heat from combustion and large water tanks to regulate the temperature of the greenhouse. How they can use that excess heat once they've maximized their storage and water to sort of reverse heat it, running absorption chillers for packing sheds.*

A number of Ag industry experts also discussed how sensors on farm equipment have changed the capabilities of the equipment. As Ag Industry Expert 1 noted, "*….sensory equipment that can sense the crop and find ones that are undersized or misshapen or whatever and knock them off the conveyor belt*."

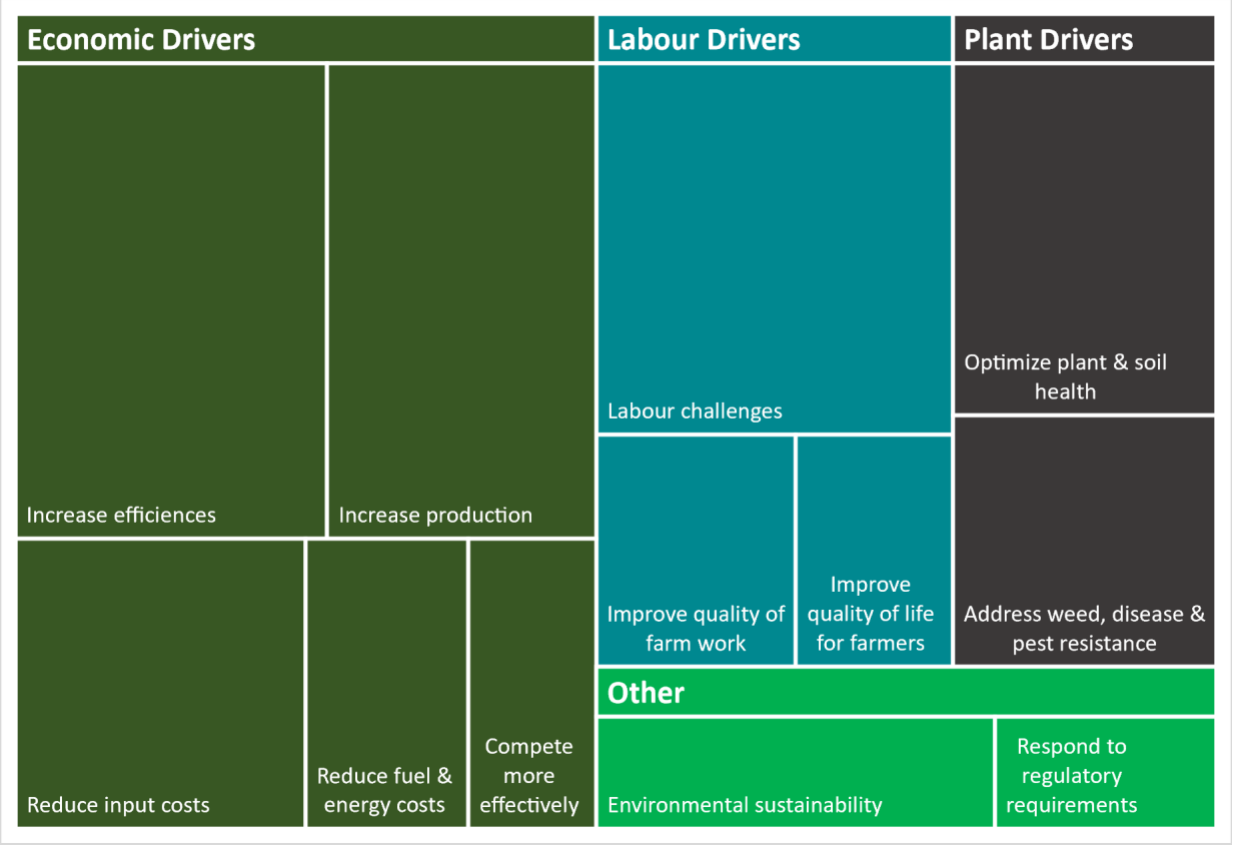
We also interviewed a number of ag-related technology companies; their products and services often fit within multiple supporting technology categories (see Table 2), with the majority being in AI/ML, robotics, remote sensing, connected devices, software & cloud computing, NextGen Farm, and big data & analytics. More specific products and services include: soil mapping platforms; food waste analytics; precision farming; field robots including those with AI/ML capabilities as well as those focused on weeding, fertilizing and harvesting; greenhouse technologies including autonomous technologies and robots for harvesting; dairy robotics; supply chain management and prediction; connected field equipment; plant and soil sensors; livestock monitoring sensors and platforms; controlled environment agriculture 'smart' facilities; and AI powered drones among others. Similarly, the ag-business experts had adopted or invested in a variety of products and/or services across the supporting technology

categories, including drones, sensors, robotics, automation, and apps for field scouting and soil sampling.[4]

3.2 Drivers for Technology Development & Adoption

As noted earlier in this report, there are a number of factors driving technology adoption in the agriculture sector. While our ag industry experts highlighted a variety of drivers (see Figure 3), some of the top responses were addressing labour challenges, increasing efficiency and production as well as reducing input costs, and optimizing plant and soil health. Our ag-related technology companies highlighted similar drivers to developing their technology products and services, with the top drivers including increasing efficiency, addressing labour challenges, and increasing production as well as optimizing plant and soil health, reducing input cost, and enhancing and/or demonstrating environmental sustainability.

Figure 3: List of Drivers for Technology Development & Adoption



Note: For illustrative purposes only
Source: Created by Authors

[4] Biotechnology was not prominent in the ag-related technology company or ag business expert interviews because our focus was on digital technologies for these interviews. However, as Ag Business Expert 3 noted *"Biotechnology is always a huge opportunity in agriculture and food."*

3.2.1 *Labour Related Drivers*

With regards to labour, our interviewees discussed a number of specific drivers including addressing labour shortages, as well as improving the quality of on-farm work. As Ag Industry Expert 11 detailed, "*Computers and robots don't get sick. They show up on time, you know. That's a big piece of it*." They further described, "*And so your potential employment draw in some of these more remote agricultural regions of the province. The population base doesn't exist there, right? So they have a different business case to automate. The talent pool isn't there."* Likewise, Ag Industry Expert 4 discussed how adopting some robotics in greenhouses is "*[…] more to tackle the labour force. So folks don't want to work in a very hot greenhouse environment, very humid*." Another Ag industry expert detailed how robotic milking systems in particular can address a number of labour issues:

> *And sometimes it's lifestyle, like I think in the case of shifting to robotic milking technologies […] I work with one farm family where it's a father daughter team and, you know, dad is just over 60, but the toll that manual milking through a high stall operation has taken on his body. You'd think he was in his 80s and daughter is coming in now to take over the operation. And they're also a medium sized field crop operation. So they're always splitting their time between the fields and the cows […]. But just the labour between both is challenging. They can sustain one additional full-time employee, but it's challenging to find that person and keep them. And so […] they're just putting in […] a robotic milker in a new barn set up. And it's kind of a quality of life decision for them […] it's obviously going to be labour efficiencies and it will allow their business to grow. But I think the most immediate thing is […] reducing the hard labour impact and […] improving their quality of life* (Ag Industry Expert 2).

Likewise, one ag-business expert noted how there are many repetitive tasks *"And there's a lot of dirty, dangerous jobs in there as well. So anytime you can automate... And we have labour issues in agriculture. You know, our farms are rural for the most part. It's hard to find trained staff"* (Ag Business Expert 3).

Our ag-related technology companies also highlighted challenges with finding skilled labour as a driver for developing their products and services. For example, Ag-Related Tech Company 5 highlighted that robotic milking systems address labour shortages and provide flexibility:

> *[…] the labour shortage is a very real thing. It's just hard to find people to do that type of work. So challenges are there and it's become accepted that this technology works, it works well. And yeah, that's the biggest driver. That's what I hear most commonly and the other biggest benefit […] you hear the most is the flexibility that you gain with that technology.*

Similarly, another company developing sensors noted that the labour shortage "*[…] motivates us in building what we're building."* More specifically, they described how *"it's hard to find a*

young [person] who wants to be a farmer or someone who is dedicated to put, like to wake up at 3 a.m. every day and go to the farm, feed the cows" (Ag-Related Tech Company 19).

Several companies also discussed how training can be a challenge, particularly because of the associated time and costs (especially acute for some commodities, such as, mushrooms) and the reliance on seasonal workers, who may not return to a specific farming operation on an annual basis. For example, Ag-Related Tech Company 5 identified that in some cases (e.g., mushrooms) it takes over six months to train someone proficiently but there can be up to a 40% labour turnover each year; in combination, these circumstances may incent farmers to use robotic harvesters.

