Deep Dives and Case Studies for TELUS Priority Verticals: **Agriculture**

Adapted from: The Socio-Economic Impacts of 5G

Deetken Insight was commissioned by TELUS to complete a comprehensive review of published research about 5G and its potential socio-economic impacts, with a particular focus on Canada. Access the full report including a bibliography here: https://deetken.com/socio-economic-impacts-of-5g/. We provide no opinion, attestation, or other form of assurance with respect to the completeness, accuracy, fair presentation, and findings from research of others that are presented in the report.

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Key Takeaways

- The agriculture and agri-food industries, including primary agriculture, processors, retailers, wholesalers and foodservice providers, account for 7% of Canadian GDP, employ 2.1 million people, and provide 1 in 9 jobs in Canada. The primary agriculture industry, which accounts for one quarter of total sector GDP, will need to evolve rapidly over the next few years to meet the demands of global population growth and food security needs, and adapt to climate change.

- Put simply, the agriculture sector needs to increase output to meet domestic and foreign demand while reducing its carbon footprint and other environmental effects such as negative impacts caused to watersheds and soil quality, and becoming more resilient to climate change. Meanwhile, input costs are on the rise and there are constant pressures for alternative uses for Canada's agricultural land..

- 5G solutions will help. The following are example 5G solutions applicable to the primary agriculture industry and the key benefits they bring:
  - Smart irrigation systems to optimize water use
  - Variable-rate technologies to optimize application of fertilizer and crop protection, and seeding
  - Smart buildings applications to optimize energy use
  - Auto-guidance of farm machinery using GPS to optimize fleet use
  - Predictive analytics to reduce machinery downtime and maintenance costs
  - Real-time monitoring of livestock to improve health management of herds

- Research indicates that leading edge smart technologies could increase global farmland productivity by 6%, add an estimated US$500 billion to global GDP by 2030 (a 7 to 9% improvement), and reduce fossil fuel use by 16%. Extrapolating to Canada, 5G and 5G-related technologies could add an additional $2.7 billion and $3.5 billion to the GDP of Canada's agricultural sector. A case study reviewed for the report found that precision application technologies could reduce pesticide use in the canola industry in Canada by up to 85%.

- 5G offers benefits to the broader agri-food industry. For example, smart labelling and packaging could reduce food waste, while fridge and bin technologies could divert what does spoil from landfills to recycling options such as animal feed or compost.

- According to the Intergovernmental Panel on Climate Change (IPCC), between 21% and 37% of total global GHG emissions are attributable to the food system, including up to 14% from activities within the food gate, 14% from land use changes, and 10% from supply

chain issues, notably from food loss and waste. In Canada, mobile wireless technologies, including 5G, applied to the primary agriculture industry could abate 10% of its emissions, or almost 2% of Canada's total emissions.

Industry Overview: The agriculture and agri-food industries, which account for approximately 9.7% of total global GDP[1] and 6.8% of Canadian GDP and in Canada employs 2.1 million people[2], will need to evolve rapidly over the next few years to meet the demands of global population growth and climate change. According to the IPCC, between 21% and 37% of total global GHG emissions are attributable to the food system, including up to 14% from activities within the food gate, 14% from land use changes, and 10% from supply chain issues, notably from food loss and waste.[3] Over the next decade, 5G will play a critical role in the agriculture and livestock industries by enabling devices and solutions that can improve crop yields, crop quality and health of the livestock. Smart farming/precision agriculture will allow farmers and ranchers to be more informed and productive. Internet of Everything-based cloud computing service in the 5G network provides flexible and efficient solutions for smart farming that will allow the automated operation of various agricultural machines for the plowing, seeding and management phases of crop farming. In turn, this will make farming operations more secure, reliable, sustainable and energy efficient. According to a McKinsey study, "if connectivity is implemented successfully in agriculture, the industry could tack on $500 billion in additional value to the global GDP by 2030. … This would amount to a 7 to 9% improvement from its expected total."[4] Extrapolating to Canada, the GDP impact of these technologies could be between $2.7 billion and $3.5 billion.[5]

Challenges faced by the agriculture industry:

1. **Population growth:** The United Nations (U.N.) estimates the global population will increase to 9.7 billion by 2050 and could peak at roughly 11 billion by 2100.[6] A 2009 study by the Food and Agriculture Organization of the U.N. (FAO) estimates that food production would need to increase by 70% to feed their forecasted world population of roughly 9 billion by 2050, based on an evaluation of farming practices, techniques and technology at that time.[7]

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[1] Link to source: https://www.slideshare.net/IFPRI-PIM/beyond-agriculture-measuring-agrifood-system-gdp-and-employment.

