CAPI
THE CANADIAN AGRI-FOOD POLICY INSTITUTE

November 2023

A White Paper on Animal Agriculture in Canada and its Regions

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Research Report

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CAPI would like to thank Grand River Agricultural Society, UFA Co-operative, Dairy Farmers of Canada, Canadian Cattle Association, and the Livestock Research and Innovation Corporation for their financial support of this project.

To ensure the validity and quality of its work, CAPI benefitted from the engagement of a steering committee as well as three rounds of consultations with a broader audience. The list of participating organizations is in the appendix.

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List of abbreviations

ADG	average daily gain
AFS	agriculture and food system
AI	artificial intelligence
CDM	Canadian Drought Monitor
COA	Census of Agriculture
COOL	country-of-origin labelling
COP	cost of production
CPI	consumer price index
DM	dry matter
DMI	dry matter intake
E per MSY	extinctions per million species-years
EBITDA	earnings before interest, taxes, depreciation, and amortization
EG&S	ecological goods and services
FFS	Farm Financial Survey
FPCM	fat and protein-corrected milk
FT	full time
GDD	growing degree days
kcal	kilocalories
LCA	life cycle assessment
Mt CO_2e	megatons (a million tons) of carbon dioxide equivalent
N	nitrogen
NGO	non-governmental organization
NIR	National Inventory Report
OIE	Office International des Epizooties (former name of WOAH)
PT	part time
RFI	residual feed intake
SM	supply management
SOC	soil organic carbon
SPS	Sanitary and Phytosanitary Measures Agreement ("SPS Agreement")
TFW	temporary foreign worker
tg	teragram (1 trillion grams or 1 million tonnes)
UN	United Nations
VDD	Veterinary Drugs Directorate
VICH	Veterinary International Cooperation on Harmonization (of Technical Requirements for Registration of Veterinary Medicinal Products)
WOAH	World Organisation for Animal Health
WTO	World Trade Organization

Note from CAPI

CAPI undertook this White Paper initiative to provide a better understanding of the effects of animal agriculture, from the broadest of perspectives, so that an audience involved in the policy dialogue – but not necessarily ensconced in animal agriculture – could identify and understand the essential strategic elements in a holistic manner, and so that a database and accompanying analyses could allow the industry to formulate proactive strategy more easily.

To facilitate this, CAPI developed an extensive framework with sufficient breadth and a balance sheet-type of structure that accounts for stocks and flows, as well as multiple dimensions through which to evaluate outcomes: environmental, human health, economic, and social. It allows the capital stocks deployed in animal agriculture to connect with flows of outputs – farm products and wastes – which may then be organized into supply chain discussions.

The resulting White Paper report involves a literature review, data analysis and visualization, and interpretation, leading to a SWOT analysis (strengths, weaknesses, opportunities, and threats). In so doing, this document attempts to strike a balance between the granular detail of original research and specific mechanisms and relationships with high-level overview and strategic perspective.

Key Takeaways

- Animal agriculture in Canada is a complex and interconnected system, and while there are differences, many challenges and opportunities are shared. Its value and impact cannot be measured with simple metrics and requires a comprehensive approach.
- Improving economic, environmental, and social sustainability across animal agriculture requires common solutions, including growth-oriented policies, investments in research and innovation and in transportation and infrastructure, and an enhanced data framework.
- Risks facing animal agriculture, such as disease, loss of grassland, markets, and extreme weather, are increasing and require greater focus and innovative policy solutions.
- Export-oriented and domestically focused value chains both have growth opportunities, but each faces unique barriers. A constructive, strategic dialogue is needed on how to unlock each value chain's full potential.
- Canadian animal agriculture has among the lowest emissions intensities in the world. Policies that integrate sustainability, food security and growth can help meet climate targets and SDGs, and build Canada's comparative advantage.

1. Executive Summary

CAPI undertook a White Paper initiative to help provide a better understanding of the effects of animal agriculture in Canada. It addresses an audience that is involved in the policy dialogue – but not necessarily ensconced in animal agriculture – to help in identifying and understanding the essential strategic elements in a holistic manner, and by providing a database and accompanying analyses to formulate proactive strategy more easily. The White Paper was developed in consultation with key stakeholders, benefiting from their insights and expertise. It led to a well-informed SWOT analysis (strengths, weaknesses, opportunities, and threats) that subsequently allowed CAPI to develop a set of strategies and thematic policy recommendations as options for industry and government stakeholders.

The key findings were the following:

- Canada's meat, poultry and egg, and dairy producers and processors contribute significantly to the Canadian and provincial economies, to the profitability of Canadian farmers, ranchers and other players in the chain, as well as to the health and well-being of rural communities and Canadian and international consumers. In 2022, animal agriculture directly generated $89.5 billion in sales: $33.6 B from livestock farm cash receipts, and $55.9 B from meat, poultry, egg and dairy product manufacturing shipments. It employed over 164,000 people and generated GDP of $14.7 billion (Agriculture and Agri-Food Labour Statistics Program, 2023; Statistics Canada, 2023b). If the indirect and induced multiplier effects of this economic activity are added, animal agriculture contributed another $32.4 billion in GDP and a further 394,000 jobs.
- Canada benefits from an abundance of natural resources that support animal agriculture. Availability of fresh water, healthy soils, natural grasslands, permanent pastures on marginal land, and a temperate northern climate with regional variation are significant aspects. Canada's agricultural land base of 154 million acres facilitates spatial dispersion of animals and mitigation of animal disease spread, especially in western Canada, which supports significant capacity. In turn, Canada's arable land allows for a comparative advantage in low-cost feed grain production
- Canadian animal agriculture operates at a global standard. It has managed impressive improvements in productivity, quality, and efficiency metrics related to feed conversion, output relative to the size of the breeding/foundation herd, and GHG emissions relative to production (GHG emissions intensity): Canada is one of the most GHG emissions efficient animal producers in the world. These are supported by past investments in science, new knowledge, innovation, and human capital. Animal agriculture also benefits from a well-connected supply chain structure and industry and marketing associations and other institutions that engender trust, help avoid or resolve disputes effectively, and promote best management practices and marketing of safe and sustainable products. Canada is also relatively free of foreign animal diseases that would limit trade, hamper productivity improvements, and impact animal welfare.
- The international market upon which Canadian pork and beef rely has become less friendly for a small economy that is a net exporter of agri-food products like Canada. This environment is evident in the non-functional WTO dispute settlement appeals body and in the increase in concerns raised before the WTO. More generally, protectionism is on the rise, with investments in animal agriculture and food processing dependent upon access and a pricing model based on international markets, making these investments structurally riskier.
- While international demand for animal proteins is expected to grow, and Canada has few competitors capable of supplying to it, Canada's productive capacity in beef and pork production has stagnated. The beef cow herd has been in decline since 2008, recently stabilizing at around 3.7 million head in 2021. The Canadian sow herd declined from just over 1.4 million head in 2008 to under 1.2 million head in 2011, and has held steady at around 1.2 million head ever since, limiting increases in Canada's pig crop to improvements in reproductive efficiency over time. With these complex and shifting sets of dynamics along with animal disease concerns, elevated risks have made it more difficult to make a business case

for investment and capital expansion in beef and pork. The challenge may be to simply retain the existing capital stock in these industries.

- Canada is a highly efficient, low-emissions producer of animal products, having lower emissions intensities than many other regions in the world for beef, milk, pork, and poultry. For instance, Canada has lower emissions of CO_2e per kg of protein than South America countries for beef. Because food security is such a pressing need and animal foods are such a core component of food security, this is not just a matter of international competitiveness. If the objective were to minimize global GHG emissions, Canada would be one of the preferred producers and net exporters, and higher emitting countries could import animal products from Canada to meet their demands and global emissions would be reduced.
- Animal agriculture in Canada is a complex and interconnected system; isolated facts or reductionist measures typically cannot characterize its challenges and accomplishments, nor its needs from policy. Rather, a portfolio of information and measures frame the policy needs of animal agriculture.

Conclusions

Animal agriculture needs to operate – and be seen as operating– in harmony with its base of natural capital, to improve animal productivity but not at the expense of biological systems overload, and to manage complex supply chains that are resilient to a range of conditions and stresses. Government policies that support industry communities, facilitate new industry organizations where they are needed, and enhance responsible industry freedom to operate, are consistent with this ongoing and shifting need. Also, government policies are needed that support industry competitiveness, such as: an enabling environment; regulatory modernization; investments in transportation infrastructure and in research and innovation; and data and information that can provide a balanced view of the role of animal agriculture in Canada's future economic, social and environmental sustainability.

A portfolio of beneficial attributes – especially biodiversity and carbon sequestration – are tied to grasslands, and grassland will readily flip into other land uses on a market basis that does not reflect the value of these attributes, and can be detrimental to them. Governments can explore policy measures that prevent the conversion of grasslands and the grazing sector, such as by facilitating conservation easements that retain land in pasture, or by providing payments for ecological goods and services (EG&S) such as carbon and biodiversity credits and management practices which increase the efficiency and profitability of beef cattle production.

The imminent threat presented by African Swine Fever has had the effect of chilling investment throughout the pork supply chain. Governments and industry associations have been very active on this issue, but the dimension of threat justifies greater action. In particular, public action on the problem of wild pigs as vessels of infection and a permanent reservoir of disease remains inadequate, apparently caught between jurisdictional restrictions in provincial departments with a wildlife mandate, and federal/provincial departments of agriculture. This presents an opportunity for coordinated federal-provincial-territorial action and policy implementation based on One Health principles.

Both pork and beef have suffered from the erosion of rules-based trade and gaps in bilateral trade agreements. Canada has led efforts to rejuvenate and strengthen multilateral rules-based trade, and these efforts should be redoubled. Enforcement efforts on market access provisions of trade agreements, notably the CETA between Canada and the EU, appear to have left gaps for Canadian beef and pork. The entry of the U.K. into the CPTPP agreement is another opportunity for Canada to more assertively position itself for beef and pork market access. In addition to market access, the federal government can provide enhanced market development support, especially in markets where Canada's presence in beef and pork has historically been small.

Much of the success of domestic-focused industries has been in their collaborative adaptation to changes in markets, technology, and policy. This needs the freedom to continue as, like all aspects of animal agriculture, there are problems to address and improvements to make. Federal and provincial governments are key stakeholders and can act to support and encourage industry development within their existing regulated structures.

Canada has been active in discussion on climate change policy, taking a whole-of-economy approach to it domestically and being heavily engaged in the international dialogue, both climate change and sustainable development goals. Canada thus has the platform, and the interest, to apply a food security filter to both national and international climate change policy, and advocate for change. Canada's comparative advantage in sustainable animal agriculture creates alignment with UN sustainable development goals (SDGs) #2 (Zero Hunger) and #12 (Responsible Production and Consumption). However, downsizing or impairing the efficiency of Canadian animal agriculture with strict emissions constraints would run contrary to the advancement of these SDGs.

2. Introduction

Animal agriculture is an essential part of the Canadian agricultural economy, serving as a foundation for farm family livelihoods and vitality in rural areas, supporting the social and cultural fabric in regions across Canada and underlying the value-addition in agri-food supply chains. It also is expected to be called upon further in the future as the demands and opportunities for animal-based products grow and expand. Equally, farm animals play a crucial role in the various facets of sustainable agriculture. This applies across many aspects: greenhouse gas (GHG) emissions, water quality, biodiversity, soil health, grasslands preservation, land use, and many others. As an example, soil can be a major factor in climate change mitigation through carbon storage, and also improved water retention through soil organic matter. Undisturbed agricultural lands have the best carbon-capturing capacity, such as natural prairies (grasslands). Cropland and tame pastures also have potential to store more carbon than they produce by implementing specific management practices such as no-till and prevention of soil erosion (Wood-Bohm, 2018).

Animal agriculture has a role in transforming inedible biomass and crop residues into edible nutrients for human consumption and into natural fertilizers for plant nutrients. This process is known as “upcycling” and makes use of products which would otherwise be returned to the ground as waste, and would emit GHGs as they slowly decompose. Instead, the digestive systems of animals generate human edible products and expedite the process of turning these waste materials into nutrients which are readily available for crops.

Despite differences across regions and species, in terms of production systems and industry structure, many of the challenges facing animal agriculture are held in common and do not fragment themselves across commodities (species) or regions, yet others are very location or species-specific. Climate change figures prominently, as do changing consumer preferences, animal welfare, food security, global competitiveness, and economic viability and resilience of key players in the system. An important aspect of this relates to the economic and environmental role of farm animals in anchoring agricultural and agri-food systems and in sustaining rural areas. Another is the contribution to healthy human diets and the problem of hunger addressed by animal-based foods. Increasing the understanding of how livestock fits into agricultural systems, providing needed economic development, and contributing critically to human health, food security, social and cultural well-being and sustainable production is essential as the livestock sector continues to evolve, investing in new technologies and practices to improve its economic, environmental, and social sustainability for future food production.

This White Paper is an attempt to provide a better understanding of the effects of animal agriculture, from the broadest of perspectives so that an audience involved in the policy dialogue- but not necessarily ensconced in animal agriculture- could identify and understand the essential strategic elements in a holistic manner, and to provide the database and analysis that could allow the industry to formulate proactive strategy more easily.

2.1 Objectives of this White Paper initiative

The purpose of this White Paper is to serve as a discussion document that provides an overview of the animal agriculture value chain and system in Canada, describes the challenges and opportunities it faces and discusses future industry strategies and policy solutions that can ensure the future sustainability, viability and resilience of animal agriculture in Canada.

The specific objectives are to:

- Provide an economic overview of animal agriculture in Canada and the regions;
- Describe and explain the role of animal agriculture in the Canadian agriculture and agri-food system, including its socio-economic and environmental impacts and the resources it requires and generates;
- Describe Canada in the global context of animal-based production, exports, supply and demand;

- Identify the challenges, opportunities and potential strategies for animal agriculture in Canada and in the regions; and
- To synthesize the findings and place the results in context for industry and government decision-makers.

2.2 Approach

The White Paper begins with a review and careful consideration of analytical framework. From this, the dimensions of information and analysis and its extent are determined for the core of the study. The bulk of the White Paper populates the framework for assessment with data and analysis. It concludes with an analysis of strengths, weaknesses, opportunities and threats (SWOT) for Canadian animal agriculture based on the findings in the paper.

2.3 Scope

This paper takes on a vast topic; making it tractable requires setting limits and focusing within them. First, we focus on the major categories of animal agriculture- beef, dairy, pork, and chicken. In places this is extended to include the broader cross-section of poultry and eggs. This passes over small ruminants, aquaculture, bees, and fur-bearing animals. Secondly, the depth at which the paper can get into in any one aspect is limited. Accordingly, much of the literature referenced is structured reviews and meta-analyses rather than original research papers.

2.4 White Paper Process

This study is conducted as a White Paper process. The process of white paper development involves the participation of a steering committee to advise and an external group of review panellists who can provide critical input and insight into the study. The steering committee was established at the beginning of the project and has provided invaluable guidance and direction for the paper. In addition, a series of consultations with external reviewers will help keep the project on track and informed with the latest and most accurate data and information. This provides for a responsive process to generate a report validated by a diverse group of experts fully engaged in the study.

2.5 Audience

The intent of the project is to develop an accessible paper for all who have an interest in animal-based foods and animal agriculture. Three specific audiences for the report's findings are industry associations, and government decision-makers (federal, provincial and municipal) and the public. Animal industry associations are frequently called upon to develop strategies or strategic plans for the industries that they represent and to communicate these effectively so they can inform government and industry decision-makers and consumers. Well-done strategies will address the nuances of the specific animal species, region, and customers that industry interacts with while leveraging more general knowledge that is common across regions and species. The study aims to provide up to date facts and information that can be used to facilitate better dialogue and make informed decisions.

3. Background and Context

3.1 Animal Agriculture in Canada

Animal agriculture around the world faces challenges as countries strive to adapt to climate change while also addressing the environmental impacts of livestock production on soil, water, land use, GHG emissions and biodiversity. At the same time, animal agriculture is increasingly seen as essential to human health and farmer livelihoods but consumers are increasingly concerned about the environmental footprint of meat consumption and new plant-based products and even lab-based meats and poultry are emerging to compete with meat production. Other challenges for animal agriculture include the emergence of zoonotic diseases transmitted from animals to humans (e.g. Avian Influenza) and vice-versa, animal care practices, and the rise in antimicrobial resistance that is blamed in part on antibiotic use in livestock production, all influencing consumer perceptions and management practices. In addition, global trade distortions from unfair trade practices and geopolitical tensions have disrupted global meat markets and trade. Hence, efforts are being made to ensure livestock production can continue to respond nimbly and flexibly to these challenges and become as sustainable as possible, economically, environmentally and socially. Much progress has been made, particularly in developed countries, to lower the environmental footprint of animal agriculture, respond to animal disease and antibiotic resistance and improve animal welfare through research, new technologies and production practices, feeding regimes and animal health, welfare and safety. But more is required.

Canada has a reputation as a producer and exporter of high quality, safe and sustainable animal products. On January 1, 2023, Canada reported an inventory of 11.3 million head of cattle, 13.9 million hogs, 809 million chickens and turkeys, and 854,400 sheep and lambs on 76,796 farms with livestock across Canada. In 2022, Canadian livestock producers earned $33.6B in farm cash receipts, exported $11.5B worth of live animals and animal products and imported $5.4B of the same. At an estimated $56 billion in sales, Canada's meat, poultry and dairy processors contributed significantly to Canada's GDP, employment and to the availability of safe, healthy food for Canadians. With a GDP of $14.8B in 2022, animal production and meat, poultry and dairy product manufacturing contributed to the profitability of Canadian farmers, ranchers, agribusinesses, processors and distributors and to the health and well-being of Canadian and international consumers. Retail sales of meat, poultry, and dairy products grew to $35 billion in 2022.

The livestock industry in Canada has made substantial progress over the past two decades in responding to the challenges it faces from climate change, animal disease, consumer perceptions of livestock and the environment, human and animal health and welfare, and society as a whole. While there is still much work to be done, the industry and all players within the animal value chain are pushing the limits to find new ways of feeding, producing, transforming and marketing animal products to ensure these challenges are addressed. For a sustainable and resilient animal agriculture industry in Canada, innovative solutions and strategies will be required that are built on strong research foundations as well as science-based information and analysis that can be communicated effectively. This will be strengthened by a supportive enabling environment where government policies and regulations help ensure animal agriculture in the future can be prosperous, resilient and sustainable. This white paper is an attempt to advance this goal.

3.2 Canadian Policy Environment and International Commitments

Canada has a reputation as a producer and exporter of high quality, safe, and responsible food products, based on a strong, reliable regulatory system. Canada is a committed participant as a signatory in many international fora that promote animal health, (i.e. the World Organization for Animal Health, formerly OIE; see Weaver *et al.*, 2017), food safety (i.e., Codex Alimentarius and WTO SPS), fair trade (i.e. World Trade Organization), human health (i.e. the World Health Organization), biodiversity (i.e. the Convention on Biological Diversity), and climate change (i.e. the IPCC and the Paris Accord). Canada, as a signatory to the Paris Climate Accord and subsequent COP summits, has committed to reducing national net GHG emissions by 40 to 45 percent below 2005 levels by 2030 and to achieving net-zero emissions by 2050 (Government of Canada, 2023). These net zero commitments were enshrined in the *Canadian Net-Zero Emissions Accountability Act* which received Royal Assent in June 2021. Canada also signed onto the Global Methane Pledge with a strategy to reduce economy-wide domestic methane emissions by more than 35% by 2030 compared to 2020 (Government of Canada, 2023). Finally, at the recent COP15 to the UN Convention on Biological Diversity (CBD) in Montreal in December, 2022, 196 countries including Canada agreed on an historic Global Biodiversity Framework (GBF) that set goals and targets to safeguard nature and halt or reverse biodiversity loss around the world, putting nature on a path to recovery by 2050 (Environment and Climate Change Canada, 2022b).Canada played an important role in the event, committing resources to support these goals, including a promise to protect 30% of lands and waters by 2030, respecting the rights and roles of Indigenous peoples and addressing the drivers of biodiversity loss, such as pollution and overexploitation of nature.

Canadian agriculture, being a contributor to GHG emissions, at 10% of the Canadian total, is also expected to play its part in mitigating and adapting to climate change. The national fertilizer emission reduction target announced in December 2020 to reduce fertilizer emissions by 30% by 2030, is a commitment to curbing nitrous oxide (N2O) emissions from agriculture, having experienced an increase over the past 15 years (Agriculture and Agri-Food Canada, 2023b). At the same time, improvements in soil management practices, such as no-till, cover cropping, 4R, and precision farming leading to carbon sequestration have helped offset some of these emissions. Both Fertilizer Canada and grain and oilseed producers across the country are working to help reach this goal. The animal agriculture industry is doing its part to reduce GHG emissions through research, and farming practices such as precision farming practices and technologies, manure management, rotational grazing, new feeding regimes and formulations, improved animal health, increased feed efficiency and improved nutrition and animal genetics that reduce environmental impacts.

Federal-provincial-territorial (FPT) Ministers of Agriculture have prioritized a more sustainable, viable and resilient agriculture and agri-food sector with their 2023-2028 five-year *Sustainable Canadian Agricultural Partnership* (SCAP) funding agreement, signed in July 2022 (Agriculture and Agri-Food Canada, 2022a). This new agreement, providing $3.5 B over 5 years, sets strong targets for reducing GHG emissions by 3 to 5 MT over the period, and aims to improve biodiversity and protect sensitive habitats as well as increase sector competitiveness, revenue and exports within an inclusive and sustainable (economic, environmental and social) agriculture and agri-food industry ecosystem. Many provinces have introduced their own policies and programs to boost sustainable agriculture, including Quebec's Sustainable Agriculture Plan 2020-2030 (Québec, 2020) and British Columbia's Sustainable Agriculture Strategic Framework (British Columbia Ministry of Agriculture and Food, n.d.)

More recently, Agriculture and Agrifood Canada (AAFC) finalized the first phase of consultations on its Sustainable Agriculture Strategy (SAS) that will set a shared direction for collective action to improve environmental performance in the sector over the long-term, support farmers livelihoods and strengthen the business vitality of the Canadian agricultural industry (Agriculture and Agri-Food Canada, 2023c). AAFC's Strategic Plan for Science is the Department's vision for the future of research and development (R&D) to adjust to the new reality and tackle the challenges of today and tomorrow (Agriculture and Agri-Food Canada, 2022b). The change begins with a paradigm shift toward sustainable agriculture, which takes into consideration the environmental, social, and economic context in which all of our scientific activities are conducted.

Because of the growing importance of sustainability as identified by governments, industry and consumers, there is also a great need to be able to measure, monitor and report on progress being made. Organizations such as the Canadian Roundtable for Sustainable Beef (CRSB, 2023), Dairy Farmers of Canada with their Pro-Action program and the Egg Farmers of Canada with their plans for sustainability have placed much effort in developing the means to verify and certify sustainable agriculture production. This is motivated by the growing market demands by consumers and by major corporate players in the agriculture and agri-food space to deliver verifiable sustainable food products in domestic and global markets. This has led to the development of important metrics for sustainability. The National Index on Agri-food Performance is one such initiative that is attempting to help Canadian producers, processors and retailers communicate clearly and consistently how Canadian agriculture and food products measure up on sustainability both at home and abroad. These initiatives will go a long way in ensuring Canada can market and deliver sustainable food products, including animal-based products, to the world and to domestic consumers.

4. Conceptual Framework for Animal Agriculture in Canada

The crucial first step in developing an assessment of animal agriculture in Canada is to establish its frame of reference, or conceptual framework. To develop the appropriate frame of reference for this study, selected studies that have developed analogous frameworks are reviewed. These are then evaluated for the Canadian animal agriculture, and the essential framework developed.

4.1 Focused Initiatives on Animal Agriculture

4.1.1 The U.S. Farm Foundation Future of Animal Agriculture in North America

The Farm Foundation in the US developed an initiative on the Future of Animal Agriculture in North America (Farm Foundation, 2004; 2006; Halbrook et al 2006). The initiative employed a white paper approach, with broad engagement from industry, government, not-for profit organizations, and academics. The focus of the initiative was on issues facing animal agriculture obtained through consultation, rather than to develop a fulsome framework and then use the framework with stakeholders to identify issues. The project identified seven key challenges to US animal agriculture (1) Economic viability of production, processing, and marketing; (2) Environmental concerns; (3) Shifts in consumer demand in North American and global demand; (4) Food safety, biosecurity, and animal health; (5) Animal welfare; (6) Community and labour issues; and (7) Global competitiveness and trade. The initiative developed options for the future under each of these headings, and further focused them into the following cross-cutting themes:

- Markets, structure, and competition
- Value in integrated markets
- Increasing demand
- Environmental regulation and litigation
- Immigration and labour
- Animal identification and traceability systems
- Community impacts

There are some remarkable similarities between this initiative and the current project, notably its white paper structure and broad nature of consultation. The issues identified remain, almost 20 years on, although some have changed significantly. For example, immigration and agricultural labour issues affecting animal agriculture have only intensified and become more urgent. There have been great advances in animal identification and traceability. Conversely, the environmental issues and fear of repressive or nuisance regulation and litigation have shifted significantly, in both substance and tone, especially with greater understanding and experience with climate change. The topic of integrated markets and trade does not contemplate the devolution of multilateral trade institutions, geo-political tensions, and greatly enhanced awareness around food security and the demand for proteins. More generally, the Farm Foundation initiative did not attempt to approach animal agriculture as a cohesive system with broad interrelated effects as we do here, electing instead to capture these implicitly in stakeholder consultations.

4.1.2 The National Academy of Sciences (NAS) Framework for Assessing the Food System

Committees operating under the US National Academies of Science published work in which analytical frameworks were developed, relevant to the assessment of animal agriculture. In *A Framework for Assessing Effects of the Food System* (Nesheim *et al.*, 2015) the NAS undertook an ambitious effort to fully characterize the effects of the food system and also how the food system is affected by influences external to it. The committee began its work by defining the following principles:

- Principle 1: Recognize Effects Across the Full Food System
- Principle 2: Consider All Domains and Dimensions of Effects
- Principle 3: Account for System Dynamics and Complexities
- Principle 4: Choose Appropriate Methods for Analysis and Synthesis

These principles were adopted by defining domains of effect and dimensions of effect of food systems. These are summarized in Table 4.1 below. The task was to document and assess the quantity, quality, distribution, and resilience associated with health effects, environmental effects, social effects, and economic effects of the food system.

Table 4.1. Domains and dimensions of effects

		Dimensions of Effect			
Domains of Effect		Quantity	Quality	Distribution	Resilience
	Health				
	Environment				
	Social				
	Economic				

As a means of using the above paradigm for assessment, the food system was conceived as a complex adaptive system, defined as “a system composed of many heterogeneous pieces, whose interactions drive system behaviour in ways that cannot easily be understood from considering the components separately.” It consists of individual adaptive actors, feedback and interdependence across multiple levels, heterogeneity, spatial complexity, and dynamic complexity.

Also in 2015, a separate initiative by the US National Academies of Science was charged with assessing the future needs for animal science research (National Research Council, 2015). The committee’s observations on its scope and assumptions are pertinent to this study:

"animal agriculture in the 21st century faces increasing and persistent challenges to produce more animal protein products in the context of an emerging, globally complex set of conditions for sustainable animal production. This, in turn, requires the rethinking of the very nature of animal science. In addition to the increasing demand for animal products in the context of globalization of food systems, these challenges include, but are not limited to, consequences for individual country and regional concerns about food security, such as the impact of geopolitical strife on food production and distribution, the intensification of production systems in the context of societal and environmental impacts, the development and maintenance of sustainable animal production systems in the face of global environmental change, and the multidecadal decrease in public funding in real dollars for animal science in the United States and variable funding worldwide" (page 51).

The committee based its work on three basic assumptions to guide its work:

- global animal protein consumption will continue to increase based on population growth and increased per capita animal protein consumption

- restricted resources (e.g., water, land, energy, and capital) and global environmental change will drive complex agricultural decisions that affect research needs.
- current and foreseeable rapid advances in basic biological sciences provide an unparalleled opportunity to maximize the yield of investments in animal science R&D

The committee identified the following specific challenges as key for meeting sustainable agriculture targets by 2050.

- Growth in demand for animal protein due to:
    - Population growth
    - Increasing global affluence
    - Increase in per capita animal protein intake
- Impact of global environmental change on:
    - Climate
    - Habitats
    - Animal feedstocks
- Water and land scarcity
- Changes in consumer preferences
- Changes in national and international regulatory requirements reflecting public concerns about animal agriculture practices
- Role of trade barriers and other governmental actions on animal agriculture in different regions of the world
- Health considerations, such as emerging infectious diseases and foodborne pathogens
- Lack of research funding in the future

The assumptions and challenges envisioned for sustainable animal agriculture for the basis for the framework were used to assess need in animal science research.

4.1.3 The Economics of Ecosystems and Biodiversity (TEEB) Accounting Framework

The United Nations Environment Programme conducted a broad initiative on The Economics of Ecosystems and Biodiversity' (TEEB); one area of focus was on agriculture and food (TEEB, 2018). Through this initiative, a comprehensive framework was developed to assess the agri-food system. The report explains that

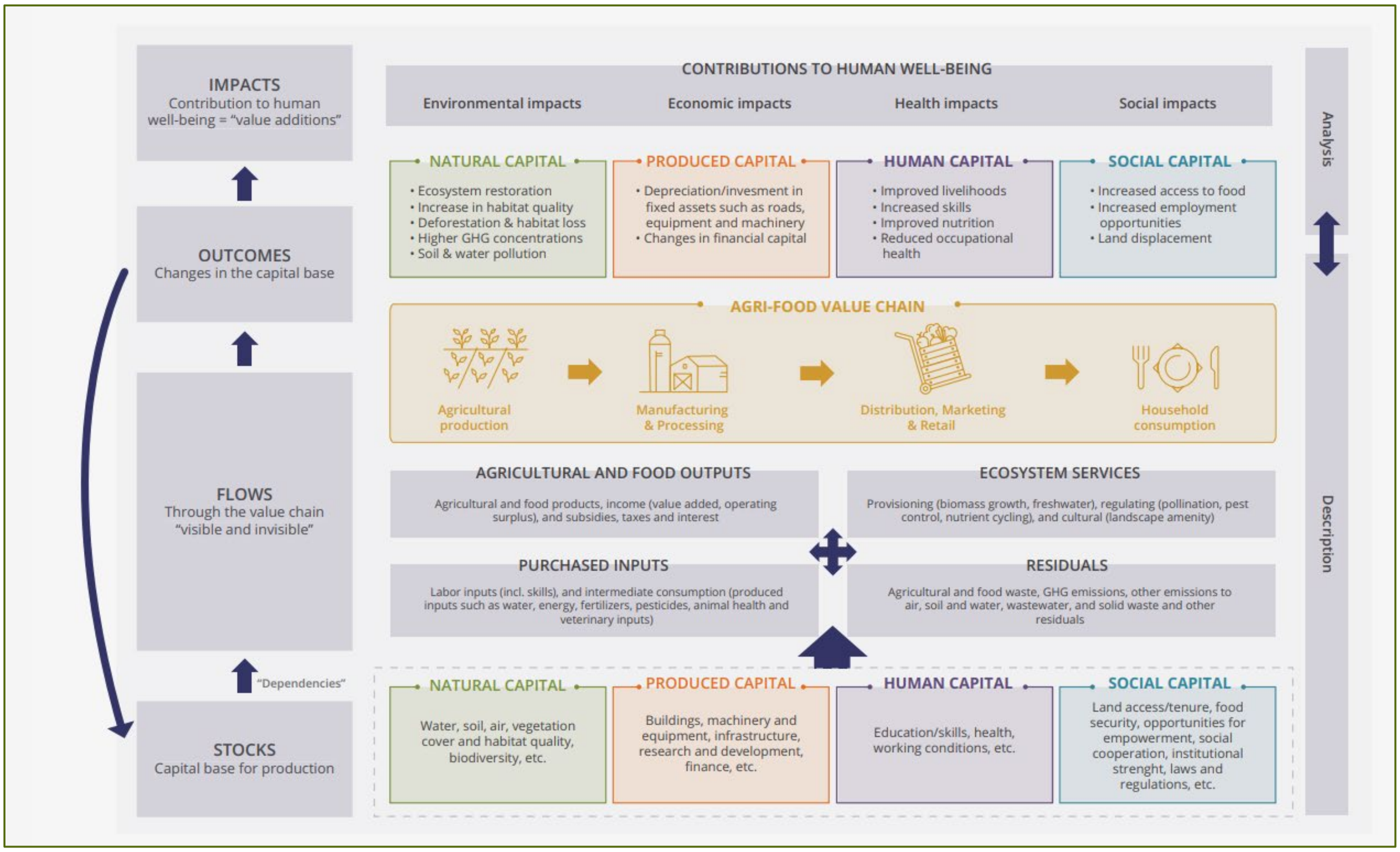
"The Framework is designed for use in two complementary but different ways. First, it can be used to describe eco-agri-food systems to ensure that different stakeholders involved – from farmers and manufacturers to consumers and local communities – have a common understanding of where they are within the system and how that system is functioning. Without a common language to describe eco-agri-food systems, there is limited potential to achieve the integrated, cross-sectoral decision-making that is required. Second, the Framework can be used to support various forms of analysis. For example, the Framework supports the assessment and comparison of trade-offs from agricultural and food policies, analysis of land use and consumption choices, and consideration of decisions concerning public and private investments."

In developing the framework, the following guiding principles were employed:

(1) *universality*: no matter the entry point or application, the same Framework can be used for assessing any eco-agri-food system, and can be used equally by policymakers, businesses, producers and citizens
(2) *comprehensiveness*: both in terms of encompassing the entire value chain, and in terms of including all stocks, flows, outcomes and impacts within an eco-agri-food system
(3) *inclusivity*: in supporting multiple approaches to assessment, including in quantitative and qualitative terms.

The TEEB framework employs elements of stocks, flows, outcomes, and impacts consistent with the above principles, and also with an accounting orientation (Figure 4.1). The stocks refer to capital- natural, human, produced (e.g. machinery and equipment), and social (e.g. institutions and networks). The flows in the system relate to conversions that occur through the use of capital- intentional and unintentional. The outcomes are given by the changes in the capital base. Outcomes are the values generated- some measured as economic output, others more difficult to measure. The TEEB report illustrates an application of the framework, based on the palm oil supply chain.

Figure 4.1. Elements of the TEEBAgriFood Evaluation Framework



Source: (2018). *TEEB for Agriculture & Food: Scientific and Economic Foundations*. Figure 6.3. UN Environment. https://reliefweb.int/report/world/teeb-agriculture-food-scientific-and-economic-foundations-report

4.1.4 The SUSFANS Model

Ingram and Zurek (2018) discuss the needs for food systems analysis in the future, and document the evolution of food systems frameworks, leading up to the SUSFANS model developed for the EU. They note that the context for food security has shifted from hunger alleviation to nutrient provision- from risk of starvation to nutrition/health. This is an important development as it allows for both problems of over- and under-consumption in food systems analysis. They note that, "even though the world currently produces enough food for all, the number of food-hungry and undernourished people worldwide reveals that our understanding and approaches are insufficient."

The authors discuss the SUSFANS project, which has built an approach for enabling an informed debate across different EU stakeholder groups underpinned by the latest scientific evidence. SUSFANS identified several steps in delivering an integrated approach to assessing the sustainable food and nutrition security of the EU food system and evaluating innovation options for the system:

(1) Develop a conceptual framework mapping the driving forces, actors, activities, outcomes, and goals for the EU food system;

(2) Devise a set of performance metrics for assessing the food system's status and innovation options across four key policy goals formulated by food system actors;
(3) Use modelling to quantify the sustainability status of food and nutrition security in the EU and to assess the potential impacts of innovation options across policy goals; and
(4) Use visualization to allow food system actors to assess the outcomes and associated trade-offs of possible innovation options in an integrated manner across policy goals.

4.1.5 The Food Sustainability Compass

Hebinck *et al.* (2021) developed a food sustainability framework intended for policy integration. They focused on the use of agri-food sustainability frameworks for use in policy processes. As such, they emphasize the importance of a framework supporting "mediation of diverse value judgements to seek broad societal support," allow for "multi-actor deliberation towards a 'shared vision'" and economic trade-offs, and be evidence-based.