3.2.2 *Economic Related Drivers*

A number of the ag industry experts discussed how adopting specific technologies are largely related to economic issues like increasing efficiency, improving yields, increasing production, and reducing input costs. For example, Ag Industry Expert 2 explained how applying a precision agriculture technology like satellite imagery in crop production, provides greater efficiencies in the use of inputs because *"[…] there's some economic efficiencies that are realized that if you're making best use of your seed, your fertilizer, your pesticide inputs.* Likewise, Ag-Related Tech Company 2 noted that with field robots there are energy savings *"[…] because these are all electric systems. So you know, per day, you're spending less than a dollar on electricity compared to how many tens of dollars for the fuel."* Another ag-related technology company described how with robotic milking systems, "*you can fill more kilograms of milking quota with less cows on a robot. So invariably through that, you're milking less cows, you're feeding less cows, you're breeding less cows, you have less manure, you use less acreage, all of that stuff starts to add up and equates to efficiency"* (Ag-Related Tech Company 7). Ag-Business Expert 3 simply stated: *"[…]if we can show them that there's something that'll save them money or make them money, they'll have a look at it."* Interestingly, Ag Industry Expert 13 discussed how adopting technologies can also free up time that can then be used for more productive activities: "*So you know, they're able to be doing other activities for the farm instead of just driving across the field, I think that is useful for them."*

3.2.3 *Other Drivers & Factors Influencing Technology Development & Adoption*

The environmental and sustainability benefits associated with particular technology products or services were also discussed by a number of ag-related technology companies. This was especially the case in discussions regarding controlled environment agriculture (CEA), the technologies involved in those systems, and robotic systems in general. For example, in discussing field robots, one ag-related technology company noted how *"In terms of emissions, there's a huge saving"* (Ag-Related Tech Company 2) because the robots use electricity rather than diesel fuel. This was echoed by another company discussing dairy robotic systems who further emphasized the environmental benefits because *"They use a lot less electricity, a lot less energy"* (Ag-Related Tech Company 7). Related to CEA, ag-related technology companies

discussed how climate change (e.g., unpredictable weather) is disrupting traditional farming. As Ag-Related Tech Company 14 stated: *"[…] the real focus is […] climate resilience."* Related to this, a few of the ag industry experts identified how sustainability considerations are driving the decision for some farmers to adopt new technologies. More specifically, regulatory requirements particularly around nitrogen applications were seen as a potential driver. For example, Ag Industry Expert 2 noted

> *I think when it comes to precision ag, it's two things. It's economics. So they want to do better with what they have. And then it's accountability related to sustainability […] And especially, you know, knowing what the government's focus is lately, they want to make sure that they can justify that nitrogen application or what have you, and show, you know, that they are doing the best that they can with what they have. So kind of backing up that whole, you know, farmers are stewards of the land kind of piece, but being able to back it up with data. I think those are our two key pieces.*

Ag industry experts also highlighted a number of other factors that influence technology adoption including the size of the farm, the importance of return on investment (ROI), as well as the importance of having a culture of innovation and support ecosystem. With regards to ROI, Ag Industry Expert 14 argued that, *"Typically, the justification for the implementation of new tech would be an ROI of 3 years. If it's fairly unproven, then a 5-year ROI isn't out of the question. But it would be that short, intermediate term investment, I think, for a longer-term payoff."* Ag Industry Expert 20 explained how organizational culture, the supporting environment, and farm size can influence technology adoption:

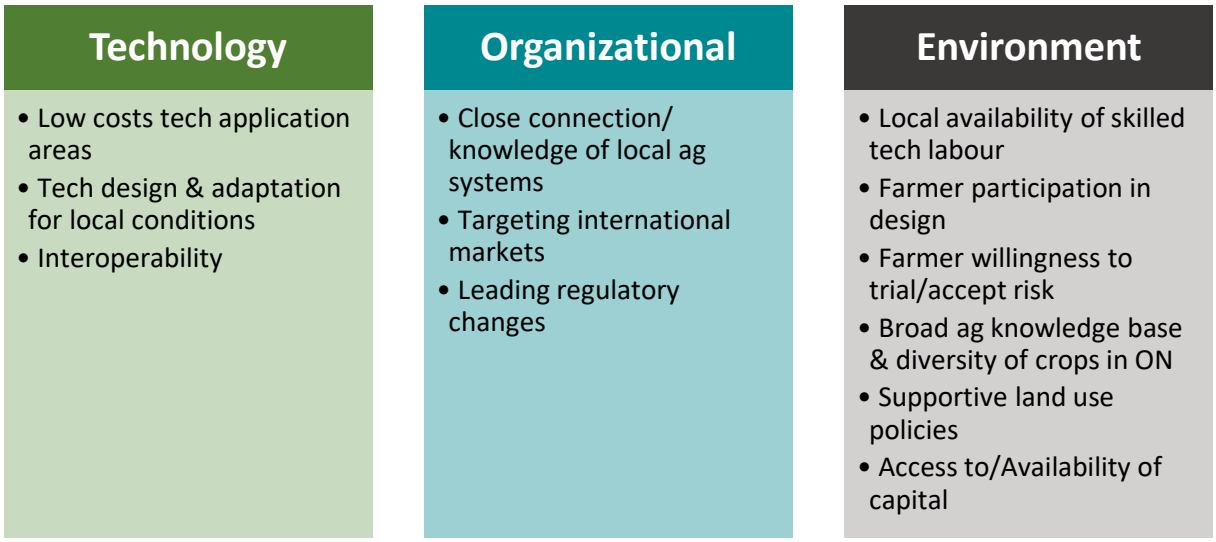
> *The competitive pressure is huge, but as well, the organizational culture is, the receptivity to the adoption of technology, having staff in place, having academic programs that are going to support that going forward so that we can ensure that, you know, students who are coming into university have access to everything that they need. And size of farm is, again, it's huge. So we see more, you know, more and more acquisition all the time and, you know, larger and larger farms. So it's in all of the above.*

Likewise, Ag-Related Tech Company 12, explained how *"[…] the generation who's taking over can't live without technology"* indicating that the pervasiveness of technology amongst youth will likely drive technology adoption in the future.

3.3 Enablers for Technology Development & Adoption

Ag-related technology companies also discussed a number of enablers that allowed them to develop and adopt specific technologies. As seen in Figure 4, responses were categorized using insights from the TOE framework (Tornatzky et al., 1990), which emphasizes the Technology, internal Organizational, and external Environment related factors that enable technology adoption.

Figure 4: Enablers for Technology Development & Adoption



Source: Created by authors

3.3.1 *Technology-Related Enablers*

Ag-related technology companies highlighted a number of specific technology-related factors including the design and adaptation of the technology for local environmental conditions or requirements, interoperability, low costs, and ease of use. For example, Ag-Related Tech Company 1 discussed how adapting technology products and services to the Ontario market is important for adoption:

> *The farmers here in Ontario, like they're already good at what they're doing right. And so you can't bring a robot from another country and say, guess what, you know, Ontario farmer, you need to stop what you're doing and do it the way they do in France. That doesn't work, right? The farmers, they aren't going to do that. They might over 25 years. But they're not going to do that today. So if we can take this machinery and adapt it to Ontario. The adoption is easier.*

While Ag-Related Tech Company 4 noted the importance of cost and ease of use:

> *So they can't be expensive tools, like lots of people will develop a tool, and then it's like 20 bucks an acre. Well, we don't need a perfect tool that's 20 bucks an acre. We need a good tool that's a dollar an acre. And so, we've focused all our products on being inexpensive and make them very simple and convenient to use.*

Similarly, Ag- Robotic Tech Company 1 discussed how familiarity can enable technology adoption. More specifically, they explained how farmers are more accepting of a robot with a diesel engine even though the interviewee thought is was inferior to the electric robots.

However, they argued: *"[…] when the farmers see it [the diesel robot] […] they see a Kubota diesel, and they see some hydraulics, all that looks familiar to them."*

3.3.2 *Organizational-Related Enablers*

A number of organizational or internal company dynamics were also discussed. For example, a majority of ag-related technology companies highlighted their close connection with, and their internal knowledge of, local agriculture systems. For example, Ag-Related Technology 7 discussed how their lab is located on a farm

> *And we're interacting with the growers and the infrastructure, doing trial and testing and actually operating on a farm right here, which is a huge advantage to interact with the farm who really understand the problems, the issues and present solutions that actually can work in the real world with the humidity, the dirt, the people involved, etc.*

They also noted how: "*having the problem actually come out of the farm is a huge advantage, I think, as opposed to someone dreaming it up in downtown Toronto or something. These problems really need to come from the growers. So that people are not coming to sell them stuff they don't need"* (Ag-Related Tech Company 5). While Ag-Related Tech Company 14 stated: *"We're still humans interacting with plants. And, you know, I never want to create a system that has become so industrialized that we lose that connection."* A number of ag-related technology companies also discussed how they strategically targeted international markets. Others noted that they are leading efforts to change government regulations to facilitate technology adoption. This was particularly the case with regards to drones and their application for uses like spraying.

3.3.3 *Environment-Related Enablers*

In terms of external environment-related factors, ag-related technology companies discussed a number of factors. These include having a locally available supply of skilled tech labour, access to and the availability of capital, and farmers participating in technology design. For example, Ag-Related Tech Company 16 described how their need for highly skilled labour, which has been facilitated through partnership with the University of Waterloo and the University of Toronto through programs like MITACS. As they highlighted, *"[…] we employ high skilled engineers and software developers. And so those are difficult to come by and extremely expensive. So we found that by partnering with universities, we've been able to get access to that talent early on and find the skilled talent we need."*

With regards to access and availability of capital, Ag-Related Tech Company 16 explained: *"So [our company] started just over a year ago out of an accelerator in Toronto based out of the Mars building. We were then funded by a large venture capital fund, a global venture capital fund out of the UK."* It is worth nothing that Ontario has a number of regional innovation centres, incubators, and venture capital firms, like RHA Ventures, which invest in early stage, agriculture and food-related startups.