[2] Link to source: https://agriculture.canada.ca/en/canadas-agriculture-sectors/overview-canadas-agriculture-and-agri-food-sector.

[3] Link to source: https://www.ipcc.ch/srccl/chapter/chapter-5/.

[4] Link to source: https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth.

[5] Based on applying the 2010 to 2020 compound annual growth rate of 'Crop and animal production' sector GDP (chained (2012) dollars) to estimate annual GDP for 2021 to 2030. The range provided is based on applying the 7% and 9% impacts to the estimated 2030 value. Link to source: Statistics Canada. Table 36-10-0434-03 Gross domestic product (GDP) at basic prices, by industry, annual average (x 1,000,000).

[6] Link to source: https://www.un.org/en/global-issues/population.

[7] Link to source: https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf.

2. **Changing weather patterns:** The variability of temperatures and precipitation and the rise in the frequency of floods and droughts because of climate change will likely have negative impact on crop yields.[8]

3. **Soil degradation:** The world's farmlands are becoming increasingly unsuitable for production. According to a study by the FAO, "the majority of the world's soil resources are in fair, poor or very poor condition. Today, 33% of land is moderately to highly degraded due to the erosion, salinization, compaction, acidification and chemical pollution of soils."[9]

4. **Water scarcity**: Water resources are also highly stressed, which places additional pressure on the agri-ecosystem and exacerbates rural poverty in certain parts of the world. According to a study by the FAO, "3.2 billion people live in agricultural areas with high to very high water shortages or scarcity, of whom 1.2 billion people – roughly one-sixth of the world's population – live in severely water-constrained agricultural areas."[10]

5. **Wastage of food:** Despite roughly 925 million people suffering from hunger globally, estimates compiled by the U.N. suggest that approximately 1.3 billion tonnes of food produced annually is lost or wasted across the entire food value chain (i.e., production, processing, distribution and end-customer consumption).[11] Analyses indicate that much of the pre-consumer waste could be avoided by refining production, manufacturing and distribution processes. Wasted food consumes approximately 30% of global agricultural land area[12] and 25% of globally freshwater.[13] A study by Value Chain Management International Inc. finds that in Canada, approximately 58% of commodities entering the food system are wasted. Of that, 24% of total waste occurs at the production level, 34% at the processing level and 13% at the manufacturing level. Distribution and retail waste accounts for 6% of total food waste and hotel, restaurant and institution waste accounts for 9%.[14]

Smart farming is expected to drive significant enhancements in food planning, production, logistics and tracking. Technologies such as the IoT, AI, ML, and BDA, supported by a ubiquitous and resilient 5G network, can help harness the value of data. This would help avert the expected future food sustainability crisis while supporting the achievement of environmental and sustainability goals of enhanced productivity, water and fertilizer optimization, and GHG emission and food wastage reduction. Mobile wireless technologies, including 5G, applied to the primary agriculture industry could abate 10% of its emissions, or 2% of Canada's total emissions.[15]

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[8] Link to source: https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf.

[9] Link to source: https://www.fao.org/3/i5199e/I5199E.pdf.

[10] Link to source: https://www.fao.org/3/cb1447en/cb1447en.pdf.

[11] Link to source: https://www.un.org/en/chronicle/article/feeding-world-sustainably.

[12] Link to source: https://www.un.org/en/observances/end-food-waste-day/background.

[13] Link to source: https://comparecamp.com/food-waste-statistics/.

[14] Link to source: https://www.secondharvest.ca/getmedia/58c2527f-928a-4b6f-843a-c0a6b4d09692/The-Avoidable-Crisis-of-Food-Waste-Technical-Report.pdf.

[15] Based on sources and Deetken analysis. Link to sources: https://www.cwta.ca/wp-content/uploads/2020/10/5G_Role_In_Fight_Against_Climate_Change.pdf; https://www.farrpoint.com/uploads/store/mediaupload/492/file/Digital_Policy_and_Climate_Change_Report_FarrPoint_2022.pdf.