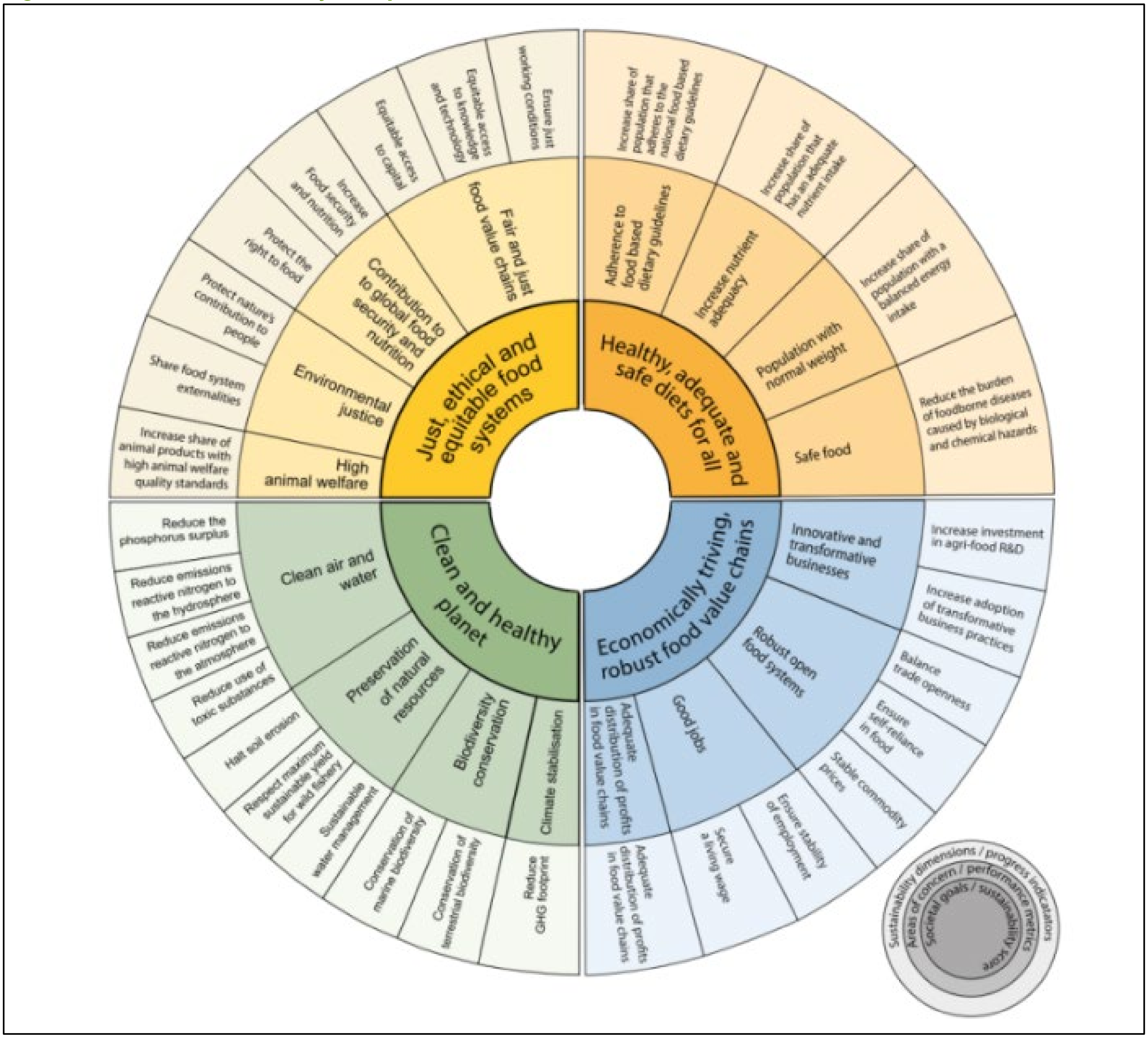
The paper provides a review of existing food systems frameworks. In reviewing food systems frameworks, it draws a distinction between "metrics-based frameworks that assess the 'status' of food systems and those that additionally aim to offer actionable policy insights" (Hebinck et al., 2021). It is also noted that frameworks based on metrics (i.e. what can be measured) are limited by drawing boundaries to exclude elements of the system that are not measured- but perhaps are conceptually understood, and important. These non-measured elements can include social justice/equity, animal welfare, food waste, and food industry structure and performance.

The authors develop a food sustainability compass, related to the European SUSFANS model. It contains four universal societal goals (1) Healthy, adequate, and safe diets, (2) Clean and healthy planet, (3) Economically thriving food systems supportive of the common good, and (4) Just, ethical, and equitable food systems. The indicators that inform these goals are

- Pragmatic: pragmatic solutions (e.g. use of proxies) are necessary when data is not available or accessible.
- Unique: redundancy and double counting of variables are avoided.
- Relevant: indicators need to capture the essence of the problem rather than be guided by data availability or previous existence of indicators; in some cases, composite indicators are necessary.

Figure 4.2 presents the graphic visualization of the food sustainability compass. It contains an inner ring consisting of the four societal goals, an intermediate ring identifying issues of concern, and an outer ring of indicators.

Figure 4.2. Food Sustainability Compass



Source: Hebinck, A., Zurek, M., Achterbosch, T., Forkman, B., Kuijsten, A., Kuiper, M., Nørrung, B., Veer, P. van 't, & Leip, A. (2021). A Sustainability Compass for policy navigation to sustainable food systems. *Global Food Security*, 29, 100546–100546. https://doi.org/10.1016/j.gfs.2021.100546

4.1.6 Canada's National Index on Agri-Food Performance

Canada's National Index on Agri-Food Performance, although not designed specifically for an animal agriculture system, provides an overview of the sustainability of Canada's agri-food sector "from food production to retail" (National Index on Agri-Food Performance, 2023b). The four pillars of the Index are the environment, the economy, food integrity, and societal well-being. Themes within these pillars range from soil and water to sustainable growth to food safety as well as food security (National Index on Agri-Food Performance, 2022, fig. 3). The following metrics in the Index are directly related to livestock: GHG intensity by species (National Index on Agri-Food Performance, 2023a, p. 30); water use in animal production (p. 25); genetic biodiversity in livestock species (p. 17); the state of biodiversity in native grassland habitats (p. 20); the use and safe disposal of livestock medications (pp. 42, 45); the use of medically important veterinary antimicrobials (p. 55); the number of cases of animal disease (p. 59); and the number of species which have an animal care code of practice under the National Farm Animal Care Council (p. 100).

Certain gaps have been observed in Canada's National index on Agri-Food Performance; here we will mention those related to livestock data. Canada's National Inventory Report (NIR), which proved a rich source of data for the Index, reports GHG emissions for crops as including forage and silage, which may be better classified under livestock. The NIR values on GHG emissions could therefore be overstated for crops and understated for livestock. For this reason, the Index did not use the GHG emissions values reported in the NIR (National Index on Agri-Food Performance, 2023a, p. 17).

Some metrics appear in the Index's inventory, but data have not been compiled due to some limitations. The status of biodiversity in native grasslands was not measured in the Index due to a lack of suitable data. Models developed by AAFC may be used in future Index updates. Another example is genetic biodiversity in livestock, or an analysis of the various livestock breeds (National Index on Agri-Food Performance, 2023a, p. 31).

The recent creation of the National Index on Agri-Food Performance may be seen as Canada's response to other global or national indices of food system sustainability, such as the Global Reporting Initiative (founded in 1997 by the United Nations Environment Programme, Tellus Institute, and CERES), the World Benchmarking Alliance (founded in 2015 by Aviva, Index Initiative, the UN Foundation, and the Business and Sustainable Development Commission), and the Sustainability Assessment of Food and Agriculture systems (SAFA, founded by the FAO), to name a few (National Index on Agri-Food Performance, 2023a, p. 18). Some perceived benefits of a holistic measurement the sustainability of Canada's agrifood system include: increased consumer trust in Canada's brand, support for sustainability claims which help access global markets (National Index on Agri-Food Performance, 2023a, p. 4), and ESG reporting for agri-food sub-sectors, companies, and producers (Marshall, 2022, p. 2).

4.2 Synthesis

The focused survey of food system frameworks, which is broader than frameworks for animal agriculture, reveals the following:

- The assumptions observed about animal agriculture, where they are explicit, vary in their application today. This is particularly evident from the Farm Foundation initiative in the early 2000's.
- It is striking how accurate its assumption about scarce labour is today, and yet how far the dialogue has come regarding environment and (especially) climate change, and also protein demand relative to the assumptions of 20 years ago.
- The assumptions made by the NAS committee on animal science research priorities seem well positioned for today, right down to the worry of cumbersome trade barriers that go some way toward characterizing the geo-political situation today.
- There are pronounced similarities in terms of the scope of frameworks. All of the observed frameworks stressed the importance of evaluating the full range of effects- a scope consistently defined across frameworks as health, environment, social, and economic effects.
- All frameworks also indicate that effects that are empirically measurable and those that are not readily measurable, or are measurable only using proxy measures or concepts, warrant inclusion. This defines the boundaries of the systems, and these boundaries define the outcomes the framework is accountable to, and the metrics of performance that must be developed and tracked.
- Each of the frameworks observed identifies as a complex-adaptive system. Nesheim *et al.* (2015) are quite specific about this, and the more recent work done on TEEB and SUSFANS essentially incorporate the complex, interconnected and adaptive characterization. This makes for a complex model containing a large number of stages, players, relationships, and feedback loops that capture the interconnectedness of systems that can create unintended consequences when one thing changes, resulting in ripple effects and the necessity to adjust or adapt (see NAS, 2015, p. 233).
- The frameworks envisaged both accounting-type frameworks, and others that resemble simulation models. Potential advantages exist with each. Simulation models present the prospect of being able to

predict, with high resolution and detail, the effects of a particular change on the system as a whole. However, they are very demanding with regard to parameters. To some degree, implementing a simulation model requires invoking an objective pursued by segments of the system- such as profit or output maximization, or conservation. An accounting framework places more attention on capital stocks, has elements of simulation to estimate flows, and then estimates the change in the capital stock and the effects/valuation of the flows. This would appear less demanding in terms of modelling parameters and prescribing objectives, but more demanding in terms of data on the various forms of capital stock.

4.3 Implications for this Study

Drawing together the above, the following conclusions were drawn. Frameworks that deal with animal agriculture and food as distinct from the food system must be narrower in scope. For example, whereas health is a fundamental element of food systems frameworks, the observed benefit/burden of health cannot be attributed distinctly to animal foods. Rather, it is certain aspects, such as prevention of certain dietary deficiencies, or certain food borne illness that can relate to animal foods. This applies more generally as certain environmental effects cannot be attributed to animal agriculture as distinct from agriculture more broadly (while others can).

Frameworks can both characterize/describe animal production systems and simulate the effects of changes. However, the first step is to develop a baseline of status, relationships and effects. This should be the focus here. The detail can be accumulated and built in to create the prospect of simulation of effects- both conceptually and empirically.

The complexity of simulation modelling of a complex-adaptive system is beyond the scope of this study. The data exist, at least to a large degree, to describe the initial (or current) stocks of the various forms of capital, and also the flows associated with these stocks. To these can be added technical parameters/relationships that characterize effects for which the data are unmeasured or non-empirical. This implies more of an accounting framework, similar in concept to the TEEB framework.

Finally, it is clear that creative and novel visuals depicting the logic and linkages in the framework will be useful in facilitating a broad discussion.

Figure 4.3 presents the implied framework structure for use in this study. Its structure is analogous to the TEEB framework, but with more specifics identified that relate to animal agriculture.

Figure 4.3. Framework for the white paper

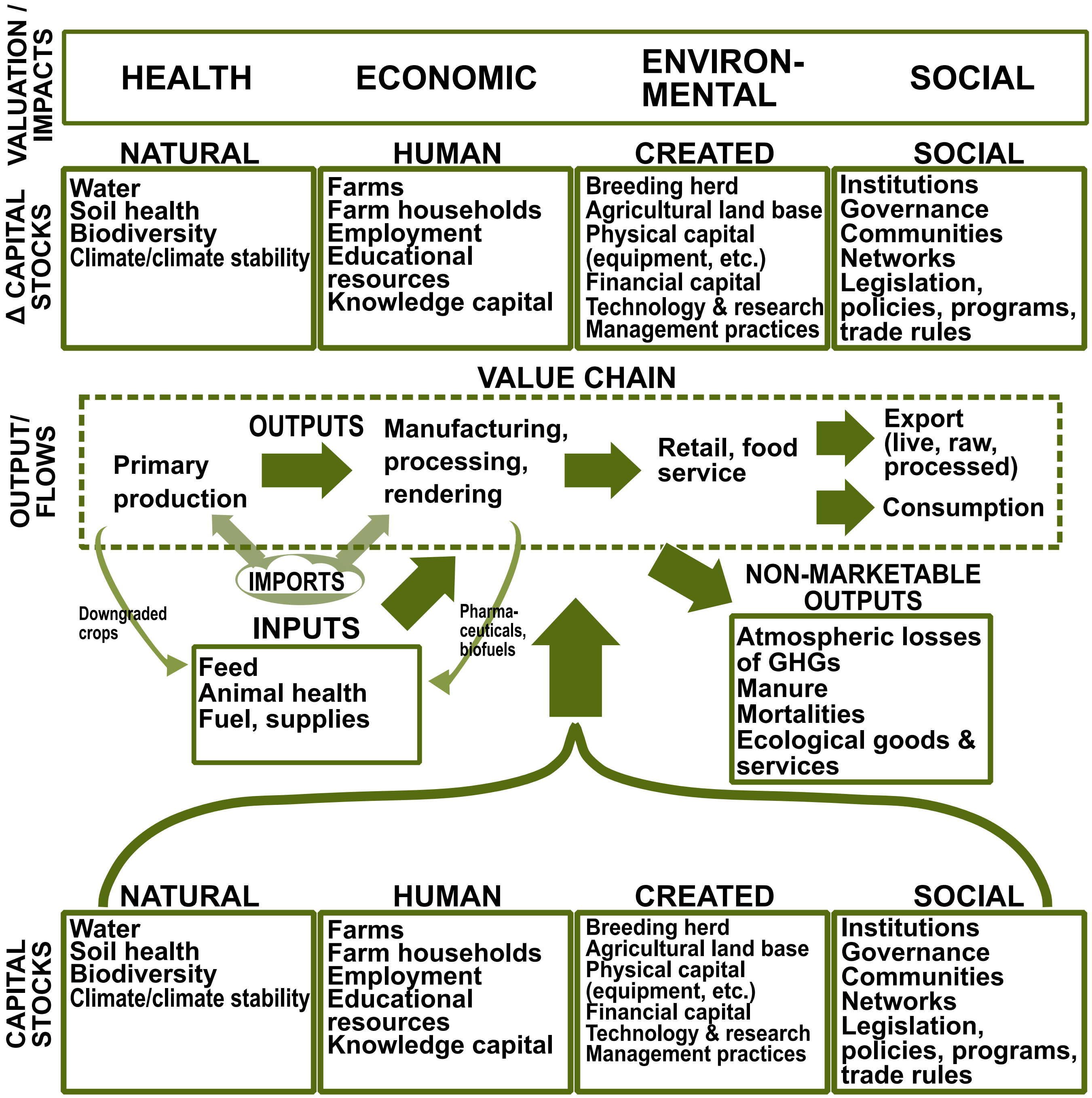


Image produced internally.

Beginning from the bottom of the figure, we have the initial base capital that defines the nature and capacity of the system: the soils/land base, water, and biodiversity that comprise the natural resource capital stock; the farms and workforce that populates human capital; the capital stocks that are created: breeding animals, farmland, equipment and finances; and the capital stock of relationships, networks, and institutions that frame interactions and cooperation.

From these are driven animal-based farm product outputs- livestock marketings, milk marketings, egg marketings, etc. These are produced supported with selected inputs provided from outside the capital stocks, such as some feeds, animal health products, and a range of supplies. It also entails the generation of non-product flows of outputs- manure, emissions, non-marketable products.

The arrows that move from stocks to flows into the value chain – with inputs and outputs, as well as along the value chain – represent technical coefficient that characterize conversions. This includes productivity measures such as stocking rates, feed conversion, usage rates, emission rates, et cetera.

These farm product output flows enter a value or supply chain where they are exported, or combined with processing inputs, processed into animal-based foods, and then sold domestically in retail or foodservice, or exported.

The nature of the flow of animal-based products and outputs influences ending period capital stocks. In general, production of flows that exceed carrying capacity will diminish the capital stock; conversely, flows can be altered to expand the inventory of capital in the various categories.

Finally, the top layer of the figure considers alternative dimensions through which to value the flows and changes in capital stocks. The level and portfolio of flows impact human health, environment, social wellbeing, and the trade-offs among flows given individual preferences, and flows relative to inputs and secondary outputs. These dimensions of valuation similarly impact the assessment of changes in capital stock.

The use of the framework is at least two-fold. First, the data and information compiled within the framework allow for a detailed, and ideally comprehensive, baseline of the size and scope of animal agriculture in Canada. Secondly, it allows for a visual and logical basis to trace the impacts of discrete changes that occur at specific points. This includes changes due to pressures on the system (e.g. from demand, policy changes, competition, disease, weather events, climate change et cetera).

To illustrate, consider the effects of restrictions on use or lack of access to specific animal health products, either on an acute/contingent basis (only an effect if there is a disease peril), or on a therapeutic/acute basis. The direct effect could be the flow of farm products that can be obtained from the capital stock, which impacts marketings and farm costs and returns- either on an incremental basis if the product is therapeutic, or as more of a sudden shock if an acute disease peril occurs. This causes farms to draw down financial capital in order to continue operating under an increased cost/reduced revenue situation. There are a broad range of secondary effects. The reduced flow of farm products shorts the value chain relative to existing capacity, creating costs to the downstream value chain from lost sales and from lost economies of size. The broader attempts to reduce the impact of the disease peril can result in culling, which reduces both marketing flows and the breeding herd stock and future flows going forward, and in turn reduces the demand for feeds. While culling ultimately reduces the supply of animal product flows, which will ultimately increase prices. The increase in value chain costs makes Canadian products less competitive, creating greater scope for imports and reduced cost competitiveness in export markets. Over time, the effects can spread more broadly, possibly impacting all aspects of the framework, so this survey of effects that draws upon the relationships in the framework is likely to be simplistic.

More generally, it will be difficult for the relationships embodied in the arrows in the framework to capture the full breadth of actual situations. For example, the stock of beef cows that ultimately generates slaughter steers can be managed under several different systems. Weaned calves can be fed solely on grass/hay to a slaughter weight, or conversely can be fed finished on a concentrated grain diet- with significant differences in daily gain, feed conversion, age/time to marketing, beef characteristics/quality, and greenhouse gas emissions. There is great diversity in how beef cattle and other animals are raised; this can also be true of other segments of animal agriculture.

The challenge engaged in subsequent sections is to give this conceptual framework meaning by populating it with the actual data and information relevant to animal agriculture in Canada, and for Canada relative to its peers in animal agriculture.

5. Capital stocks in Canadian animal agriculture

In keeping with the framework described above, there are four types of capital stocks in animal agriculture, which are listed and defined below:

(1) *natural capital* – water, soil, climate, and biodiversity;
(2) *human capital* – farms, households, labour, and educational resources;
(3) *created capital* – the breeding herd, the agricultural land base, physical capital such as equipment, financial capital such as total assets; and
(4) *social capital* – institutions, communities, and other networks related to animal agriculture.

5.1 Natural capital

5.1.1 Surface water

Surface water levels and flows are tracked at station level across Canada. Samples are taken at streams by federal or provincial workers, and data are available as far back as 1860 (although in that year, there were only two stations: Sault Ste. Marie and the Niagara River) (HYDAT, 2023, calculations performed internally). Data were restricted to May through August in order to avoid incomplete data through the winter months (Schindler & Donahue, 2006).

Data for the last ten years are pictured here and show that the monthly mean of daily flows of surface water fluctuate year by year. For instance, many provinces saw an increase in the monthly mean daily levels in 2020 (BC, AB, SK, MB, NB, NL), but all provinces saw a decrease from 2020 to 2021 because 2021 was a particularly hot and dry year. In some cases there are multiple consecutive years of reduced flows- for example, Ontario and Quebec 2020-22- but mostly the water flows alternate on an annual basis.

Figure 5.1. Percent change in monthly mean of surface water daily flows, by province

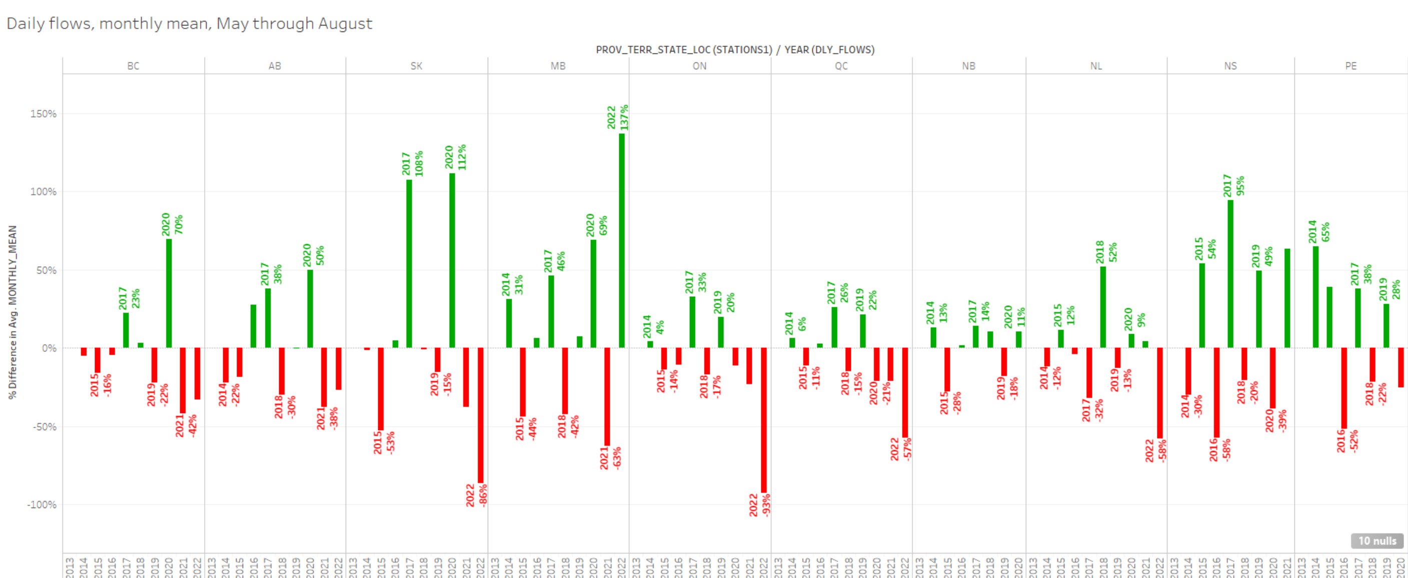


Image created internally. Data source: (HYDAT, 2023, calculations performed internally). *National Water Data Archive: HYDAT* [Service description]. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/monitoring/survey/data-products-services/national-archive-hydat.html.

5.1.2 Water quality

AAFC publishes an index of risk of water contamination, with 100 representing no risk (a “perfect score”). Data for 1981 through 2016 are presented in Table 4.1 below, showing that water quality indices across Canada have declined somewhat, indicating heightened risk due to water quality. Of the four components of Canada’s national water index (nitrogen, phosphorus, coliforms, and pesticides), the greatest contributor to the decrease from 1981 to 2011 was nitrogen, with a decline in the score from 88 to 74, indicating an increase in risk of water contamination by nitrogen (AAFC, 2021). The risk of nitrogen contamination worsened the most in Alberta (the Red Deer and Qu’Appelle River basins), Saskatchewan, and Manitoba (the Carrot River and South Saskatchewan River basins) (AAFC, 2021, fig. 3).

Table 5.1. Index of risk of water contamination, by component (AAFC).

	1981	1986	1991	1996	2001	2006	2011	2016
Nitrogen	88**	85**	87**	79*	64*	81**	69*	74*
Phosphorous	75*	71*	72*	69*	70*	68*	68*	73*
Coliforms	80**	82**	81**	78*	77*	76*	79*	80**
Pesticides	88**	86**	86**	88**	86**	85**	71*	-
***GOOD (60-79) **DESIRED (80-100)**								

Sources:
(1) Agriculture and Agri-Food Canada. (2022, June 16). Nitrogen Indicator. https://agriculture.canada.ca/en/agriculture-and-environment/agriculture-and-water/nitrogen-indicator
(2) Agriculture and Agri-Food Canada. (2021aa, June 3). Phosphorus Indicator. https://agriculture.canada.ca/en/agriculture-and-environment/agriculture-and-water/phosphorus-indicator
(3) Agriculture and Agri-Food Canada. (2022c). Pesticides Indicator. https://agriculture.canada.ca/en/agriculture-and-environment/agriculture-and-water/pesticides-indicator
(4) Agriculture and Agri-Food Canada. (2022b). Coliforms Indicator. https://agriculture.canada.ca/en/agriculture-and-environment/agriculture-and-water/coliforms-indicator

5.1.3 GDDs (growing degree days)

Growing degree days are a standard way of measuring the heat units in an area. Annual cumulative GDDs (May through September) are pictured here for Lacombe, Alberta, and Harrow, Ontario for the past century. GDDs are calculated with a base of 10 for Ontario (corn GDDs), whereas for Alberta, the mean temperature is used, which is equivalent to wheat GDDs. Each image clearly identifies which years were omitted due to missing data observations. Data were gathered from daily weather station temperature readings (Environment and Climate Change Canada, 2023a), and images were created internally.

Both figures here show an increase in variability in recent years. The red arrows have been added to draw attention to extreme swings from year to year which were not experienced for most of the 20th century. For instance, Figure 5.2 shows that in Alberta, 1998 was a very warm year (cumulative GDD=2,252), followed by a cold year (GDD=1,851 in 1999). Other instances of yearly swings include a jump from 2000 to 2001 (1,892 GDDs to 2,056 GDDs) and 2010 to 2011 (1,803 GDDs to 2,056 GDDs).

Figure 5.2. Growing degree days (wheat), Lacombe, Alberta (1908-2022).

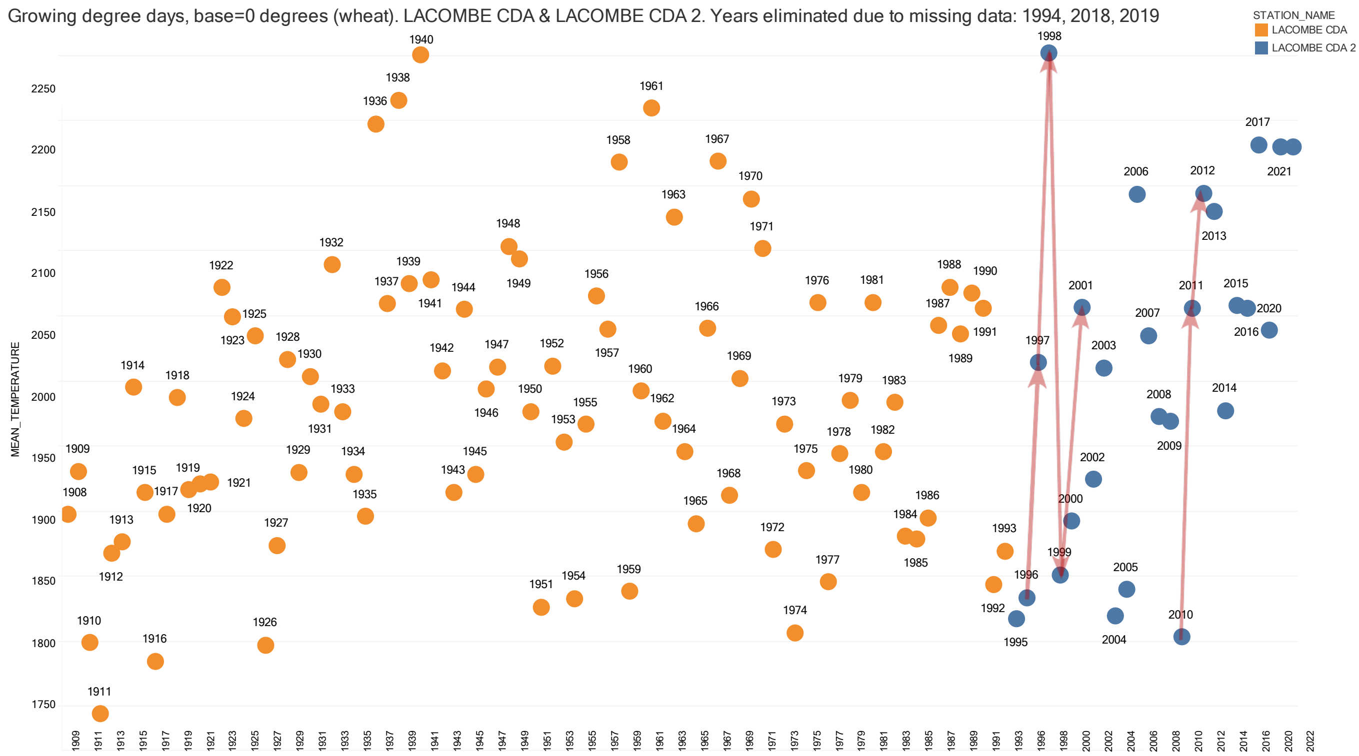


Image created internally. Data source: (HYDAT, 2023, calculations performed internally). *National Water Data Archive: HYDAT* [Service description]. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/monitoring/survey/data-products-services/national-archive-hydat.html.

Figure 5.3 shows that GDDs have experienced greater fluctuation in Ontario since the 1990s. While GDDs seemed to cluster and not change much from year to year in the ‘60s, ‘70s, and ‘80s, drastic swings were seen between 1999, 2000, and 2001 (GDDs = 1,627 to 1,208 to 1,535) and from 2009 to 2010 (GDDs = 1,184 to 1,644). In addition to the sheer jump in GDDs between two consecutive years, these swings tend to move in opposite directions (one hot year followed by a cold year, followed by a hot year), and they happen after years which are unseasonably warm or cold.

Figure 5.3. Growing degree days (corn), Harrow, Ontario (1918-2022).

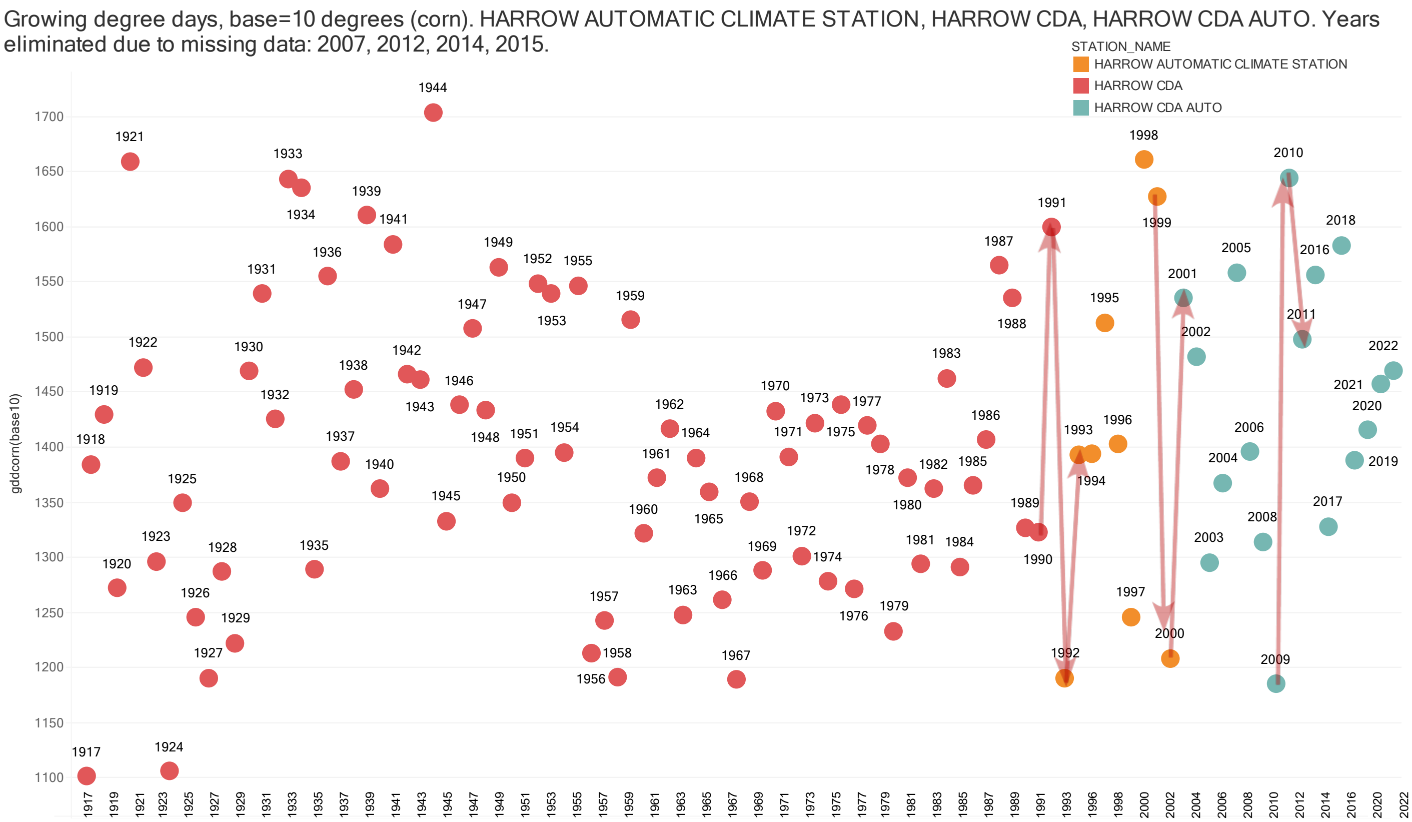


Image created internally. Data source: HYDAT. (2023). *National Water Data Archive: HYDAT* [Service description]. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/monitoring/survey/data-products-services/national-archive-hydat.html.

Other jurisdictions are presented in the appendix (PEI; Lennoxville, Quebec; Baldur, Manitoba; and Outlook, Saskatchewan) and generally depict the same trends as described above for Ontario and Alberta.

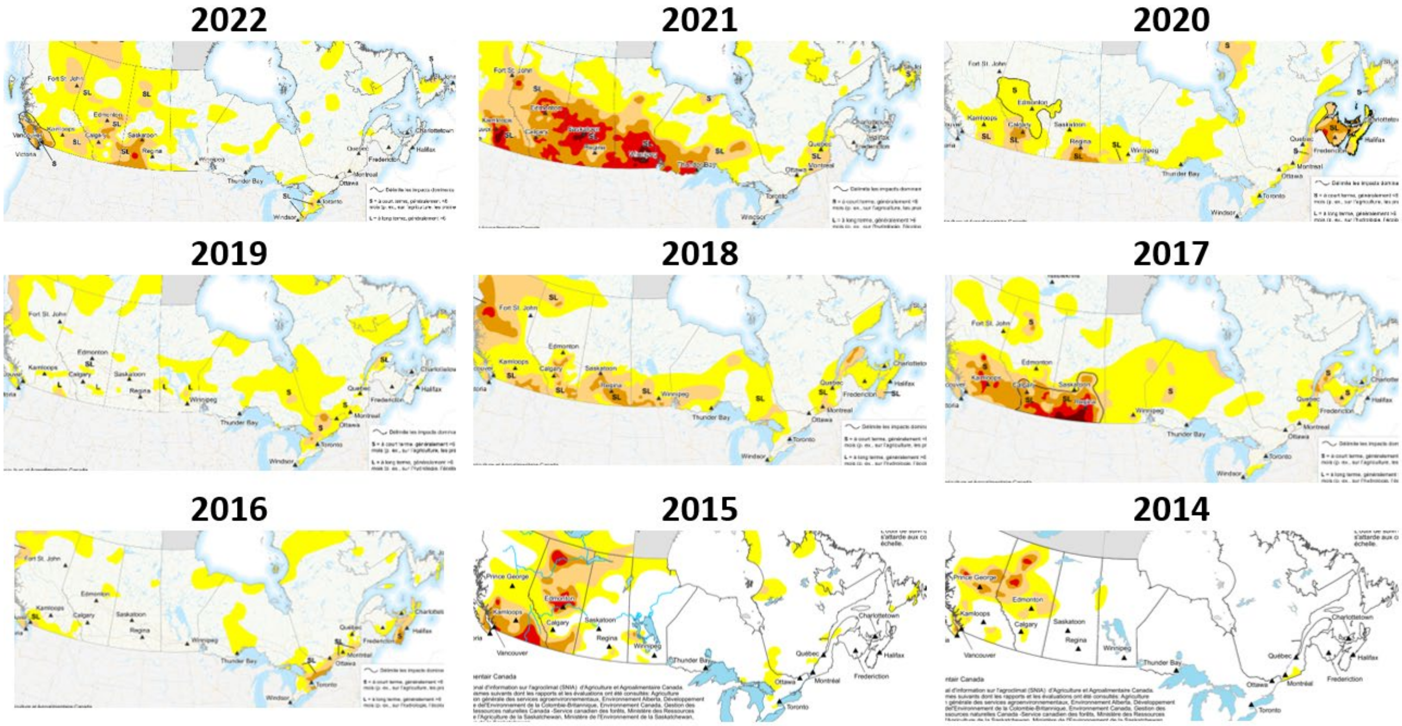
5.1.4 Precipitation

Precipitation data are available by weather station across Canada. Precipitation, whether snow or rain, is an important factor, but not the only factor contributing to the amount of moisture available in the growing season; other factors include snowpack in the watershed, snow retained by crop residue, drainage, soil health, and root penetration. Frequency of precipitation also matters.

The Canadian Drought Monitor (CDM), pictured here, produces monthly maps which describe drought conditions. Drought conditions take into consideration many factors: precipitation, temperature, satellite imagery of vegetation, stream flows, and drought indicators from the agriculture, forestry, and water management sectors (Agriculture and Agri-Food Canada, 2023d).

As pictured here, the colouration varies from grey – no drought – to red, meaning extreme drought (Agriculture and Agri-Food Canada, 2023d). The year 2021 had extreme drought conditions (as measured in September), with red spots also in 2015 and 2017.