Collaboration with farmers in designing and testing the technologies was also highlighted by a number of ag-related technology companies. For example, Ag-Related Tech Company 1, in discussing the development of field robots, stated its, *"The farmers who have put their hands up initially to work with us."* They further explained how farmers they work with have the tacit knowledge required to understand whether a task can be automated, explaining that:

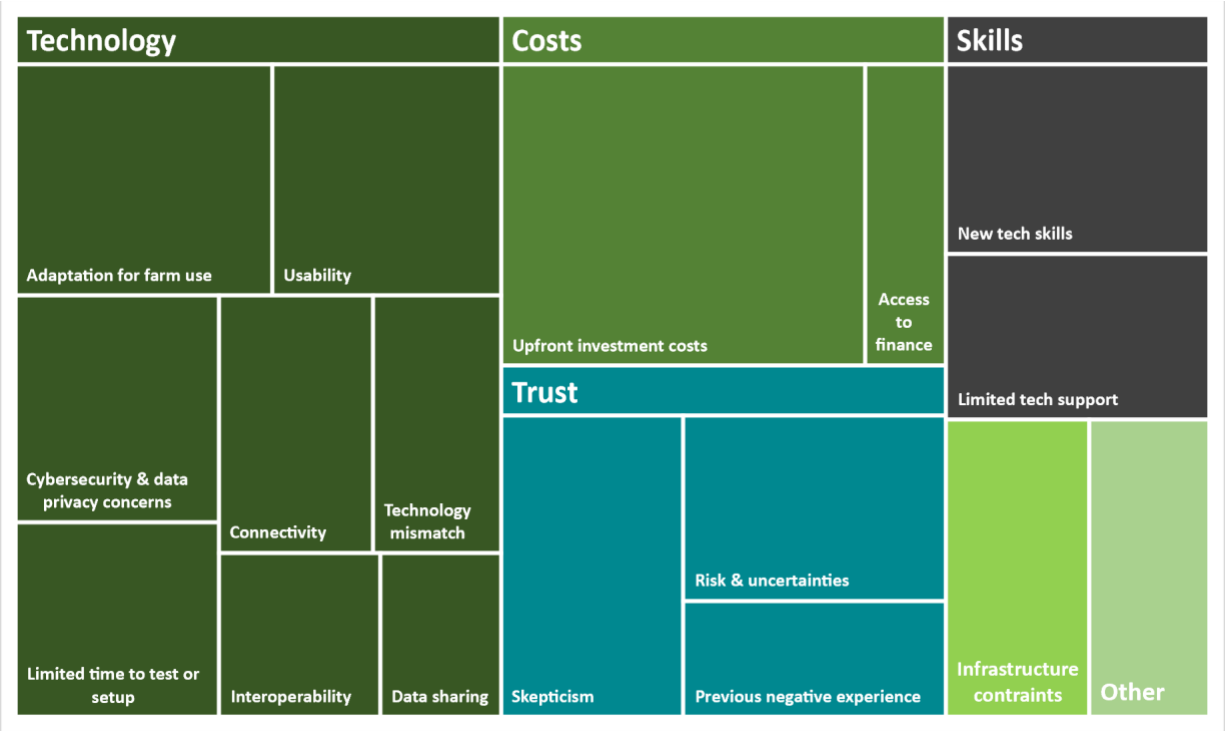
> *They have a really good understanding of their business, and how it operates. And because when it comes to using a robot, you have to understand, like every little task that's being done. […] And have a value on that. What is that task worth? And could I have an automated machine of some kind doing that instead of a person?*

They also discussed how the farmers they work with *"[…] are willing to accept that there's a better way to get things done."* Relatedly, a number of ag-related technology companies, discussed how they work with farmers who are willing to accept the risks involved in the trial a new technology. As Ag-Related Tech Company 20 stated: *"Yeah so I think it's farmers. We are working with adventurous farmers."*

3.4 Barriers for Technology Adoption

Our interviewees discussed a large number of barriers to adopting technologies. Figure 5 shows the range of barriers identified in our interviews, which we have categorized as follows: costs; trust; technology; skills; infrastructure constraints; and other barriers.

Figure 5: Barriers to Adopting Technologies



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3.4.1 *Costs, Risks & Trust Related Adoption Barriers*

Our ag industry experts discussed a number of barriers related to the implementation costs, risks, and trust involved in adopting new, and sometimes unproven, technologies. For example, Ag Industry Expert 4, discussed the importance of reliability and trust:

> *There's also issues sometimes in terms of technology, especially when you're looking at robotics. Again, you run into a similar situation with, you know, you have all these competitors in the market. Some of them are not from Canada, from outside of Canada, coming in and saying that your robotics can do these amazing things. And then they don't. And then you reach out to the company after you invest a million dollars and they're no longer in business. And so knowing which technology is reliable and which is the one that's going to be here in the next five years can be an issue.*

Ag Industry Expert 4 further argued: *Some of these robots they put on the farm, they're like a million dollars. And if they break down and you can't service them or get replacement parts, that money goes out the window.* While Ag Industry Expert 7 highlighted how there is a "[…] *crematorium of dead equipment that never worked as was sold. It didn't reach the specs, or*

it worked for three weeks, and then we couldn't get the parts." They further noted that after-sales service is critical to address this barrier.

Costs and a combination of other factors were also highlighted by ag business experts. For example, Ag Business Expert 5 noted *"A lot of these new technologies are very interesting, but if they're not cheaper, more productive, or a combination of the two, they're a tough sell."* This was echoed by Ag Industry Expert 9 who argued: *"If you have a product where you're making them change, you know, it doesn't work on my John Deere tractor. I'm going to have to put down a quarter of a million dollars more […] you have to teach me how to be a software programmer, you know, blah, blah, blah. Every one of those hurdles, you know, you lose more of your crowd."*

Related to this, Ag Industry Expert 3 highlighted how previous negative experiences with technology adoption can also be a barrier: "*I don't know what you'd call it, the failed first-time effect where you've tried it, you bought this piece of machinery or you bought into some service and the payback hasn't been worth it. And so you kind of go, well, forget this. I know what I'm doing. And you may not engage in technology in the future until it really blows you away."* Similarly, Ag-Related Tech Company 6 highlighted problems with what they termed "*snake oil technologies*" that do not work well or add value. Technology failure was also highlighted by Ag Business Expert 5 who stated: "*Actually, the biggest problem is just getting stuff to work. Most of what we're working on or have tried has failed*."

In addition, Ag Industry Expert 4 discussed how there are no industry or technology standards, like ISO standards, for equipment and robotics in the greenhouse sector, which adds to the uncertainty and risks with adopting new technologies. Finally, another Ag industry expert argued: *"[…] that integrating a new process or replacing an existing process within the farm operations can be very disruptive and so they need to be reasonably assured that that it will work right? And farms don't go from 100% manual to 100% automated overnight"* (Ag Industry Expert 18). Ag-Related Tech Company 1 also discussed how, for some farmers, the risk associated with adopting robotics is *"[…] too scary for them"* because *"When you put a robot into a crop that's worth $10,000 an acre. And you say I'm going to leave that robot cultivating all night long. How do you know that there's not going to have a $50,000 loss when you wake up in the morning?"*

3.4.2 *Technology & Skills Related Adoption Barriers*

A number of technology and skills related barriers were also discussed (see Figure 5 for an overview). With regards to technology barriers, ag industry experts discussed issues with technology mismatch or the lack of adaptation for specific agricultural uses. Ag Industry Expert 12 explained how some technology producers have experience in other sectors, like automotive, defence and manufacturing, but have less experience in designing their products to operate effectively in a "*dynamic, outdoor environment*." They further noted, *"[…] they struggle to understand the need for ruggedness, durability, length of time the thing has to run, the fact that there's not an electric plug, you know, right next to the thing to charge it up and*

stuff like that. The whole bunch of logistics stuff like that that they're struggling with." This was echoed by one of the ag-related technology companies, who explained how *"[…] sometimes they're not built robust enough for actual field conditions"* (Ag-Related Tech Company 1). Another ag industry expert discussed how technology needs to solve a real problem: *"So I think one of the greatest things is, is it actually solving a problem and helping me to answer that question?"* (Ag Industry Expert 15). They further explained that farmers also have to know how to work with the technology effectively and how these factors are interrelated with costs:

> *And tied to that, I think, is the ability for people to work with the technology effectively to allow it to solve the problem. So there's a bit of a hurdle there, probably. I think cost is part of it. But these are all interrelated, right? You know, I don't know how much I'm going to spend. If I don't see a clear return on investment, well, I don't know. But if I see a massive one, I'd be willing to spend quite a bit on that or anywhere in between, depending on what the actual value could be to a farm. So they're all kind of interrelated.*

This was reiterated by one ag business expert, who noted that in the past some farm innovations were "*made by a farmer for farmers*. […] [however] *As the technology gets more sophisticated […] there's a disconnect between the problem to be solved on the farm and the expertise to make a solution."* (Ag Business Expert 5).

Another industry expert also highlighted issues with interoperability, or the ability for different products or systems to work together:

> *I think that is a major issue for a lot of the precision agricultural technologies […]you're often buying into an ecosystem of services that are under one company, like John Deere, for example. And I think that there's questions around governance of data that comes out of that, but also just fundamentally, if you really want to maximize the value of the data you're generating through all these sensors, having access to more of an open source set of options for where you can use that data and what you can get out of it* (Ag Industry Expert 6).