Potential Digital Solutions Supported by 5G	Types of 5G Capabilities Leveraged
1. **Distributed soil sensors** that monitor and measure soil parameters such as moisture or temperature, identify issues such as diseases or insects, and enable informed farming decisions.[16] 2. **RFID, bar code and other identification technologies** that build a safe traceability system for agricultural products and enhance the added value of agricultural products.[17] 3. **Weed and crop monitoring** to track positive and negative dynamics of crop vegetation development in real-time.[18] 4. **Routing and monitoring of livestock** supports real-time management of herds to track the location, health and needs of individual animals and to adjust their nutrition, thereby preventing disease and enhancing herd health. With this information, farmers can also identify sick animals so they can be separated from the herd to prevent the spread of disease.[19, 20] 5. **Smart irrigation** through the use of controllers and devices which reduce water usage by using precise real-time and location-dependent information about site conditions. Data generated from IoT soil sensors and drones can help generate heat maps that highlight problem areas. Advanced machine learning algorithms can process this data and distribute water where it's needed most. 5G's speed and throughput facilitate the real-time transmission of these large data sets.[21] 6. **Connected farming machinery** that use GPS-enabled auto-steer to automate machine use and deployment, thereby leading to optimized operation and substantial fuel savings.[22] Automated farming equipment (e.g., smart milking equipment) and vehicles (e.g., harvesting trucks) can be controlled remotely by a central operator (human or AI), with 5G facilitating the real-time transfer of the massive amounts of data generated.[23, 24]	1. **Ultra-low and predictable latencies with quality-of-service guarantees (URLLC)** even with a heavy load and many users. 2. **Extremely high bandwidth for data transmission (eMBB),** enabling the transfer and download of massive data files, high-resolution images, videos and supporting AR/VR. 3. **Massive IoT (mIoT)** - 5G will be able to facilitate a large network of IoT devices and sensors. 4. **Fixed wireless access (FWA)** - ubiquitous and low-cost networks in rural areas. 5. **More deployment flexibility** for sparse and dense options. 6. **Mobility capabilities to ensure a smooth handover** between base stations. 7. **Reliability of device interoperability** and low device cost at scale. 8. **Location awareness** for navigating, real-time locating and positioning.

[16] Link to source: https://www.mdpi.com/1424-8220/21/5/1693/pdf?version=1614850188.

[17] Link to source: https://www.barcodesinc.com/news/bar-coding-and-rfid-enable-food-supply-chain-traceability-and-safety/.

[18] Link to source: https://www.5gradar.com/features/ways-5g-will-change-farming-and-agriculture.

[19] Ibid.

[20] Link to source: https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth.

[21] Link to source: https://www.5gradar.com/features/ways-5g-will-change-farming-and-agriculture.

[22] Link to source: https://newsroom.aem.org/download/977839/environmentalbenefitsofprecisionagriculture-2.pdf.

[23] Link to source: https://www.5gradar.com/features/ways-5g-will-change-farming-and-agriculture.

[24] Link to source: https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth.

7. **Building and equipment management** through "prescriptive maintenance and real-time environmental adjustments, aimed at improving performance and extending the useful life of farm equipment and other assets as well as decreasing the risk of mold, fire and other threats."[25] 8. **Drones for farming** for surveillance and remote interventions based on image analysis and connected sensors. Data from the drone allows users to monitor fields, livestock or autonomous machinery (e.g., driverless harvesting trucks). Drones can help isolate problem areas on a large farm and also enable autonomous, targeted (reduced) application of pesticides and herbicides.[26, 27] They have the ability to spray fertilizers, pesticides and herbicides 40 to 60 times faster than is possible with manual application.[28] **9. Smart greenhouses** that "leverage IoT and connected devices to create a self-regulating microclimate conducive to crop production. These controlled environments eliminate the struggles of inclement weather and predators while delivering real-time insights to farmers for optimum efficiency. Farmers using smart greenhouse crop monitoring systems can leverage insights from big data and analytics to regulate crop spraying, irrigation, lighting, temperature, humidity, and more."[29]	
Potential Operational Benefits	**Potential ESG Benefits**
1. **Increase in farmland productivity** by "an estimated 4% as a result of current precision agriculture adoption and has the potential to further increase 6% with broader precision agriculture adoption."[30] 2. **Improved fertilizer application (right source, right rate, right time and right place) efficiency** by "an estimated 7% and has the potential to further improve an additional 14% with broader adoption of precision agriculture technologies."[31]	1. **Ensured food security and resilience and reduced dependency on imports** by increasing crop and livestock yields, decreasing food spoilage and waste, and increasing food quality and access. [U.N. SDG - 1 and 2] 2. **Decrease in fossil fuel use** by "an estimated 6% as a result of current precision agriculture adoption [with] the potential to further decrease 16% at full precision agriculture adoption."[35] [U.N. SDG - 12]

[25] Ibid.