Figure 5.4. Canadian drought monitor, September snapshots

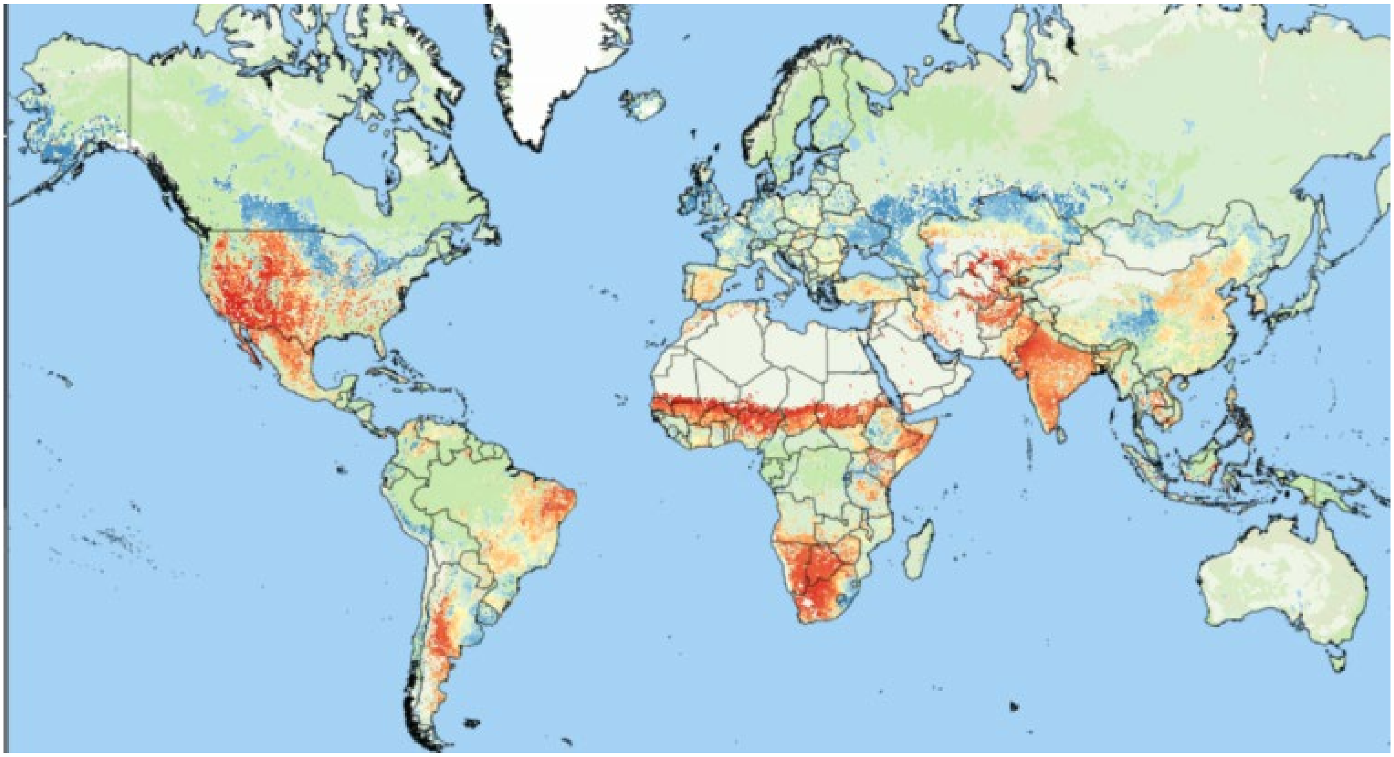


Source: (Agriculture and Agri-Food Canada, 2023a). *Canadian Drought Monitor—Open Government Portal* (Addition resources: Pre-packaged maps) [dataset]. Government of Canada. https://open.canada.ca/data/en/dataset/292646cd-619f-4200-afb1-8b2c52f984a2.

5.1.5 Soil

Soil can be a major factor in climate change mitigation through carbon storage, and also improved water retention under increased levels of soil organic matter. Undisturbed agricultural lands have the best carbon-capturing capacity, such as natural prairies (grasslands). Cropland and tame pastures also have potential to store more carbon than they produce by implementing specific management practices such as no-till and prevention of soil erosion (Wood-Bohm, 2018). Figure 5.5 shows the estimated SOC levels throughout the world, with red indicating the lowest levels (0 to 25 tonnes of carbon per hectare) and blue, the highest (60 to >300 tonnes). The majority of Canada is green (50 to 55 tonnes per hectare), with blue areas in the southern Prairies and eastern provinces (FAO, 2020).

Figure 5.5. Estimates of SOC (tonnes of carbon per hectare)



Source: Global Soil Information System, FAO.

Soil health and carbon capture are complex systems. Focusing solely on carbon storage may have unintended consequences on outcomes such as crop yields, moisture retention, biodiversity, and economic returns of the farm (Samson, 2021; Smukler, 2019).

5.1.6 Biodiversity

As the global population of humans increases and agricultural production expands to feed them, areas of mature forests and natural lands are projected to shrink by 13% by 2050 (FAO, 2017). Land use changes, including deforestation, settlement, conversion to large annual crop areas and increased pesticide use, are increasingly putting pressure on biodiversity globally. Polluted streams and waterbodies are also contributing to the decline. According to the OECD, about one-third of biodiversity in rivers and lakes worldwide has already been lost (OECD, 2012). The insect population, which is another indicator of biodiversity health, is globally in decline. Also, increasingly, humans are coming into contact with wildlife that is contributing to zoonotic risks of diseases spreading from animals to humans to create pandemics like COVID.

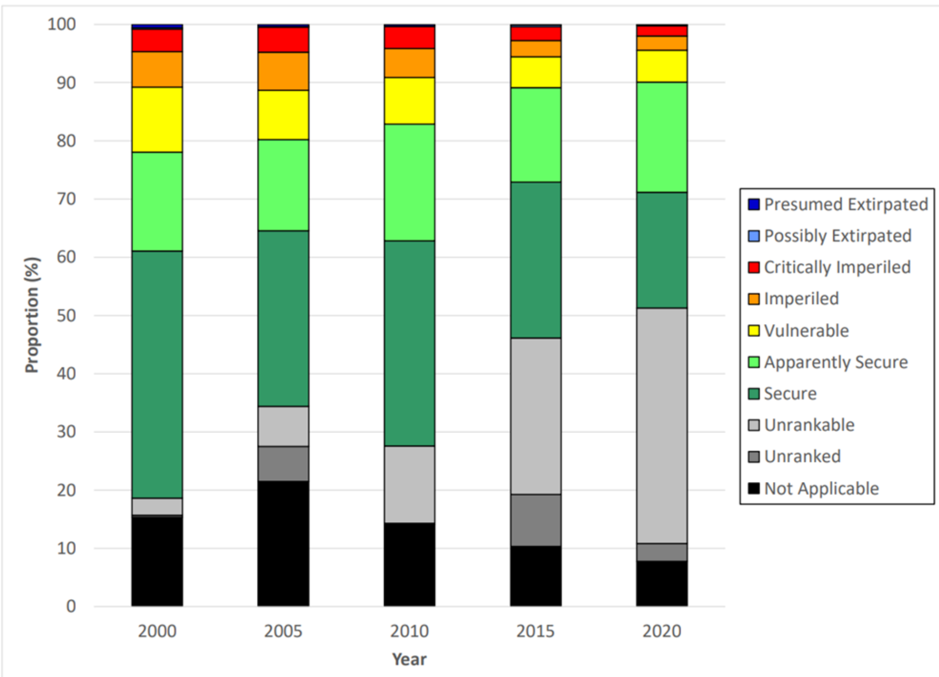
Agriculture and Agri-Food Canada (AAFC) compiles an index on wildlife habitat capacity on agricultural land, defined as the ability of the landscape to support breeding for wild terrestrial vertebrates. The wildlife habitat capacity on agricultural lands index score for breeding ranged from 35.48 in 2000 to 34.27 in 2015, a small decline. A score of 100 means that all land is highly suitable for the reproduction of all potentially occurring land species.

More generally, biodiversity in Canada has declined, as documented by the Canadian Endangered Species Conservation Council (2022). Their report observed that:

At the national level... 873 species are critically imperiled, 1,245 are imperiled, 2,765 are vulnerable, 9,562 are apparently secure, and 10,038 are secure. Among those species, 20% (one *in five) have some level of risk in Canada" (Canadian Endangered Species Conservation Council, 2022).*

Figure 5.6 is reprinted from the Council's most recent report. It shows that, compared with 2015, in 2020 there was reduction in species reported as secure, and an increase in the proportion reported as apparently secure, with the proportion of imperiled and critically imperiled steady. The survey includes wild species that could be present on agricultural lands, as well as others unlikely to be on agricultural lands (such as marine animals).

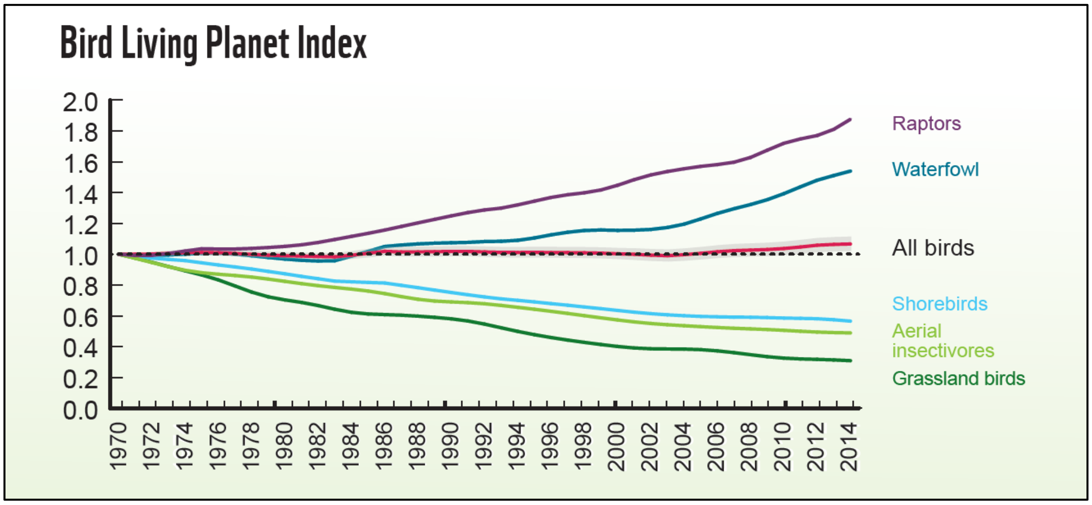
Figure 5.6. Proportion of each rank category at the national level in the reports of the Wild Species series.



Source: Reprinted from Canadian Endangered Species Conservation Council. (2022). Wild species 2020: The general status of species in Canada. National General Status Working Group. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/reports/Wild%20Species%202020.pdf.

In its 2017 report on Canada, the World Wildlife Fund (WWF) reported that half of our monitored species are in decline, with an average decline of 83% over the 1970 to 2014 period (WWF, 2017). Some wildlife groups have experienced larger declines than others: 54% of mammals, 51% of fish, 48% of birds and 50% of amphibians and reptiles. There has been some improvement in certain bird species, such as raptors and waterfowl (Figure 5.7). For species at risk (SAR) in Canada, populations declined by 43% between 1970 and 2002, with a 28% decline after legislation was introduced in 2002.While some measures introduced, such as restrictions on pesticide use, limits on fishing and hunting, and restored wetlands, there are still measures that are needed to prevent further declines. Agricultural producers play a role through adopting a range of best management practices (BMPs) that protect habitat and lead to greater biodiversity, while government and voluntary sector initiatives such as Ducks Unlimited (DUC), Nature Conservancy of Canada (NCC), and Alternative Land Use (ALUS) can also help protect wildlife habitat. (See Yildirim *et al.*, 2019 for a description of these initiatives.)

Figure 5.7. World Wildlife Fund Index of Bird Populations



Source: Reprinted from (World Wildlife Fund, 2017, fig. 13, p. 24). *Living Planet Report Canada.* https://wwf.ca/report/lprc-2017/

5.2 Human capital

Human capital in animal agriculture industries includes farm operators, unpaid and paid farm household members, labour on farms and labour throughout the value chain, from farm inputs such as feed, feed specialists, fuel and veterinarians, to processors, distributors, and retailers.

5.2.1 Veterinarians

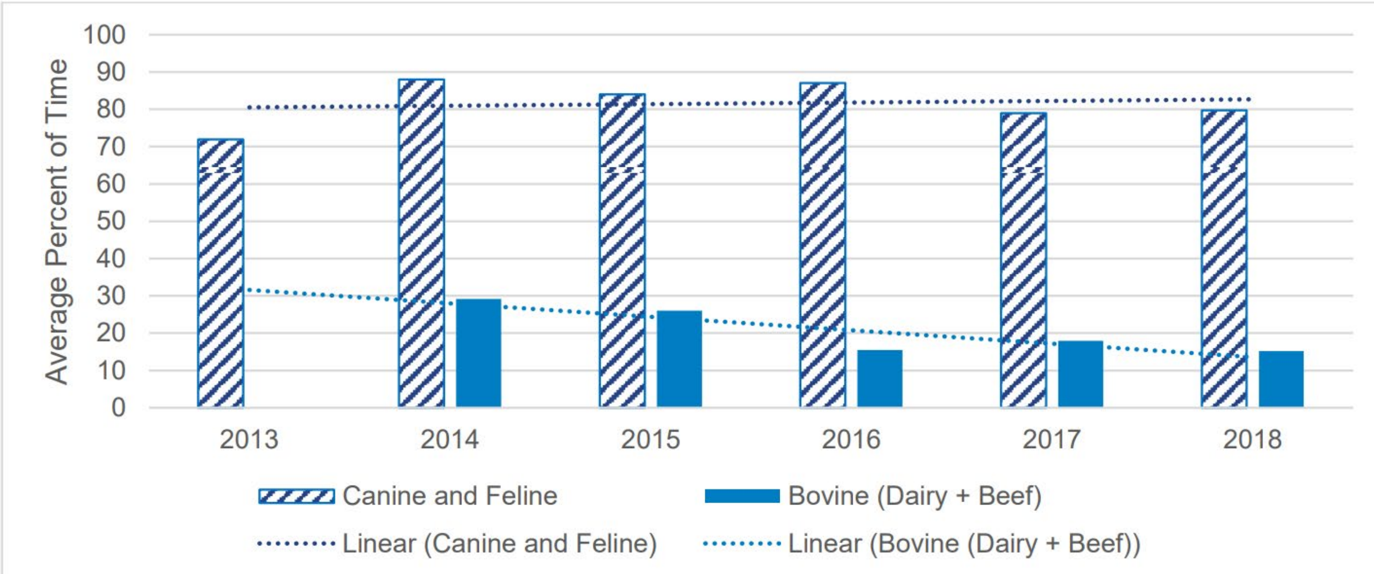
Veterinarians support animal health in a variety of roles, notably as practitioners. Increasingly, there is a separation in specialization between food animal practitioners and companion/small animal veterinarians.

There are five vet colleges in Canada: (1) the Atlantic Veterinary College at the University of Prince Edward Island; (2) Faculté De Médecine Vétérinaire at Université de Montréal; (3) the Ontario Veterinary College at the University of Guelph; (4) the Western College of Veterinary Medicine at the University of Saskatchewan; and (5) the Faculty of Veterinary Medicine at the University of Alberta.

The number of veterinarians in 2022 was 15,322 (Canadian Veterinary Medical Association, 2023). In 2017, 10% of veterinary practices were "large animal" practices (363 ÷ 3467), compared with 64% companion animal practices (2218) and 26% mixed (909) (Weaver, 2017, tbl. 13). A 2020 study found that there were needs for more food animal vets in six provinces: BC, Saskatchewan, Manitoba, Ontario, Quebec, and New Brunswick (Canadian Veterinary Medical Association, 2020, p. 23). More specifically, in Quebec in 2019, the following figures represent the share of veterinarians who spend at least 10% of their time working with these food animal species: 14% dairy (382 ÷ 2646); 2% beef (44); 1% swine (34); and 1% poultry (20) (Canadian Veterinary Medical Association, 2020, p. 25).

Dairy and beef provide the largest demand for acute care veterinarian services. Figure 5.8 shows that the time spend by new graduates with bovines (dairy and beef cattle) has been decreasing. In 2014, 30% of new graduates' time was spent with bovines; in 2018, this had dropped to approximately 15% (Canadian Veterinary Medical Association, 2020, p. 32). This data comes from surveys of new graduates, and areas of specialty may be inferred from this data.

Figure 5.8. Time allocation of new graduate veterinarians



Source: Canadian Veterinary Medical Association. (2020). *2020 CVMA Workforce Study: Final Report*. Page 32. https://www.canadianveterinarians.net/media/ak3lonad/2020-cvma-workforce-study-final-report.pdf.

5.2.2 Employment

According to industry associations, approximately 822,732 persons are employed in the four major sectors of animal agriculture (beef, dairy, pork, and chicken/eggs), representing 36% of all workers in agri-food in Canada. Table 5.2 shows the breakdown of employment by sector, as reported by respective industry associations. These figures represent employees earning salaries or wages, as well as self-employed persons, working in primary agriculture and food processing. This does not include food retailers, food wholesalers, or foodservice providers.

Table 5.2. Employment in animal agriculture

	Jobs (direct and indirect)
Beef	347,352
Dairy	195,115 (2021)
Pork	134,000*
Chicken	101,900 (2018)
Eggs	18,544 (2018)

*31,000 on farm and 103,000 off farm

Sources: Beef Cattle Research Council, 2021; (Dairy Farmers of Canada, 2021); Arnason, 2023 (Manitoba Pork); Chicken Farmers of Canada, 2020; Canadian Pork Council, 2023.

5.2.3 Temporary foreign workers

The number of TFWs in agriculture and agri-food has increased by 44% since 2017, reaching 212,838 workers in 2022 from 147,914 in 2017 (not pictured here; Statistics Canada, 2023e). This includes primary production of crops and livestock as well as food and beverage manufacturing (Agriculture and Agri-Food Labour Statistics Program, 2023b). Figure 5.9 shows that the subsectors which employ the greatest number of TFWs in agriculture and agri-food are greenhouses, vegetable and melon farming, and fruit and tree nut farming. From a livestock perspective, cattle and ranch farming employ the greatest number of TFWs in the animal agriculture sector, but only represent 4.42% of all TFWs working in agriculture and agri-food. Hog and pig farming employed 3,948 TFWs in 2022; poultry and egg, 3,316; and other animal production, 3,298 (Agriculture and Agri-Food Labour Statistics Program, 2023b).

Figure 5.9. TFWs in agriculture and agri-food, 2022

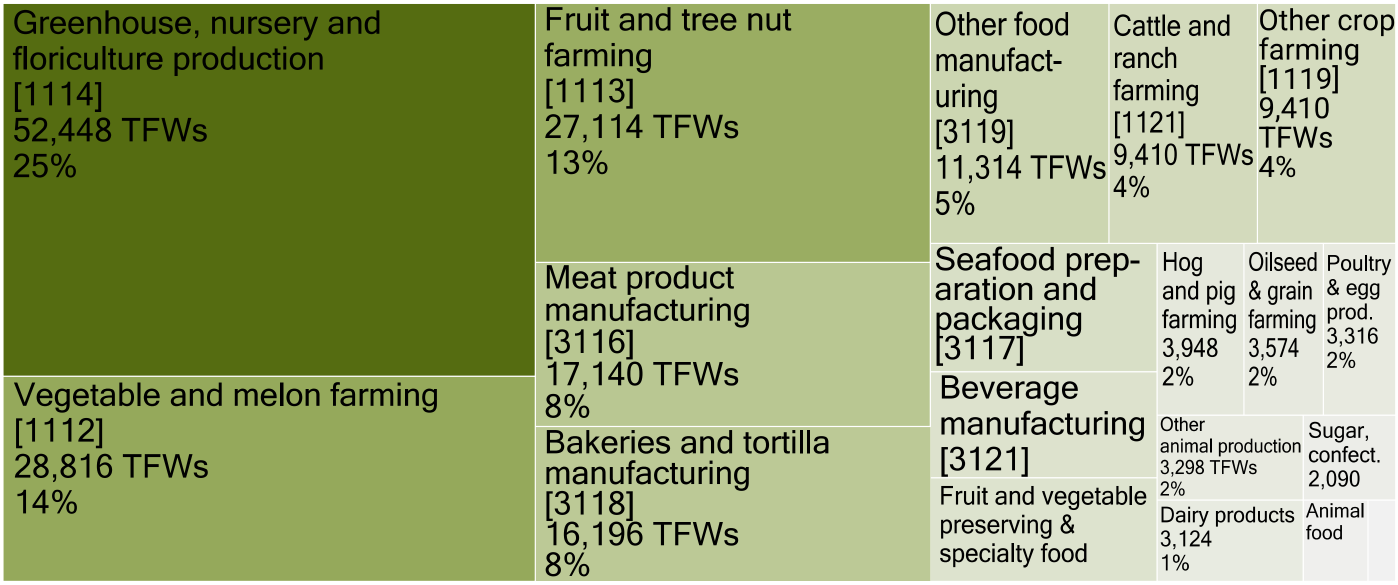


Image created internally. Data source: (Agriculture and Agri-Food Labour Statistics Program, 2023b). *Temporary foreign workers in the agriculture and agri-food sectors, by industry* (Table 32-10-0218-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210021801.

The stock of human capital that motivates flows into the agri-food value chain includes the adjacent industries involved in supplying and processing raw animal products. Figure 5.10 presents estimates of the stock of employees engaged in feed (animal food) manufacturing, dairy and ice cream processing, red meat primary processing, rendering and meat further processing, and poultry processing. The table shows that, across the manufacturing segments, in 2021 there was a stock of about 86,000 in direct labour roles manufacturing animal-based food products and feed, and just over 25,000 in non-manufacturing roles.

Figure 5.10. Persons Employed in Animal-based Food Processing and Feed Manufacturing, Canada, by NAICS code

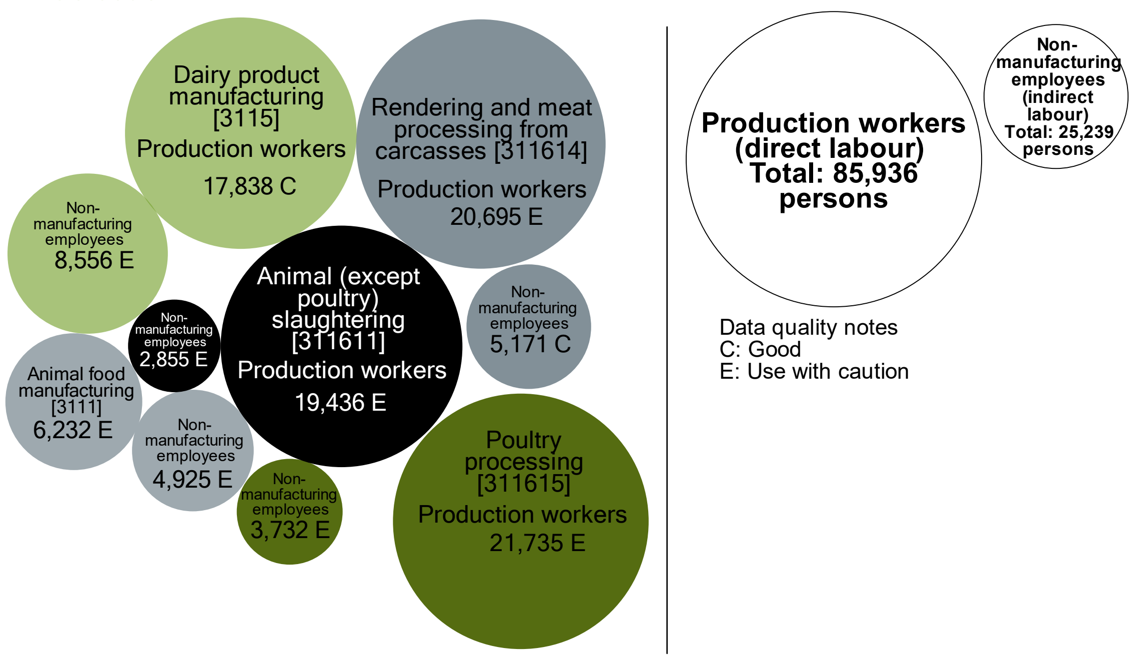


Image created internally. Data source: (Annual Survey of Manufacturing and Logging Industries, 2023)

Table 5.3 shows the total number of salaried employees in agriculture, including the number of full-time and part-time workers, seasonal employees, on agricultural operations with at least one employee (Agriculture and Agri-

Food Labour Statistics Program, 2023a). The number of operations in dairy and milk, beef and feedlots, and hog and pig farming has decreased since 2016, while the number of poultry and egg operations has increased (Agriculture and Agri-Food Labour Statistics Program, 2023a). Simultaneously, the total number of employees has increased in each commodity except beef and feedlots, which saw a decrease by 6% of total employees from 2016 to 2021 (Agriculture and Agri-Food Labour Statistics Program, 2023a).

The number of employees per operation has increased from 2016 to 2021 for dairy and milk operations, beef and feedlots, and hog and pig farming. This may be a symptom of increasing farm sizes in Canada as the industry consolidates and as the average age of farm operators increases (Statistics Canada, 2022f).

Table 5.3. On-farm employment per operation, by sector, 2016 to 2021

	Agricultural operations with at least one employee			Number of employees (full-time, part-time, and seasonal)			Employees per operation		
	2016	2021	↑↓	2016	2021	↑↓	2016	2021	↑↓
Dairy and milk [11212]	6,597	6,166	↓7%	31,104	31,717	↑2%	4.7	5.1	↑9%
Beef & feedlots [11211]	4,591	4,022	↓12%	15,606	14,642	↓6%	3.4	3.6	↑7%
Poultry and egg [1123]	2,050	2,114	↑3%	15,006	15,163	↑1%	7.3	7.2	↓2%
Hog and pig [1122]	1,264	1,140	↓10%	10,977	11,031	↑0.5%	8.7	9.7	↑11%

Table created internally. Data source: (Agriculture and Agri-Food Labour Statistics Program, 2023a). *Employees in the agriculture sector, and agricultural operations with at least one employee, by industry* (Table 32-10-0215-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210021501. Percentage change and employees per operation computed manually.

Although not shown here, the breakdown of full-time, part-time, and seasonal employees is also available. The 2% increase in the number of employees in dairy and milk was associated with a 7% increase in full-time employees, offset by a 2% decrease in part-timers and a 3% decrease in seasonal employees from 2016 to 2021. In beef and feedlots, the 6% decrease in total employees was associated with a 16% decrease in seasonal employees. In poultry and egg production, total employees increased by only 1%, the product of an 8% increase in full-timers offset by decreases in part-time and seasonal employment. In hog and pig farming, part-time employment fell by 21%, while full-time and seasonal employment increased by 4% and 5% respectively, for a net result of a 0.5% increase in the total number of employees (Agriculture and Agri-Food Labour Statistics Program, 2023a).

Table 5.4. Change in employment (FT, PT, and seasonal) by agricultural operation type, 2016 to 2021

	Dairy and milk [11212]		Beef and feedlots [11211]		Poultry and egg [1123]		Hog and pig [1122]	
	2016	2021	2016	2021	2016	2021	2016	2021
Total employees	31,104	31,717 (+2%)	15,606	14,642 (-6%)	15,006	15,163 (+1%)	10,977	11,031 (+0.5%)
Full-time	15,098	16,100 (+7%)	7,547	7,535 (-0.2%)	7,979	8,597 (+8%)	7,284	7,563 (+4%)
Part-time	7,844	7,707 (-2%)	3,149	2,954 (-6%)	3,401	3,200 (-6%)	1,619	1,283 (-21%)
Seasonal employees	8,179	7,909 (-3%)	4,918	4,153 (-16%)	3,636	3,367 (-7%)	2,086	2,185 (+5%)

Table created internally. Data source: (Agriculture and Agri-Food Labour Statistics Program, 2023a). *Employees in the agriculture sector, and agricultural operations with at least one employee, by industry* (Table 32-10-0215-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210021501. Percentage change computed manually.

5.3 Created capital

Created capital in animal agriculture includes the foundation or "mother" herd, the agricultural land base, physical capital such as equipment, and financial capital such as total assets.

5.3.1 Breeding herd

As at January 1, 2023, there were 3,562,000 beef cows; these cows were located on beef operations according to the Livestock Survey (Statistics Canada, 2023h). The 2021 Census of Agriculture reported 3,776,389 beef cows (Statistics Canada, 2022b). This discrepancy of approximately 200,000 head can be explained by the fact that the Census of Agriculture asks producers to report the number of head on May 11, 2021 (Statistics Canada, 2022e), while the Livestock Survey reports the number of head on January 1, 2023.

As at January 1, 2023, there were 969,000 dairy cows, and they were all located on dairy operations, according to the Livestock Survey (Statistics Canada, 2023h). There were 1,231,000 sows and gilts over 6 months of age, and 7,852,035 layer and broiler breeders (Statistics Canada, 2023h).

Figure 5.11. Breeding herd size, 2023

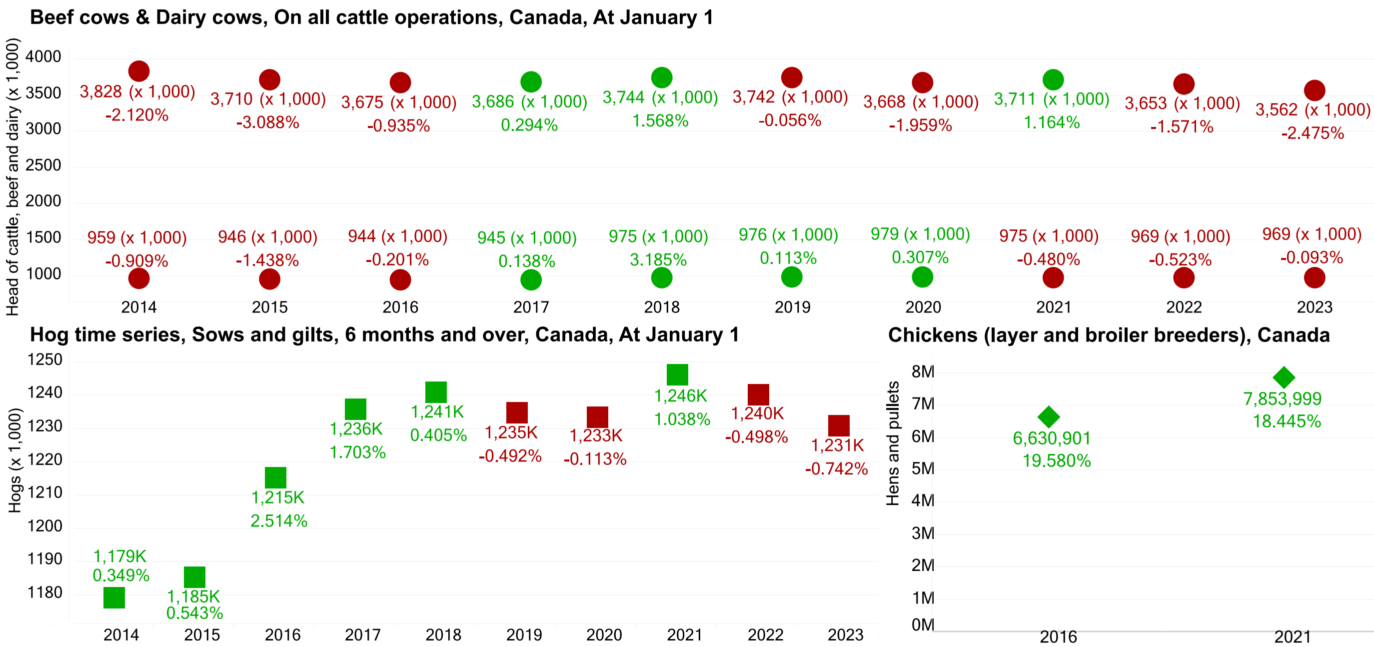
Beef cows	3,562,000
Dairy cows	969,000
Sows and gilts	1,231,000
Layer and broiler breeders (pullets and hens)	7,852,035

Source: Statistics Canada. (2023, February 28). Cattle statistics, supply and disposition of cattle. Livestock Survey. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210013901

As a time series, the breeding herd in Canada has been in gentle decline and has not increased for all livestock groups studied here, with the exception of chicken (laying hens and broiler breeders). The image here shows year-over-year declines in red, and increases in green. Cattle are represented by circles (beef on the top row, dairy on the bottom row), hogs by squares, and chickens by diamonds. Beef cows, dairy cows, and hogs have decreased in 2022 and 2023 (as at January 1st each year); this decrease has been less than 1% each year with the exception of beef cows which decreased by 2.5% from 2022 to 2023. The mother herd for poultry and egg production, however, rose by 19.58% from 2011 to 2016, and by 18.45% from 2016 to 2021. From 2011 to 2021, the number of pullets and hens rose from 5,543,889 birds to 7,853,999 birds (not pictured here). From 2014 to 2023, the number of beef cows fell from 3,828,100 to 3,562,400 and the number of dairy cows fell from 1,184,000 to 969,000. The number of sows and gilts six months of age and over increased from 1,179,000 to 1,231,000 (2014 to 2023).

Livestock breeding herds have not always been on the decline. Hog numbers increased from 2014 to 2018 and again in 2021, peaking at 1.246M sows and gilts. The latest figure (1.231M at January 1, 2023) is not far below this peak. Beef cows have declined most years over the past decade, but dairy cows made modest gains from 2017 through 2020.

Figure 5.12. Breeding herd sizes, 2014-2023



5.3.2 Agricultural land base

Canada has a total farm area of just under 154 million acres, as of the 2021 Census of Agriculture: 93.6 million acres in crops, 11.9 million acres in tame/seeded pasture, 1.3 million acres in summerfallow, and 46.8 million acres classified as "other land," which includes natural pasture (Census of Agriculture, 2022b). Figure 5.13 shows the pasture land (tame or seeded as well as natural land for pasture) by province in 2021. In terms of pasture land acres, Alberta has the largest endowment at 20.4M acres, comprising 41% of the province's total farm area (land in crops, Christmas trees, natural land for pastures, tame or seeded pasture, summer fallow and chem fallow, woodlands and wetlands, and "other" land such as acres too wet to seed) (Census of Agriculture, 2022c). British Columbia has the largest share of its agricultural land in this category, with 62% of total farm area (3.5M acres in pasture) (Census of Agriculture, 2022c). Saskatchewan has the second largest pasture area, with 16.3M acres of pasture land, making up 27% of its total farm area (Census of Agriculture, 2022c). "Total farm area" includes land in crops, Christmas trees, natural land for pastures, tame or seeded pasture, summer fallow and chem fallow, woodlands and wetlands, and "other" land such as acres too wet to seed (Statistics Canada, 2022c). Alberta had the greatest area of pasture (natural and tame) in 2021: 20,376,045 acres, followed by Saskatchewan with 16,324,537 acres. Pasture represents 41.45% of all of Alberta's farm area, and 27.09% of Saskatchewan's (Census of Agriculture, 2022c).

Figure 5.13. Pasture land and as share of total farm area by province, 2021

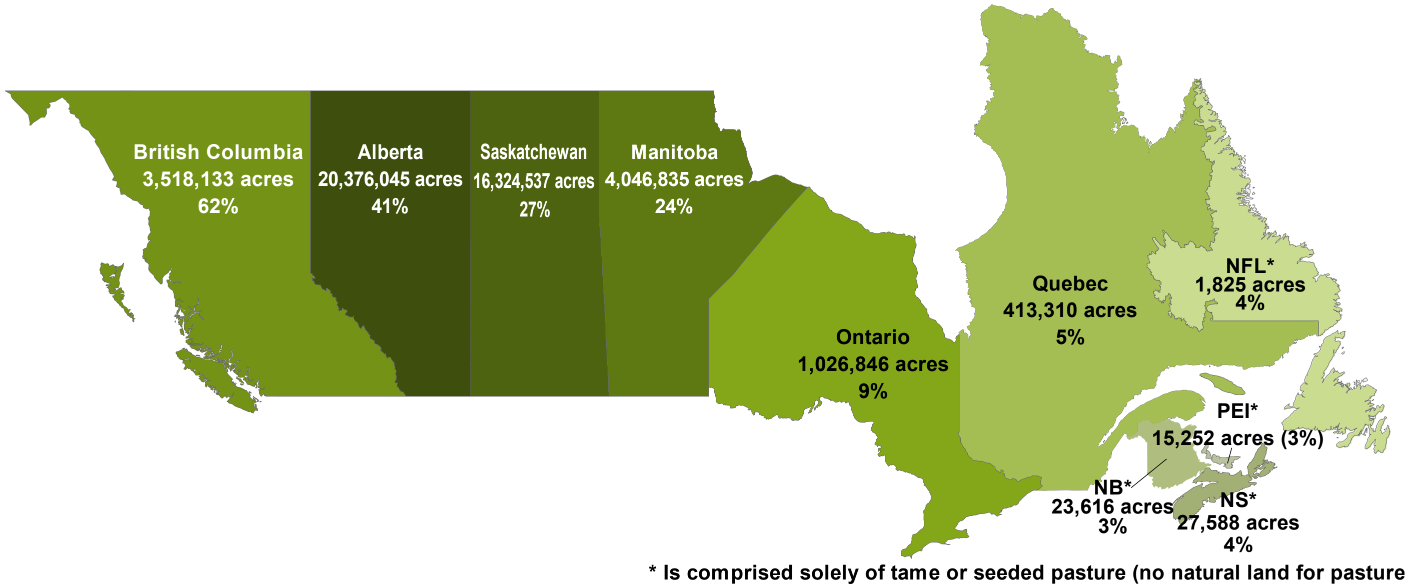


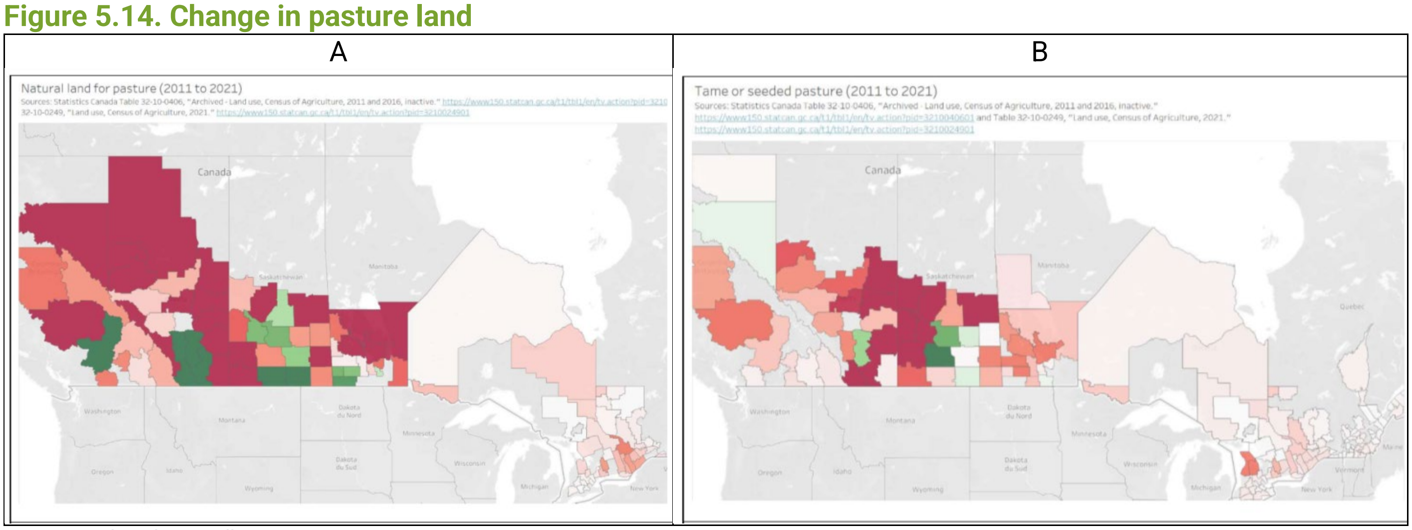
Image produced internally.
Data sources:

(1) (Census of Agriculture, 2022b). *Land use, Census of Agriculture, 2021* (Table 32-10-0249-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210024901.