It is worth noting that challenges around interoperability and agricultural technologies have recently been highlighted in the media, including the associated costs with necessarily buying all products from the same company (Duhatschek, 2024). Similar to other research, industry experts also highlighted concerns regarding data privacy and cybersecurity. For example, Ag Industry Expert 15 stated,

> *[…] we know, data is worth something. We don't always know what all it's used for. And farmers, depending on how sensitive they are about their data, may be more inclined to jump in or may be more inclined to steer clear on some of these because of the data, lack of clarity sometimes in terms of what value they're going to get out of it as a farmer."*

While Ag Industry Expert 2 explained how farmers often ask *"[…] what's happening with my data, how secure is it?"*

Ag industry experts also discussed how a lack of skills can be a barrier to technology adoption. This was in relation to both the skills needed to operate technologies and use them to their full potential, as well as the "service infrastructure" (Ag Industry Expert 18) required to maintain and service the equipment. For example, Ag Industry Expert 2 noted that "*There's a lot of data collected in these processes that we don't necessarily see farmers make great use of. And so managing that data and using it is a very barrier in and of itself*." Ag-Related Tech Company 3 also highlighted how *"farmers might be hesitant to adopt these new technologies if they don't know what they're doing. You know, if they lack information and training and then the reverse is true as well […] Like having that skilled labour to understand the farming side of things."*

In addition, several industry experts discussed the availability of service technicians as a barrier to technology adoption. As Ag Industry Expert detailed:

> *And so that type of infrastructure, if you will, service infrastructure, may or may not exist with some of these new technologies. So that's another hurdle or obstacle to adoption because the farmers are thinking about what happens when it breaks down and if it's something they can fix. Then because it's mechanical, that makes it a little bit easier to adopt if it's something that will require software upgrade and no one is in the office until Monday, that's a serious problem for a farmer. They can't wait three days to talk to someone and then another X number of days or weeks to get a part. Or if there's a software fix, you know, is there...and so in some cases farmers will ask if there is a way to go fully manual if under, you know, extreme conditions. Whereas if that chip is not working, is the equipment just dead, right, and there's no mechanical option as a base functionality. And so these also will impede its adoption.*

This was elaborated upon by Ag Industry Expert 6 who explained how farmers in Ontario have often travelled to Europe to purchase technology, but this leads to challenges in identifying how to access assistance from service technicians when necessary. Likewise, Ag Business Expert 2 noted that *"[…] support for technology. It's a huge gap. Companies launch something and then don't support it very well, and farmers take it up, and then they can't get support or they're frustrated by it."*

3.4.3 *Other Technology Adoption Barriers: Supporting Infrastructure*

Interviewees discussed a number of other barriers to technology adoption that are worth noting. Perhaps not surprisingly, rural broadband was seen as a significant barrier to technology adoption. As Ag Industry Expert 6 stated: *"I mean, the biggest [barrier] has been rural broadband access and the ability to really leverage the technology."* While Ag Industry Expert 2 further detailed how farmers will avoid purchasing new technologies if internet connectivity is needed. They argued that farmers *[…] avoided or will delay purchasing new equipment that relies on an Internet connection as a result of poor connectivity.* They also advocated that if governments are "*[…] very keen on seeing farmers adopt precision ag tech"* then access to reliable broadband is required. Ag business experts also discussed challenges with broadband

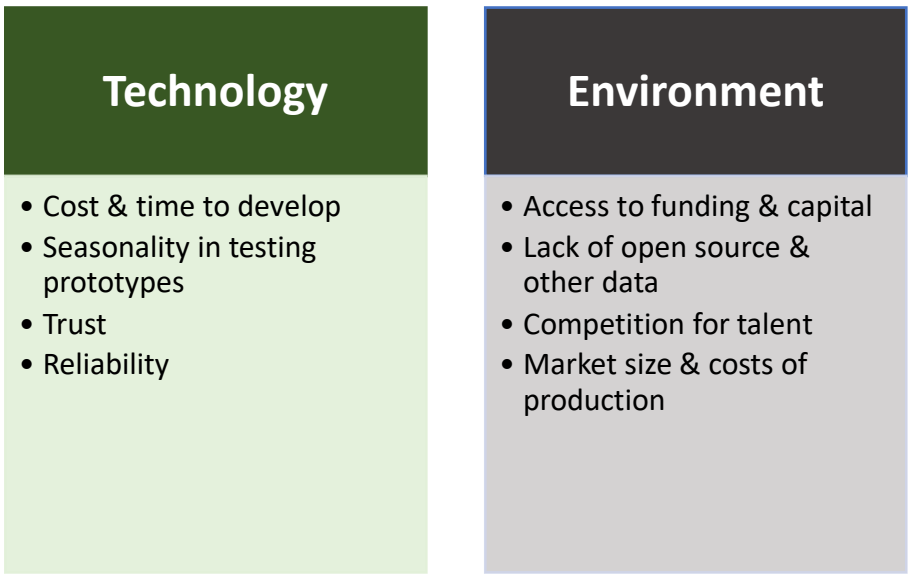
and cellular coverage. For example, Ag Business Expert 1 explained how they operate in regions where the cell signal is not strong enough to support the use of many digital technologies.

It is worth nothing that a few ag industry experts discussed how there is a growing trend towards land tenure models where farmers rent or lease land. They argued that, as a result, farmers might not invest in new technologies. However, this is an area that requires further research.

3.5 Barriers for Developing Technologies

Ag-related technology company interviewees also identified a number of specific barriers to developing or offering their particular product or service. Most of these barriers fall in the categories of technology-related or external environment-related factors (see Figure 6).

Figure 6: Barriers for Developing Technologies



Source: Created by authors

3.5.1 *Technology-Related Development Barriers*

Ag-Related technology companies highlighted a number of technology-related barriers, including the associated costs and time required to develop technologies, as well as the challenges with seasonality when testing prototypes and adopting technologies. For example, with regards to the costs and time, Ag-Related Tech Company 5 noted how the initial development of their robot began in 2014, but their first sales only occurred a decade later in 2024. As they further explained: *"You can't just buy these robotics off the shelf or the vision system off the shelf. It all had to be custom built in-house. So the cost and time and skill to do that is a serious barrier to entry."* Similarly, Ag-Related Tech Company 24 stated, *"[…] we're*

finding it's very expensive, very time consuming, especially for a smaller Canadian company, to be developing hardware and keeping up with the market" while Ag-Related Tech Company 23 noted that there is often a lot of R&D involved in creating hardware *"[…] some of it might not work. And then you would have to basically ditch that and that's money wasted."*

Challenges with seasonality in Ontario were emphasized as a barrier for prototype testing. Ag-related technology companies highlighted how there is often only one relatively short growing season for most field crops in the province, which can present a range of challenges. As Ag-Related Tech Company 11 noted,

> *Especially in a country like Canada, we only grow crop once a year. If someone wants to test it twice and commercially sign up on the third time, that's a three-year sales cycle. The long, long sales cycle is an issue, especially for small companies that are venture funded, because in a lot of cases, venture capitalists don't have the patience for a three-year sales cycle*

Related to this, some ag-related technology companies discussed how seasonality is also a barrier to demonstrating and ultimately encouraging farmers to adopt technologies. As Ag-Related Tech Company 2 explained for many farmers *"[…] it's their only livelihood and in Ontario they get only one chance at it a year. It's very hard to do business that way."* They also noted that by comparison in California, there are often three crop growing seasons per year meaning that if one crop has a problem, there are opportunities to recover. However, this is not an option in Ontario, which makes it challenging for ag-related technology companies to sell their products as their customers (farmers) have to take on greater risk.

3.5.2 *Environment-Related Barriers to Technology Development*

Ag-related technology companies also highlighted a number of external environment related barriers to technology development, including access to funding and capital, a lack of open source and other data, competition for talent, market size and costs of production. With regards to access to funding and capital, ag-related technology companies discussed a number of issues with government funding in particular, including limited funding amounts, matching requirements, and the paperwork involved in funding applications and reporting. For example, one Ag-Related Tech Company noted that:

> *a lot of the funding programs that exist are terrible. The paperwork is terrible, the requirements are terrible. You know, […] you're trying to fit […] square pegs into round holes that kind of stuff […] we're grateful for what we get. But […] they're not the best.*

They also noted that the amount of funding is often not sufficient and that the funding programs are "piecemeal". This was echoed by another Ag-Related Tech Company who explained how they managed to get several grants, however, *"[…] that number was just enough to keep us alive, but not flourish, not grow in any way*. While another Ag-Related Tech Company emphasized how programs that require matching funds can be a challenge

for smaller companies because *"[…] you gotta have money to get money."* Others noted how some private funders, like VCs, are less interested in ag-tech. For example, Ag-Related Technology Companies discussed how they are often too small for venture capitalists or that venture capitalists and angel investors often seek higher ROIs.

A number of ag industry experts and ag-related technology companies also discussed how the size of the Canadian market is too small to justify the local production of ag-related technologies. As Ag-Related Tech Company 2 explained: *"Our production is low capacity […]. In fact, we only make to order right now. And this has been a big problem. The only customers that we have, without fail, every one of them who have bought a robot, have only done so after they received a government grant."* Market size and production barriers were also echoed by ag industry experts. For example, Ag Industry Expert 6 explained:

> *I don't think there's a desire or an expectation that Canada is going to start producing these technologies and so what we have seen over a long period of time is a shift away from buying equipment locally to them being heavily dependent on international sales like imports and so you have seen a real loss over time in regional supply chains around equipment because it's just not something anymore that I think anyone is expecting it from an effect like it doesn't make economic sense for Canada to develop these supply chains for the size of industry we have here and then demand*