[26] Ibid.

[27] Link to source: https://www.5gradar.com/features/ways-5g-will-change-farming-and-agriculture.

[28] Link to source: https://www.businessinsider.com/smart-farming-iot-agriculture.

[29] Ibid.

[30] Link to source: https://newsroom.aem.org/download/977839/environmentalbenefitsofprecisionagriculture-2.pdf.

[31] Ibid.

[35] Link to source: https://newsroom.aem.org/download/977839/environmentalbenefitsofprecisionagriculture-2.pdf.

3. **Significant savings and simultaneous protection of the fragile farm ecosystem.** For example, a study conducted by the European Parliamentary Research Service finds that early, accurate detection and localized pest and disease treatment have the potential to reduce pesticide costs by up to 85%.[32] A study by the Association of Equipment Manufacturers et al. finds that herbicide usage "has been reduced by an estimated 9% as a result of current improved precision agriculture application practices and has the potential to further decrease 15% at full precision agriculture adoption."[33] Broader precision agriculture adoption enabled by 5G is also expected to result in a decrease in seeding, fuel and energy, labor and asset maintenance costs.[34] 4. **Increased human productivity and performance** and decreased level of unnecessary human intervention. Creation of new jobs by 5G in data analytics and farm management. 5. **Enhanced cyber and physical security** through real-time security monitoring and threat assessment via drones and industrial cameras.	3. **Reduced water use** by "an estimated 4% as a result of current precision agriculture adoption [with] the potential to further decrease by 21% at full precision agriculture adoption."[36] [U.N. SDG - 6] 4. **Improved worker health and safety** with the use of autonomous agriculture vehicles and drones for tasks where human involvement may be tedious or dangerous. [U.N. SDG - 3] 5. **Improved access to connectivity and integration into the end-to-end food value chain** will drive an increase in food safety and traceability and a reduction in food waste, thereby reducing GHG emissions and supporting global climate change goals. [U.N. SDG - 2, 8, 9, 10, 12 and 14] 6. **Shift of skills** and access to better professional jobs; in-field AR support for e-learning and expert advice in remote areas. [U.N. SDG - 8]
Estimated Economic Benefits	**Example Metrics Potentially Impacted by 5G**
1. 5G applications in agriculture could add an estimated US$500 billion to global GDP by 2030, and $2.7 billion to $3.5 billion to Canada GDP in 2030. [37]	1. Access to the 5G network 2. Number of 5G-enabled digital solutions implemented 3. Estimated total value realized from 5G enabled digital solutions that are implemented 4. Increase crop and livestock yield 5. Decrease in fertilizer, pesticide, and herbicide use per output 6. Decrease in water and energy use per output 7. Decrease in crop storage and transportation costs 8. Increase in farmland utilization rate 9. Decrease in food crop wastage and improved livestock health 10. Decrease in GHG emissions 11. Decrease in workplace injuries 12. Increase in labor force skills index

Select case studies:

[32] Link to source: https://www.europarl.europa.eu/RegData/etudes/STUD/2016/581892/EPRS_STU(2016)581892_EN.pdf.

[33] Link to source: https://newsroom.aem.org/download/977839/environmentalbenefitsofprecisionagriculture-2.pdf.

[34] Link to source: https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth.

[36] Ibid.

[37] Based on sources and Deetken analysis. Link to sources: https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth; Statistics Canada. Table 36-10-0434-03 Gross domestic product (GDP) at basic prices, by industry, annual average (x 1,000,000).