(2) (Census of Agriculture, 2022c). *Land use, Census of Agriculture historical data* (Table 32-10-0153-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=321001530.

The two panels below show the change from 2011 to 2021 in natural land for pasture (panel A) and tame or seeded pasture (panel B) at the census division level. The red shapes represent losses and the green represent gains, with deeper colours representing more acres. The greatest losses of grasslands (native and managed) being converted to cropland are in Saskatchewan and Alberta because these provinces have the greatest number of acres to lose.

Figure 5.14. Change in pasture land



Images produced internally.
Data sources:

(1) (Census of Agriculture, 2022b). *Land use, Census of Agriculture, 2021* (Table 32-10-0249-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210024901.

(2) (Census of Agriculture, 2017). *Land use, Census of Agriculture, 2011 and 2016, inactive* (Table 32-10-0406-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210040601.

5.3.3 Financial capital

Farms raising food animals account for extensive capital investment. The most direct measure of this investment is in the value of livestock themselves. The most up to date source of data on the capital stock of livestock on farms is collected in the Farm Financial Survey on a biannual basis. This is presented below in Figure 5.15. The figure shows that investment in livestock on farms in Canada increased from 2009 to 2015, and has been relatively stable since, valued at just over $16 billion. The inventory value of market livestock has broadly increased since 2009, while the value of breeding stock peaked in 2017 and has decreased gently since (Farm Financial Survey, 2023a).

Figure 5.15. Value of Livestock on Farms, Canada, 2009-2021 biannual data

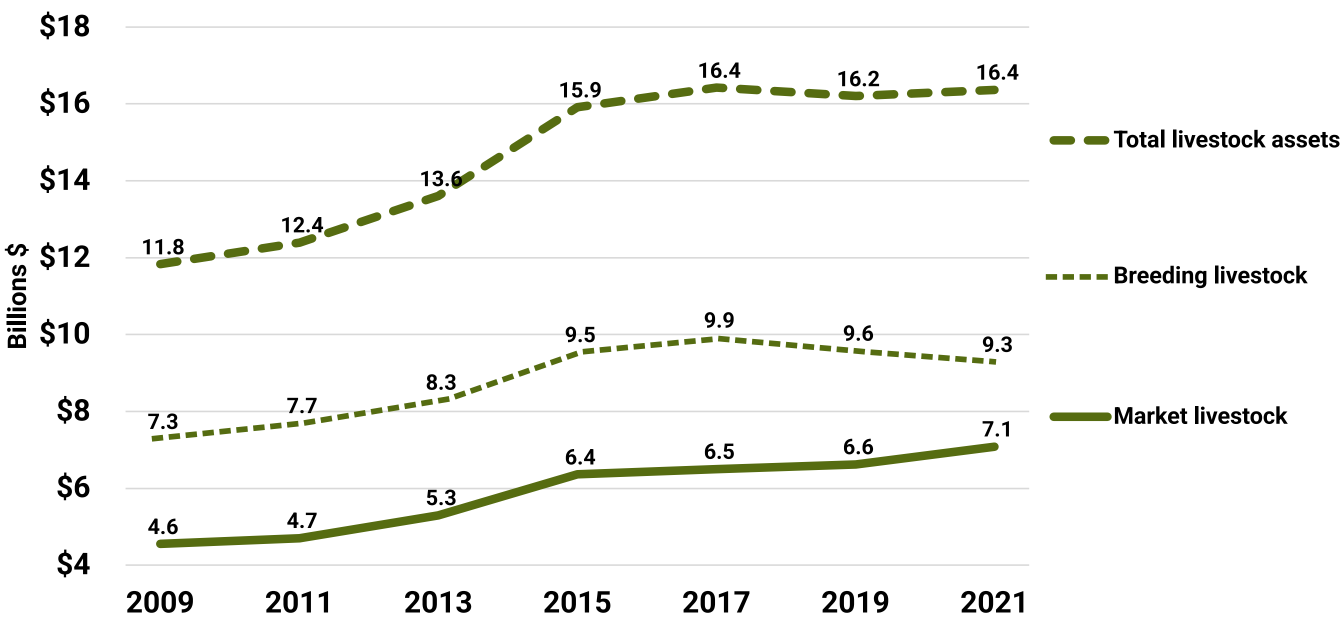


Image produced internally.
Data source: (Farm Financial Survey, 2023a). *Farm financial survey, Canadian and regional agricultural balance sheet (gross farm revenue equal to or greater than $25,000)* (Table 32-10-0101-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210010101.

Figure 5.16 below provides an aggregate estimate of the value of capital on farms identified as beef, dairy, hog and pig, poultry and egg, and other animal production (Farm Financial Survey, 2023b). The figure shows that in 2021, an estimated 44,000 farms in Canada are livestock farms based on the principal source of revenue identified in the Farm Financial Survey. While the number of livestock farms estimated has been in decline since 2009, the aggregate value of assets deployed in animal agriculture has been increasing, recently valued at $191 billion in assets, and about $143 billion in net worth.

Figure 5.16.Total Aggregate Assets and Net Worth: Beef, Dairy, Hog and Pig, Poultry and Egg, and Other Livestock

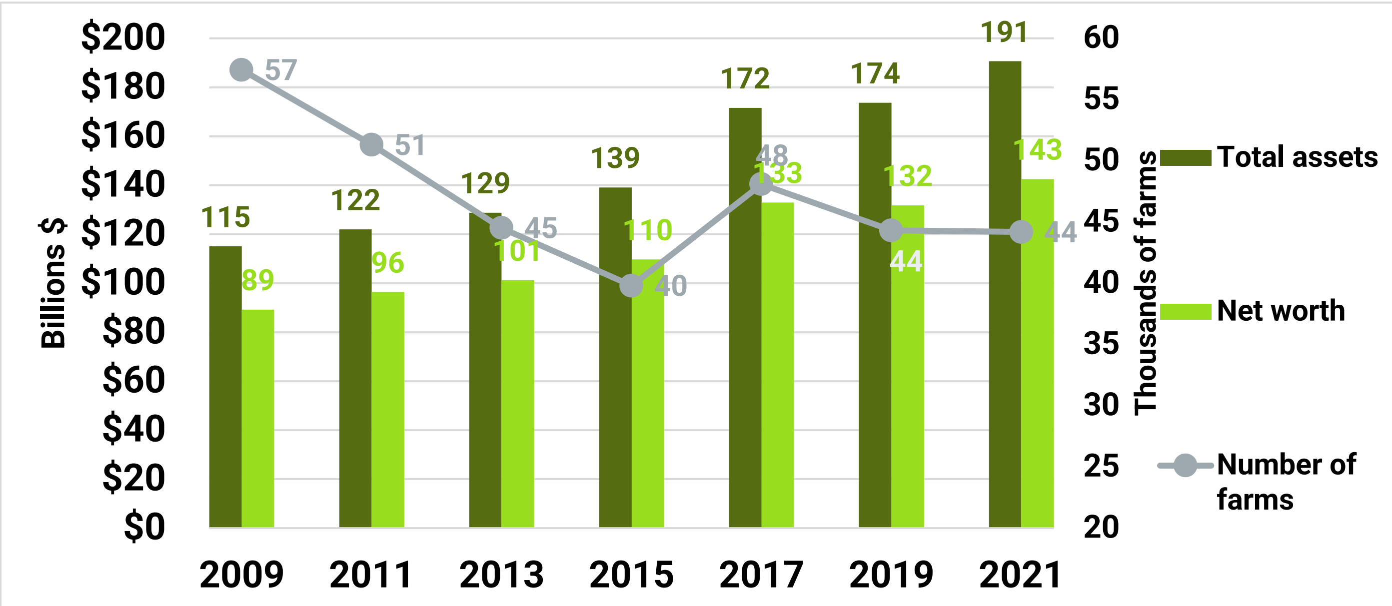


Image produced internally. Aggregates computed by multiplying average per farm by the number of farms for each farm type, then summing the five types (beef, dairy, hog/pig, poultry/egg, other animal production).
Data source: (Farm Financial Survey, 2023b). *Farm financial survey, financial structure by farm type, average per farm (gross farm revenue equal to or greater than $25,000)* (Table 32-10-0102-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210010201.

Financial Returns in Animal Agriculture

Financial returns are commonly assessed based on operating profitability and on returns on assets. For example, a common measure of operating profitability is the ratio of earnings before interest, taxes, depreciation, and amortization (EBITDA) to sales. A variety of measures financial returns performance exist, such as return on assets or return on equity, and most are dependent upon financial structure.

The public database regarding farm financial performance is contained in the Farm Financial Survey (FFS), and the performance metrics that can be obtained from it are limited based on the data that are collected. The best proxy for operating profitability in the FFS is net cash farm income. Sales is constructed based on "farm sales" and "program payments" collected in the FFS. Total assets are also collected in the FFS.

The FFS data is presented since 2001. However, prior to 2009 the data was reported as an average per farm for farms exceeding $10,000 in gross farm income on an annual basis; for 2009 to 2021 the data are averages per farm are for farms exceeding $25,000 in gross farm income. The data are fragmented by major farm type. The beef cattle farm category encompasses all segments- cow-calf, backgrounding, and feedlots; because these segments operate under very different economic models, the results for cattle present some difficulty in interpretation. The other animal production category likewise takes in a broad range in farm enterprises, and also presents some limitations with regard to interpretation.

Figure 5.17 below presents the ratio of net cash farm income/(farm sales + program payments), as a proxy for EBITDA/sales. The figure shows this ratio ranging from 20 to 25 percent for dairy farms (grey bars) to under 5 percent for other animal production. The figure shows dairy farms (grey bars) and poultry and egg farms (dark bars) with the highest ratio, averaging 20 to 25 percent for dairy farms and 15 to 20 percent for poultry and egg farms, on a generally stable basis. Hog farms (bright green lines) have a ratio that is lower than either dairy or poultry and egg farms, and is much more variable over time. Cattle (hollow lines) and other operating returns have been generally lower than the other commodity segments (Farm Financial Survey, 2017, 2023b).

Figure 5.17. Farm Operating Returns versus Operating Revenue, Average per Farm

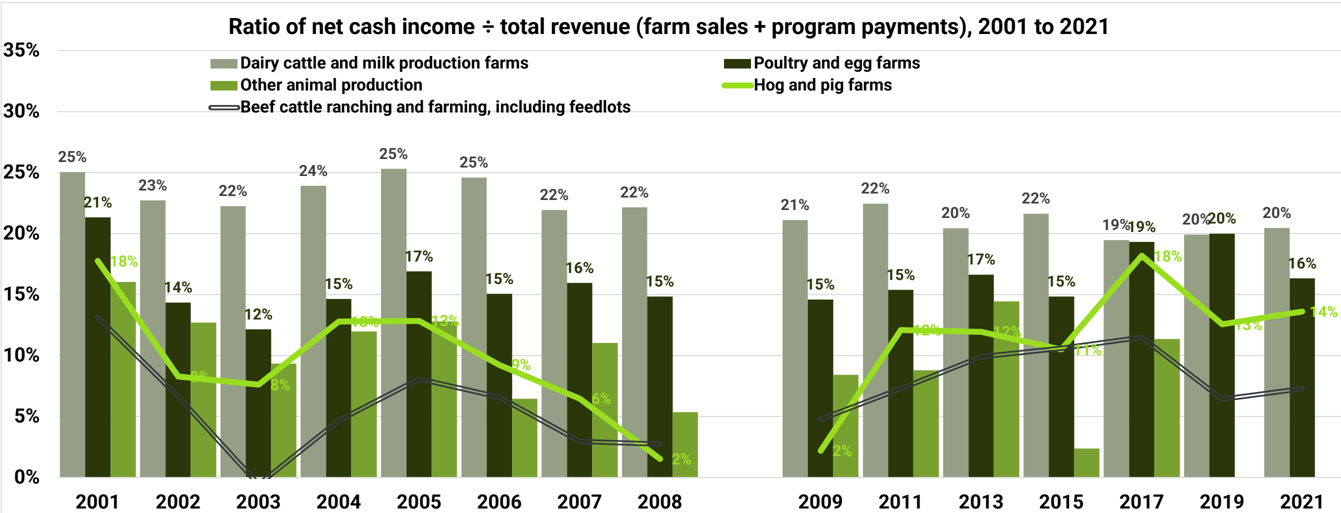


Image produced internally. Prior to 2009, data are for farms >$10,000 gross farm revenue, annual basis. For 2009-21, data are for farms >$25,000 gross farm revenue, biannual basis.

Sources:

(1) (Farm Financial Survey, 2017). *Farm financial survey, financial structure by farm type, average per farm (gross farm revenue equal to or greater than $10,000)* (Table 32-10-0287-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210028701

(2) (Farm Financial Survey, 2023b). *Farm financial survey, financial structure by farm type, average per farm (gross farm revenue equal to or greater than $25,000)* (Table 32-10-0102-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210010201

Figure 5.18 presents the ratio of net cash farm income to total assets. It shows that financial performance relative to the value of assets is comparatively stronger for hog, cattle and other animal farms. Since 2009, financial returns for hog farms have generally been the highest, mostly 4-5 percent, although the returns are clearly the most variable for hog farms. Returns against assets were stable but comparatively lower for dairy and poultry and egg farms, mostly ranging around 3 percent.

Figure 5.18. Farm Operating Returns versus Assets, Average per Farm, 2001 to 2021

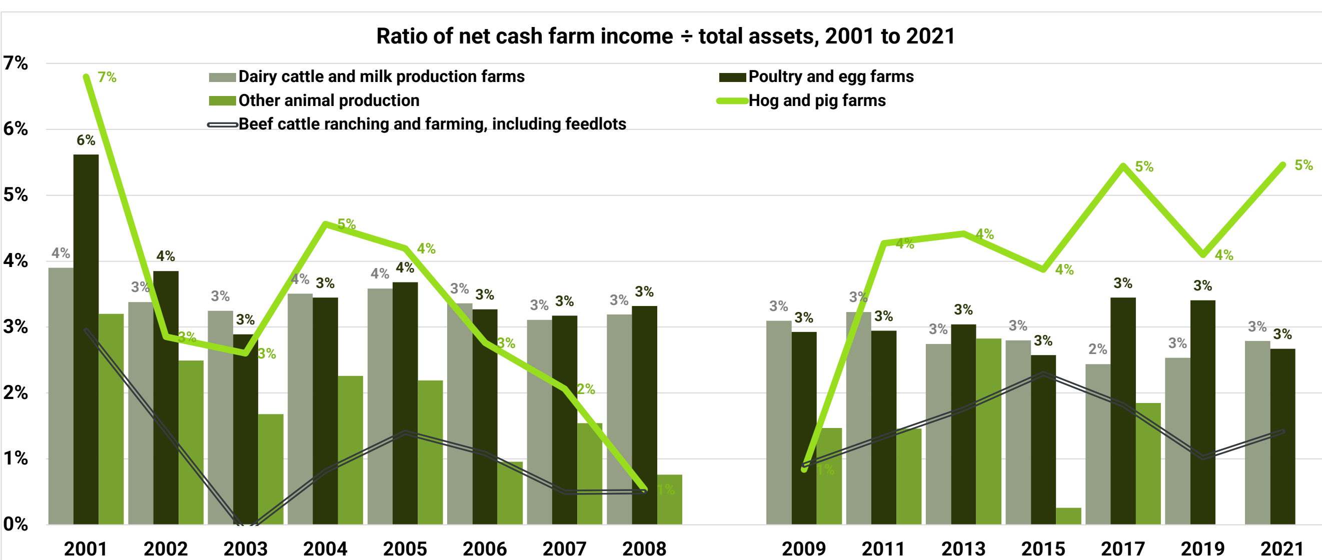


Image produced internally. Prior to 2009, data are for farms >$10,000 gross farm revenue, annual basis. For 2009-21, data are for farms >$25,000 gross farm revenue, biannual basis.

Sources:

(1) (Farm Financial Survey, 2017). *Farm financial survey, financial structure by farm type, average per farm (gross farm revenue equal to or greater than $10,000)* (Table 32-10-0287-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210028701

(2) (Farm Financial Survey, 2023b). *Farm financial survey, financial structure by farm type, average per farm (gross farm revenue equal to or greater than $25,000)* (Table 32-10-0102-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210010201

The difference between Figure 5.17 and Figure 5.18 lies solely in the denominator. Effectively, the results show that for a unit of operating revenue, dairy and poultry farms are clearly return the most in operating earnings, and do so on a stable basis. Conversely, a unit of assets generate lower operating earnings in dairy and poultry versus hogs, though the hog returns are much more volatile. Put differently, it takes a higher level of assets employed in dairy and poultry to generate the same earnings as in hogs, ignoring the effect of earnings volatility that negatively influences hog farm returns.

5.4 Social capital

James Coleman, the creator of the term "social capital," explained the concept in the following way:

> *Social capital… comes about through changes in the relations among persons that facilitate action. If physical capital is wholly tangible, being embodied in observable material form, and human capital is less tangible, being embodied in the skills and knowledge acquired by an individual, social capital is less tangible yet, for it exists in the relations among persons. Just as physical capital and human capital facilitate productive activity, social capital does as well. For example, a group within which there is extensive trustworthiness and extensive trust is able to accomplish much more than a comparable group without that trustworthiness and trust. (Coleman, 1988, p. S100).*

Social capital, as a stock influencing how participants in the livestock sector interact, is comprised of relationships developed in organizations, collective activities, and networks (Reimer, 2005). Some of the outcomes of social capital are mutual trust, reciprocity, collective identity, a sense of shared future, and cooperation (Flora, 2007). These outcomes can also loop around and become part of the capital stock as an asset or a liability (Reimer, 2005). The manifestation of these are a sense of community- emphasizing a common project, a common identity, a common historical narrative, and common loyalty (Brooks, 2019).

Social capital can be arranged into four categories: market, bureaucratic, associative, and communal (Reimer, 2005). Norms of behaviour, values, perspectives and ways of operating surround each of them in such a way that particular expectations emerge to reinforce the legitimacy of action. These norms become formalized into law with associated methods of enforcement. Some take longer to develop than others, and some are more difficult to change. Some of them are particularly relevant for the livestock sector. This includes market relations and associative relations.

Market relations are based on the exchange of goods and services within a relatively free and information rich context, explained by a classical economic market. They are about individuals bringing surplus goods, searching for those things they desire and striking an exchange that is mutually exclusive (Reimer, 2002). These relations are developed when producers and other players decide to participate in the value chain as buyers or sellers. A case study of the beef value chain in Alberta found that beef producers developed a degree of trust with their buyers and others in the value chain, and that this social capital contributed to the success of the supply chain (Lipton & Spyce, 2011). Economic benefits can ensue from this type of social capital, such as farms hiring locals as farm workers (Lipton & Spyce, 2011, p. 1).

Associative relations are based on shared interests (Reimer, 2005, p. 5); examples include clubs, spectator events, online forums, and any other location (in-person or virtual) where participants have shared interests and valued outcomes. These types of relations usually have focused objectives and have various degrees of structure (Reimer, 2005, p. 5).

Bureaucratic relations are based on a rationalized division of labour and the structuring of authority through general principles and rules (Ibid.). They are more impersonal and formal, where individuals relate more through the roles they are assigned than through individual characteristics. A critical feature of these relations is the explicit or implicit articulation of rights and entitlements founded on formal charter or legal document and backed up with law and access to enforcement. The level of social capital is strongly related to the ability of institutions to enforce rights.

Communal relations are based on strongly shared identity where members are treated equivalently based on characteristics like birth, ethnicity, or location as a basis for equivalence. Family, friendship, and clan relationships are common examples. Communal relations require a high level of trust and loyalty, especially where exchanges are long term or if objects of exchange are unclear (Reimer, 2005). Communal relations exist in Canadian agriculture, especially when farms of the same type (such as cow-calf operations or dairy farms) are located near each other. Table 5.5 shows the distribution of livestock farms in Canada by type (Statistics Canada, 2022a). The vast majority of beef farms are located in Alberta; Quebec and Ontario have the vast majority of dairy farms and hog/pig farms; Ontario and BC are the leaders in poultry and egg producers; and Ontario is by far the leader in sheep and goat farming (Table 5.5).

Table 5.5. Distribution of livestock farms by farm type and province, 2021

	Beef ranching and farming, including feedlots	Dairy cattle and milk production	Hog and pig farming	Poultry and egg production	Sheep and goat farming	Other animal	Total livestock farms
Canada	39,633	9,403	3,016	5,296	3,575	15,873	**76,796**
NFL & Lab.	44	27	1	19	21	19	131
PEI	269	157	7	22	24	62	541
NS	526	202	10	154	72	281	1,245
NB	344	162	9	53	33	139	740
Quebec	2,395	4,422	1,276	913	628	1,789	11,423
Ontario	7,986	3,188	1,189	2,061	1,309	4,556	20,289
MB	3,574	238	245	263	174	1,015	5,509
SK	7,610	122	50	145	205	1,488	9,620
Alberta	14,601	393	136	400	473	4,174	20,177
BC	2,284	492	93	1,266	636	2,350	7,121

The definition of a *census farm is*: "a unit that produces agricultural products and reports revenues or expenses for tax purposes to the Canada Revenue Agency" (Statistics Canada, 2022a).

Table created internally. Data source: (Statistics Canada, 2022a). *Farms classified by farm type, Census of Agriculture, 2021* (Table 32-10-0231-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210023101

Valued outcomes are important in social capital, for shared values foster cooperation and communication. Examples of outcomes achieved through high social capital include climate adaptation (Fletcher *et al.*, 2020) and technology adoption (Micheels & Nolan, 2016), especially in the Prairies, and profitability. This latter outcome is not always the most important outcome, as evidenced by the existence of some animal agricultural operations which continue to operate, despite continued low or negative profits. One way to understand such operations is the strong link between animal agriculture and culture or social capital.

The members of social capital networks can vary, depending on the type of relation (market, bureaucratic, associative, and communal). A suggested list of members in the livestock sector's social capital network is displayed here.

Figure 5.19. Members of the social capital networks, by type of relation

Market relations	Bureaucratic relations	Associative relations	Communal relations
Buyers and sellers Labour force (non-family)	All levels of government Industry associations Local institutions	4-H Farm management clubs	Family Friends

5.4.1 Institutions

Social capital is difficult to measure because it refers largely to relationships and trust. A prospective indicator of trustworthiness and trust are the institutions that are maintained in animal agriculture. They facilitate knowledge transfer and mobilization; coordinate farm products marketing through producer marketing boards; and support farmer education and extension such as through breed associations, soil and crop improvement associations, women's' institutes, and farm safety associations. Farm supply and marketing cooperatives are collective responses to market access issues. Farmers also collaborate under quasi-judicial alternate dispute resolution institutions; and organizations to support farmers in difficulty such as farm debt review boards.

The multitude of institutions form a complex network, each with unique abilities to strengthen the livestock industry and help it to produce goods and services, both animal products and environmental goods and services. The list of institutions in the appendix serves not as a comprehensive list, but as an illustration of the breadth and depth of institutions that are involved in animal agriculture.

A related aspect is the ability of animal sectors to change or create new institutions – an indicator that sufficient trust exists for animal industries to create and support new industries to meet new collective demands, or reform existing institutions to meet changing demands. Several important examples exist in animal agriculture. Animal industries in multiple provinces created farm animal councils to address issues of public perception of animal agriculture; some of them have merged with plant agricultural organizations to broaden their base, and the provincial farm animal councils were instrumental in establishing the Canadian Centre for Food Integrity. A National Farm Animal Care Council was established several years ago to establish standards and harmonize welfare and handling standards for farm animals. More recently, Animal Health Canada was developed to coordinate provincial efforts in animal health policy and provide a national umbrella to address animal health, disease, and welfare issues.

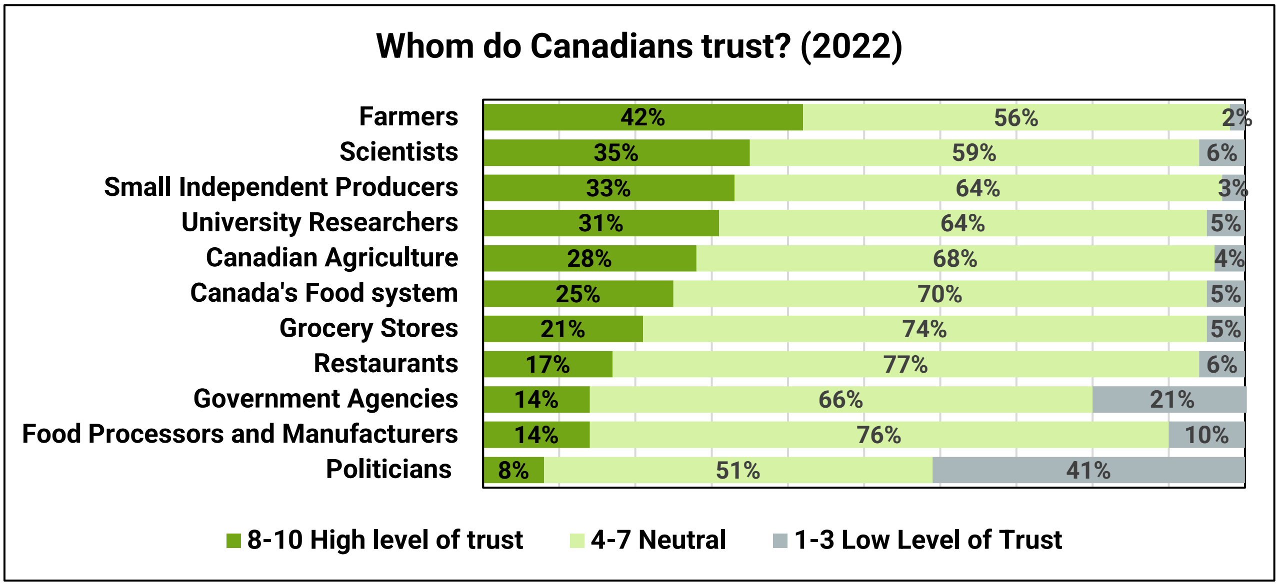
5.4.2 Implications related to social capital

Animal agriculture is endowed with institutions that facilitate many of its complexities: markets, product standards, acceptable processes for animal health and welfare, etc., built up over a very long period of time. These have had the robustness and security of a community within and across industry segments, even as it has had to evolve over time. However, this cannot be taken for granted, and social capital can fall into decline. Mussell and Hedley (2021) observed long-term structural shifts in farm structure in Canada (including livestock farms): "wide swaths of farms are being left behind-previously viewed as viable family businesses – in the wake of rapid growth in the large and very large segments" (pg. 8). Mussell (2021) worried that "a collapsing middle of the distribution of farms… threatens the community constituted by agriculture, with its commonality of interests and views, and institutions developed to support them" (p. 2). Moreover, targeted campaigns can be very effective at swaying public opinion toward or away from animal agriculture (see section 8.2). Constant work is required to renew social capital, and queue up new issues to be addressed and determine the most appropriate manner to address them.

Social capital which fosters trust is also key to ensure that animal agriculture, the food system and its products are well perceived and accepted by consumers and the public. This is sometimes captured by the concept of "social license." In the context of animal agriculture, social license allows livestock operations situated near urban areas to continue to operate despite odours, noise or citizens' views of animal welfare, and livestock production. Consumers' positive perceptions and willingness to purchase meat, poultry and dairy products is influenced by social capital related to the public's trust in the food system.

Public trust in agriculture, the food system and its products is a concern of many in the animal agriculture industry. Public opinion surveys are regularly conducted by industry and governments who strive to strengthen the public's trust in the industry. The Canadian Centre for Food Integrity (CCFI) is responsible for monitoring public sentiment around agriculture and food. In its most recent poll, CCFI identified how trust in the agriculture and food system remains relatively strong and farmers are considered the most trustworthy of all other food system stakeholders (Figure 5.20). In 2022, 42% of those Canadians polled expressed a high level of trust in farmers. This was followed by trust in scientists and small independent producers at 35% and 33%. Politicians and food processors/manufacturers were the least trusted stakeholders, at 8% and 14% of respondents.

Figure 5.20. Trust in the Canadian agriculture and food system

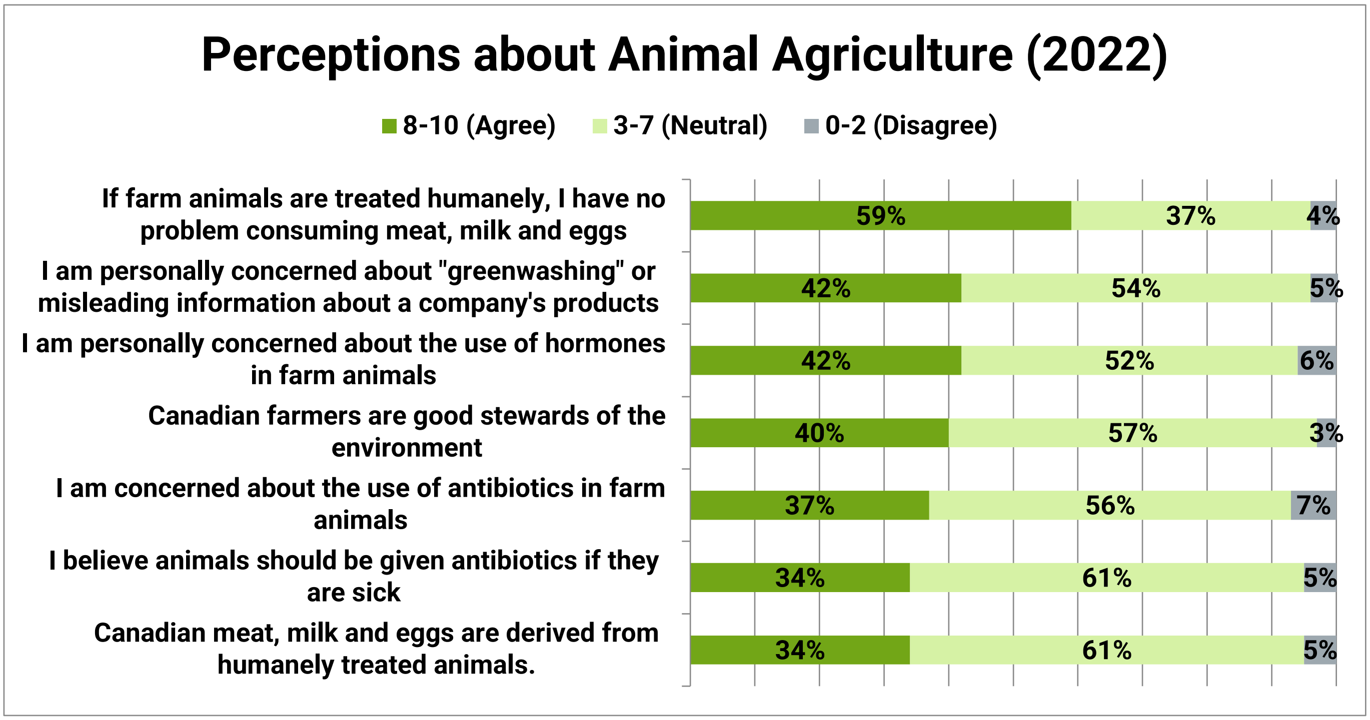


"Thinking of the Canadian food system, how would you rate your trust in the following groups?" Base: All respondents (n=2918). Reproduced from Canadian Centre for Food Integrity, 2022.

Another public opinion poll conducted by the Saskatchewan Ministry of Agriculture in 2020 also sought the public's perceptions of agriculture in the province (Government of Saskatchewan, 2022). Because of the importance of cow-calf operations in Saskatchewan, some results were relevant for perceptions around animal agriculture operations in the province. Residents were asked to rate their trust in Saskatchewan farmers and ranchers and their behaviour: 85% reported that they trusted Saskatchewan farmers and ranchers and 70% trusted them to take care of the environment. 71% reported they agreed that livestock are treated humanely by farmers and ranchers and 60% supported the growth of intensive livestock development in their communities.

CCFI also asked Canadians about their perceptions of food production in Canada. Some of the responses that are relevant to animal agriculture are provided in Figure 5.21. When asked about the humane treatment of animals, 59% of respondents reported they have no problem consuming meat, milk and eggs if farm animals are treated humanely. Less than half (42%) are concerned about companies "greenwashing" or providing misleading information when labelling their products as environmentally friendly. The same share of respondents (42%) were concerned about hormone use in farm animals while 37% were concerned about antibiotic use and 34% believed animals should be given antibiotics if they are sick. A similar share of respondents (34%) believed that Canadian meat, milk and eggs are in fact derived from humanely treated animals. It continues to be important for those players in animal agriculture, from scientists, to veterinarians, to producers and processors to ensure they do not lose the public's trust in their industry for the future prosperity and sustainability of animal agriculture in Canada.

Figure 5.21. Public Perceptions of Food Production and Animal Agriculture



Reproduced from Canadian Centre for Food Integrity, 2022

5.5 Governance and regulations

The animal agriculture industry is regulated by a broad array of regulations operating at federal and provincial levels. The federal *Health of Animals Act* serves as an umbrella that establishes standards for the welfare of farm animals with respect to disease, toxic substances, and transport, care and handling. It also establishes the authority for inspection of premises, regulation of facilities, and compensation for losses associated with animals ordered destroyed.

With regard to meat, meat products, milk, and dairy products, federal regulations operate under two main legislative frameworks. First, all meat and meat products sold in Canada must comply with the *Food and Drugs Act* and Food and Drugs Regulations made under this Act. The *Food and Drugs Act,* which is overseen by Health Canada, prohibits the sale of unsafe food products and establishes minimum health and safety provisions for all foods sold in Canada. It prohibits the sale of unfit or poisonous food (s. 4(1)), prohibits the manufacture, preparation, preservation, packaging, or storage of food for sale under unsanitary conditions (s. 7), and makes it unlawful to label, package, treat, process, sell, or advertise any food in a manner that is false, misleading, or deceptive or is likely to create an erroneous impression regarding its character, value, quantity, composition, merit, or safety (Food and Drugs Act, n.d., sec. 5(1)). The *Food and Drugs Act* grants Parliament the power to make regulations for "carrying the purposes and provisions of this Act into effect" (s. 30(1)).

Products destined for interprovincial and international trade fall under the federal *Safe Food for Canadians Act and its Regulations* (SFCA + R), which apply to slaughter and processing activities. Prior to December 2018, meat production was overseen by the federal *Meat Inspection Act* and its regulations. In response to recommendations that the federal government "simplify and modernize federal legislation and regulations which significantly affect food safety" (Government of Canada, 2009, p. 88), the different authorities administered and enforced by the Canadian Food Inspection Agency (CFIA) (the *Meat Inspection Act,* the *Fish Inspection Act*, the *Canada Agricultural Products Act*, the food provisions of the *Consumer Packaging and Labelling Act*, and the 14 sets of associated regulations) were consolidated into a single statute and accompanying set of regulations.

Dairy and poultry products fall under a range of federal legislation regulations dealing with farm products marketing, including the *Canadian Dairy Commission Act*, the *Farm Products Marketing Agencies Act*, and the *Agricultural Products Marketing Act*. The federal government regulates approval of animal health products and feeds under Health Canada (Veterinary Drugs Directorate) and the Canadian Food Inspection Agency,

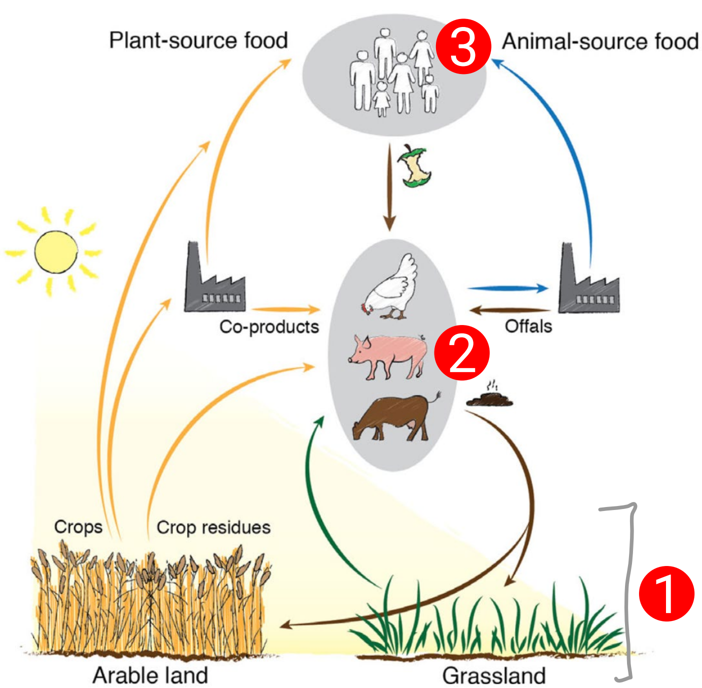
Provinces also have extensive authorities with regard to animal agriculture, notably under provincial meat inspection regulations, provincial milk acts, and provincial farm products marketing regulations.