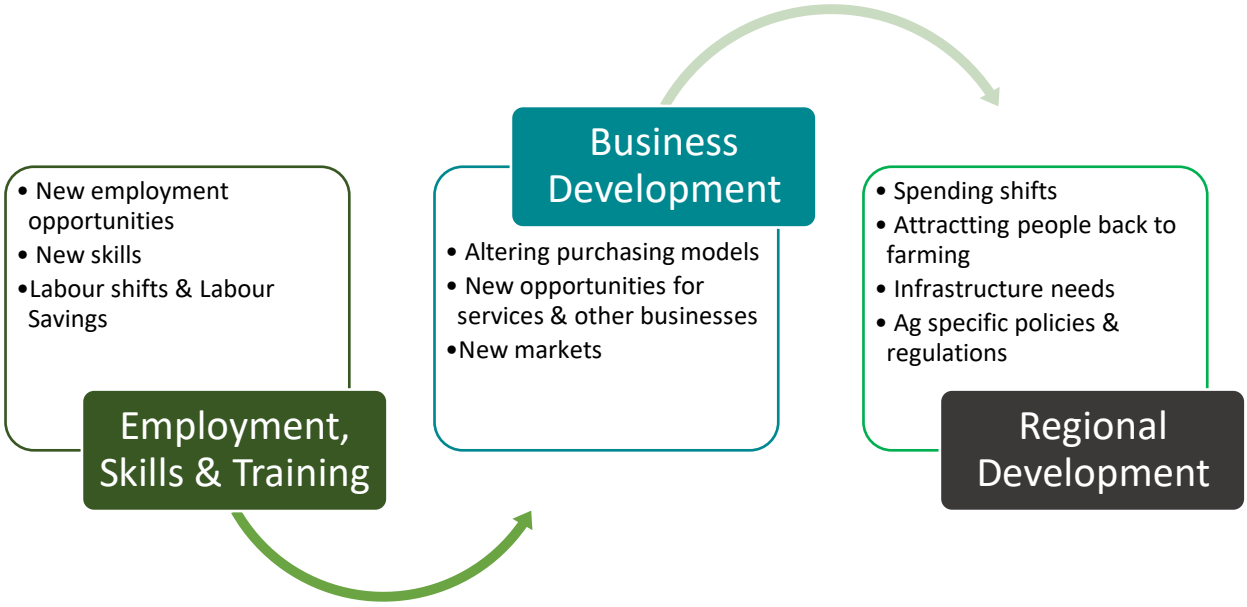
Likewise, Ag Industry Expert 7 estimated that roughly 70% of horticultural equipment is manufactured in offshore locations due to the costs associated with production:

> *[…] we have, in Ontario specifically, but you could argue Quebec as well, probably one of the best automation manufacturing zones, regions in the world. The problem with that is a lot of this focus around automotive and aerospace, which is a very high-end product. So the cost of manufacturing it here, while it could be the best system available, it could be one of the priciest systems available. So it's sometimes cheaper to source from Europe and pay the postage, basically, than it is to actually manufacture it here. So that's a bit of a problem. The other thing is, the companies that are in those automotive and aerospace sectors are used to very different market conditions.*

3.6 Impacts on Rural Development

As part of the technology assessment, we were particularly interested in identifying any impacts on employment, skills and training, business development, and regional development (see Figure 7). With regards to employment, we asked whether adopting specific technologies had changed the number of jobs, the type of work available on farms, and the skills and training requirements of these jobs. In addition, we inquired about the business development impacts, including opportunities for procurement or servicing. Similarly, we were also interested in identifying regional development impacts, such as infrastructure needs.

Figure 7: Impacts on Rural Development



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3.6.1 *Employment, Skills & Training*

Overall, interviewees discussed how adopting technologies can have several impacts on employment, which are often specific to the technology, the type of work, and even the farming operation. There was also a consensus that the impact of adopting technologies is extremely nuanced, especially with respect to overall changes in the number of jobs on a farm. As Ag Industry Expert 3 explained:

> *I've often heard from some farmers that, you know, if you're not trying to get rid of jobs on your farm, you're doing a bad job. […] But the issue with the labour savings technologies is that […] it doesn't necessarily eliminate a job because workers are doing lots of jobs. So, you know, if you're in a greenhouse and you bought the robotic picker, those workers would still be needed to do packing. So that kind of thing.*

Similarly, Ag Industry Expert 2 noted, "*So maybe the way to look at it is it adds capacity, right? Not necessarily replacing jobs, but adds overall capacity.*" Likewise, Ag-Related Tech Company 2 stated that with field robots, "*Instead of looking at replacing labour, which we have not been able to do, and none of the robots have been able to do, honestly. What they have been able to do is make one person more efficient*."

A number of interviewees discussed how labour-saving technologies are addressing labour market needs. More specifically, the industry often struggles to find workers for more labour intensive and manual work, which results in a reliance on seasonal workers to fill the gap. As Ag Industry Expert 4 noted, *"So folks don't want to work in a very hot greenhouse environment, very humid. We get a significant amount of seasonal workers that come and do that work."* Similarly, Ag Industry Expert 7 explained,

> *"I don't know what the number is today, but last year, I think it was 60,000 temporary farm workers in Canada. That's a lot. It's up from 20% from three years previously, pre-COVID type levels. If we can use technology to mitigate against that, get a better ROI, get better sustainability, I think that's good."* Similarly, Ag-Related Tech Company 5 explained how *"[…] we're not replacing, we're actually providing labour for the labour gap that exists."*

A few industry experts discussed specific technologies that have eliminated the demand for labour. For example, Ag Industry Expert 2 noted that with robotic milkers, *"It's a reduction in labour."* Similarly, Ag Industry Expert 13 noted that a farmer adopting an auto steer combine might replace someone who was doing that work previously and *"that could potentially be […] a loss of a job there."* However, they further explained that other technologies might in fact lead to more people working in the field: *"In the case of soil sampling, it may actually be there are more people working in this field providing those kind of agronomic services to the farmer."* Likewise, one of the ag-related technology companies argued that adopting their technology could lead to an increase in production, resulting in an employment increase: *"So it would actually […] likely increase employment, even though the system itself is actually designed to increase efficiency […] if we're able to increase efficiency, farmers are then able to expand their operations. And as they expand their operation, local employment will increase."*

Most interviewees discussed how technology adoption results in new types of employment opportunities with new skills requirements rather than a net loss of employment opportunities. For example, Ag Industry Expert 14 explained:

> *We employ 32,000 people in Ontario so a third of that would be that low skilled. So, the harvesters and the on-farm needs, pruning, the deleafing...just that really hands-on labour. But we do see, with the adoption of the technologies that we've discussed, a shifting of where those jobs are required. Not elimination but actually opportunity to upskill. So they're no longer a tomato picker, they're a robotics engineer or robotics technician because some of these technologies. So not...it's just labour displacement not elimination.*

Likewise, Ag Industry Expert 4 explained how with automation:

> *You don't need that human labour anymore to do that. But you do need a different type of skills now where humans now have to go and maintain those equipments or be overseeing*

it. So instead of being in the greenhouse under those humid and hot conditions, they're just going to be going in there to replace the equipment or take the equipment away so they can wash it or sanitize it. So it's a shift of skills. And so there will be an impact there.

While Ag-Related Tech Company 3 explained how adopting new technologies like AI and robotics will *"[…] disrupt the work environment [and] I think a lot of it is transitioning people from low, skilled labour to high skilled labour."* This was also emphasized by Ag-Business Expert 3 who indicated that new technologies will *"[…] hopefully keep the high value […] kind of differentiated jobs and then let go some of the ones that, you know, nobody wants to be out there weeding with a hoe on a hot day."*

Related to this, ag industry experts discussed the growing need for high-tech skills in the agricultural industry. As Ag Industry Expert 4 noted:

Yeah, I think, you know, you need more engineering and technical skills to be able to do these. You're going to need more on-site, you know, somebody with background in like IT computers, electronics. A lot of these technologies rely on sensors. Sensors mean they collect data. Data means servers, which means you need these more complicated systems on-site. You need somebody that can see those as well.

This was echoed by Ag Industry Expert 13 who specified "*Engineering and computer science for sure, it's moving into the agriculture space*." Likewise, Ag-Business Expert 4 argued that for agronomists *"[…] basically you almost need to be an IT guy in the same realm that you need to be an agronomist."* Ag-related technology companies also emphasized the need for skills related to data analytics, software development, and hardware development while ag-business experts also highlighted coding and programming skills. For example, Ag-Related Tech Company 3 noted that with the adoption of more indoor farming technologies:

there's so much data that needs to be collected and just having the idea on how to interpret data, collect data and use this to make informed decisions on how these facilities should be run is a really big skill gap that's missing. And that's where these growers are recruiting these tech companies to come. Bring in that data expertise.

Similarly, Ag-Related Tech Company 10 explained how with connected field equipment, like combines, that *"along with the change in technology in these machines, the needs or skill set of an operator has most certainly changed."*

However, some ag industry experts also emphasized that technical skills need to be coupled with industry-specific knowledge about agriculture. As Ag Industry Expert 15 stated: *"So what I'm seeing is I got a lot of computer science type people, but they're not connected to what the problem is and what the farm is. And so that disconnect is causing some challenges, I think, in terms of developing products*." Likewise, Ag Industry Expert 3 discussed how an ag-related technology company explained, "*We're always looking to find those programmers that are interested in, you know, working in rural areas. So there's a skills gap there as well on the on the*

providers.*"* This was echoed by ag-related technology companies who discussed the importance of having knowledge of the agriculture industry. For example, Ag-Related Tech Company 1 explained how

> *"a farmer knows that they have to cultivate a field at a certain depth, at a certain speed, at a certain timeframe. But the robot doesn't know any of those things*.*"* They continued, "*So how do you translate that knowledge from the farmer to the technician, […] to the machine. Like there's a gap that's missing like a farm manager type gap that's missing, that doesn't exist. And then that person also […] should be able to understand basis electronics."*

To address these skills gaps, ag industry experts discussed opportunities for colleges, universities, and governments to focus on upskilling, micro-credentials, and new skills, trades, and training programs that are specific to the industry. As Ag Industry Expert 4 simply stated, "*You need universities or colleges to be teaching these skills to the next wave of workers that are going to have […] to be able to maintain this equipment*." While Ag Expert 7 argued that we need to offer more skilled trades training:

> *I think we've grown the university sector too much. I mean, due respect to both of us, how many PhDs do you need? There's a role for them, but we're tens of thousands of tradespeople short in Canada. I'd like to see more focus on the college system in the technician, co-op, apprentice-type methodologies.*

While Ag Expert 14 discussed micro-credential opportunities, like industry-specific technician programs. An ag-related technology company also noted how colleges will likely "[…] *provide the actual in the field […] boots on the ground*" (Ag-Related Tech Company 1).