Precision Agriculture in Canola Farming[38]	
Background	▪ In 2018, Saskatchewan harvested over 12 million acres of canola, with total production of over 10.9 million tonnes. Roughly 90% of Canada's total canola production is exported to foreign markets.[39] ▪ Canola operations make use of fertilizers and pesticides to combat invasive plants, harmful insects and disease and promote higher crop yields. Larger operations use several tractors or manned aircraft to administer fertilizers and pesticides, which often under- or over-spray certain areas and consequently place crops, human health and the environment at risk.
Improvement areas	▪ Aerial scanning and detection by unmanned drones, in combination with large-scale IoT sensor networks, allow for autonomous, targeted application of fertilizers and pesticides – thereby reducing overall usage.
Economic and societal impacts	▪ A study by the European Parliamentary Research Service suggests that early, accurate detection and localized pest and disease treatment can reduce the use of pesticides by up to 85%.[40] In addition to cost savings, these precision agriculture techniques would result in health and environmental benefits, as well as higher crop yields. [U.N. SDG 12] ▪ For Saskatchewan's canola industry, an 85% reduction in pesticide usage would equate to roughly $360 million in annual savings. Once 5G networks are deployed and precision agriculture practices become more widely adopted, the average Saskatchewan oilseed farmer could expect to realize up to $40,000 in annual savings.[41]
5G capabilities used	▪ eMBB ▪ mIoT ▪ Power efficiency
CapEx requirements	▪ Unmanned drones, IoT devices and data analytics applications; other potential purchases include edge computing and private network infrastructure.
Maturity timeline[42]	▪ Current state: Connectivity requirements of precision agriculture can be supported by existing 4G networks; however, the implementation of large-scale IoT sensor networks and real-time video analysis will require 5G's bandwidth and speed capabilities. ▪ Short-term: Fixed wireless access and network slicing will allow 5G networks to support additional IoT applications in rural areas. ▪ Long-term: autonomous machine learning and satellite, content-based analytics that further augment the benefits of precision agriculture.

Viticulture Disease Mitigation[43]	
Background	▪ In 2019, Canada's viticulture industry earned roughly $1.5 billion in total revenue and provided over 45,000 full-time equivalents jobs.[44]

[38] Link to source: https://www.cwta.ca/wp-content/uploads/2019/11/Accelerating-5G-in-Canada-V11-Web.pdf.
[39] Ibid.
[40] Link to source: https://www.europarl.europa.eu/RegData/etudes/STUD/2016/581892/EPRS_STU(2016)581892_EN.pdf.
[41] Link to source: https://www.cwta.ca/wp-content/uploads/2019/11/Accelerating-5G-in-Canada-V11-Web.pdf.
[42] Link to source: https://www3.weforum.org/docs/WEF_The_Impact_of_5G.pdf.
[43] Link to source: https://www.cwta.ca/wp-content/uploads/2019/11/Accelerating-5G-in-Canada-V11-Web.pdf.
[44] Link to source: https://www.winegrowerscanada.ca/wp-content/uploads/2022/08/RPT-Canadian-Wine-Economic-Impact-2019-1.pdf.

Viticulture Disease Mitigation[43]	
	▪ Grapevine Leafroll Disease (GLD) is one of the most common viruses impacting vineyards globally and can be difficult to identify from the ground. The disease can reduce berry weight and delay time to maturity by up to four weeks.[45] ▪ A Halifax-based vineyard has initiated a digital vineyard pilot project, which involves flying a 4G-enabled drone over a winery to conduct real-time analysis of vineyard health.
Improvement areas	▪ An automated approach to vineyard monitoring would enable the timely identification, isolation and treatment of infected or at-risk vines necessary to mitigate adverse outcomes from GLD. ▪ Unmanned aerial reconnaissance using 5G-enabled communications networks would allow for greater volumes of data and imagery to be transmitted in real-time so farmers can quickly take action to mitigate losses attributable to crop disease.
Economic and societal impacts	▪ An Accenture study finds that "for an average 50-acre Okanagan vineyard, [GLD] could impact yield by as much as 30%. If left undetected and untreated in a timely manner via targeted [vine replacement], this would result in an economic loss on average of $18,000 annually.[46] 5G-enabled unmanned aerial drone reconnaissance enables farmers to quickly detect and treat GLD such that crop yields are improved. [U.N. SDGs 2 & 12]
5G capabilities used	▪ eMBB
CapEx requirements	▪ Unmanned drones and data analytics applications; other potential CapEx purchases include edge computing and private network infrastructure.
Maturity timeline[47]	▪ Current state: Connectivity requirements of aerial drone monitoring can be supported by existing 4G networks, however, real-time high-resolution video analysis will require 5G's bandwidth and speed capabilities. ▪ Long-term: autonomous machine learning that further augments the benefits of drone reconnaissance

[45] Link to source: https://brocku.ca/ccovi/wp-content/uploads/sites/125/2016-03-02.-CCOVI-Lecture-Series.-Urbez-Torres-Grapevine-viruses-in-BC.pdf.

[46] Link to source: https://www.cwta.ca/wp-content/uploads/2019/11/Accelerating-5G-in-Canada-V11-Web.pdf.

[47] Link to source: https://www3.weforum.org/docs/WEF_The_Impact_of_5G.pdf.