6. Farm product flows

The flows of livestock products embody transformations from inedible or low-value products, as feedstuffs, to edible and higher value products to be consumed by humans. This process, also known as upcycling, draws upon the various capital stocks with the addition of inputs. Upcycling draws from the concept of trophic levels in biology, illustrated in Figure 6.1. The lowest trophic level (#1) contains all plant life; these plants capture the sun's energy and convert it into digestible nutrients through photosynthesis. In turn, consumers at trophic levels 2 and 3 consume these plants. Upcycling takes place when a lower trophic level consumes the leftovers, or waste, from a higher trophic level. As Figure 6.1 shows, this can be plants absorbing nutrients from animal dung; or, in the case of livestock upcyclers, they consume leftovers from humans (such as apple cores). Other feedstuffs which count as upcycling include crop residues and other plant products unfit for human consumption. The upcycling process is complete when humans, in turn, consume animal products such as meat, dairy, and eggs.

The conversions extend beyond upcycling of energy as Figure 6.1 suggests. As animals consume feeds, they upcycle energy, nutrients, and protein from plants. As this occurs, there are emissions that move outside of the system, and are not entirely captured by decomposers. In particular, these include greenhouse gases (GHGs) associated with global warming, nitrogen and phosphorus compounds linked to eutrophication, and mortalities or dead stock.

Figure 6.1. Upcycling and trophic levels

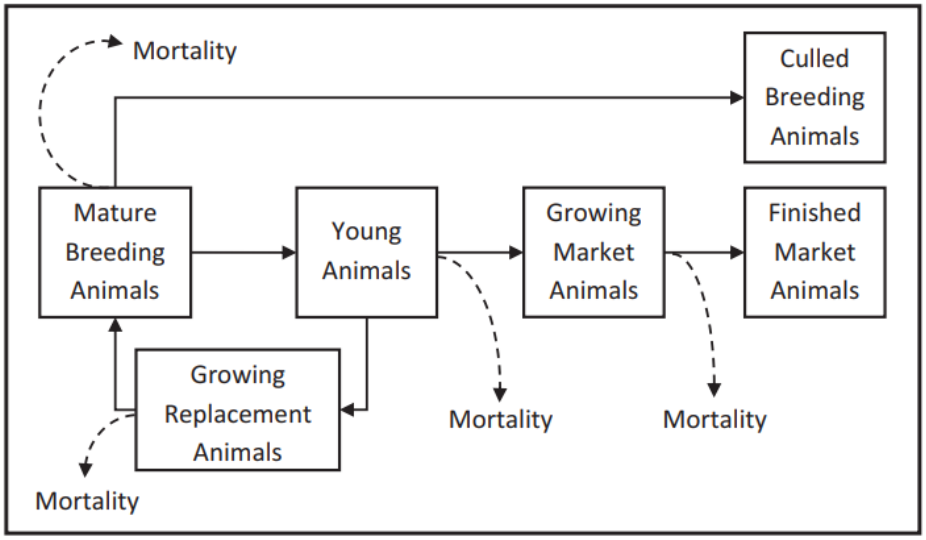


Source: Van Zanten, H. H. E., Herrero, M., Van Hal, O., Röös, E., Muller, A., Garnett, T., Gerber, P. J., Schader, C., & De Boer, I. J. M. (2018). Defining a land boundary for sustainable livestock consumption. *Global Change Biology*, *24*(9), 4185–4194. https://doi.org/10.1111/gcb.14321

6.1 Characterizing stock-flow dynamics

The upcycling of energy and protein contained in feeds by farm animals occurs in a dynamic system, in which feeds are required to maintain the stock of breeding animals, power the growth of production animals – accounting for the needs to replace culled breeding animals and mortalities with young stock – and the trade-off of production animals with animals retained for breeding purposes. Figure 6.2 below, reprinted from Peters *et al.*, 2014, provides an illustration of the structure and dynamics of the system. Breeding animals give rise to young animals that are either retained as breeding replacements or moved into grow and finish stages as production animals. Throughout the system, there are losses associated with mortalities, essentially representing losses of energy and protein obtained from feeds lost from breeding animal replacement and production into human foods.

Figure 6.2. Flows and the dynamics of animal stocks



Source: Peters *et al.*, 2014.

Table 6.1 below summarizes the production parameters characterizing the system above for beef, dairy, swine, chicken, eggs (layers), and turkey production. These present a physical baseline reference of animal and product flows, from which the discussion of feed and feed efficiency powering these flows can be built.

Table 6.1. Performance metrics of animal product systems

		Beef cattle	Dairy cattle	Swin e	Chicke n	Layer s	Turke y
Age at first birth or placement in breeding flock	Days	730	730	333	147	118	210
Length of breeding cycle	Days	365	365	183	301	348	210
Reproduction rate	Head per cycle	0.92	0.86	10.9	157	186	81
marketings	Head per cycle	0.75	0.48	8.21	146	81	73
Retained replacements for breeding	Head per cycle	0.12	0.29	0.36	1	1	1
Mortalities	Head per cycle	0.05	0.09	2.35	10	104	7
Steer Marketings	Head per cow	0.42	0.27				
	Weight, kg	604	604				
Heifer Marketings	Head per cow	0.32	0.11				
	Weight, kg	531	531				
Cull Cow Marketings	Head per cow	0.1	0.22				
	Weight, kg	545	650				
Barrows and Gilts	Head per cycle			8.2			
	Weight, kg			120			
Cull Sows	Head per cycle			0.29			
	Weight, kg			175			
Male Broilers	Head per cycle				73.4		
	Weight, kg				2.59		
Female Broilers	Head per cycle				73.4		
	Weight, kg				2.13		
Male Turkeys	Head per cycle						37.1
	Weight, kg						16.1

Female Turkeys	Head per cycle						37.1
	Weight, kg						7.5
Milk marketed	Kg per cycle		10500				
Eggs marketed	Eggs per cycle					16.4	

Source: Peters *et al.*, 2014.

6.2 Efficiency in energy and protein conversion

A central concern of animal agriculture is feed efficiency: the rate of transfers of energy, nutrients, and protein between trophic levels (such as from plants to farm animals), and associated losses. This is complicated by the range of digestive systems in farm animal species and the range of nutrient contents in prospective feedstuffs. Table 6.2 provides an illustration, based on basic macronutrient parameters of selected common feedstuffs. The table shows that the energy and crude protein content vary across feedstuffs, and that digestibility and conversion of feedstuffs also vary according to species and digestive tracts. For example, the metabolizable energy in grains is generally the highest in swine across feed types, followed closely by chicken. Ruminants (such as cattle) have the lowest levels of metabolizable energy in all feed categories displayed here, save barley silage. However, ruminants have a broader range of feeds that are lower in dry matter content that can provide a source of nutrition, notably forages and ensiled feeds. The preparation of feeds through milling, cracking/rolling, steam extrusion, et cetera, also impacts digestibility.

Table 6.2. Nutrient values in feeds

	Soybean meal	Canola meal	Field Peas	Corn grain (ground)	Feed wheat	Barley	Wheat shorts	Fat, mixed	Alfalfa silage	Grass hay (bluegrass)	Barley Silage	Corn Silage	Corn Distillers Grain with Solubles	Meat and bone meal
Dry matter (DM) share	0.88	0.91	0.89	0.88	0.9	0.88	0.89	1	0.362	0.89	0.35	0.3	0.92	0.93
Metabolizable energy, swine (kcal/kg)	**3797.8**	**2935**	**3416**	3714	**3607**	**3299**	2638	7850	-	-	1540	**2981**	**3070**	2184
Metabolizable energy, chicken (kcal/kg)	2724.7	1924	2385	**3862**	3450.6	2843	**3165**	**8723**	-	-	1540	-	2760	**2236**
Metabolizable energy, cattle (kcal/kg)	3070	1570	2010	1960	3220	1940	1610	4540	1350	1380	**2240**	1570	2040	1620
Crude protein(share)	0.53	0.41	0.253	0.1	0.2	0.14	0.16	0	0.17	0.13	0.12	0.083	0.25	0.54

Emphasized numbers represent the species most easily digests each type of feed, indicating the greatest feed efficiency in each column.

Sources: National Research Council, United States-Canadian Tables of Feed Composition: Nutritional Data for United States and Canadian Feeds, Third Revision (1982).

The nutritional requirement of farm animals also varies by species. This is summarized in Table 6.3 for swine, chicken, the feedlot segment of beef production (growing steers), and dairy. The most fundamental aspects are dry matter (DM) requirement, energy, and protein. In order for an animal to self-limit feed intake, it must feel full from eating; this is summarized in the dry matter requirement, which is generally tied to an animal's body weight. The table shows that the dry matter requirement is highest for dairy cows (20.65 kg per head per day weighing 650 to 800 kg) followed by growing steers (13.62 kg per head per day; growth in the range of approximately 400 to 700 kg), hogs, and then broiler chicken. Energy and protein are required for an animal's basic bodily maintenance requirements, growth, and milk or egg production.

Table 6.3. Basic nutritional requirements of livestock species, adapted from NRC estimates (dry matter basis)

Feed Ingredients	Market Hogs	Broiler Chickens	Beef (growing steer)	Dairy (large frame)
Metabolizable energy (kcal/kg of feed)	3539	3596	2841.409692	2600
Roughage-fibre (per kg of feed)	0	0	0.1	0.5
Protein (per kg of feed)	0	0	0.098	0.18
Lysine (per kg of feed)	0.0011	0.0013	0.0000	0.0000
Calcium (per kg of feed)	0.0074	0.0112	0.0035	0.0090
Phosphorus (per kg of feed)	0.0000	0.0000	0.0021	0.0045
Available phosphorus (per kg of feed)	0.0028	0.0039	0.0000	0.0000
Micro mix of vitamins and minerals, monogastrics (per kg of feed)	0.00	0.01	0	0
Micro mix of vitamins and minerals, ruminants (per kg of feed)	0	0	0.002	0.002
Max. meat and bone meal + pork meal + poultry meal (per kg of feed)	0.05	0.05	0.035	0.035
Dry matter (DM) intake, kg/day/head	0.75	0.008	13.62	20.65
Dry matter intake, tonnes/year/head	0.275	0.0031	4.9713	7.53725
Max. roughage, percentage DM			21%	21%
DM Feed requirements, tonnes/animal/growing period	0.275	0.0031	4.4	9.8185

The efficiency of transfers from feeds to animal growth and production entails multiple measures. One metric is animal growth rate on feed, measured as average daily weight gain for a given diet in an animal relative to its feeding period. Associated metrics are: fat and protein-corrected milk (FPCM) yield for dairy cows (milk production per time period on a given diet), and the lay rate in hens (per feed input). Another metric is feed conversion ratio, usually stated as the mass of feed per mass of animal gain, with variants that consider feed relative to milk production (FBCM/dry matter intake) or egg output vs. feed. Alternatively, its reciprocal measures the amount of gain for a given feed input. A final measure is residual feed intake (RFI), which measures actual feed consumption relative to predicted feed consumption for an animal's maintenance functions.

Most commonly, feed efficiency measures are applied to distinct grow-finish segments of the production systems. However, Peters *et al.* (2014) estimate feed conversion for the overall animal system for beef, dairy, swine, chicken, turkey, and eggs. This is presented in Table 6.4, fragmented by specific feed ingredients. Feed conversion ratios (in pounds of feed per pound of liveweight) are the lowest for monogastric animals – poultry (3.069 for turkeys, 2.812 for layers, and 2.189 for broilers) and swine (2.938) – while feed conversion ratios are much higher (less efficient) for the ruminants – beef (14.971) and dairy cattle. The table also shows that monogastric animal diets are based on corn and soymeal as feedstuffs, while the feedstuffs in ruminant diets heavily involve forages: pasture grazing, hay, alfalfa silage, and corn silage.

Table 6.4. Whole-cycle feed conversion, by major feed ingredient

	lb feed (DM)/lb liveweight							
	Mid-Maturity Grass Hay	Grazed forages	Corn Silage	Alfalfa Haylage	Corn	Soymeal	Minerals	*TOTAL*
Layers (eggs)					2.010	0.566	0.235	*2.812*
Broilers (meat)					1.431	0.677	0.081	*2.189*
Turkeys (meat)					1.995	0.972	0.102	*3.069*

Beef cattle (meat)	5.088	7.611			2.141	0.132		*14.971*
Dairy cattle (milk)	0.243		0.956	0.418	0.133	0.074		*1.8223*
Dairy cattle (meat)	1.415		0.598	0.262	1.793	0.252		*4.319*
Swine (meat)					2.365	0.573		*2.938*

Source: Peters *et al.* (2014) Supplementary dataset

A multitude of studies exist that assess and/or test interventions to improve feed efficiency. A small selection of Canadian studies, conducted with a range of objectives – but useful as benchmarks – are presented in Table 6.5. Because there is no single defined measure of feed efficiency (Seymour *et al.*, 2020), multiple metrics are used, recognizing that RFI is primarily used for ordinal comparisons of animals within a single species, and not as a benchmark across species. Similarly, while average daily gain can be used to calculate rates of gain at a point in time, the magnitude is dependent upon the relative weight of the species.

The table shows that conversion of concentrated dry feedstuffs is generally most efficient in chicken; Zuidhof *et al.* (2014) observed a whole lifecycle feed conversion of 1.92 kg of dry matter intake per kg gain in commercial broilers. Feed conversion was less efficient (2.5 kg DMI per kg gain) in swine, observed by Patience (2015); however, the data were for the grow-finish component of the production cycle and omit the (short) period from weaning through the nursery stage where feed conversion is relatively efficient. Feed conversion in beef cattle is less efficient than swine; however, this focuses on the portion of cattle feed using dense grain diets, and omits the pre-wean and backgrounding phases. Seymour et at (2020) found that dry matter feed intake/FPCM settled into a steady range of about 0.625 kg dry matter intake per kg of fat- and protein-corrected milk production in Holstein heifers in the first half of their lactation. It can be anticipated that feed efficiency will fall in the later half of the lactation, with decreases in FPCM.

Table 6.5. Selected studies of feed efficiency in Canada

	Broiler Chicken (Ross 308)	Swine	Beef Cattle	Dairy
Kg DMI/kg gain	1.918	2.5	6.35	
Kg DMI/FPCM kg				0.625
ADG kg/day	0.07425	1.02	1.82	
FPCM kg/day				32
Feeding Period days	56	82	123	40-135 days in milk
Start Weight (kg)	0.044	31.0	418	
End Weight (kg)	4.202	115.0	644	
Source	(M. J. Zuidhof *et al.*, 2014)	(Patience *et al.*, 2015)	Data compiled from >200 studies, 2011-16 by Feedlot Health Mgmt. Inc.	Seymour *et al.*, 2020

DMI: dry matter intake. FPCM: fat- and protein-corrected milk. ADG: average daily gain.

A relatively new metric of feed efficiency breaks macronutrients down into human digestible and non-digestible, to orient the feeding of farm animals relative to direct human use of products in feed. Mottet et al (2017) considered feed efficiency, based on feed conversion, differentiating between feedstuffs that are consumed by humans versus human inedible feedstuffs, and inedible byproducts derived from a human edible product. The effect was to separate into categories inedible feedstuffs (grasses, fresh legumes, and silage) and edible feedstuffs (grains and oilseeds), inedible feedstuffs produced on land convertible to edible feedstuffs, and inedible feedstuffs supplied as a byproduct of edible feedstuffs (soymeal). Using this distinction, they observed that "to produce 1 kg boneless meat requires 2.8 kg human edible feed in ruminant systems and 3.2 kg in monogastric systems" (Mottet *et al.*, 2017). This finding underscores the importance of interpretation on the meaning of feed conversion ratios and how they are utilized in calculations of the overall efficiency of various forms of livestock protein production.

6.3 Improvements in growth productivity

Zuidhof et al (2014) compared a range of biometric and allometric measures using two University of Alberta Meat Control strains unselected since 1957 and 1978, and a commercial Ross 308 strain (2005). The study compiled a range of results, including feed conversion ratio (grams of feed per grams of body weight gain) as well as daily gain. The results showed that the 2005 commercial strain had a cumulative feed conversion ratio at 56 days on feed of 1.918 versus 2.135 for the 1978 strain, and 2.854 for the 1957 strain. The results for daily gain are presented in Figure 6.3 and show that the 2005 strain had a body weight of 4.202 kg at 56 days; the 1978 strain had a body weight of 1.808 kg; and the 1957 strain had a body weight of 0.905 kg. This represents a 99.78% increase from 1957 to 1977, and a 132.41% increase from 1977 to 2005.

Figure 6.3. Absolute and relative weights of broiler chickens, by strain

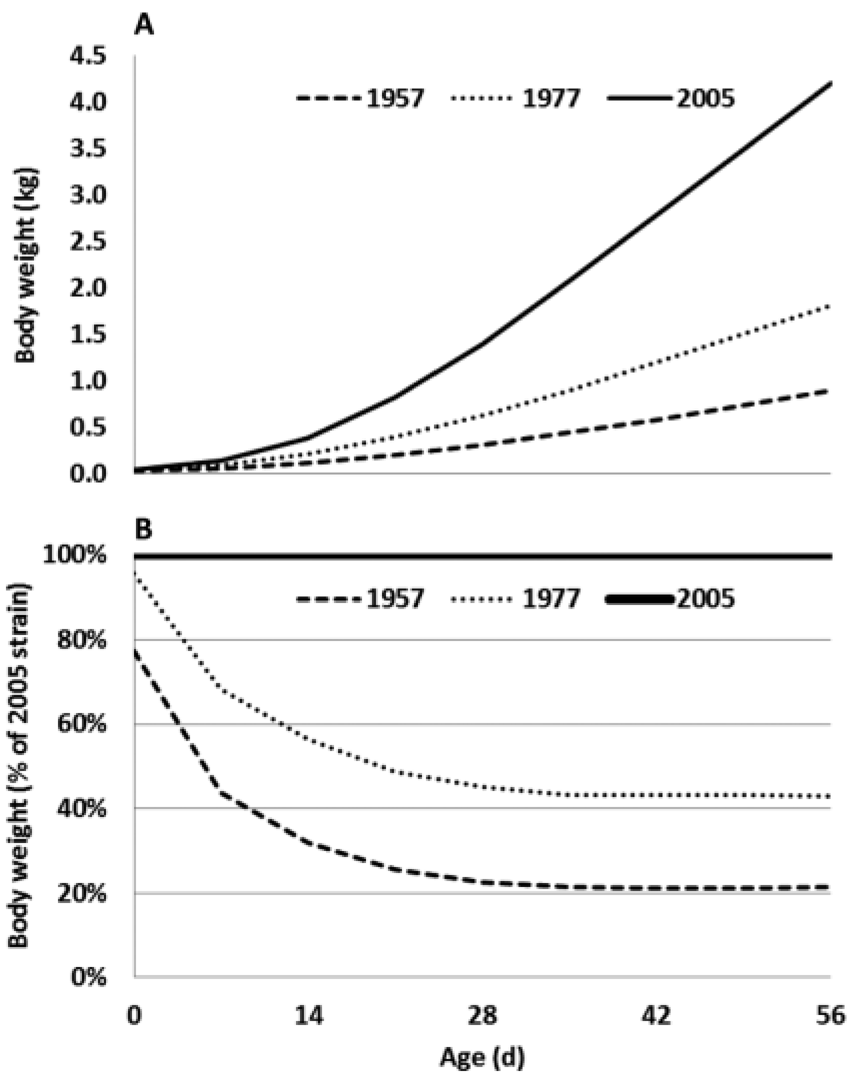


Figure 2. Absolute (panel A) and relative (panel B) BW of mixed sex University of Alberta Meat Control unselected since 1957 and 1978, and Ross 308 broilers (2005).

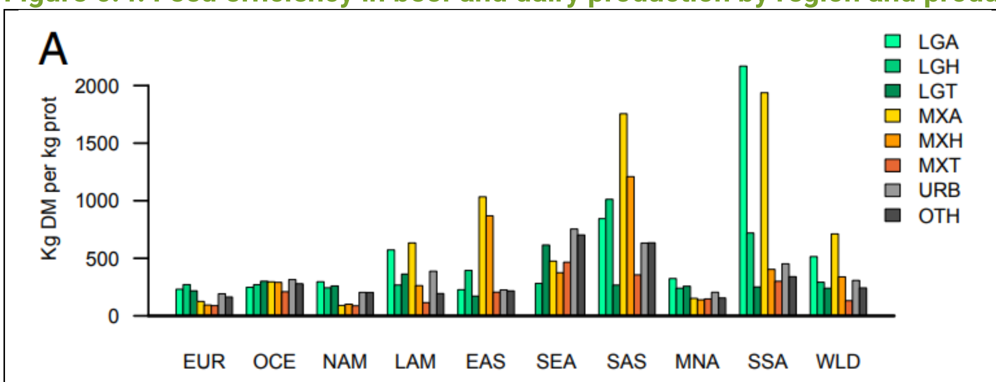
Source: Reprinted from Zuidhof *et al.*, 2014.

Patience *et al.* (2015) reviewed the effect of energy in feeds and feed intake and conversion in swine. Drawing from data obtained by Beaulieu *et al.* (2009) in both research and commercial settings, it was observed that when feeder pig starting and finishing weights were held constant, feed conversion ratio (kg feed per kg gain) decreased (improved) as the energy in the diet was increased, with daily gain almost unchanged. For the diets tested, feed conversion ratios ranged around 2.5 kg of feed per kg of weight gain, with average daily gain ranging in a tight band around 1.0 kg per day.

In assessing the economic sustainability of Canadian cattle segments, the Canadian Roundtable for Sustainable Beef (CRSB) observed that "[i]n the cow-calf sector pounds weaned per cow averaged 553 lbs in 2013, up 28 lbs from 1998 with an average growth of 1.87 lbs per year. The measurement method of pounds weaned per cow accounts for changes in reproductive efficiency, death loss and weaning weight. This is primarily driven by changes in genetics and management. In the feedlot sector, feed efficiency has improved from 10 pounds of feed needed to produce every pound of beef (10:1) in the 1950s to 6:1 in the 2010s (BCRC, 2012). All other practices being consistent, steer carcass weights have increased on average 7 pounds per year. Beef quality has also improved over time (Canadian Roundtable for Sustainable Beef, 2016).

Feed efficiency also has a great variation across regions of the world. This was estimated by Herrero *et al.* (2013). They considered comparative feed efficiency, greenhouse gas emissions, and a range of outputs for beef cattle, dairy cattle, small ruminants, swine, and poultry. Their results showed marked differences in feed conversion for a given animal category across countries. This variation is shown in Figure 6.4 below, illustrating feed conversion in beef and dairy production across region and production system. The figure shows that the feed conversion ratios in Europe and Russia (EUR), North America (NAM), and Oceania (OCE) are much lower in terms of kg DMI per kg of protein produced (and therefore more efficient) than South Asia (SAS) and sub-Saharan Africa (SSA) in beef, and Southeast Asia (SEA) and SSA in dairy, almost regardless of production system.

Figure 6.4. Feed efficiency in beef and dairy production by region and production systems



LGA: livestock grazing arid
LGH: livestock grazing humid
LGT: livestock grazing temperate
MXA: mixed arid
MXH: mixed humid
MXT: mixed temperate
URB: urban systems
OTHER: other systems

Production regions: Europe and Russia (EUR), Oceania (OCE), and North America (NAM), and the developing regions of Southeast Asia (SEA), Eastern Asia (EAS), South Asia (SAS), Latin America and the Caribbean (LAM), sub-Saharan Africa (SSA), and the Middle East-North Africa (MNA).
Source: Herrero et al., 2013.

6.4 Emissions and losses

Livestock manures contain a portfolio of nutrients in volumes and consistency that range across species. These are summarized in Table 6.6 below. Farm animals generate emissions: manure macronutrients (nitrogen, phosphorus, and potassium); atmospheric emissions from manure in storage (mainly methane); atmospheric emissions from enteric fermentation in the form of methane (in ruminants); and coliforms contained in manure. Manure volumes are essentially proportional to animal weight, with dry matter content highest for poultry, followed by swine, and lowest for ruminants. Manures contain a suite of macronutrients nitrogen (N), phosphate (P_2O_5), and potash (K_2O) consistent with fertility in plants and uptake by crops.

The fate of these emissions is important in assessing environmental effects. The macronutrients contained in livestock manures are, in effect, recycled as nutrients taken up by crops and substituted for chemical- or mineral-based fertilizers. The methane emissions are described by the biogenic carbon cycle, in which methane emitted decomposes to CO_2 in the atmosphere in about 12 years and is absorbed by plants, which are then consumed by ruminants, restarting the cycle (recall Figure 6.1). This differs from methane emissions emitted by petroleum, comprised of long-sequestered methane newly released to the atmosphere, external to the biogenic cycle.

GHG emissions can also leak out of the system, and standards and effective manure management are crucial. Greenhouse gas emissions of manure in storage can be influenced by storage facility type and application method; increasingly, feed additives are being developed that mitigate methane emissions; genetic selection for low GHG emissions is a new dimension in animal breeding. Excessive applications of manure can result in offsite losses of phosphorus that contribute to eutrophication of waterways and leaching of nitrogen contained in manure into groundwater. The relative balance of manure applications with the land base used to produce the feed depends upon the nutrient content of the manure, the agronomic requirements of the crop, and whether agronomic balance is rated on nitrogen or phosphorus.

Table 6.6. Animal Manure Typical Volume, Dry Matter, and Nutrient Analysis

	Manure deposition		Manure Nutrient Analysis**		
	Kg/day*	Approx. Dry Matter %**	kg/tonne dry matter		
Beef Cow	55	29.5	6.4	10.5	23.7
Beef Calf	22	31.7	10.7	17.7	21.5
Dairy Lactating Cow	68	27.3	8.4	13.2	23.8
Dairy Dry Cow	38	27.3	8.4	13.2	23.8
Dairy Calf 150 kg	8.5	27.3	8.4	13.2	23.8
Dairy Heifer 440 kg	22	27.3	8.4	13.2	23.8
Dairy Veal 118 kg	3.5	31.7	7.3	11.4	20.5
Layer	0.088	40.9	40.1	43.5	27.4
Swine Gestating Sow 200 kg	5	29.7	11.4	30.0	20.2
Swine Lactating Sow 192 kg	12	29.7	11.4	30.0	20.2
Swine Boar 200 kg	3.8	29.7	11.4	30.0	20.2
Slaughter cattle	29.41	31.5	9.5	16.5	21.0
Broiler	0.1	62.8	27.1	32.8	28.7
Turkey-male	0.27	51.9	29.3	46.4	33.1
Turkey-Female	0.16	61.0	36.4	34.3	24.9
Swine Nursery Pig	1.33	29.7	11.4	30.0	20.2
Swine Grow-Finish	4.67	29.7	11.4	30.0	20.2

*Source: American Society of Agricultural Engineers Standards Guidelines Data adapted from ASAE D384.2 March 2005, Manure Production and Characteristics
**Source: OMAFRA Manure Databank https://www.ontario.ca/page/2023-table-2-manure-databank#section-4 N is spring applied; P2O5 is long term

Box 6.1. Crops feed livestock, and livestock feed crops

A grain corn crop in Ontario has an expected yield of 174 bushels/acre, or about 10.9 tonnes/ha. Based on total life cycle utilization of corn for hogs, broiler chickens, and dairy cows, this hectare (10.9 tonnes of corn) supplies the grain corn portion of the diet for about 42 market hogs, 3,234 broilers, 8.4 beef steers, or 126 milk cows. Based on the nutrient content of manure and the fertility requirements of corn, the nitrogen fertility for this hectare can be provided by about 30 market hogs, or 279 broilers, or 5.4 beef steers or 3.2 dairy cows.

However, in practice, manure is applied to meet phosphorus fertility requirements. The phosphorus removal of grain corn per hectare is provided by 5 market hogs, or 106 broilers, 1.4 beef steers, or 1 dairy cow, and the residual nitrogen fertility demand is supplied by commercial fertilizer.

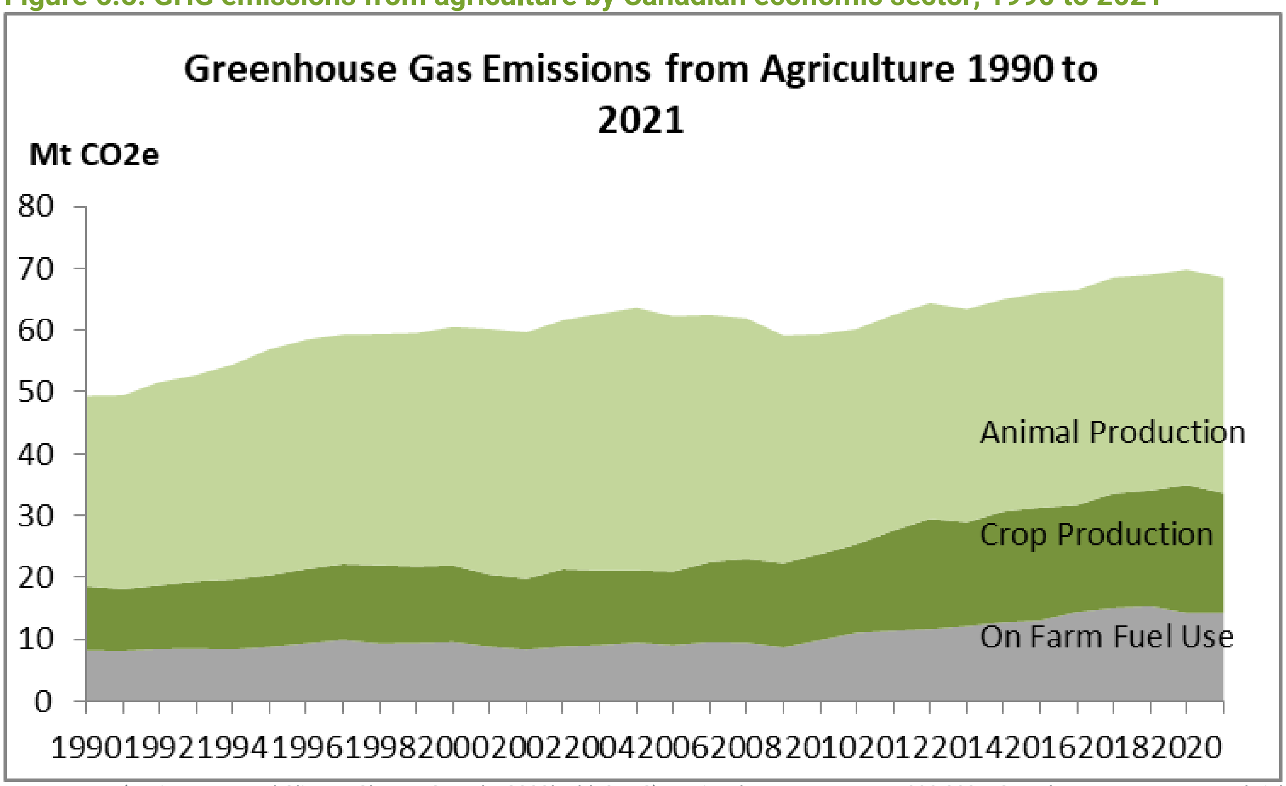
Thus, the upcycling of corn into pork, chicken, beef, and milk generates nutrients that help replace the fertility nutrients embodied in the corn consumed, and provides surplus nutrients that can be applied to other crops – both connected directly with and grown in rotation with feed crops, and others distinct from animal agriculture.

6.5 Livestock, life-cycle analysis and the environment

There has been substantial research on understanding the impact of livestock on the environment, including GHG emissions, water and soil quality, carbon sequestration and biodiversity. In Canada, the most recent estimates of GHG emissions from agriculture and livestock production are available from Environment and Climate Change's (ECCC) National Inventory Report (NIR) (Environment and Climate Change Canada, 2023b, pt. 1). In 2021, GHG emissions from agriculture (including on-farm energy use) were 69 MtCO_2e, down slightly from 2020 but up from 64 MtCO_2e in 2005 (Figure 6.5) (Environment and Climate Change Canada, 2023b, pt. 1). Agriculture accounted for 8% of Canada's total emissions (Figure 6.6) or 10% when including on-farm fuel use; these shares of total Canadian emissions were unchanged from 2020. Livestock (that is, enteric fermentation – mainly ruminant digestion – and manure management) contributed 5% of all GHG emissions in Canada in 2021 (Figure 6.6). At 35 MtCO_2e, GHG emissions from animal production (beef and dairy cattle, swine, poultry, and others) from all sources of GHG emissions (*i.e.*, CO_2, CH_4, and N_2O) accounted for 51% of agricultural emissions (including on-farm energy use), relatively unchanged over the past decade.

Emissions from animal production come primarily from methane (CH4) from enteric fermentation from ruminants and from the anaerobic decay of manure. These were estimated at 28 Mt CO_2e in 2021, down from 42 Mt CO2e in 2005. According to ECCC (2022), agriculture is responsible for 30% of Canada's total methane emissions, with 71% of that being attributed to beef production (Environment and Climate Change Canada, 2022a). Enteric fermentation resulting from the digestive process in ruminants, such as cattle, goats and sheep, accounts for 86% of Canadian's agricultural methane emissions, while stored manure emissions account for the remaining 14%. One reason for the dramatic decline in methane emissions since 2005 is related to the reduction in the size of the beef cattle herd over this period. Other reasons relate to improved genetics, feeding regimes and faster weight to market (Legesse *et al.* 2015). Nitrous oxide (N_2O) from manure management accounted for an additional 3.9 Mt CO_2e (Environment and Change Canada, 2023b, pt. 1, p. 149). Emissions from crop production were down in 2021 due to the drought on the Prairies and emissions from on-farm energy use were unchanged in 2021 at 14 Mt CO_2e.

Figure 6.5. GHG emissions from agriculture by Canadian economic sector, 1990 to 2021



Data source: (Environment and Climate Change Canada, 2023b, tbl. 2—12). *National Inventory Report 1990-2021: Greenhouse gas sources and sinks in Canada*. Government of Canada. https://publications.gc.ca/collections/collection_2023/eccc/En81-4-2021-1-eng.pdf. Image created internally.

Figure 6.6. Emissions in Canada by IPCC sector, 2021

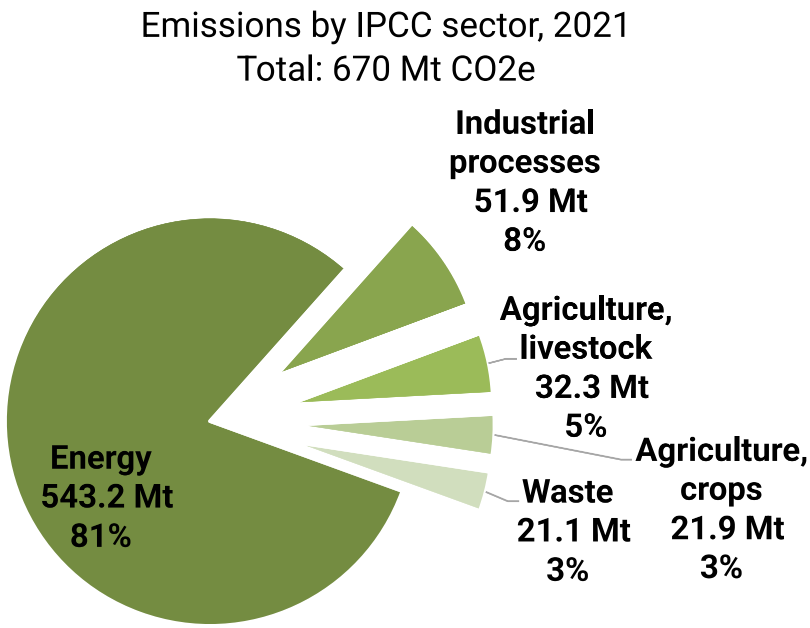


Image produced internally. Does not include carbon offsets from land use, land use change, and forestry, which totalled negative 17.3 Mt CO2e in 2021. Does not include on-farm fuel use (see Figure 6.5).
Source: (Environment and Climate Change Canada, 2023b, Table 2-3). *National Inventory Report 1990-2021: Greenhouse gas sources and sinks in Canada*. Government of Canada. https://publications.gc.ca/collections/collection_2023/eccc/En81-4-2021-1-eng.pdf

6.5.1 Life Cycle Assessment of Environmental Impacts of Beef Production

In Canada, animal production varies by region, with the Prairies dominating for beef cattle production, combining both intensive production systems with high animal densities finished in feedlots, and low-density pasturing systems for cow calf operations (ECCC, 2023, part 1, p. 151). Grassland pastures that support grazing cattle represent a significant carbon stock, with the potential for additional carbon sequestration under appropriate practices, yet still represent a net contributor to emissions (Pogue *et al.*, 2018). Feedlot cattle produce lower amounts of enteric CH_4 than grazing cattle due to the shorter retention of grain-rich feedlot diets in the rumen. Hence Legesse *et al.* (2015) argued that the cow-calf sector accounts for about 80% of total GHG emissions from a typical Western Canadian beef production system when considering all emissions from cows, bulls and their progeny, from the cropland that supplied forage/feed, on-farm energy use and the manufacture and application of inputs (fertilizer, herbicides) (Legesse *et al.*, 2015).