Ag industry experts also noted that ag technology producers have a role to play in providing training related to their specific products and services. This was also discussed by a number of ag-related technology companies. Interviewees identified how their companies offer training and support, including toll free numbers, 24/7 service lines, and farm management support advisors. Ag Related Tech Company 23 also noted, some government grants require upskilling for farmers and the importance of training their clients:

> *There are some grants provided by the government that if you're given this grant as a company, part of the requirements of it is that you need to upskill your farmers. So I see like a big source of upskilling coming from those opportunities. But yeah, like as a software provider, you need to teach your client anything and everything that they need. And as I mentioned, like if you're releasing a new feature that you think is going to be beneficial for their overall goals with the software, then that's provided 100%.*

3.6.2 *Business Development*

We were also interested in the impact of technology adoption on business development, particularly new opportunities for procurement, venture creation, and business models. Our ag industry experts noted a number of impacts, including how some ag technology are altering purchasing models for new products and services. For example, one ag industry expert described how for newer, high-tech tractors and combines, many farmers are leasing this equipment rather than purchasing it due to the high initial investment costs:

> *[…] most farmers don't buy, they lease […] Because to […] buy one of the big tractors that they use out here. You're looking at three or $400,000 to buy a big combine, combine and header you're looking over a million dollars for some of those big combines now […] so it's a leasing game. They'll lease it every year from the dealership […] and then the dealerships continue to serve, come out and service them when there's a breakdown or something they'll come out to the field and service it* (Ag Industry Expert 1).

This was also observed by some of ag-technology related companies. For example, Ag-Related Tech Company 1 explained how they purchase robots that can then be rented by farmers since the initial cost of purchasing the technology is often a barrier to adoption. As they explained:

> *We have purchased the robots ourselves. We've taken that risk. And I found customers to rent them and then if they rent them, then, you know, we kind of get our money back over time. But it reduces that risk factor. So now you on your 50 acres, you can say, instead of paying 350,000, you can say I'm going to pay 50,000 or 60,000 for that rental which is roughly the cost of a hand weeding crew for the year. And the ROI is much closer to what you are already spending. And so it's kind of a way to bridge that gap.*

Another ag-related technology company explained how they either sell their robot or offer a robot-as-a-service model where they charge a per kilogram rate for the robot's output (Ag-Related Tech Company 5). Similarly, another ag-related technology company discussed how they refurbish their older robot and sell them at a lower cost, which still provides "the benefits of automation" and allows farmers to enter the market (Ag-Related Tech Company 7).

In addition, a number of ag industry experts discussed how there are new opportunities for other service and business providers. As Ag Industry Expert 2 explained, *"[…] we're seeing a growth in independent agronomists. So, yeah, less folks working directly with a particular provider of service, whether that's, you know, a crop input supplier or whether that's, you know, a major precision ag company, a lot more independent folks."* They further discussed that for robotic milking systems, in particular, there has been growth in the services needed to support the on-farm adoption of robotic milking systems:

> *In the case of robotic milking, I think we're not necessarily seeing growth in more of the robotic providers, but I think that all of the services that support bringing that in to your farm situation. So the barn builders, the engineers, the designers, all of the various pieces*

that go along with bringing that in. Because […] I can't think of a scenario where you just have a barn that's ready to go and you plunk the robotic milker in. It's usually incorporated in an entirely new build or certainly a significant renovation. So there's a whole piece that comes along supporting that.

Similarly, Ag Industry Expert 14 discussed how the greenhouse sector in Ontario is growing at an "unprecedented rate", leading to the observation that "*[…] the information tech, the automation and robotics companies [are] more and more interested in setting up more than just satellite locations in the region and the region is primarily Windsor-Essex."* Many ag-related technology companies also identified business development opportunities specific to their business. For example, some interviewees highlighted how their technology product or service targeted a wider, global market. One ag-related technology company explained that they launched their product in Canada, as well as in the Netherlands. While Ag Business Expert 3 argued that companies should initially target the US market rather than the Canadian market because *"[it's 10 times the size of the market, 75 cent dollar […] And if you can compete down there, you can win well in Canada."*

3.6.3 *Regional Development*

Ag industry experts also discussed a number of broader regional development implications related to adopting technology, alongside the regional infrastructure and policies needed to support technology adoption. For example, Ag Industry Expert 12 noted that some technologies have had a negative impact on regional development. They argued that

"[…] If anything, they've [technologies] hurt the regions because there's much less dollars spent locally from farms than there ever used to be." They further continued that: "*there's less people employed. They're not buying their supplies from the hardware store in town. They're buying it from the, you know, the DeLaval dealer who could be, you know, an hour and a half away type of thing and that would be the same for all the technologies*."

Ag Industry Expert 15 also identified that with some new technologies, it is possible for work to be conducted remotely rather than being tied to a specific place. As they explained:

You don't always have to have a person right there doing it at a local site. So I think there's just more and more of that. When you just think of digital technologies and where that's going. You see it with other aspects of life where you get remote work and everything too, right? It doesn't matter necessarily where you are, you can make it work. And so I think there's an element of that that may affect regional development and whatnot.

However, a number of the ag-related technology companies discussed how adopting technologies provides new career opportunities in agriculture that are more attractive to a younger workforce. For example, Ag-Related Tech Company 2 noted that after working with robots or drones, students *"come back with a whole different view that agriculture doesn't have*

to be dirty and […] it doesn't have to be toiling in the sun. It can be fun." While Ag-Related Tech Company 7 also discussed how robotic milkers, in particular, are making dairy farming more attractive to younger generations. This was echoed by Ag-Business Expert 2 who described how technologies have *"[…] refreshed a lot of young people's desire to become involved in the industry."* An ag-related tech company working in CEA, noted that their product is helping to address food insecurity and food quality issues in remote, Indigenous communities, highlighting an additional regional development opportunity by (Ag-Related Tech Company 14).

Ag industry experts also discussed the specific regional infrastructure needed to support ag technology adoption, including energy, broadband, and more current and accessible LiDAR and soil maps. With respect to energy, Ag Industry Expert 14 noted that

> *The infrastructure isn't really helping [the] expansion of many businesses down here at the moment. There's no electricity and there's no water…not that water is a huge need for the tech companies or robotics companies that are coming down but for greenhouse expansion, it certainly is. But on that electricity side, yes, so it's a constrained grid. So even that commercial or industrial business development is exceedingly challenged to do so*.

Another Ag industry expert noted that government policies and regulations for autonomous vehicles also need to take into consideration rural and agricultural contexts:

> *For instance, the policies regarding or regulations regarding having an autonomous vehicle move from field to field, especially if they need to cross a public road in order to get to the next field. And so once it touches a public road, then a different set of rules would apply. So that's the type of policy infrastructure that need to be put in place* (Ag Industry Expert 18).

Ag-related technology companies also discussed a number of infrastructure constraints including access to broadband and battery charging infrastructure. For example, Ag-Related Tech Company 16 explained how one of their biggest infrastructure needs is broadband:

> *Broadband is one of the biggest issues we run into. Some of our farms run on Starlink because our technology is hosted on the cloud and we need constant communication with our facilities. It's sometimes difficult because a lot of the rural farms that we work with do not have a local internet connection.*

In addition, Ag-Business Expert 5 highlighted how high quality, reliable cellular reception is not universal across the province and this can be a limiting factor for using some technologies.

3.7 Responses to Rural Development Impacts

We asked interviewees to provide information on any organizations, initiatives, or programs that respond to the impacts identified above. Interviewees discussed a range of stakeholders involved including the private sector, all levels of government, postsecondary institutions and

industry associations (see Figure 8).[5] For example, one ag industry expert discussed how RBC Ag has offered sessions on big data while another explained how Ontario Craft Wineries, Tourism Partnership of Niagara and Wine Growers Ontario commissioned Deloitte to prepare a report on the wine sector in Ontario. Another ag industry expert discussed how *"There's appetite for collaboration with the sector. So you know, the various robotics companies or IT companies […] [They] are expanding their operations here and looking to collaborate with farms to prove and validate their IP"* (Ag Industry Expert 14).

Figure 8: Responses Stakeholders

Source: Created by authors

Ag industry experts noted that within Ontario there have been longstanding collaborations with the University of Guelph. Ag Industry Expert 7 noted that historically the University of Guelph has been engaged with the industry *"[…] because of the way that they get funding through the province."* However, they noted a shift over the last several years:

> *[…] there's been a lot of other universities and colleges over the last two to three years that have started to say, you know, we've got good programs, we've got good abilities to help in the ag sector as well. What about us? […] locally Niagara College, for example. But you had other places like Durham. [the University of Waterloo], you know, in their own niches. But Windsor is another one.*

[5] It is worth noting that one ag industry expert discussed how unions are increasingly becoming engaged, particularly in relation to seasonal workers.

Ag industry experts emphasized how there is a growing interest across universities in the province in working with the industry. As Ag Industry Expert 14 explained:

> *Post-secondary institutions. University of Windsor and the University of Western are looking to get much more involved with the sector. St Clair College […] is a good example there but Conestoga College and Lambton College are other institutions that are looking to, I would say, penetrate the ag sector for opportunities.*

Ag-related technology companies also highlighted a number of industry partnerships and programs, both existing and in development, including with the University of Western Ontario, the University of Waterloo, Lambton College, Fanshawe College, and Conestoga College.

Interviewees provided a number of specific responses, detailed below, as well as a number of general responses needed to facilitate technology adoption. For example, one ag industry expert discussed how their organization discusses the 'right to repair' while several others talked about the need for skilled labour, education, and training. Several ag industry experts also discussed the need for broadband and noted that this is one *"[…] of the roadblocks that government can do something about to help facilitate the adoption of technologies."* (Ag Industry Expert 2). Another ag industry expert further suggested a program similar to one in the United States to support precision agriculture technology adoption:

> *There's a lot of money, both federal and provincial that's being rolled out towards connectivity in rural areas. It's a matter of making sure that it's like robust and reliable and contiguous as well, because it's still very patchy, the connectivity, but that's been a very positive front. I haven't seen it as sort of directed at precision ag tech as I'd like, but yeah. In the States, they've got the Precision Ag Connectivity Act, which is basically it binds FCC and USDA to work together to find gaps in connectivity specifically for the adoption of precision agricultural connectivity or precision agricultural technology adoption* (Ag Industry Expert 2).

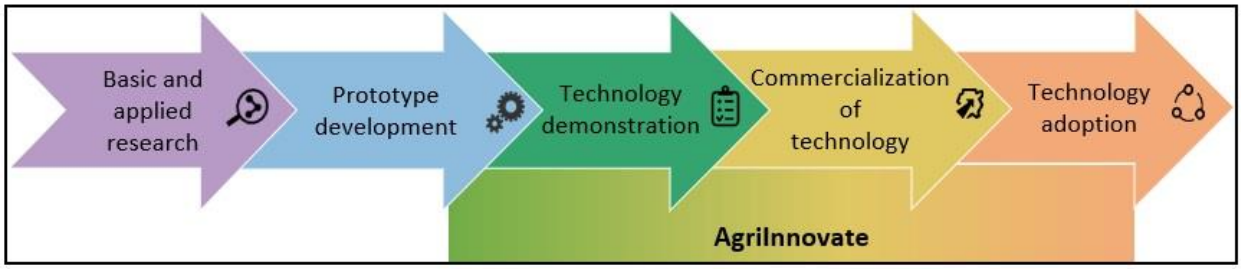
However, as ag-related technology companies noted, some farmers are turning to the private sector (e.g., Starlink) to address this broadband infrastructure deficit.

3.7.1 *The AgriInnovate Program – Government of Canada*

The AgriInnovate Program is administered by Agricultural and Agri-Food Canada, a department within the Federal Government, and is a program within the Sustainable Canada Agricultural Partnership (Sustainable CAP). The objective of the AgriInnovate program is to incentivize "targeted commercialization, demonstration and/or adoption of commercial-ready innovative technologies and processes that increase agricultural and agri-food sector competitiveness and sustainability benefits" (Government of Canada, 2024a). This is accomplished through repayable contributions, which are available to for-profit organizations that are incorporated in Canada and focused on eligible activities (see Figure 9) including technology demonstration, the

commercialization of technology, and technology adoption (for more information see Government of Canada, 2024b).

Figure 9: Eligible Activities Within the Innovation Continuum



Source: Government of Canada, 2024b

3.7.2 *Bioenterprise – Canada's Food & Agri-Tech Engine*

Bioenterprise - Canada's Food & Agri-Tech Engine has 20 years of experience in agri-tech innovation and is focused on strengthening connections within the industry, accelerating innovation, and helping businesses grow (Bioenterprise 2024a). They offer a number of programs, including: Alberta Yield, the Fertilizer Accelerating Solutions & Technology Challenge, FoodShift Program, GreenShoots, Northern Food Security Challenge, OAFRI Commercial Stream, SmartGrowth Program, Quebec Agtech Accelerator Program, and The Green Pursuit – A Sustainability & Innovation Challenge (Bioenterprise 2024b).

3.7.3 *Homegrown Innovation Challenge – Weston Family Foundation*

The Homegrown Innovation Challenge was created in February 2022 by the Western Family Foundation. The challenge is focused on creating and delivering market-ready systems that can produce berries out of season in Canada. The Challenge is providing over $33 million to 11 teams that include producers, farmers, engineers, scientists and technologists (Weston Family Foundation, 2024a; 2024b).

3.7.4 *Canadian Food Innovation Network*

The Canadian Food Innovation Network is an organization that provides funding for "transformative foodtech projects" and encourages collaboration in the food and beverage ecosystem (Canadian Food Innovation Network, 2024). Their membership includes companies, investors, government, incubators and accelerators, and academia and research centres. It is funded by the Government of Canada's Strategic Innovation Fund and focuses on three strategic pillars: Smart Product & Process Development; Food Ecosystem Sustainability; and Agile & Safe Supply Chains (see Figure 10). Their funding is specifically for industrial research, development, and demonstration activities (technology readiness levels from 1 to 7) and

delivered through a number of programs including, Innovation Boosters, the Food Innovation Challenge, and FoodTech Next.

Figure 10: Three Key Strategic Pillars

Source: Canadian Food Innovation Network, 2024

3.7.5 *Smart Farms Network – Olds College, AB*

The Smart Farms Network, led by Olds College in Olds Alberta, is a pan-Canadian network of smart farms who are "[…] committed to sharing data and expertise that will help farmers, industry and developers better understand, use and develop smart agricultural technologies" (Olds College, 2024). The network was created in 2021 with funding from the Canadian Agri-Food Automation and Intelligence Network (CAAIN). Members of the network include: the Olds College Smart Farm, Discovery Farm Langham (SK), Lakeland College (AB), the University of Saskatchewan (USASK) Livestock and Forage Centre of Excellence (LFCE), Manitoba Beef & Forage Initiatives Inc. (MBFI), Enterprise Machine Intelligence & Learning Initiative (EMILI) (MB), Lethbridge College (AB), and Discovery Farm Woodstock (ON). The overall vision of the network is to "accelerate the development and adoption of agriculture technologies across Canada by providing a platform for knowledge transfer and [the] dissemination of information related to [the] utilization of technologies and data for Canadian agriculture" (Olds College, 2024).

3.7.6 *Careers in Ag – Agricultural Manufacturers of Canada*

Careers in Ag was created by the Agricultural Manufacturers of Canada as a response to what they describe as "[…] our industry's greatest challenge – incenting and attracting talent to support sector growth today and fuelling the ingenuity of the future" (Agricultural Manufacturers of Canada, 2024). It is a partnership between industry, academia and government to highlight careers within the agricultural and agricultural manufacturing sectors

through a centralized website – CareersinAg.ca. The website includes jobs postings, news, and events as well as information on training and skills development and scholarships. It also includes a number of profiles from ambassadors that showcase a variety of careers in the sector.

3.7.7 *The Ag Robotics Working Group – Government of Ontario, OMAFRA*

The Ag Robotics Working Group is a consortium led by the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA). It was created in 2021, when Haggerty AgRobotics approached OMAFRA for assistance to test and conduct demonstration projects using the Naio Oz robot in a variety of field settings e to determine its limitations and potential in Ontario (Moyer, 2021). The Working Group has grown to include over 50 members, including OMAFRA staff, other levels of government (e.g., municipal and federal), ag robotics and ag-related technology companies, growers and growers' associations, other agri-businesses, and universities and colleges. The Working Group strives to build cross-functional teams to introduce new technologies to Ontario's agriculture sector in order to solve problems and integrate into current production systems. The goal of the Working Group has evolved from testing new technologies to determine how they will fit into Ontario agricultural production systems to also include discussions about future technologies, building and enhancing collaborations, conducting on-farm demonstrations, and building teams to apply for funding opportunities (Obeid, 2022).

3.7.8 *Ontario Agri-Food Innovation Alliance – OMAFRA & University of Guelph*

The Ontario Agri-Food Innovation Alliance is a collaboration between OMAFRA and the University of Guelph (previously the OMAFRA-U of G Partnership). The goal of the alliance is to "advance research and innovation that: contributes to the success and competitiveness of the province's agri-food sector; and promotes rural economic development" (Government of Ontario, 2023). The alliance includes a number of funding programs including, a Research Program, a Knowledge Translation and Transfer Program, a Highly Qualified Personnel Program, the Gryphon's Leading to the Accelerated Adoption of Innovative Research Program, an Undergraduate Student Experiential Learning Program, and a Special Initiatives Program (Government of Ontario, 2023).

3.7.9 *Vineland Research & Innovation Center*

The Vineland Research & Innovation Centre, located in the Niagara region, has a focus on "horticulture-related innovation, from research and development to commercialization" (Vineland Research & Innovation Centre, 2024). Vineland is an independent, not-for-profit organization that receives funding from the provincial and federal governments, as well as a variety of national and international companies and associations. Vineland has a number of facilities including farms, greenhouses and research laboratories. They focus on five major research programs: Biological Crop Protection, Consumer, Sensory & Market Insights,

Horticultural Technology Solutions, Plant Responses and the Environment, and Plant Variety Development (Vineland Research & Innovation Centre, 2024).

3.7.10 *Greenhouse Technician Program – St. Clair College, ON*

The Greenhouse Technician Program was launched in September 2023 at St. Clair College in Windsor. The program was created in response to a shortage of skilled workers in the region (Maru, 2023). It is a two-year program where students learning about the greenhouse sector through coursework, lab work, and experiential learning (e.g., greenhouse visits, placement) (St. Clair College, 2024).