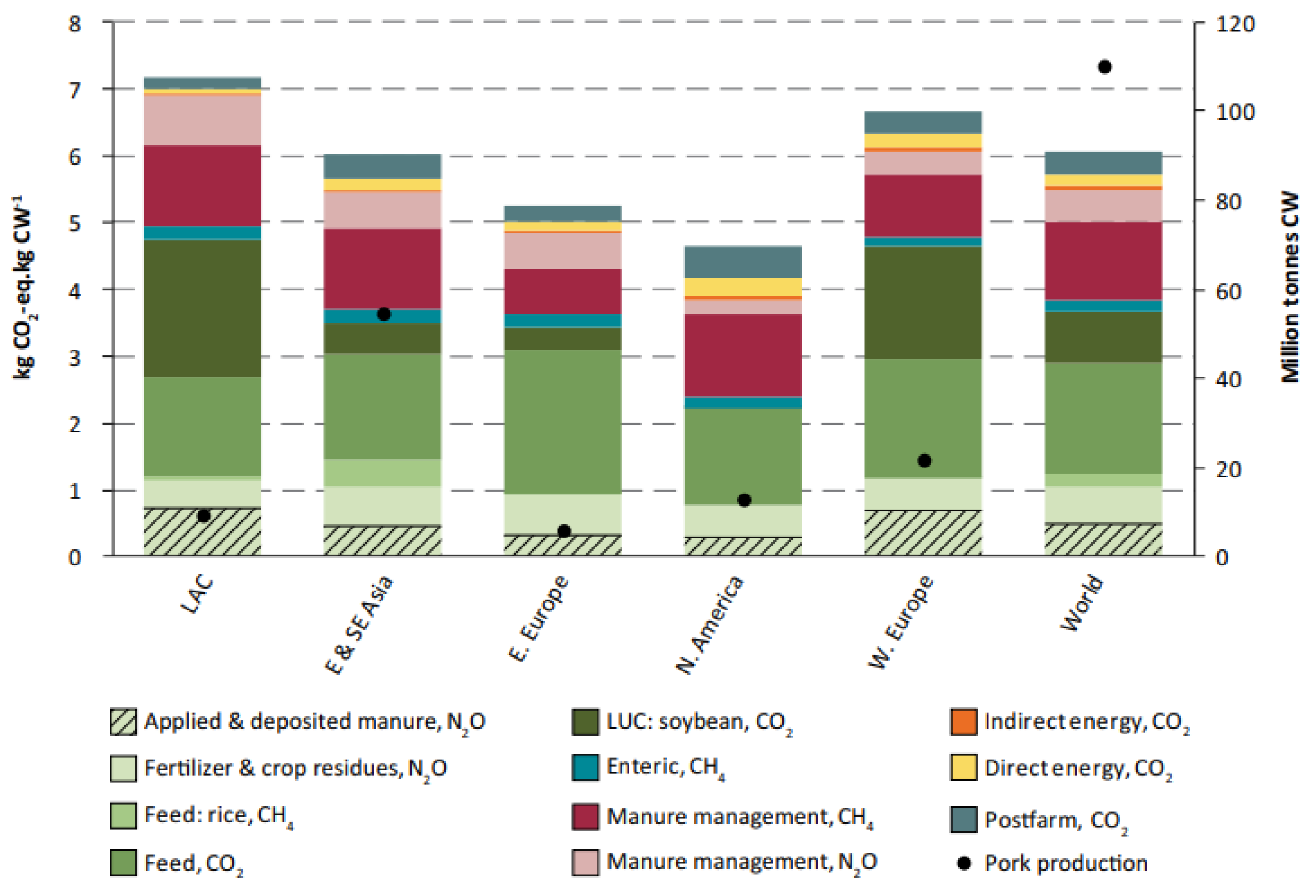
Over time, Canadian beef production efficiency has improved and hence is now some of the most GHG-efficient in the world (Figure 6.7). In the study by Legesse *et al.* (2015), using the HOLOS model, a life cycle analysis (LCA) estimated that from 1981 to 2011 GHG emissions per kilogram of beef produced declined from 14 kg CO2e/kg to 12 kg CO2e/kg live weight between 1981 and 2011 (by 14%). This was the result of increased average daily gain and slaughter weight, improved reproductive efficiency, reduced time to slaughter, increased crop yields and a shift towards high-grain diets that enabled cattle to be marketed at an earlier age. Canadian cattle GHG intensity is now about 30 % below the international average (Legesse *et al.*, 2015).

6.5.2 Life Cycle Assessment of Environmental Impacts of Pork Production

Swine production, too, which takes place in high-density, intensive production facilities primarily in Quebec, Ontario and Manitoba, has become much more GHG efficient with developments in genetics, management, and feed efficiency. Figure 6.7 shows that North America (Canada and the United States) has the lowest emissions intensity (approximately 4.7 kg CO_2e/kg carcass weight) compared to other regions in the world (Gerber et al., 2013, fig. 19). This figure is supported by the Canadian Pork Council, who reported that Canada's emissions intensity figure is 4.43 kg CO2e/kg CW (Groupe Agéco, 2018, p. 15). Notably, Spain (located in West Europe) is the #1 net exporter of pork in the world (see Figure 10.16), and yet West Europe has a relatively high emissions intensity (approximately 6.7) – higher even than the world average of approximately 6.0 kg CO2e/kg CW (Gerber et al., 2013, fig. 19).

Research shows how progress has been made in improving other environmental performance indicators of pork production around the world. Andretta *et al.* (2021) analyzed how a precision feeding system that fed pigs individually according to individual nutrient requirements, could reduce lysine intake by up to 26%, and nitrogen and phosphorous excretion by 30 and 14% respectively without affecting the productive pig performance (Andretta *et al.*, 2021). Hence production costs could be reduced by 10% and risks of eutrophication and nitrification mitigated. Andretta *et al.* argued that a precision feeding system that fed pigs individually was able to reduce the impact of climate change by 7% in swine (Andretta *et al.*, 2021).

Figure 6.7. GHG emissions of pork by region of the world, 2013



* Regions accounting for less than 1 percent of world production are omitted.

Source: GLEAM.

Source: Reprinted from Gerber, P. J., Steinfeld, H., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., & Tempio, G. (2013). *Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities.* Food and Agriculture Organization of the United Nations, FAO. https://www.fao.org/3/i3437e/i3437e.pdf

6.5.3 Life Cycle Assessment of Environmental Impacts of Dairy Production

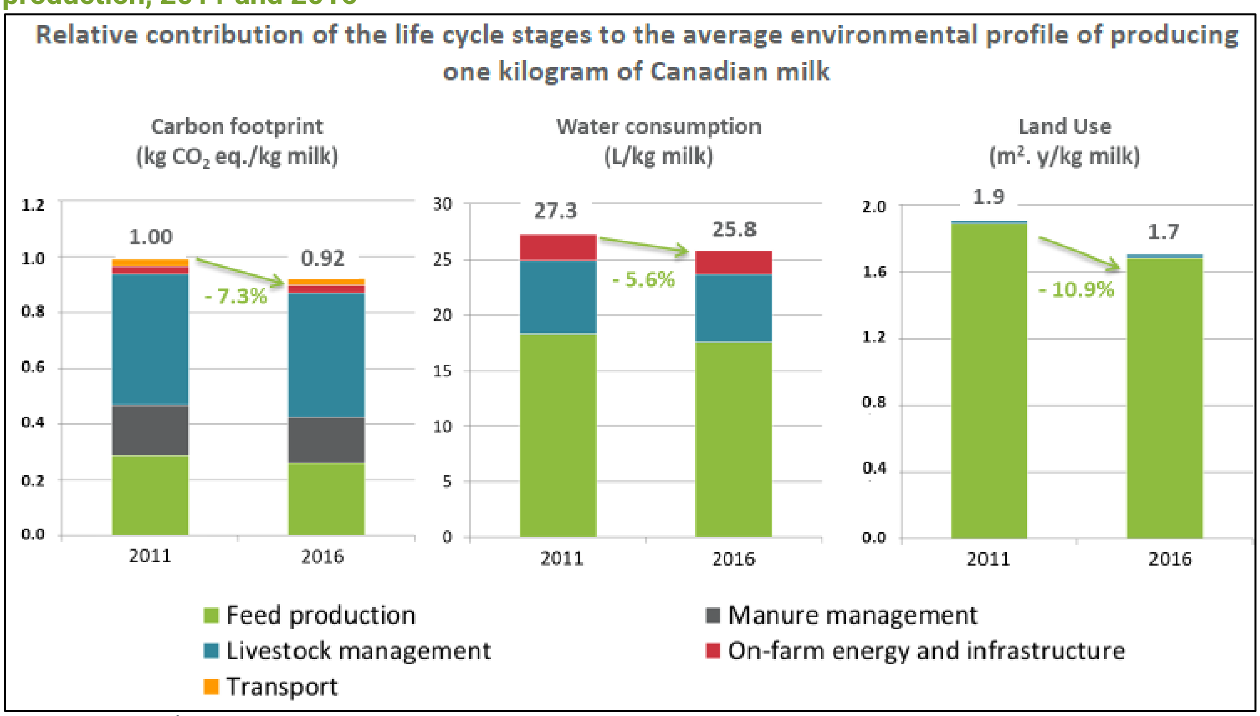
Similarly, dairy production in Canada is relatively low GHG intensive compared to many other countries. Most dairy production takes place in Eastern Canada in intensive facilities and production has intensified significantly since 1990, affecting both milk productivity and management approaches. Vergé et. al (2013) estimated that milk produced in Canada has an environmental footprint of 1.0 kg CO_2e per kg of milk, whereas the global average is 2.4 kg CO_2e per kg produced.

The Canadian dairy industry has traditionally focused on improving attributes related to production such as milk yield, reproduction, health, longevity and their overall shape (Hailu, 2018, p. 8). This led to a significant increase in productivity in the dairy industry, with milk yield increasing by 122.5% between 1956 and 2017; and by 10.5% between 2007 and 2017. This lowered GHG emission intensity as a result (Hailu, 2018). Dyer *et al.* (2007) found that GHG emissions per kilogram of milk decreased by 35% between 1981 and 2001, from 1.22 kg CO2e/kg to 0.91 CO2e/kg, primarily as a result of a 57% reduction in the dairy cow population while total milk production increased. As a result of continued focus on improving genetics and feed efficiency, while also targeting methane emission reductions, such as in Quebec through funding for a new Living Laboratory (Agriculture and Agri-Food Canada, 2023e), dairy farmers are expected to see further improvements in the GHG emissions intensity of dairy production in Canada.

More recent research by Groupe AGÉCO for the Dairy Farmers of Canada updated a Life Cycle Assessment (LCA) for Canadian dairy production in 2016 that saw the sector's carbon footprint, water consumption and land use associated with milk production decrease significantly (Figure 6.8). An LCA is an internationally recognized approach to assess the impacts associated with all of the stages of a product's life. Their approach assessed the life cycle of milk production in Canada from raw material extraction to milk transport from the farm to the processor's gate. They considered key resources needed during this process, from the resources and energy requirements as well as the emissions related to the production and use of on-farm inputs, such as fertilizers, electricity, barn infrastructure, feed production, on farm activities such as growing crops and storing manure and transport activities. The results are presented in Figure 6.8 below.

The carbon footprint, water consumption, and land use associated with milk production decreased by 7.3%, 5.6% and 10.9% respectively, between 2011 and 2016. Livestock management was deemed the main contributor to the reduction in the carbon footprint because of the role of enteric fermentation for methane emissions. Due primarily to increased cow productivity, enteric emissions decreased from 0.47 to 0.44 kg CO_2e per kg of milk between 2011 and 2016. However, for water consumption and land use impacts, the environmental impacts of crop production played an important role.

Figure 6.8. Relative contribution of life cycle stages to the average environmental profile of dairy production, 2011 and 2016



Source: Groupe AGÉCO for Dairy Farmers of Canada (2018)

6.5.4 Life Cycle Analysis of the Canadian Poultry Industry

For poultry, Vergé *et al.* (2009) found that between 1981 and 2006 total GHG emissions from the Canadian poultry industry increased by 40%, primarily due to rising nitrous oxide (N_2O) emissions from feed (Vergé et al., 2009). However, because of productivity gains over the same period that increased market live weights and higher turnover cycles, the GHG emission intensity of chicken meat decreased by 19%, from 1.19 to 1.0 kg of CO2e/kg live weight (p. 220). Turkey production also became more GHG efficient, falling by 50% from 2.16 to 1.44 over the period, and the GHG emissions in egg production fell by 8%. Because of the importance of N_2O emissions in estimating GHG emissions intensity on a life cycle basis, the authors argue that the most important target for enhancing current mitigation efforts would be management of the poultry diet with respect to N efficiency. This would require crops with low N application rates, high yields, or both as well as with high feed value. Also because poultry production involves intensive housing, heating and ventilation are significant fossil fuel energy terms and are good targets for GHG mitigation. Hence future research should include monitoring of the heat flows in and out of poultry barns as well as the energy balances of these buildings (Vergé et al., 2009).

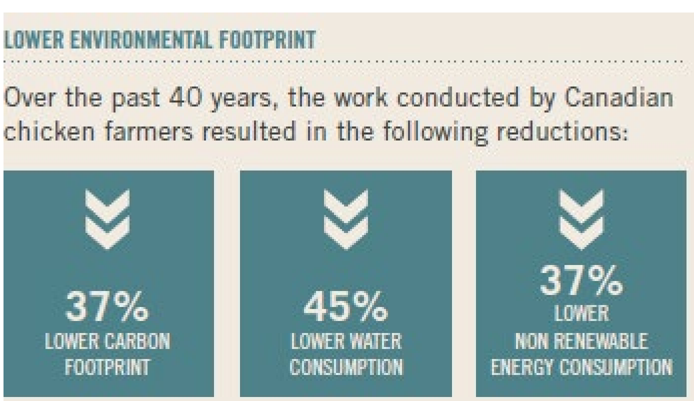
Chicken Farmers of Canada commissioned Groupe AGÉCO to undertake a life cycle analysis of chicken production in Canada (Chicken Farmers of Canada, 2018a). The study was designed to measure the environmental and social performance of Canada's chicken sector, from hatching egg to processor. The study found that since 1976, environmental performance significantly improved because of major productivity gains and significant improvements in feed conversion ratios. Per kilogram of chicken, the carbon footprint of Canadian chicken is lower than that of other livestock commodities produced in North America, based on FAO's assessment of global livestock emissions (Table 6.7). Also, in the last 40 years, the carbon footprint of the sector was reduced by 37% and water consumption was reduced by 45% (Figure 6.9). Currently 62% of the entire sector's energy use comes from renewable sources, with chicken feed accounting for the bulk of renewable energy consumption (Chicken Farmers of Canada, 2018b, p. 3).

Table 6.7. Emissions intensity of chicken production, 2017

Country/region	Emissions (kg CO_2e per kg of chicken)
Canada	2.4
North America	3.0
Western Europe	4.4
Latin America and the Caribbean	4.4
Near East and North Africa	5.0
South Asia	5.1
East Asia and Southeast Asia	6.7

Source: Reproduced using figures from Chicken Farmers of Canada. (2018b, p. 2). *Sustainability assessment of the Canadian chicken value chain.* https://www.chickenfarmers.ca/wp-content/uploads/2018/08/CFC_ENG_F_Simple.pdf. Based on data from FAO's GLEAM, 2017.

Figure 6.9. Improvements in sustainability in Canadian chicken farming



Source: Chicken Farmers of Canada. (2018b, p. 1). *Sustainability assessment of the Canadian chicken value chain.* https://www.chickenfarmers.ca/wp-content/uploads/2018/08/CFC_ENG_F_Simple.pdf.

6.6 Synthesis of farm product flows: feed and environmental effects

Farm animals are the essential upcyclers of solar energy captured by plants into food products that are edible for humans. Feed and feed efficiency is the fundamental tie between animals and agricultural land use. The characteristics of the agricultural land base and conditions influencing crop yields and quality determine the feasibility of various forms of farm animal production. Regions with high quality soils and a supportive climate for grain crops used as feeds can support greater numbers of farm animals in grain feeding stages, especially monogastric animals (like poultry and swine) that require a diet composed heavily of grain ingredients. Conversely, ruminants can make use of a broader range of feedstuffs, much of which can be produced from lesser quality soils and harsher climates.

The relationships among farm animals, feed crops, and the land base are complex. The stock represented by the breeding herd must be constantly fed and replaced due to culling and mortality; as such, the breeding herd and the subsegments of replacements represent a type of "overhead" that must be carried by the flow of production animals and products, and the associated feed. The larger the animal and the longer the breeding cycle and grow-finish period, the greater the overhead cost of the sustaining breeding herd.

The feedstuffs range in their density of nutrients. The nutrient requirements of the animals vary by species, not just in proportion to body weight and the demand for dry matter in feeds. In general, monogastric animals extract greater energy efficiency in feedstuffs compared with ruminants; however, ruminants can digest a much greater range of feedstuffs – notably forages – and as such, inedible materials can be used as a source of energy and protein in a ruminant's diet in place of grains and proteins edible by humans. However, these relationships are complex: for example, digestibility of feedstuffs can be altered through feed preparation (*e.g.*, cracking, grinding, roasting of feedstuffs). This means that basic feed efficiency – feed conversion – requires careful interpretation.

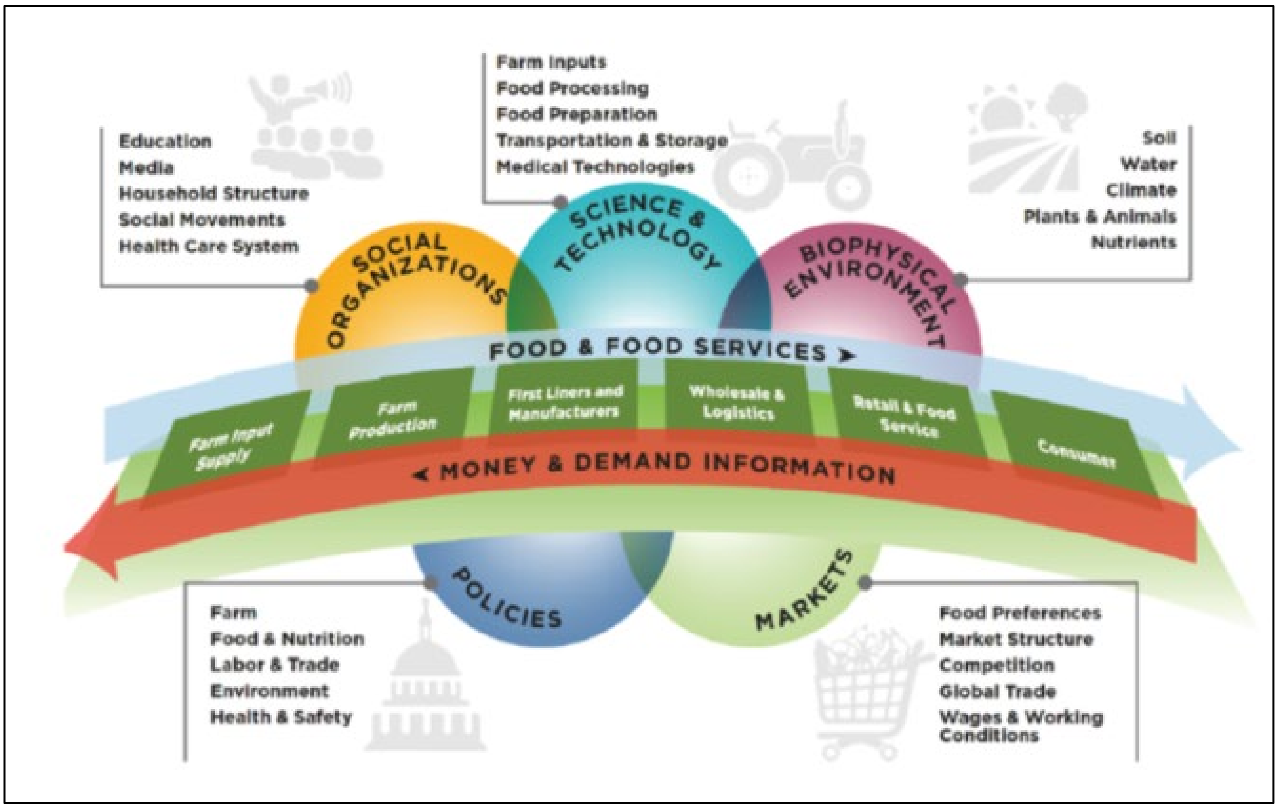
In turn, feedstuff nutrient content and digestibility contributes to the nutrient content of manure excreted, which also varies by species and the physiology of digestive systems. Manure can provide the nutrients for fertility of crops and a critical element of synergy to the livestock-crop mixed farm. At the same time, this dynamic can generate offsite losses: atmospheric, through runoff, and through leaching. An interesting observation is that while conversion rates of feedstuff energy into gain, based on feed conversion ratio, are the highest with poultry, after adjusting for dry matter variances in manure, poultry manure contains relatively high levels of nutrients, especially nitrogen and phosphate.

7. Animal agriculture value chains

Animal agriculture value chains are just one of many value chains that make up the Canadian agriculture and agri-food system (AFS). As described in Section 4.1.2, the NAS Food System Framework is a complex, adaptive, and dynamic system (Figure 7.1). While animal agriculture value chains are just one component of the Canadian AFS, they are highly integrated with other value chains, particularly crops, as a source of feed and destination for manure and other by-products. They are also highly dependent on many agri-businesses, including veterinarians, feed specialists and machinery and equipment providers and are important contributors to the broader economic, biophysical and socio-political context in which the AFS operates.

The Food system framework also emphasizes the importance of the various actors involved in the system and the role these actors play, given their diverse goals and interests in producing farm and food products profitably, while also improving the health of plants, animals and humans and protecting the environment (NAS, p.44). All actors in the system make decisions that shape the food system each day with positive or negative consequences for health, the environment, the economy, or society.

Figure 7.1. Framework for assessing effects of the food system



Reprinted from: Committee on a Framework for Assessing the Health, Environmental, and Social Effects of the Food System et al., 2015

Traditionally, the value chain or supply chain is presented in a linear direction, as shown in Figure 7.1, beginning with farm inputs (and agribusiness services) that provide the raw materials for primary agricultural production, followed by their transformation through manufacturing or processing into higher-value food and non-food products that are then transported and distributed by wholesalers, retailers and food service providers to domestic consumers or through exports to international markets. In this particular diagram, there are two important flows that move in opposite directions: the left-to-right flow reflects the flow of goods and services from raw product towards consumers as they are transformed with added value. At the same time, there is an opposite flow of money or compensation to the actors involved in the value chain, along with information about consumers' preferences and market demands for their products.

Of course, traditional value or supply chains are self-contained and make no reference to the natural, human, created, or social capital that the system depends upon. These are visualized below. Canada has a competitive advantage inasmuch as the country is well endowed with an abundance of these natural resources (water, land, climate) and infrastructure, a well-educated workforce, and a stable economy benefiting from democratic rule of law and relative trust in political institutions, governance, and an enabling business and policy environment.

The importance of science, its institutions, R&D and the innovation ecosystem that supports the Canadian agriculture and agri-food system have also been important for animal agriculture. New knowledge and technology, developed through scientific research, and transmitted throughout the animal agriculture value chain have contributed to its progress, building up created capital. Scientific knowledge generated in public or private (educational) institutions and laboratories have been particularly important over the past century in developing new genetic breeds, new feed formulations, pharmaceuticals and animal disease treatments. Animal agriculture has benefited significantly from this science, knowledge and technologies that continue to help the industry improve animal health, quality, productivity, and environmental impacts for the benefit of producers, consumers, the environment and the economy. Other innovations such as precision farm practices for livestock, digital applications, and new feed formulations that raise productivity and reduce GHG emissions are just a few of these promising new developments.

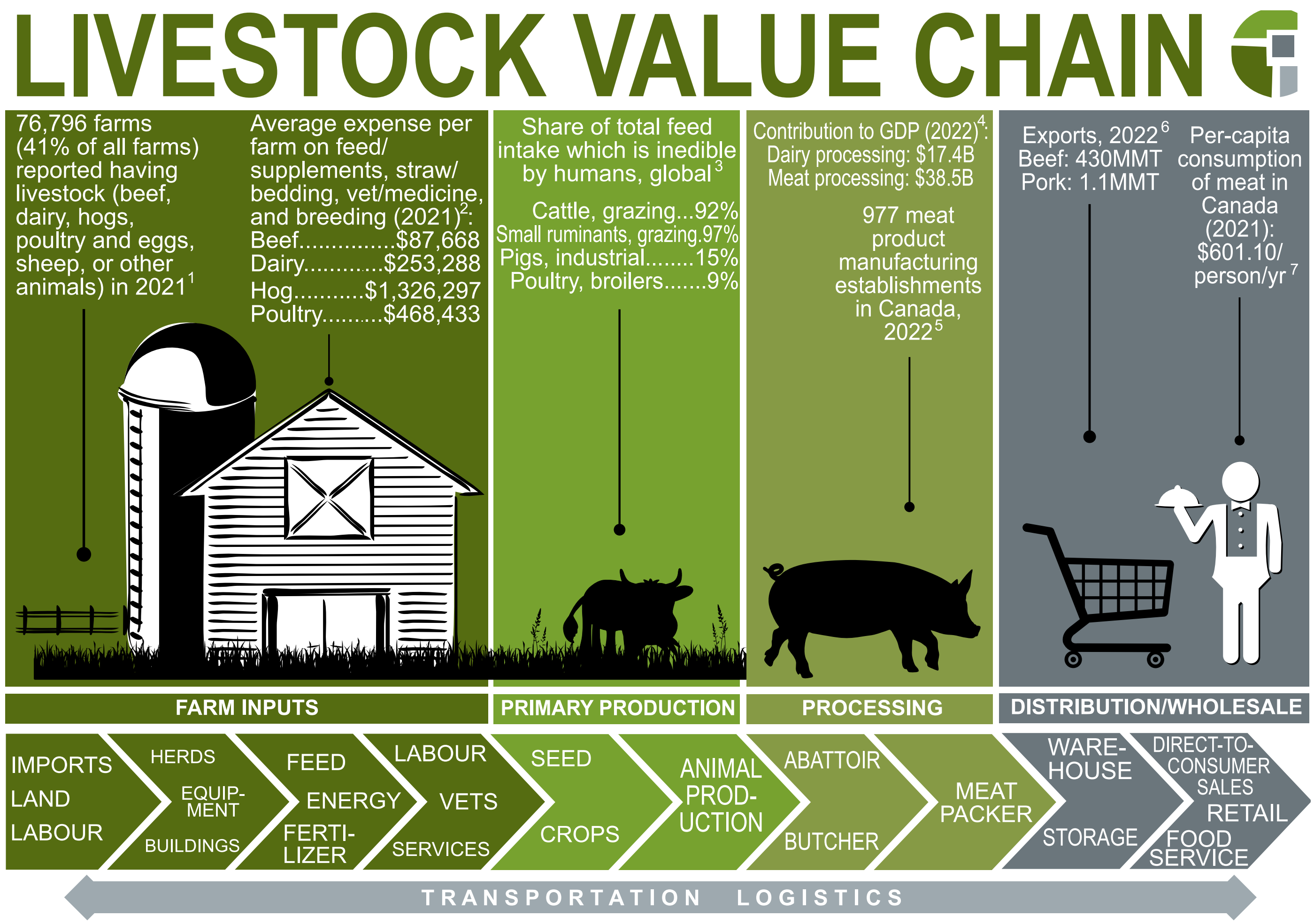
7.1 The Structure of Animal Agriculture Value Chains

The animal agriculture value chain, like other value chains in the AFS, starts with raw materials and inputs that go into primary production, before being transformed through processing, transportation, distribution by wholesalers, retailers and foodservice to reach consumers in both domestic and international markets. Given the unique nature of animal agriculture compared to crops, there are unique actors involved in animal agriculture industries Figure 7.2 illustrates the structure of this animal agriculture value chain, beginning with farm inputs which feed into primary production, leading to processing (meat packing, rendering, and further processing), ending with distribution, both domestic and exports markets.

In 2021, 41% of all farms in Canada reported raising livestock (Statistics Canada, 2022d). The average expense per farm on feed/supplements, bedding, vets/medicine, and breeding was highest ($1,326,297) for pig farms; this does not include the actual purchase of livestock (Agriculture Taxation Data Program, 2023).

The processing panel in Figure 7.2 shows that dairy processing contributed $17.4B of GDP in 2022, and meat processing, $38.5B (see Table 7.3) (Monthly Survey of Manufacturing, 2023).

Figure 7.2. Animal agriculture value chain



Sources:
1. Census of Agriculture. (2021). *Number and proportion of farms by farm type, Canada, 2021.*
2. Agriculture Taxation Data Program. (2023). *Farm operating revenues and expenses, annual* [dataset]. (Table 32-10-0136-01). Statistics Canada.
3. Mottet et al. (2017). Supplementary table S1-2. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security, 14*, 1-8.
4. Monthly Survey of Manufacturing. (2023). *Manufacturers' sales, inventories, orders and inventory to sales ratios, by industry (dollars unless otherwise noted)* (Table 16-10-0047-01) [dataset].
5. Innovation, Science and Economic Development Canada. (2023). *Meat product manufacturing - 3116 - Businesses.*
6. CIMT, HS 0201 and HS 0202: exports from Canadian provinces to world.
7. Agriculture and Agri-Food Canada. (2022). *Customized Report Service – Canadian pork meat trends.*

Image created internally.

7.1.1 Farm Inputs

In addition to traditional farm inputs, such as land, labour and energy, animal agriculture also requires inputs such as specialized feed, breeding stock, veterinarian and feed specialist services as well as some very unique machinery, equipment and technologies, all well-grounded in science. This is to ensure that Canada's livestock are healthy, productive and welfare standards are maintained.

For animal agriculture, feed is perhaps the single most important input in animal production and the key point of integration with crop agriculture. According to the Animal Nutrition Association of Canada (ANAC), Canadian livestock consumed approximately 28.8 million tonnes of feed in 2020, two thirds of which was purchased from around 470 commercial feed mills, with another one third produced in on-farm feed mills (ANAC, 2021). A significant portion of feed for ruminants are provided through forages and from grazing, and this feed supply can only be estimated.

The primary purpose of feed mills is to meet the animals' nutritional needs to optimize health and production efficiency (ANAC, 2021, p. 11). Least-cost formulation is an important tool to ensure that finished feed products have the desired properties while making use of available ingredients and meeting the goals of the livestock producer, all while keeping costs as low as possible. A range of ingredients, including domestic agricultural products and by-products as well as non-feed ingredients (e.g., medications), feed additives, and specialty products are utilized to create different feed products for various livestock species and categories within species. The different types of prepared feeds include complete feeds, supplements, and premixes. According to data obtained from income tax records, purchased feed costs can account for up to 20% of total expenses for beef cattle farms, up to 54% for hog farms, up to 41% for poultry farms and up to 29% for all animal production. The comparative cost of feed is the critical determinant in competition among producers for feeder livestock, and the location of livestock feeding, as explained in Box 7.1.

The Canadian feed industry is a critical partner in animal value chains. A collaborative effort is required between nutritionists, feed manufacturers, distributors, suppliers, and farmers to optimize animal health and production through economic feeding practices. The manufacturing process of each mill is unique, complex, and utilizes a wide range of ingredients and inputs to formulate a customized product to meet individual animals' nutritional requirements as well as the needs of different farm operations.

Box 7.1. Based on economics, livestock move to feed

Feed conversion ratios well over 1.0 dictate that it will invariably cost more to transport feed to animals than it does to transport animals to feed. This causes livestock feeding to occur in areas where feedstuffs are produced and available at low-cost.

To illustrate, suppose a group of 100 feeder steers are being raised from 800 lbs to 1400 lbs on a barley diet, and the feed conversion ratio is 6.

Total barley required is:

$$(1400 - 800) \times 100 \times 6 \\ = 360{,}000\ lbs\ or\ 163\ tonnes$$

If a truck can transport 40 to 50 tonnes, then it would take approximately 4 trucks to move barley to cattle:

$$163\ tonnes\ \div 40\ tonnes\ per\ truck \\ = 4.1\ trucks\ to\ bring\ feed\ to\ livestock$$

To bring feeder cattle to barley, with 50 head per truck, it would take 2 trucks to bring livestock to feed:

$$100\ steers\ \div 50\ steers\ per\ truck \\ = 2\ trucks\ to\ bring\ livestock\ to\ feed$$

This difference in transportation cost is leveraged into competitive bids for feeder animals: the regions with the most available and lowest-cost feed can sustainably pay the most for feeder livestock.

The exceptions to this rule are:

- Temporary salvage measures (e.g. due to local drought
- Subsidies paid to maintain livestock in feed deficit areas
- Exceptionally low (*i.e.*, efficient) feed conversion ratio.

Table 7.1. Feed ingredients

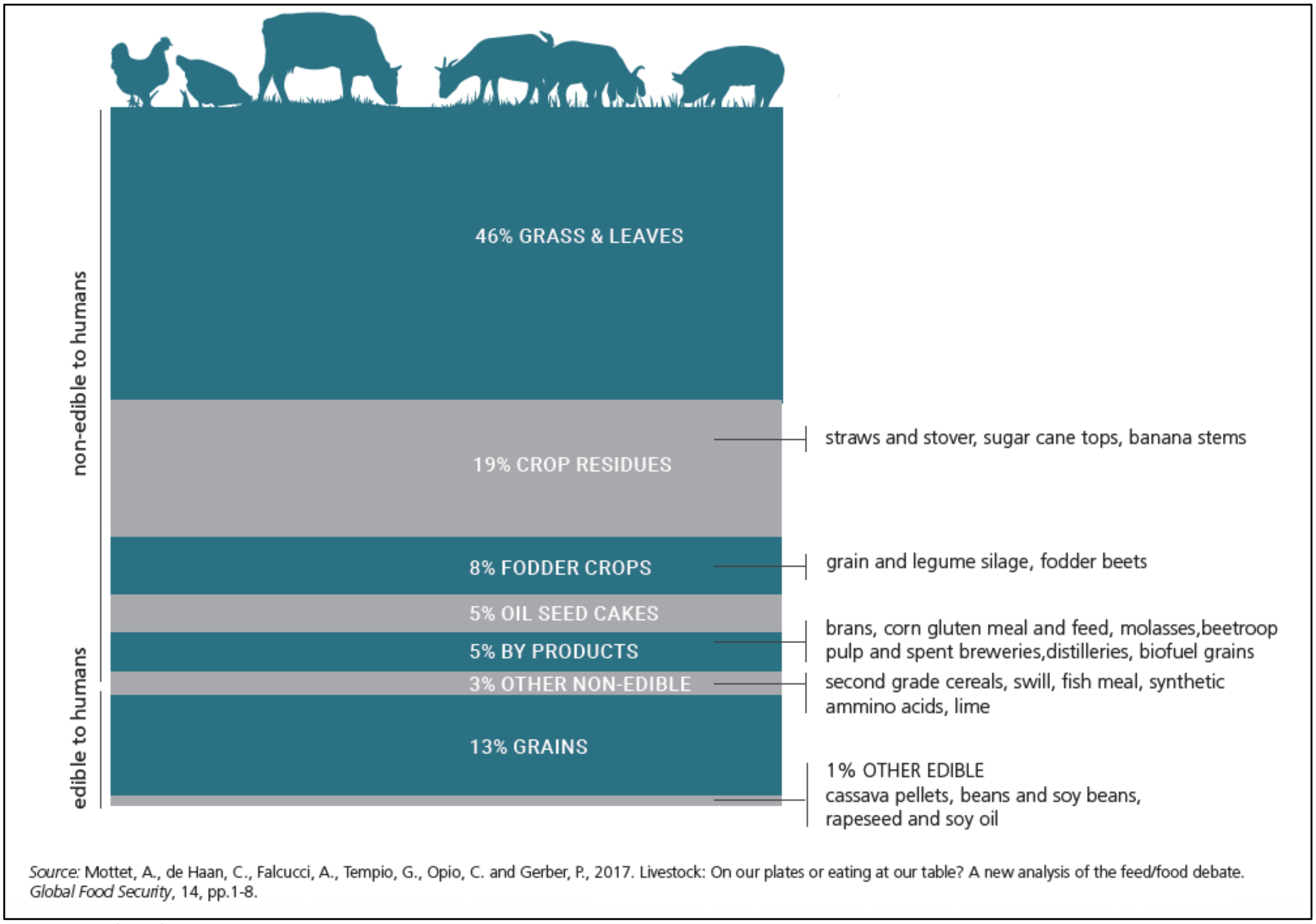
Feed ingredients	Key livestock species
Cereals and pulses	
Wheat	Cattle, poultry, swine
Barley	Cattle, poultry, swine
Corn	Cattle, poultry, swine
Grain by-products	
Pea/lentil screenings	Cattle, poultry, swine
Oat hulls	Cattle, poultry, swine
Soy hulls	Cattle, poultry, swine
Bakery meal	Cattle, poultry, swine
Wheat shorts	Cattle, poultry, swine
Plant-based proteins	
Canola meal	Cattle, poultry, swine
Soybean meal	Aquaculture, cattle, poultry, swine
Distillers' grains with solubles	Cattle, poultry, swine (dependent on life stage)
Pulses	Aquaculture, cattle, poultry, swine
Animal-based proteins	
Fish meal	Cattle, poultry, swine
Meat and bone meal	Poultry, swine
Fats/oils	
Vegetable oil	All livestock
Grease	All livestock
Tallow	All livestock
Trace minerals	
Iodine, iron, manganese, selenium, zinc	All livestock
Cobalt	All livestock except poultry and swine
Copper	All livestock except sheep
Macro-minerals	
Calcium, phosphorus, magnesium, sodium, potassium	All livestock
Sulphur	Cattle, goats, sheep
Vitamins	
Water soluble (vit. B, C)	Calves, horses, poultry, swine
Fat soluble (vit. A, D, E, K)	All livestock

Table created internally. Data source: ANAC. (2021). Fundamentals of the Commercial Feed Industry in Canada. Animal Nutrition Association of Canada. https://www.anacan.org/feed-industry/public-resources/fundamentals-of-the-commercial-feed-industry/.