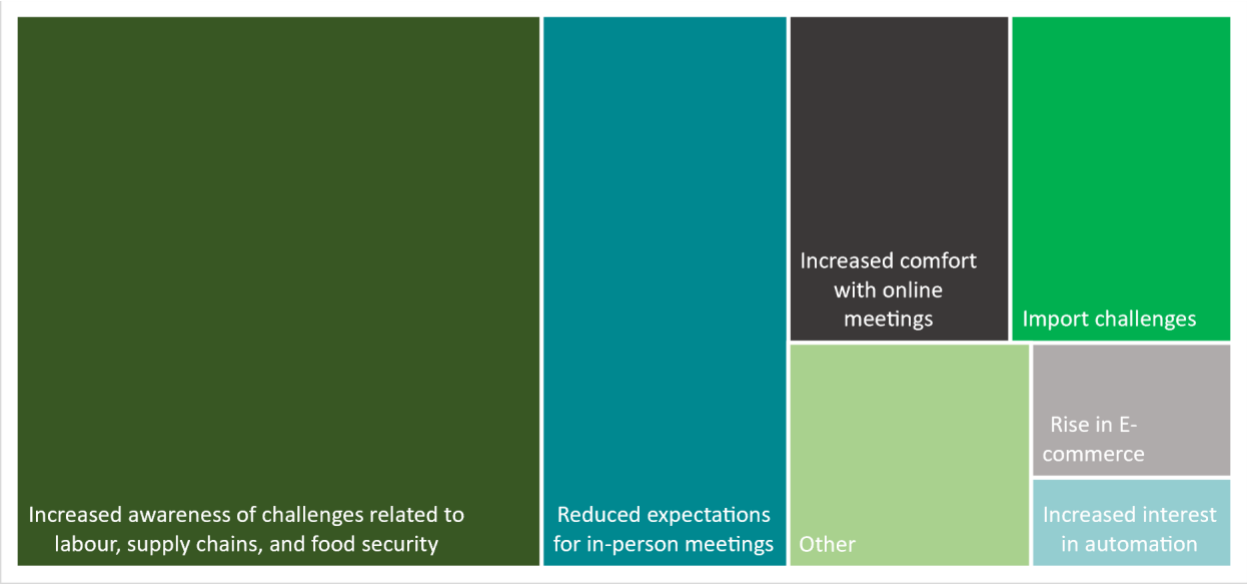
3.7.11 *Palette Skills*

Palette Skills is a national non-profit organization whose purpose is to connect Canada's most innovative companies with the talent they need to grow. Supported by the Government of Canada and University of Toronto, Palette Skills works with partners across the country to build a national upskilling system that creates new career paths for untapped talent to meet their full potential. The organization's Automation and Digital Agriculture Specialist Program is an intensive upskilling program that combines theoretical learning with practical, hands-on experience. Participants learn from industry experts in emerging technologies such as GIS, IoT, drones, AI, robotics, and big data (Palette Skills, 2024).

3.8 COVID-19 and AgTech Adoption

Given that this project was funded during the height of the COVID-19 global pandemic, we were also interested to learn if the pandemic had an impact on agtech adoption. Interviewees noted a number of shifts, including an increased interest in automation; an increased awareness of challenges related to labour, supply chains, and food security; challenges related to imports and supply chains; and a greater comfort with digital tools like online meeting tools while also reducing the need for in-person meetings (see Figure 11).

Figure 11: COVID-19 Impacts & Technology Adoption



Note: For illustrative purposes only
Source: Created by authors

For examples, Ag Industry Expert 6 provided a detailed overview of the impacts related to the industry's reliance on European technology:

> *So at the peak of the pandemic, it created a lot of challenges in particular for those European technologies that were in Canada. Getting service technicians into Canada at that time was a nightmare. And so a lot of people had real issues with being able to maintain their equipment. And I do think it has driven conversations about how there can be more resiliency and self-sufficiency in Canada from a maintenance perspective as these technologies get a little more widespread. At the end of the day, if you're the only person in Canada using a piece of equipment, there's no way you're going to, short of training yourself to the extent you can, service those things. But it did drive an understanding, and I think in the food processing and value-added space as well, that we need to look at more resiliency in Canada around how we avoid global issues like this challenging our ability to keep our equipment running. But I think sort of more generally what it did was drive home the importance of supply chain logistics.*

Similarly, Ag Industry Expert 7 also highlighted how the COVID-19 pandemic led to a growing awareness of the need for automation, concerns with the supply chain, and the need for more strategic thinking. As they argued:

> *COVID has highlighted all the fallacies of the system that were not really acknowledged pre-COVID. It's heightened the need to bring in automation. It's heightened the concerns around supply chain. It's heightened the needs around food security. So they were all*

> *there, but it was sort of in the back. There wasn't what I would call a strategic view on it. It was very tactical. COVID has shown the need to move and think in scenarios strategically for doing the what-ifs and how do I deal with it. And highlighted the things that were sort of on the back burner that could fail if you weren't thinking strategically.*

With regards to specific labour impacts, one ag-related technology company simply stated: *"It really drove home how fragile our labour system is"* (Ag-Related Tech Company 1). In addition, one ag industry expert described how the horticulture sector was unable to meet their labour needs due to travel restrictions and their reliance on seasonal workers. As a result, they indicated that *"[…] there was a lot of crop that was never harvested"* (Ag Industry Expert 12). While another ag industry expert discussed how labour shortages have persisted: *"So coming out of COVID, we found that people just couldn't get workers and everyone stayed home. And then that continues to be so. And when you ask people, you just can't get workers, can't get people to show up"* (Ag Industry Expert 19). A number of ag-related technology companies also noted that there was an increased interest in adopting robots and autonomous technologies. As Ag-Related Tech Company 3 described:

> *There is a really heightened focus on technologies […] such as robotics and automation, to mitigate the impact on the farms. So a lot of farms started adopting, like remote monitoring and automation, […] like farmers turned to technology solutions that were allowing them to manage and monitor their operations from a distance and this was ultimately reducing the need for the physical presence on the farm.*

Interviewees also highlighted a number of supply chain issues related to the pandemic. For example, one ag industry expert noted that farm equipment became more expensive and harder to acquire. Similarly, Ag Industry Expert 20 stated how, *"The shortage of computer chips was just devastating for everyone because all of a sudden we've got technology in place and now all of a sudden we can't resource it. And that was huge."* Supply chain challenges were also emphasised by ag-related technology companies. For example, Ag-Related Tech Company 19 discussed how their company was impacted by a shortage in semi-conductors which prevented them from getting product to their customers. They described the supply chain as "totally broken."

Finally, it is worth noting that a number of interviewees highlighted how the pandemic increased the industry's comfort with online digital meeting tools and phone conversations compared to relying exclusively on in-person meetings. As Ag-Business Expert 3 explained:

> *The positive is all the farmers and the agribusinesses got used to Zoom and Teams and doing things virtually. So, you know, we had a real pop, I would say, in productivity because now people aren't jumping on planes and jumping in pickup trucks and having to do everything physically. I am much more productive today than I was pre-COVID because I never used these tools.*

This was echoed by Ag-Business Expert 2 who noted: *"being able to do zoom calls and work with growers that way, less face to face. And now that the pandemic's over, we're still using those tools. Just because it made us more efficient."*

4 Future Considerations

Finally, we asked ag industry and ag business experts about future ag-related technologies and their potential impacts on rural development. A number of ag industry experts discussed an increase in robotics and automation, especially modular systems that offer more flexibility and weeding systems that provide better accuracy & efficiency (e.g., laser weeding). For example, one ag industry expert stated that, *"[…] automation is going to increase. I think just because of the amount of food that we need and food security and the labour shortages that we have, I think we're going to need more automation"* (Ag Industry Expert 4).

In addition, ag industry experts highlighted a growing emphasis on AI/computer vision being paired with robotics, cloud computing and IofT. Some also noted using AI-based satellite imagery analysis. A number of ag industry experts discussed how there is growing interest in machine learning and predictive analysis. Similarly, ag business experts highlighted how the use of AI will increase in the industry. For example, Ag Business Expert 2 stated*: "[…] anything AI, machine learning or big data analysis or just tools to get the right information to the proper decision makers faster."*Ag Industry Expert 6 detailed a number of shifts including robots for tender fruit picking, secure ledgers for supply chains, and *"[…] dramatic gains in the sophistication of farm management by virtue of more advancements in software, AI and interoperability between those systems."* A number of ag industry experts also discussed more emphasis on greenhouses and more high-technology, including robotics, being integrated into these controlled environment systems.

With regards to future considerations for rural development, ag industry experts reinforced the observation that the impacts on employment will be nuanced. For example, Ag Industry Expert described how adopting new technologies will lead to a "displacement of numbers." However, they further noted that

> *"I don't think the savings will be as much as the stories being told that it will be. Because somebody's gotta manage all these fleets of robots and stuff, right? And you're gonna have to pay them more. So they'll be less people employed, but you can't find the people anyways. So how much does it impact? It's hard to say."*

Similarly, Ag Industry Expert 13 indicated that, in their view, farming would likely become more labour intensive with technology adoption versus less labour intensive. However, as they explained,

> *"[…] it's not necessarily in the field labour intensive. It's more in the computing. […] And you know the amount of data coming in and so on, right? People looking at the data,*

what can we do with the data, so you know, it's a different kind of knowledge-based labour, I would say. But then you still need people out there to fix things when they get broken […]

Looking to the future, interviewees highlighted a number of drivers and opportunities related to technology adoption. More specifically, ag industry experts discussed how labour and sustainability considerations will continue to drive decisions to adopt technologies, particularly due to shifting consumer preferences and regulations like those in Europe with regards to sustainably grown agricultural products. While ag-technology companies emphasized opportunities for improving environmental impact and sustainability, increasing competitiveness, and improving the lifestyle and welfare of farmers.

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