Not all feed is suitable for humans

The feed industry is a major user of Canada's domestic grain supply with 80% of barley, 60% of corn, and 30% of wheat grown domestically being utilized in Canadian feed manufacturing (ANAC, 2021, p. 6). The feed industry provides grain and oilseed farmers with a consistent market for the sale of their products. It also provides a cost recovery stream for waste and by-products of other agriculture and agri-food production, or products that are below human grade that, if not fed to animals, would otherwise have minimal economic value and might end up in landfill, where their GHG impact is far higher (Holder, 2022). A study by Mottet *et al.* (2017) argues that about 86% of livestock feed at the global level is not suitable for human consumption and if it were not consumed by livestock, such as crop residues and by-products, it would be wasted as human population grows and consumes more and more processed food (FAO, 2022a). Globally, only about 13% of global livestock dry matter intake is from grains which are also be eaten by people (Figure 7.3). These grains represent about one third of global cereal consumption (FAO, 2022a).

Figure 7.3. Global sources of livestock feed



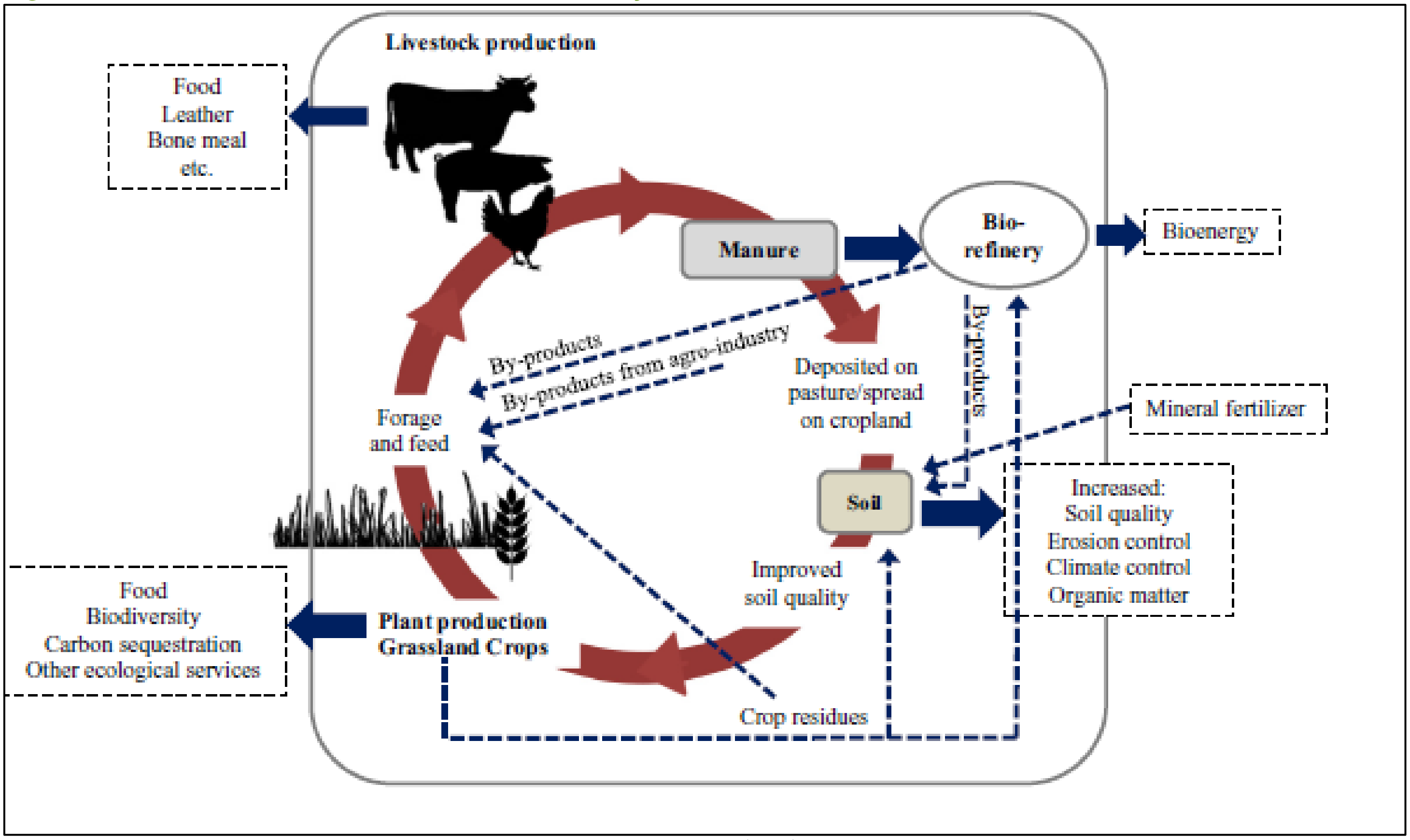
Source: FAO. (2022). *More fuel for the food/feed debate.* Food and Agriculture Organization of the United Nations, FAO. https://www.fao.org/3/cc3134en/cc3134en.pdf.

Ruminants play an important role turning products that are inedible by humans into edible, nutrient-dense proteins (Canadian Cattle Association, 2023b). In the Canadian context, weather-damaged crops (e.g., feed grade wheat), potato waste, apple waste, and other agricultural by-products (malting barley from the beer brewing process) would otherwise pose a disposal problem, and instead become feedstuffs for feedlot cattle. At the national level, an inedible product that Canada has a natural abundance of is grass and forages. Grasslands, which may be either unsuitable for crop production and/or are critical to wildlife populations and biodiversity habitat, are grazed and converted into a protein source. Finally, ruminants play an integration role and can increase the efficiency of existing systems. For example, sheep and goats graze marginal lands or orchards, thereby increasing the efficiency while "giving back" in the form of manure (Canadian Cattle Association, 2023b).

Beyond meat and dairy products: livestock also provide by-products that provide nutrition and other consumer products

The feed industry also makes use of by-products from the animal agriculture industry, such as meat and bone meal, beef tallow and grease – products of the rendering industry, that provide energy, fats and protein for animal nutrition. Livestock are referred to as "up-cyclers," upgrading inedible plants and plant by-products to high-quality protein and essential micro-nutrients, vitamins and minerals (Ominski *et al.*, 2021, p. 596). In addition to serving as a valuable source of nutrients, numerous by-products used for consumer products are garnered from livestock. This includes hides, tallow, blood, hooves, horns, organs and bones which are used to produce marketable commodities including pharmaceuticals, cosmetics, leather, brushes, adhesives, charcoal, shampoo, glass, and pet food (Ominski *et al.*, 2021, p. 596). In this way, livestock are the original "circular economy" (Figure 7.4).

Figure 7.4. Livestock and the circular bio-economy



Source: Ominski, K., Gunte, K., Wittenberg, K., Legesse, G., Mengistu, G., & McAllister, T. (2021). The role of livestock in sustainable food production systems in Canada. *Canadian Journal of Animal Science*, 101(4), 591–601. https://doi.org/10.1139/cjas-2021-0005.

7.1.2 Breeding stock

Breeding stock is another key input into the animal agriculture value chain. Through animal genetics research and breeding, the animal industry has been able to make impressive gains in productivity, feed use efficiency, meat quality and environmental performance. Productivity gains have allowed animal agriculture to produce more output with a decreasing number of inputs, hence contributing to the sustainable intensification of animal agriculture. Genomic selection of animals in the dairy and beef industries have recently been targeting feed efficiency and reduced methane emission traits, in addition to increased productivity, thereby leading to improved environmental performance of Canadian animal products. Greater feed efficiency in particular has resulted in dramatic increases in productivity and reduced GHG emissions intensity. For example, over a 30-year time period (1981 to 2011), Canadian beef producers have reduced GHG emissions per kg carcass weight by 15%, ammonia emissions by 17%, water use by 20% while using 24% less land (Legesse *et al.*, 2015). Similarly, Vergé estimated that GHG intensity (CO_2e/kg) decreased by 19% for chicken meat, by 8% for eggs, and by 50% for turkey meat, between 1981 and 2006 (Vergé et al., 2009). Hailu (2018) found that improving feed efficiency through genomic technologies simultaneously boosts industry competitiveness by lowering input costs and enhancing environmental sustainability. Quebec and Ontario, which account for the bulk of milk production in Canada, are increasingly focusing research on reducing methane emissions from dairy cows. Quebec, as an example, recently announced research that targets reducing methane emissions for each kilogram of milk produced in Quebec dairy herds by 14 % to 16 % between now and 2028. This research will make use of a tool that measures methane in samples of milk collected from different farms across the province.

7.1.3 Animal Product Processing

In terms of value added, meat, poultry and dairy manufacturing added an additional $9 billion to GDP, accounting for about one third of food processing industry GDP. This is in addition to the animal food (feed) manufacturing industry which contributes $1.6 B to GDP. Estimates of the beef, chicken, and dairy sectors' contributions to the Canadian economy have been reported by industry associations and are presented in section 9.

Of the 977 meat product manufacturing establishments in Canada in 2022, (including rendering, poultry slaughtering and prepared meat products), the bulk of them are small (432) with 5 to 99 employees, and medium (118) with 100 to 499 employees (Table 7.2) (Innovation, Science and Economic Development Canada, 2023b). About 115 of them are considered micro establishments, with fewer than 5 employees. The remaining 25 establishments are large with 500 and more employees. These are generally owned by large meat processors that slaughter and prepare meat products to market outside the province or in international markets, as federally inspected plants. Some of these larger companies include Maple Leaf Foods, Cargill Ltd, JBS Food Canada Ltd, Harmony Beef Company Ltd., and Atlantic Beef Products Inc.

Table 7.2. Establishments producing meat and poultry, by employment size, 2022

Province/territory	Micro (1-4 employees)	Small (5-99 employees)	Medium (100-499 employees)	Large (500+ employees)
Ontario	36	166	40	10
British Columbia	19	44	12	3
Quebec	18	97	39	4
Alberta	11	52	15	3
Saskatchewan	10	25	5	1
Manitoba	5	26	1	4
Nova Scotia	5	10	1	0
New Brunswick	4	4	3	0
Newfoundland and Labrador	4	6	1	0
Prince Edward Island	2	1	1	0
Yukon	1	1	0	0
Northwest Territories	0	0	0	0
Nunavut	0	0	0	0
Canada	**115**	**432**	**118**	**25**

Table created internally. Data source: Innovation, Science and Economic Development Canada. (2023, May 25). *Meat product manufacturing—3116—Businesses.* Canadian Industry Statistics. https://ised-isde.canada.ca/app/ixb/cis/businesses-entreprises/3116.

Federally inspected plants are inspected by the Canadian Food Inspection Agency (CFIA) according to federal standards in order to be able to export interprovincially or internationally. According to AAFC, there were 19 federally inspected plants processing beef in Canada in 2022 with 7 in Alberta, 1 in B.C. and 1 in Manitoba, 6 in Ontario, 1 in PEI and 3 in Quebec (Agriculture and Agri-Food Canada, 2021b). There were 25 federally inspected hog plants in 2022, distributed primarily in Quebec and the Atlantic (10), B.C and Alberta (6), Saskatchewan/Manitoba (5) and Ontario (4). Some of these included Maple Leaf Foods Ltd, Olymel L.P., HyLife Foods LP, Conestoga Meat Packers Ltd., and Les Viandes Du Breton Inc. among others.

Meat processing is considered fairly concentrated in Canada. During the COVID pandemic, when some of the Canadian meat packing plants were forced to close down due to employee illness and supply bottlenecks and farm level prices of cattle fell as supplies became backlogged, there was increased concern that meat processing in Canada had become too concentrated, with too much market power, leading to risks of price gauging, vulnerability and potential shortages. Rude (2020) analysed the issue for CAPI and explained that the top four beef and pork processors at the time accounted for 96% and 78% of sales respectively (Rude, 2020). In terms of beef, Cargill's High River and Guelph plants, JBS-Lakeside's (Brooks, Alberta) and the much smaller Harmony (Balzac, Alberta) plant made up the top four plants in this sector, while Olymel and Maple Leaf Foods dominated hog slaughter, with most of the operations in Quebec. However, in a Canadian context, feedlots and other producers have the option to export their live animals for slaughter in the US. So, when analysis was done re-estimating concentration adjusted for trade, the resulting shares of sales for the top 4 plants declined to 78% and 68% respectively. Rude argued that because the border remained open during the COVID pandemic, the industry adjusted after some initial difficulties leading to resilience. Cargill-High River and JBS Brooks each process over 1.1 million animals a year which is comparable to large plants operating in the US. These plants are highly efficient and low cost, able to produce high volumes for the large retailers (Rude, 2020, p. 5). Small and medium processors would have a cost disadvantage and a hard time competing on price unless selling niche products. Thus, Temple Grandin argues "(t)he bottom line is, there will always be a trade-off. Big suppliers are low cost efficient and fragile. More numerous local producers are more high cost and expensive, but the entire supply is more robust with both" (Grandin, 2020). In a sense, having both structures serves as a risk mitigation strategy.

In 2022, manufacturing sales from meat and dairy product processing rose to $38.5 and $17.4 billion respectively. Meat and poultry processing remains the most important food manufacturing industry in Canada, at 27% of the total.

Table 7.3. Manufacturing shipments for Meat Processing and Dairy Processing

Manufacturing sales for meat and dairy processors, by NAICS code, 2022 (billions of dollars)	
Manufacturing [31-33]	853.6
Food manufacturing [311]	141.6
Animal food manufacturing [3111]	11.9
Grain and oilseed milling [3112]	20.3
Dairy product manufacturing [3115]	17.4
Meat product manufacturing [3116]	38.5
Animal slaughtering and processing [31161]	38.5
Rendering and meat processing from carcasses [311614]	*10.7*
Poultry slaughtering and processing [311615]	*9.7*
All other food manufacturing [31199]	6.1

Source: (Monthly Survey of Manufacturing, 2023). *Manufacturers' sales, inventories, orders and inventory to sales ratios, by industry (dollars unless otherwise noted)* (Table 16-10-0047-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1610004701.

7.1.4 Food distribution, retail, and food service

The large multinational meat and poultry processors supply most of the large domestic retail outlets in Canada with meat and poultry and dairy products including Overwaitea Foods Group, Loblaw Companies, Costco, and all the other major retailers. Supplying large retail outlets requires consistent supply and uniform product. The larger federal packers produce the volume necessary to service these markets (Serecon Inc., 2022).

7.1.5 Consumer Demand for Meat, Poultry and Dairy Products in Canada

Meat, poultry and dairy products continue to be an important food item for Canadian consumers. In 2022, Canadian meat sector retail sales (including beef, chicken, lamb, pork, packaged or fresh turkey, and other similar meat categories) were $17.5 billion in 2022, while retail sales of eggs and dairy products were another $17.2 billion, according to Statistics Canada's retail commodity survey (Retail Commodity Survey, 2023). Consumer prices were up significantly for these products in 2022, due to the spike in overall inflation that has seen food price inflation persist. Red meat prices were up 8% in 2022, as were poultry (7%), eggs (10.7%), and dairy product prices (8.6%). Higher commodity prices as well as supply chain disruptions raised costs leading to these price increases (Statistics Canada). Per capita availability, which reflects consumption, are displayed in Figure 7.5. Values reflect retail weights and are not adjusted for loss, spoilage, or waste at the retail, restaurant, or household levels (Retail Commodity Survey, 2023). Chicken consumption per person has risen steadily since the 1970s; from 2021 to 2022, the increase was 3%, from 34.43 to 35.38 kg/person/year (Statistics Canada, 2023d). Beef and veal consumption fell from the late '70s to 2015 and has been relatively steady since, with a 3% increase from 2021 to 2022 (17.75 to 18.24 kg/person/year) (Statistics Canada, 2023d). The story is similar for pork, though with more volatility apparent in Figure 7.5, and a 7% gain from 2021 to 2022 (14.38 to 15.33 kg/person/year) (Statistics Canada, 2023d). Dairy and egg consumption are shown in Figure 7.6.

Figure 7.5. Consumption of beef/veal, pork, chicken, and mutton/lamb, Canada, 1970-2022

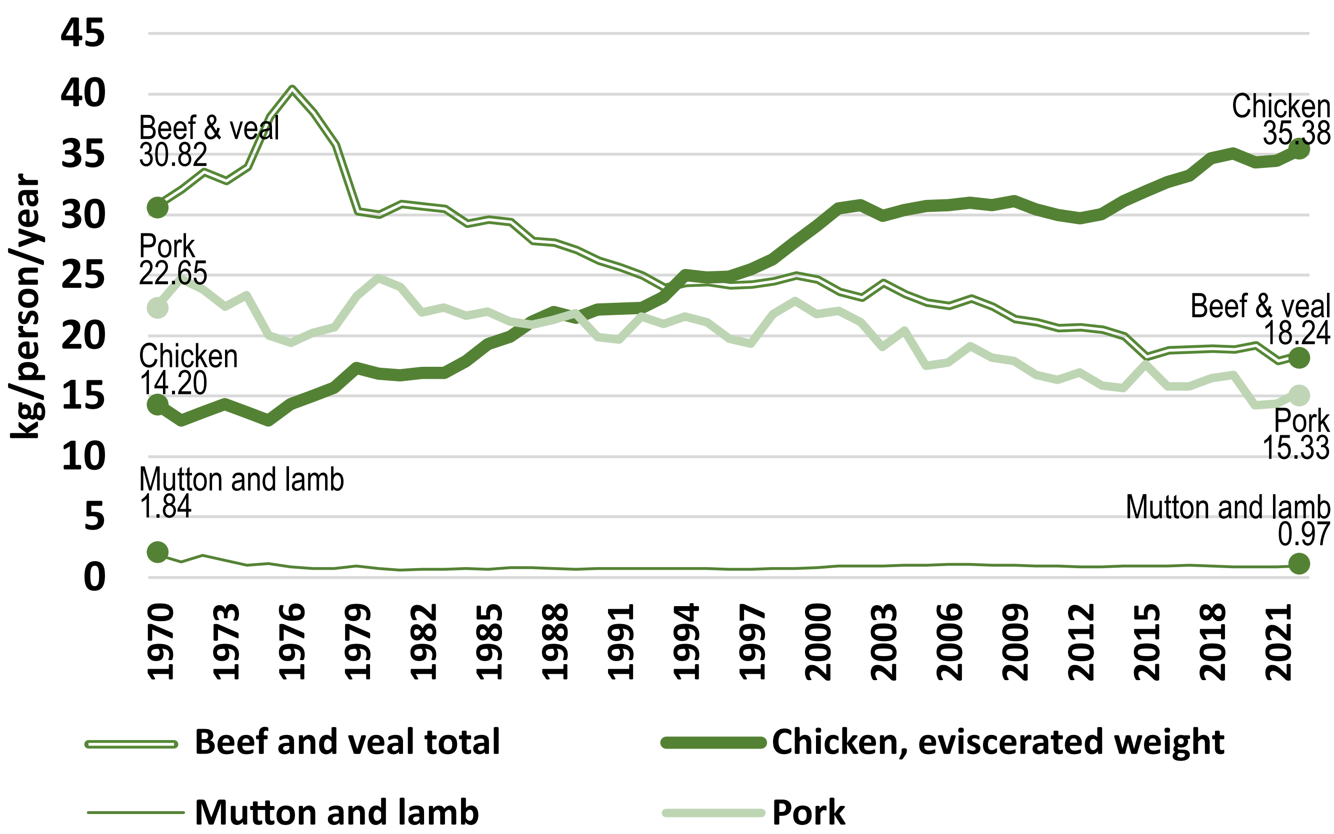


Image created internally. Data source: (Statistics Canada, 2023d). *Food available in Canada* (Table: 32-10-0054-01) [dataset].

The consumption of eggs and dairy are shown here in terms of kilograms. For dairy, units are kg milk solids, which is made up of butterfat and non-fat solids such as protein and other solids (Statistics Canada, 2021). Dairy is measured on the left axis and eggs, separately on the right axis, as the units are not meant to compare the consumption of dairy vs. eggs. The units do, however, allow for trends analysis. Dairy consumption per capita (the dark line) has fallen since the '70s, with a 4% decrease from 2021 to 2022 (24.30 to 23,26 kg/person/year). Egg consumption dipped considerably from the '70s to the '90s, but has since recovered to approximately the 1970 level; consumption rose by 1% from 2021 to 2022 (15.24 to 15,33 kg/person/year) (Statistics Canada, 2023d).

Figure 7.6. Consumption of eggs and dairy, Canada, 1970-2022

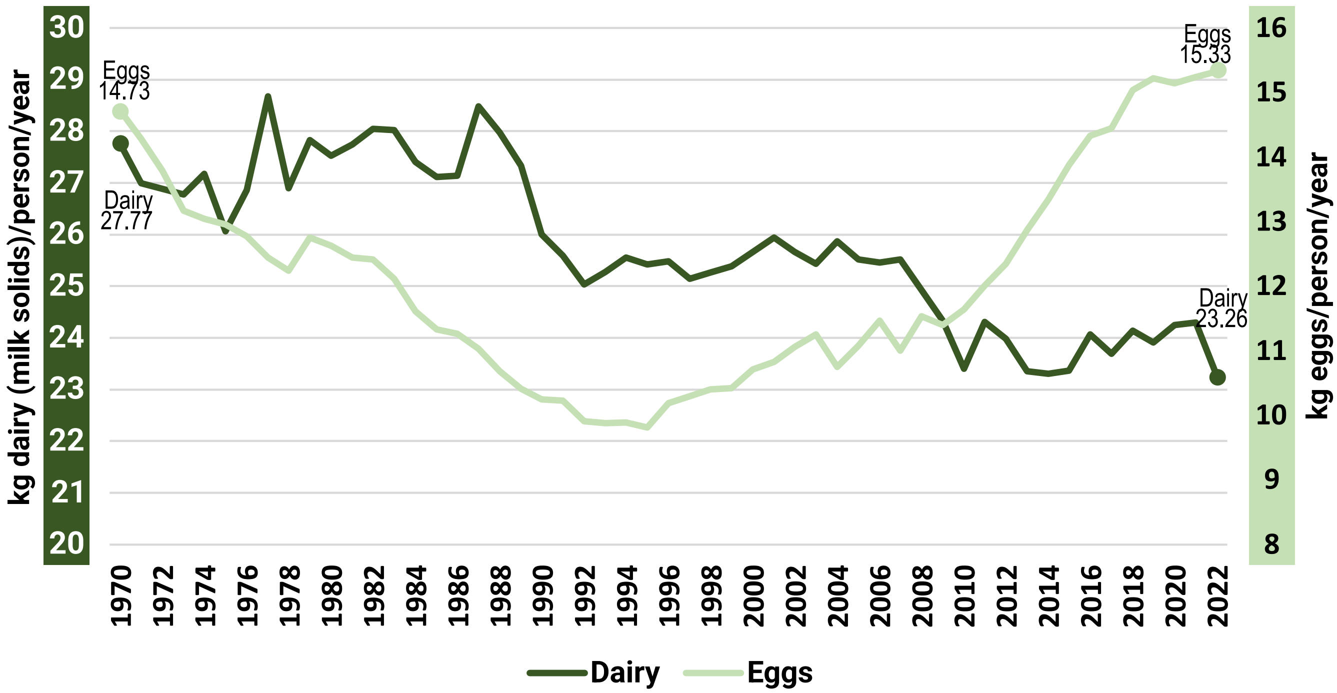


Image created internally. Data source: (Statistics Canada, 2023d). *Food available in Canada* (Table: 32-10-0054-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210005401.

As a share of household spending, meat accounted for 14% of average household spending on food, with beef at 4%, pork at 1.4%, poultry at 3.4% and processed meat products at 5.3%. Dairy products accounted for 8% of household spending and eggs at 1% in 2019.

7.1.6 Trade in Animal Products

Some animal agriculture products in Canada are important traded commodities. Canada was the fourth largest exporter of pork and beef in the world in 2021 (Workman, 2022). In 2022, Canada exported $ 11.5 B in beef, pork, poultry and dairy products. Fresh and chilled beef and pork exports accounted for the bulk of these exports at $3.3 B and $3.8 B respectively. Poultry and dairy production in Canada operate under a supply management system where production levels target domestic requirements and exports are quite small. Imports of live animals and meat, poultry and dairy products were $5.4 B in 2022, with live animals, fresh and chilled beef and pork and dairy products accounting for the majority of imports at $ 0.8 B, $ 0.9B, $ 0.7B and $1.3 B for these categories, respectively.

7.2 Beef Value Chain

Figure 7.7. Beef value chain

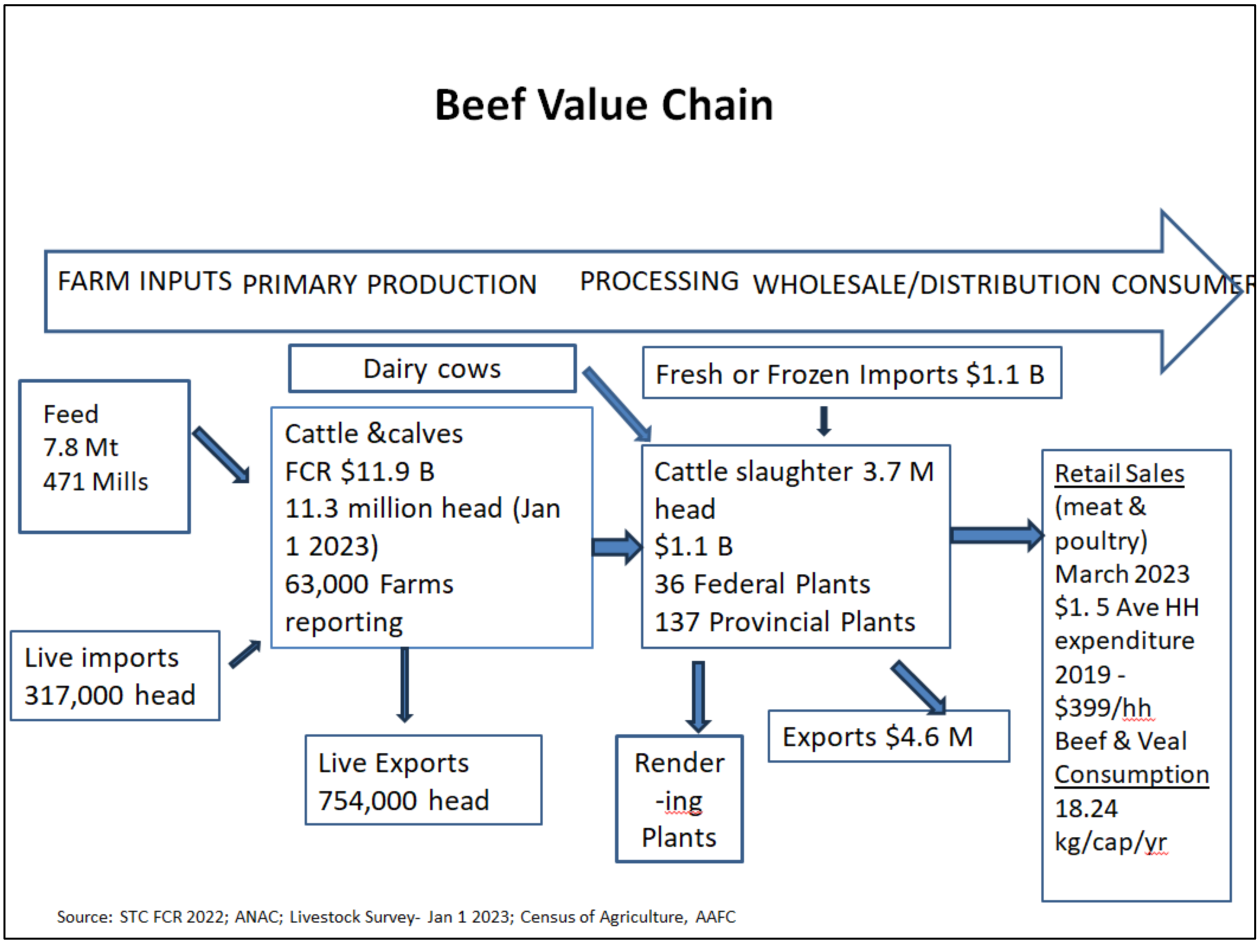


Image produced internally.

The beef value chain describes the value-added activities and interactions that lead to the transformation of beef cattle from breeding to feeding and ultimately to marketing safe, healthy and sustainable beef products that are sold to Canadian consumers and in international markets. These activities are dependent upon the health of the sector along the supply chain, by all players from producers in the cow/calf sector, to the feedlots and the meat packers to the research scientists, feed specialists, veterinarians, meat inspectors, auctioneers and truck drivers who get the product to market. The foundation of this value chain includes the individuals who operate Canada's 60,000 beef farms, ranches, and feedlots, making important management decisions that protect the land resources, working with it in a beneficial way to sustain cattle production for the long term (Canadian Cattle Association, 2023a).

Key challenges for the beef value chain include labour shortages, feed costs, access to capital, climate change that has led to drought and extreme weather events, meat processing concentration, interprovincial trade barriers from regulations, market access issues and consumer health and environmental concerns with red meat consumption and growing plant-based protein products.

7.2.1 Primary Production

According to the 2021 Census of Agriculture, there were 39,633 beef farms, ranches and feedlots in Canada, accounting for 21% of the 189,000 farms (including livestock, grains and oilseeds, horticulture, et cetera).

However, if one considers any farms reporting beef cattle, the number rises to 63,000 farms in 2021, according to the Census.

As of January 1, 2023, there were 9.4 million head of cattle and calves on beef operations, including cow-calf, feeder and stocker operations; there were an additional 1.9 million cattle and calves on dairy operations. This beef operation number was down 2.4% from a year ago (January 1, 2022) and 2.3% from the previous three-year average (2020 to 2022). Canadian cattle inventories have been on a general decline since January 2013, although they have been flat since 2016. Alberta held the largest cattle inventories on January 1, 2023, contributing 42.7% to the national total, followed by Saskatchewan (19.3%) and Ontario (14%) (Statistics Canada, 2023g).

Supply and disposition statistics report that international imports of live cattle averaged 317,200 head in 2022, while live cattle exports were 754,000, almost entirely to the United States for breeding, feeding, and processing. Feeder cattle exports to the US represented 26% of live exports, according to AAFC, reinforcing the significant integration between the two countries' agricultural trade (Agriculture and Agri-Food Canada, 2021a).

Livestock receipts from cattle and calves in 2022 were $ 11.9 B, up from an average of $9.6 B over the 2019 to 2021 period. Cattle and calf receipts accounted for over 40% of total livestock receipts. While cattle marketings were fairly constant over this period, the increase in prices, up 14% over 2021, drove these higher receipts.

Beef operation costs were also affected by the recent run up in commodity prices, as feed costs tend to be a fairly significant component of farm costs. According to 2021 tax filer data, the average beef farm (including feedlots) spent 20% of average operating expenses on feed, supplements, straw and bedding. Livestock purchases were a significant expense for these farm types, at 73% of the total. According to the Animal Nutrition Association of Canada (ANAC):

> *In 2020, Canadian livestock consumed approximately 28.8 million tonnes of feed; roughly two thirds produced in close to 470 commercial feed mills with the remaining one third produced on on-farm feed mills… (ANAC, 2021)*

7.2.2 Meat Processing

If cattle are not exported live or held back as breeding stock, then they are backgrounded, and sold to aggregators for finishing in feedlots to be fed out and slaughtered for meat. In 2022, 3.7 million head of cattle were slaughtered in Canada, contributing to sales (shipments) of $31.7 B and $10.1 B in value added by Canada's meat product manufacturers. Meat processing is the largest food manufacturing industry in Canada, accounting for almost one third of food manufacturing shipments. Meat processing plants can be found in all provinces of Canada (except the territories) but the largest ones are primarily in Alberta, Ontario, B.C., Quebec, Saskatchewan, and Manitoba. According to AAFC, there were 19 federally inspected cattle slaughtering plants in Canada in 2022, with most in the Prairie provinces, primarily Alberta, but 6 in Ontario and 4 in Quebec and the Atlantic (Agriculture and Agri-Food Canada, 2021b). Some of the larger firms include Cargill Ltd, JBS Food Canada Inc., Harmony Beef Company Ltd, Atlantic Beef Products Inc. and Jacques Forget Ltée, among others.

Table 7.4. Federally Inspected Cattle Slaughtering Plants in Canada, 2013-2022

	Number of plants by province – cattle									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Western provinces	6	8	9	8	10	10	10	10	10	9
Ontario	7	7	6	6	6	6	6	5	6	6
Quebec/Atlantic	6	6	6	6	5	4	4	3	3	4
Canada	19	21	21	20	21	20	20	18	19	19

Source: Agriculture and Agri-Food Canada. (2021b, June 15). Distribution of Slaughtering Activity. Red Meat and Livestock Market Information. https://agriculture.canada.ca/en/sector/animal-industry/red-meat-and-livestock-market-information/slaughter-and-carcass-weights/distribution-slaughtering-activity.

7.2.3 Retail and Food Service Sales of Beef and Consumer Demand for Beef

Canadian consumers continue to purchase meat products primarily at retail and at restaurant chains. AAFC reported that in terms of retail sales, purchasing fresh meat from over the counter was the largest preferred consumer choice, followed by chilled raw packaged and processed meat (Agriculture and Agri-Food Canada, 2019, sec. “Retail market in the beef industry”). Furthermore, frozen meat is expected to be the fastest growing category in volume terms with a CAGR of 2.6%, followed by continued growth in the fresh meat – counter (1.7%) and chilled raw packaged and processed meat (1.7%) during 2018-2023.

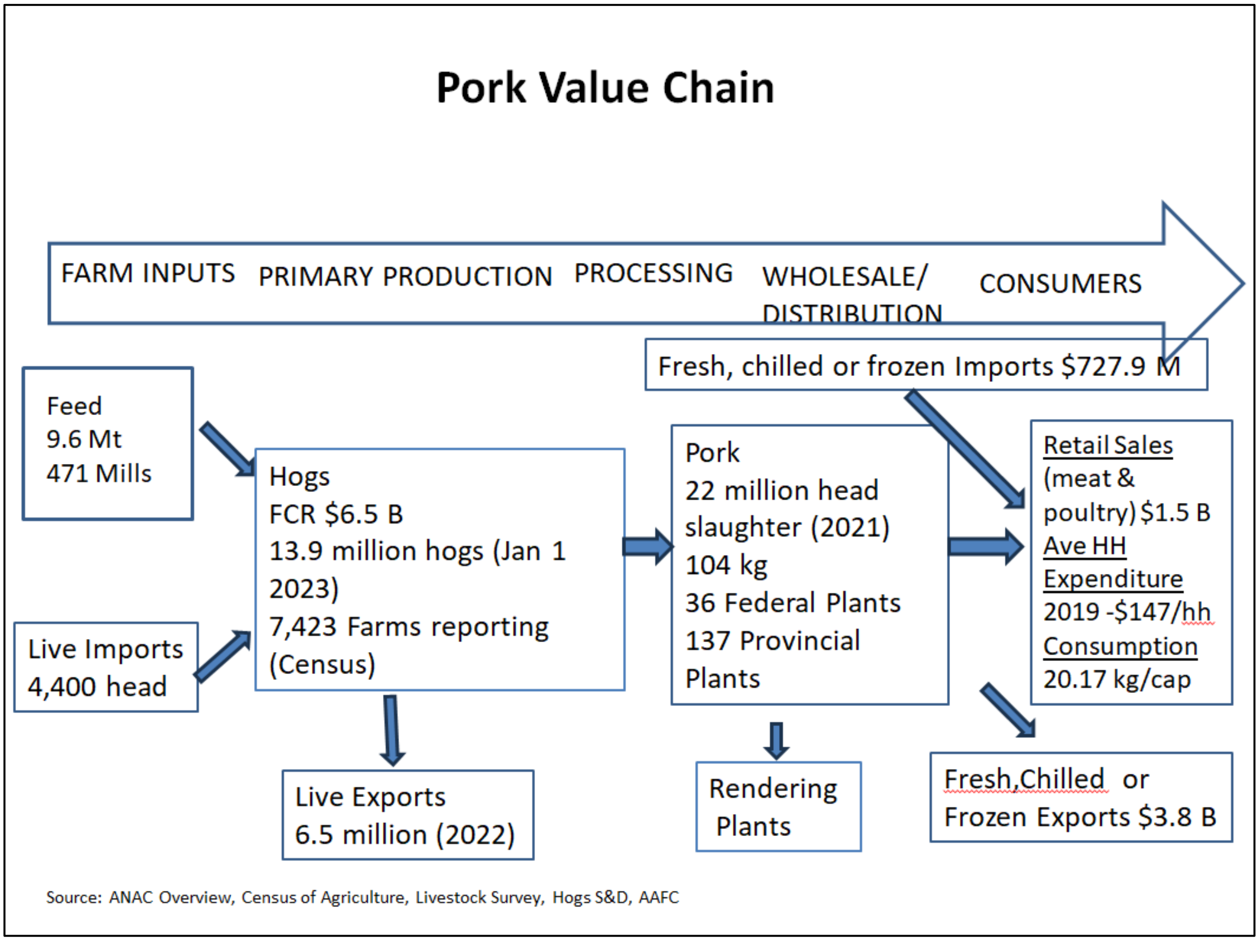
The beef foodservice industry in Canada pulled in US$2.6 billion in 2018, which includes the on-trade of beef varieties such as burgers and grills, meatballs, ribs, sausages and other beef products. Foodservice profit operators selling beef products represented 87.0% of the market share distributed mainly in the restaurant services, while institutional non-profit operators held the remaining market share of 13.0% distributed mainly in the education services in 2018 (Agriculture and Agri-Food Canada, 2019, sec. “Retail market in the beef industry”).

7.3 Pork Value Chain

Similarly, the pork value chain describes the value-added activities and interactions that lead to the transformation of pork from breeding to feeding and ultimately to marketing pork products that are sold to Canadian consumers and exported internationally. These activities are dependent upon all participants in the chain from research scientists, feed specialists and veterinarians, to producers of market hogs and weanlings to the meat packers, to the meat inspectors, and truck drivers who get the product to market. The foundation of this value chain includes the individuals who operate Canada’s 3,016 hog and pig operations.

Key challenges for the pork value chain include the threat of a foreign animal disease, such as African Swine Fever, trade disruptions and volatile markets, high feed and energy costs, labour shortages, access to capital, access to processing capacity, interprovincial trade barriers from regulations, and environmental policies.

Figure 7.8. Pork value chain



7.3.1 Primary Production

Canadian hog producers reported 13.9 million hogs on their farms on January 1, 2023, down 1.7% from the same time last year, with Quebec, Ontario and Manitoba accounting for over 80% of the hogs. Hog production has become a more concentrated industry, with more large farms with an average of 1,963 hogs per farm in 2021 compared to 902 hogs in 2001.

Supply and disposition statistics report that international imports of live hogs averaged 4,400 head in 2022, while live hog exports were 6.5 million head, overwhelmingly to the United States for feeding, processing, and breeding stock. Livestock receipts from hogs in 2022 were $ 6.5 B, up from an average of $5.2 B over the 2019 to 2021 period.

Operating costs on hog farms were adversely affected by the recent run up in commodity prices, as feed and energy costs tend to be a fairly significant component of farm costs. According to 2021 tax filer data, the average hog farm spent 46% of average operating expenses on feed, supplements, straw and bedding. Livestock purchases were also a significant expense for these farm types, at 21% of the total.

7.3.2 Pork Processing

In 2022, 22 million hogs were slaughtered in Canada, contributing to sales (shipments) of $31.7 B and $10.1 B in value added by Canada's meat product manufacturers.

Table 7.5. Federally Inspected Hog Slaughtering Plants in Canada, 2022

Number of plants by province - hog - 2022

Province	2022
British Columbia/Alberta	6
Saskatchewan/Manitoba	5
Ontario	4
Quebec/Atlantic	10
Canada	25

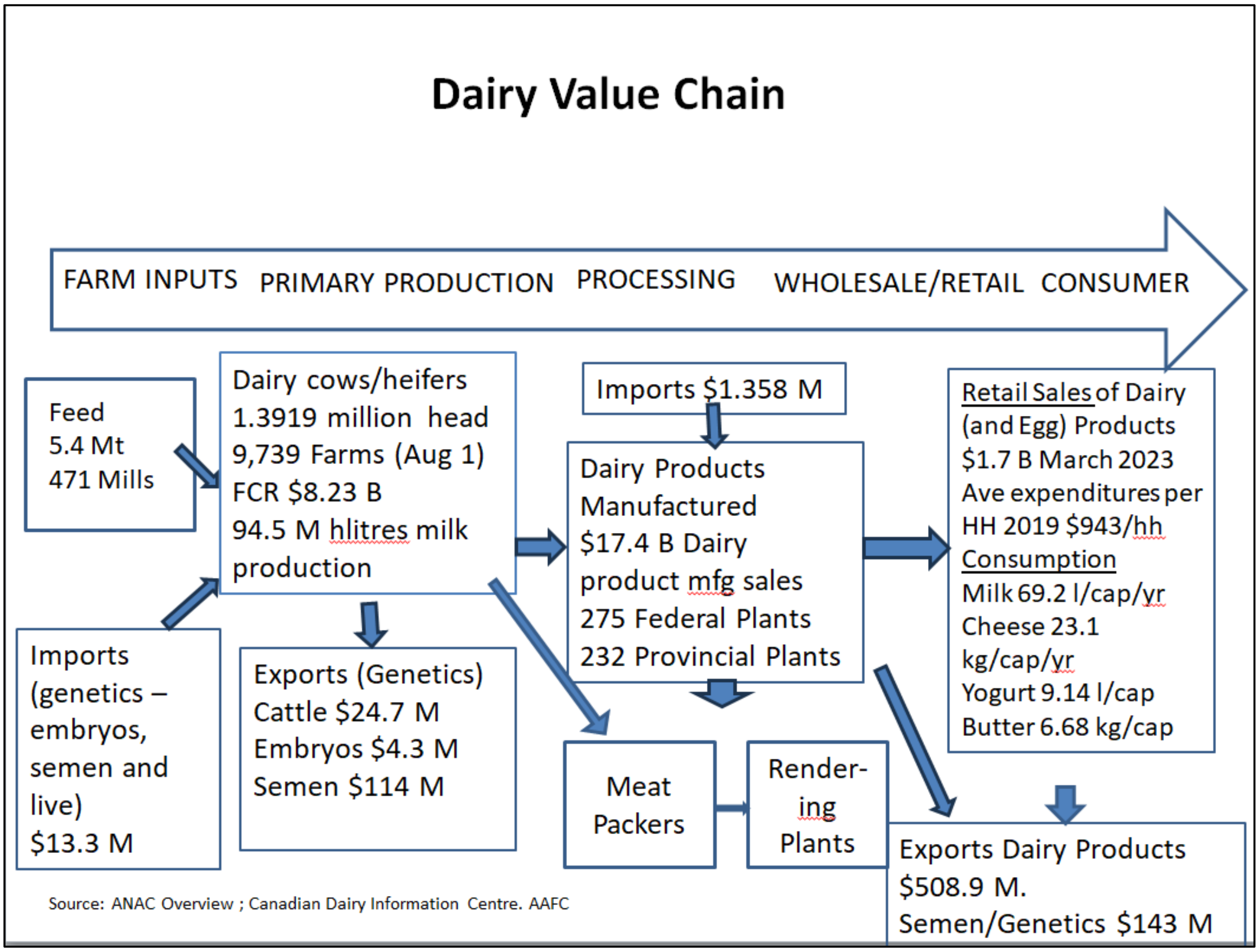
Source: Agriculture and Agri-Food Canada. (2021b, June 15). *Distribution of Slaughtering Activity*. Red Meat and Livestock Market Information. https://agriculture.canada.ca/en/sector/animal-industry/red-meat-and-livestock-market-information/slaughter-and-carcass-weights/distribution-slaughtering-activity.

There were 25 federally inspected hog plants in 2022, distributed primarily in Quebec and the Atlantic (10), B.C and Alberta (6), Saskatchewan/ Manitoba (5) and Ontario (4). Some of these included Maple Leaf Foods Ltd (Manitoba and Alberta), Olymel L.P. (Quebec and Alberta), HyLife Foods LP (Manitoba), Sofina (Ontario) Conestoga Meat Packers Ltd. (Ontario), and Les Viandes Du Breton Inc. (Quebec) among others. However, there are no federally inspected hog plants in Atlantic Canada, restricting out-of-province exports. Canada was one of the top three exporters of pork products in 2021, with exports of fresh, chilled or frozen pork products worth $3.8 B in 2022. Canada exports to many countries around the world including Japan, South Korea as well as the U.S. According to Rude (2018), pork processing is less concentrated than beef processing in Canada, although this is evolving. AAFC estimates of concentration as measured by the share of sales accounted for by the top four largest pork processing companies (CR4) was estimated at 64% compared to beef companies 95% in 2022 (Agriculture and Agri-Food Canada, 2021b).

Consumption of pork remained strong in 2022, averaging 15.33 kg per person, up from 14.4 kg/person in 2021.

7.4 Dairy Value Chain

Figure 7.9. Dairy value chain



The Canadian dairy value chain is one of the key contributors to the Canadian economy. This industry operates under a regulated milk supply management system to address problems of chronic milk surpluses, unstable prices, and fluctuating producer and processor revenues that were common in the 1950s and 1960s (Jones, 2018).

Milk supply management has three primary functions: production discipline, administered pricing, and import discipline. The Canadian Dairy Commission sets prices based on demand, market conditions and cost of production, while simultaneously taking into consideration the perishability of the final product (Dairy Processors Association of Canada, 2023). Provincial marketing boards allocate production quotas and are involved in determining prices and production.

The dairy value chain describes the value-added activities and interactions that lead to the transformation of dairy products from breeding to feeding and ultimately to marketing safe, healthy, and sustainable milk and dairy products that are sold to Canadian consumers. These activities are dependent upon all players in the chain from research scientists, feed specialists and veterinarians, to dairy producers and their products, and to milk, cheese and dairy product processors, inspectors, and truck drivers who get the product to market. The foundation of this value chain includes the individuals who operate Canada's 9,403 dairy farms operations. The average farm had 87 dairy cows in 2021, up from 48 in 2001.

Key challenges for the dairy value chain include higher costs of production related to feed and energy, labour shortages, market growth and pressure from imports, impacts of climate change, environmental policy, and responding to consumer perceptions around environmental impacts and competition from non-dairy milk substitutes in the domestic marketplace.

7.4.1 Primary Production

Canadian dairy producers reported 969,000 dairy cows on their farms on January 1, 2023, down 1.2% from the same time last year, with Quebec, Ontario and the Atlantic provinces accounting for over 80% of the dairy cows.

Milk produced on farms is sold for either the fresh, fluid market or for the industrial market where it is transformed into cheese, yogurt and other processed dairy products. Approximately one third of milk produced on farms is used for fluid milk purposes and the remaining two thirds is sold for dairy product manufacturing (Statistics Canada, 2023f).

Farm cash receipts for dairy operations averaged $8.2 B in 2022, up significantly from a year earlier (11.5%) and compared to the previous three-year average (15.6%). Operating costs on dairy farms were also affected by the recent run up in commodity prices, as feed and energy costs tend to be a fairly significant component of farm costs. According to 2021 tax filer data, the average dairy farm spent 29% of average operating expenses on feed, supplements, straw and bedding. Livestock purchases were also a significant expense, at 5.3% of the total.

Under milk supply management exports of dairy products are sharply limited and dairy imports are constrained by Tariff Rate Quotas. Canadian imports of dairy products have increased under trade agreements with the EU (Comprehensive Economic and Trade Agreement (CETA)), under the Comprehensive and Progressive Agreement on Trans-Pacific Partnership (CPTPP), and under the Canada-US-Mexico Agreement.

The Canadian dairy industry is known for its high-quality dairy genetics and hence exported live cattle, embryos and semen in the amount of $143 M ($24.7 M, $4.3 M and $114M respectively) to countries around the world (Canadian Dairy Information Centre, 2022).

7.4.2 Dairy Product Manufacturing

In 2022, there were more than 406 dairy processing plants across the country, most centred in Ontario and Quebec (Table 7.6). 275 of them were federally licensed, while 232 were provincially licensed. [1] By size, 16.5 % (67) were micro plants (with fewer than 5 employees), 65% (265) were small plants (with between 5 and 99 employees), another 16.5% (67) were medium-sized plants, (with 100 to 499 employees) and the remaining 2% (7) were large plants, with 500 and over employees. Most were centred in Ontario and Quebec, but most provinces had some small processing plants to look after regional needs. Dairy processing plants process everything from fluid milk to yogurt to cheese to sour cream and ice cream.

Milk quota was originally distributed to the provinces according to national milk production shares in the period when milk supply management was initially established in the early 1970's. For this reason, Ontario, Quebec and B.C. have most of the milk quota. Some of the major players in the dairy processing sector include Saputo, Agropur, Lactalis, Becker's and Ultima Foods. The dairy processing sector is the second largest food manufacturing sector, employing over 27,000 in 2022 (Canadian Dairy Commission, n.d.).

Consumption of dairy products slowed in 2022. Per capita consumption of butter and cheese fell to 3.57 and 14.8 kg/person respectively, while fluid milk and yogurt fell to 45.06 litres/person and 8.89 litres per person in 2022. Retail commodity sales of dairy and egg products reached $17.2 M in 2022 based on Statistics Canada's retail commodity survey.

Table 7.6. Dairy Product Manufacturing Number of Establishments by Size, 2022

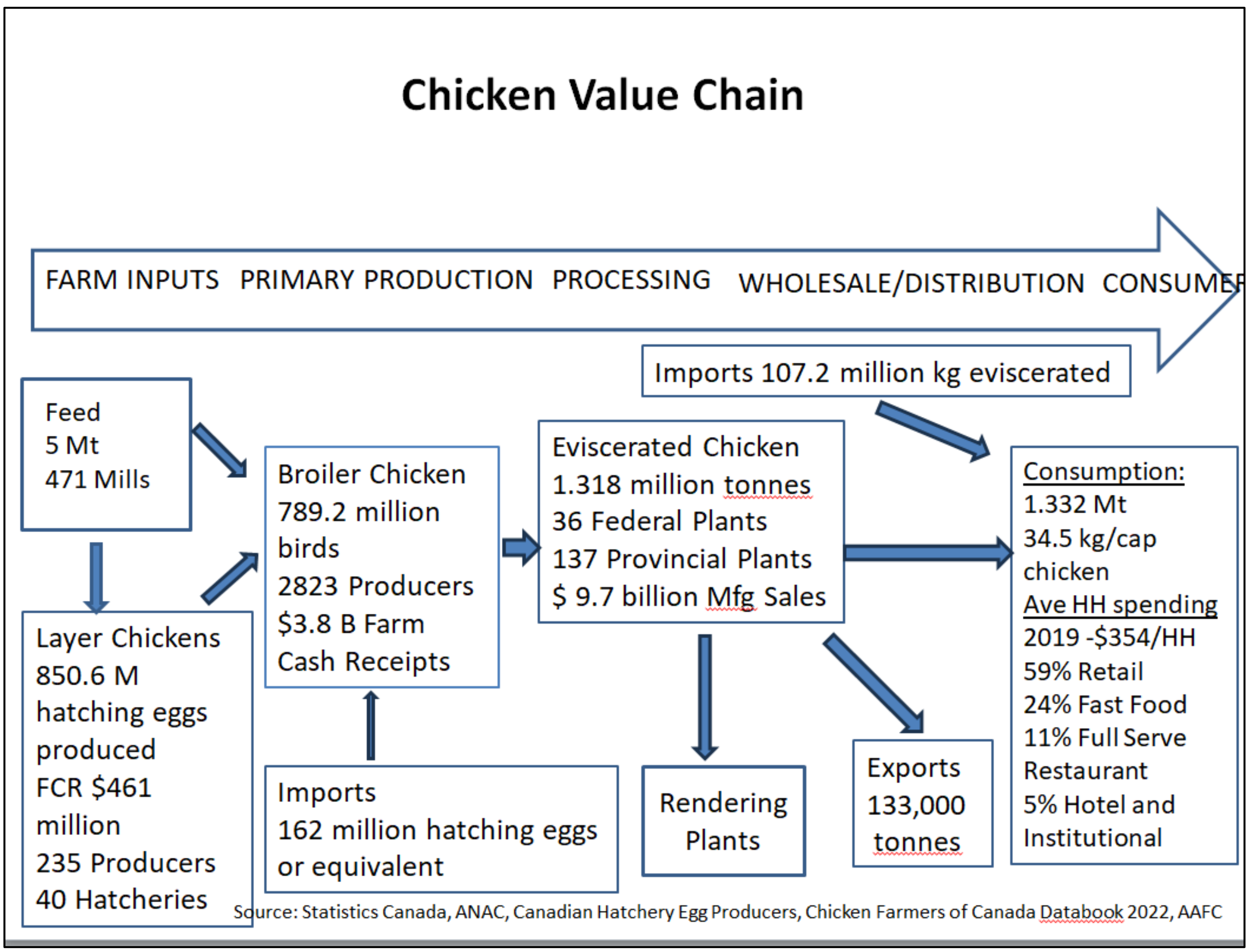
Province/territory	Micro (1-4 employees)	Small (5-99 employees)	Medium (100-499 employees)	Large (500+ employees)
Ontario	25	93	22	4
Quebec	21	96	24	3

British Columbia	13	36	7	0
Alberta	5	15	6	0
Nova Scotia	1	3	3	0
Prince Edward Island	1	6	1	0
Saskatchewan	1	1	1	0
Manitoba	0	9	2	0
New Brunswick	0	4	1	0
Newfoundland and Labrador	0	2	0	0
Northwest Territories	0	0	0	0
Yukon	0	0	0	0
Nunavut	0	0	0	0
Canada	**67**	**265**	**67**	**7**
Percent distribution (%)	***16.5***	***65.3***	***16.5***	***1.7***

Data source: Innovation, Science and Economic Development Canada, 2023a.

7.5 Chicken Value Chain

Figure 7.10. Chicken value chain



Canadian chicken, turkey, and egg value chains are part of the poultry value chain, which also operates under a supply management system. This value chain includes organizations that govern the industry including the Chicken Farmers of Canada, the Turkey Farmers of Canada, the Canadian Hatching Egg Producers, the Canadian Broiler Hatching Egg Producers, the Egg Farmers of Canada and provincial organizations.

The chicken value chain described above shows the value-added activities and interactions that begin with breeding of broiler and layer chickens, to hatching eggs, to feeding and ultimately to marketing safe, healthy and sustainable chicken products sold to Canadian consumers and for industrial uses. These activities are dependent upon all players in the chain from research scientists, feed specialists and veterinarians, to broiler and layer chicken producers, and to chicken processors, inspectors, and truck drivers who get the product to market. The foundation of this value chain includes the individuals who operate Canada's 2800 farms. The average farm produced 633,000 kg of chicken in 2001.

Key challenges for chicken and egg producers are primarily related to animal disease, such as Avian Influenza, which has seen whole flocks exterminated throughout the country in recent breakouts, as well as the cost of feed, energy and labour, due to labour shortages.

7.5.1 Primary production

The supply chain for Canadian chicken begins with broiler breeder farms that supply hatching eggs to hatcheries. Hatcheries supply day-old chicks to broiler chicken farms for placement on feed. Canadian chicken producers reported 782 M birds on their farms on January 1, 2023, down 1.2% from the same time last year, with production in Quebec, Ontario, Manitoba and B.C., accounting for the majority of farms.

Farm cash receipts for chicken operations were $3.8B in 2022, up significantly from a year earlier (14.2%) and especially compared to the previous three-year average (25.9%). Chicken appears to continue to be a sought-after protein source for Canadian consumers, with such growth.

Operating costs on poultry and egg farms were also affected by the recent run up in commodity prices, as feed and energy costs tend to be a fairly significant component of farm costs. According to 2021 tax filer data, the average poultry farm spent 39% of average operating expenses on feed, supplements, straw and bedding. Livestock purchases were also a significant expense for these farm types, at 23% of the total.

7.5.2 Chicken manufacturing

According to the Chicken Farmers of Canada, in 2022, there were 173 chicken processing plants across the country, most centred in Ontario and Quebec. 36 of these plants were federally licensed, implying they can market interprovincially or internationally, while 137 were provincially licensed (Chicken Farmers of Canada, 2022b).

Chicken production is distributed across all provinces in approximate proportion to the consumer market and due to Canada's system of supply management. State-of-the-art poultry plants that slaughter and process up to 25,000 broiler chickens per hour account for the majority share of poultry meat output. Among the largest processing companies are: Lilydale Foods (Sofina) (Alberta, Saskatchewan and British Columbia), Maple Leaf Poultry (Ontario and Alberta), Maple Lodge Farms (Ontario, New Brunswick and Nova Scotia), Olymel (Québec, N.B. and Ontario), Exeldor (Québec, Manitoba) and Sunrise Poultry (British Columbia, Alberta, Ontario and Manitoba). Most poultry processors operate their own egg hatcheries that sell chicks to producers who then sell the finished birds back to the processors on a live-weight basis (The Canadian Encyclopedia, 2015).

Consumption of chicken continued to grow in 2022, despite price increases. Per capita availability (consumption) of chicken rose to 35.4 kg/person while eggs rose to 15.3 kg/person in 2022. Turkey consumption on the other hand was down slightly to 3.34 kg/person.

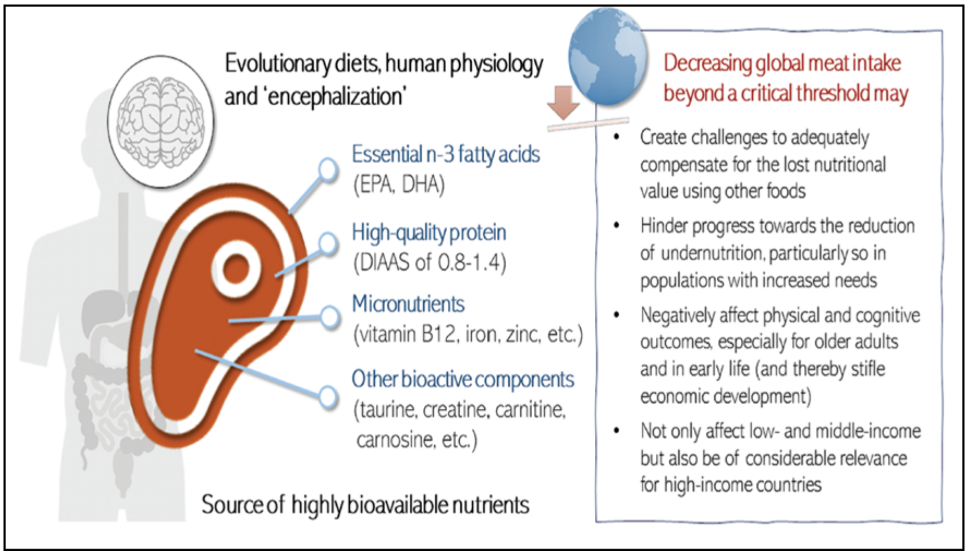
7.6 Contribution to human health

The effect of animal-based foods on human nutrition and health is becoming increasingly recognized in recent research (see Beal et al., 2023; FAO, 2023; Haile & Headey, 2023; Leroy et al., 2023; Moughan, 2021). Topics of study range from the health benefits of eating meat and dairy to the dangers of eliminating these foods from the human diet, and much more. This section can by no means cover the extant literature on the correlation between human health outcomes and the plethora of diet choices; rather, this section provides an overview of the different ways these correlations are measured and understood in the literature.

7.6.1 Red meat: nutritional composition and global deficiencies

Figure 7.11 shows how important meat is in the human diet and the expected impacts on health if intakes are reduced. Animal-based foods provide high-quality and readily digestible protein, are rich in energy and provide readily absorbable and bioavailable micronutrients, more easily obtained from animal-based foods than from plant-based foods. An inadequate intake of some of the major micronutrients relative to what is recommended during pregnancy and childhood, such as iron, zinc and calcium, can lead to health problems that affect growth and educational attainment (FAO, 2018).

Figure 7.11. The role of meat in human nutrition and potential complications without it



Reprinted from Leroy, F., Smith, N., Adesogan, A. T., Beal, T., Iannotti, L., Moughan, P., & Mann, N. (2023). The role of meat in the human diet: Evolutionary aspects and nutritional value. *Animal Frontiers*, 13, 11–18. https://doi.org/10.1093/af/vfac093.

Recent FAO statistics show that one tenth of the global population is affected by undernutrition, with three billion adults and children unable to afford healthy diets. Micronutrient deficiency or "hidden hunger" affects more than two billion people worldwide and nearly a third of women of reproductive age suffer from anaemia (FAO, 2023). Specific nutrient demands differ by life stage. So for example, pregnant and breastfeeding women, infants, children and adolescents have higher demands per kilogram body weight for most, but not all, essential nutrients than adult men, non-pregnant and non-breastfeeding women or the elderly. Malnutrition in early childhood can affect the child's growth and physical and intellectual development, labour productivity during adulthood and even lead to increased disability and a lower lifespan. Poor maternal nutrition impairs fetal development and contributes to low birthweight and subsequent child malnutrition. Hence, in this era of growing food insecurity around the world, more nutrient dense food, not just more food, will be required to sustain and ensure the world's population can achieve higher quality of life and less poverty and hunger, as set out in the UN Sustainable Development Goals (United Nations, 2023).

With almost 800 million people globally facing hunger and nearly one in three people in the world affected by moderate or severe food insecurity in 2022 (FAO, 2023), it is important to recognize how animal agriculture contribute to food security, healthy diets and improved nutrition.

Also, as the world's population grows and food demand increases and as the demand for protein and higher value food products rises over the next 25 years, it will be particularly important for animal agriculture to play a role in boosting nutrition for the world's population at the same time that it addresses their environmental impacts.

7.6.2 Vitamins, macronutrients, and micronutrients

Vitamin B12

Vitamin B12 is important for the body's red blood cell formation and nerve function (Health Canada, 2012). It is the only vitamin created by bacteria (University of Kent, 2013), such as the bacteria present in ruminants' stomachs (Watanabe & Bito, 2018). Although it cannot be made by either humans or animals, vitamin B12 can accumulate in animal tissues and then be consumed by humans. Vitamin B12 is often added to livestock feed as a supplement; humans then acquire this B12 when consuming meat, dairy, and seafood.

Absorption of vitamin B12 is complex and is affected by the condition of the stomach and gut, such as the presence of enzymes (Health Canada, 2012). Malabsorption increases with age and certain medications which are more common in elderly populations (Kolber & Houle, 2014). Vitamin B12 deficiencies can lead to anemia and fatigue.

The recommended daily intake of vitamin B12 is 2.4 micrograms for persons aged 14 and older, and 1.8 micrograms for children aged 9 to 13 years (Health Canada, 2023c). The foods with the highest vitamin B12 content per serving are clams (84 micrograms per 3-ounce serving), liver (71 mcg/3-ounce serving), and fortified cereal (6 mcg/1-cup serving) (Harvard Health Publishing, n.d.). The bioavailability of vitamin B12 is thought to be three times higher in dairy products than in meat, fish, and poultry; and it is 50% more bioavailable in supplement form than in food sources (Allen, 2010; Vogiatzoglou et al., 2009; Tucker et al., 2000; as cited in National Institutes of Health, 2022).

Iron

The daily recommended intake of iron is 11 mg for children aged 7 to 12 months, 10 mg for ages 4 to 8, 8 mg for male adults and females aged 51 or older, and 18 mg for females aged 19 to 50 (Health Canada, 2023b). The RDA is 1.8 times higher for vegetarians due to lower bioavailability of iron from plant-based foods compared to animal sources (Health Canada, 2023b). A diet with sufficient iron helps prevent iron deficiency anemia, a condition where the body's blood lacks red blood cells, the carriers of oxygen from the lungs to the body's tissues (Mayo Clinic, 2022). The level of iron in the body can be affected by intake of iron-rich foods, the condition of the gut or small intestine, pregnancy, blood loss (usually through regular menstruation or blood donating), and the intake of vitamin C, which enhances iron absorption (Mayo Clinic, 2022).

The 2019 Global Burden of Disease project estimated the prevalence of anaemia in 15- to 49-year-old non pregnant females globally at 30% and 13% in high income countries. Canadian studies estimate this number at between 9.1% and 9.6% for women in this age group (Cooper et al., 2023). Estimates for anaemia prevalence in children under 5 years were 40% globally and 12% in high income countries, with Canadian estimates below 5.9% (Cooper et al., 2023).

These findings for Canada are based on research showing how some Canadians, particularly women of child-bearing age, teen girls and children, are suffering from nutrient deficiency in iron and need to eat more animal-based products. Nutrient deficiency occurs when people consume less than recommended amounts identified by health professionals and the FAO and the World Health Organization (WHO). Cooper et al. (2023) estimated the prevalence of iron deficiency and anemia in Canada for specific age and gender groups. Table 7.7 shows how 10.5% of boys and girls 3 to 4 years of age suffer from iron deficiency while 5.9% suffer from anemia, based on the Canadian Health Measures Survey cycles 3-6 (2012-2019). Particularly striking is the prevalence of iron deficiency in women of childbearing years (19 to 50). Females in this age group reported higher prevalence of iron deficiency (20.4%) compared to males at 1.0%. Similarly, teen girls, ages 14 to 18 reported iron deficiency in 22.4% of girls, compared to only 3.8% in boys of the same age group. Elderly females and males reported iron deficiency in only 3.8% and 0.9% of cases.

Table 7.7. Prevalence of Iron Deficiency and Anemia in Canada by Age and Gender

Canada, by age and gender	Prevalence of anemia	Prevalence of iron deficiency
Boys and girls, 3-4 yrs	5.9%	10.5%

Males, all ages	4.0%	2.0%
5-13 yrs	4.5%	6.9%
14-18	4.2%	3.8%
19-50	2.2%	1.0%
51-79	6.2%	0.9%
Females, all ages	8.3%	13.4%
5-13 yrs	5.1%	9.0%
14-18	9.1%	22.4%
19-50	9.6%	20.4%
51-79	7.2%	3.8%
Total	6.1%	7.4%

Table created internally. Data source: Cooper, M., Bertinato, J., Ennis, J. K., Sadeghpour, A., Weiler, H. A., & Dorais, V. (2023). Population Iron Status in Canada: Results from the Canadian Health Measures Survey 2012–2019. Table 4 and Table 3. *The Journal of Nutrition*, 153(5), 1534–1543. https://doi.org/10.1016/j.tjnut.2023.03.012.

Calcium

Calcium is important for healthy bone growth and maintenance (Farrell & Houtkooper, 2017). Adequate calcium intake is especially important in adults over the age of 50, when the body's bone remodelling process slows (Osteoporosis Canada, 2023). The daily recommended intake of calcium is 700mg for children aged one to three years, 1,000 mg for ages 4 to 8, and 1,000 to 1,300mg for adults, depending on age, gender, and pregnancy (Health Canada, 2023b).

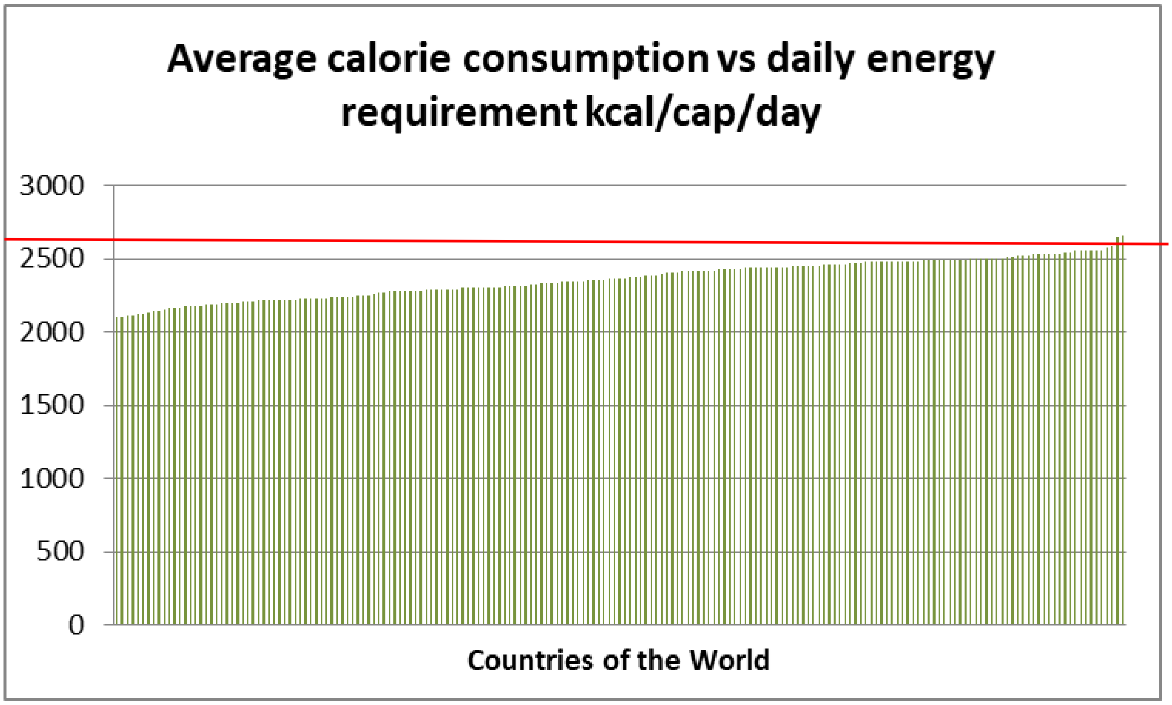
According to Health Canada, in 2009, 19.2% of women and 3.4% of men aged 50 or older reported having been diagnosed with osteoporosis in Canada reflecting calcium deficiency. Canada's Community Health Survey, conducted by Statistics Canada and Health Canada, reveals a concerning decline in calcium intake across an 11-year span, coinciding with reduced dairy consumption. Consequently, 68% of Canadians do not consume enough calcium (Dairy Farmers of Canada, 2023). Fortified beverages have the greatest amount of calcium per calorie (~12 mg of calcium per calorie), followed by lambs' quarters (8mg/calorie), cooked greens (~4mg/calorie), and skim milk (~3.5mg/calorie) (Dietary Guidelines for Americans, 2019; rates calculated internally). In terms of servings, the foods with the highest calcium content per serving are dairy products (such as plain yogurt, 332mg per 175mL), fortified beverages (such as fortified plant-based milk, 300mg per 250mL), and seafood (such as salmon with bones, 240mg per 105g) (Osteoporosis Canada, 2023).

Calories

With regard to meat and calorie consumption, many countries, particularly high-income countries in the EU, Canada, the United States, Australia, New Zealand, and Brazil consume excess calories and protein beyond recommended daily amounts, contributing to both health impacts (*i.e.*, obesity and chronic diseases such as high blood pressure, diabetes, and heart disease) and environmental impacts (*i.e.*, GHG emissions, land use concerns, water contamination by animal agriculture). Out of 15 dietary risk factors for diet-related deaths at the global level, the consumption of processed meat and red meat were ranked as 13th and 15th (Afshin et al., 2019, as cited in OECD, 2020, p. 12). It is estimated that while 1.9 billion persons live with food insecurity, even more people are overweight or obese (OECD, 2020, p. 12). In Canada, 64.7% of the adult population (18.8 million persons) is overweight or obese: 30.0% are obese (8.7 million adults) and 34.7% are overweight (10.0 million adults) (Canadian Community Health Survey, 2023). The number of obese or overweight adults in Canada increased by 9% from 2018 to 2022 (Canadian Community Health Survey, 2023). Many studies, from Searchinger *et al.* (2019), Willett *et al.* (2019) and the EAT-Lancet diet, to Poore and Nemecek (2018), and Health Canada in its recent Canada Food Guide (Health Canada, 2023a), recommended substantially reducing protein and meat consumption as well as eating fewer calories to improve environmental and health outcomes.

Traditionally, food adequacy has been measured by calorie intake. According to FAO data, about two thirds of all countries are consuming sufficient calories to meet average per capita daily food energy requirements (Figure 7.12). Each bar on the x-axis represents one country or territory ranked by calorie consumption. Average daily energy requirements of 2,353 kcal/capita/day are recommended by the FAO and shown by the red line. Individual energy requirements vary of course depending on age, sex, height, weight, pregnancy/lactation, and level of physical activity as well as by rural or urban location and income. According to these results, just one third of countries fail to consume average recommended daily calories per day per person and are undernourished. The remaining two-thirds are overconsuming calories.

Figure 7.12. Average calorie consumption vs. daily energy requirement, kcal/capita/day



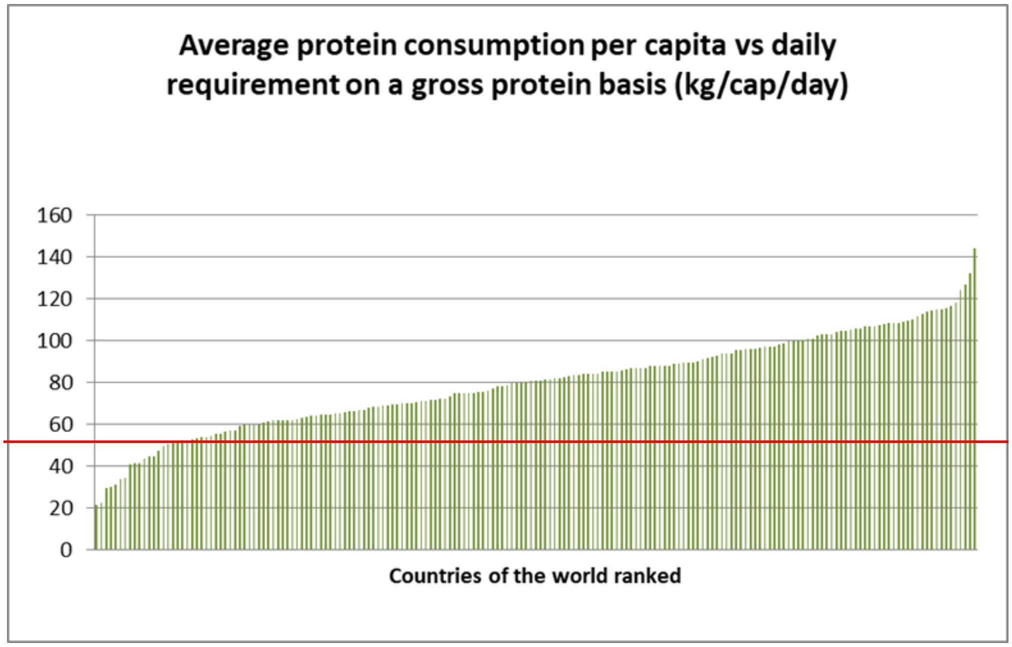
Reprinted from (Ranganathan et al., 2016) and FAO; as cited in Vaughn Holder presentation to the Beef Farmers of Ontario (Ontario Beef, 2023, March 8). BFO AGM 2023 Keynote Speaker—Dr. Vaughn Holder. https://www.youtube.com/watch?v=GWxOlqJMpMI

Protein

Protein is important for growth, including building and repairing cells and tissues (Health Canada, 2019a) and making enzymes and hormones (HealthLink BC, 2019). Animal-based proteins are known to be more readily digestible than plant-based proteins, but consuming a mix of plant proteins may actually increase the digestibility of plant proteins (Herreman et al., 2020, tbl. 3). Factors such as processing, extrusion, and cooking can also increase or decrease the digestibility of amino acids in foods (Bailey, Mathai, Berg, & Stein, 2019; Friedman, Gumbmann, & Masters, 1984; as cited in Herreman et al., 2020).

A chart similar to Figure 7.12 was developed by ranking countries by average daily per capita protein consumption and showing them relative to their recommended daily amounts (Figure 7.12). This chart shows how average daily protein consumption per capita exceeds the recommended daily average of 50 g/capita/day in most countries when “gross” protein is used. Countries such as Brazil, the EU, the U.S., and Canada are on the far right of the chart, showing how much greater actual consumption is relative to the recommended levels.

Figure 7.13. Average protein consumption per capita (plant and animal) vs. daily requirement, using "gross" protein

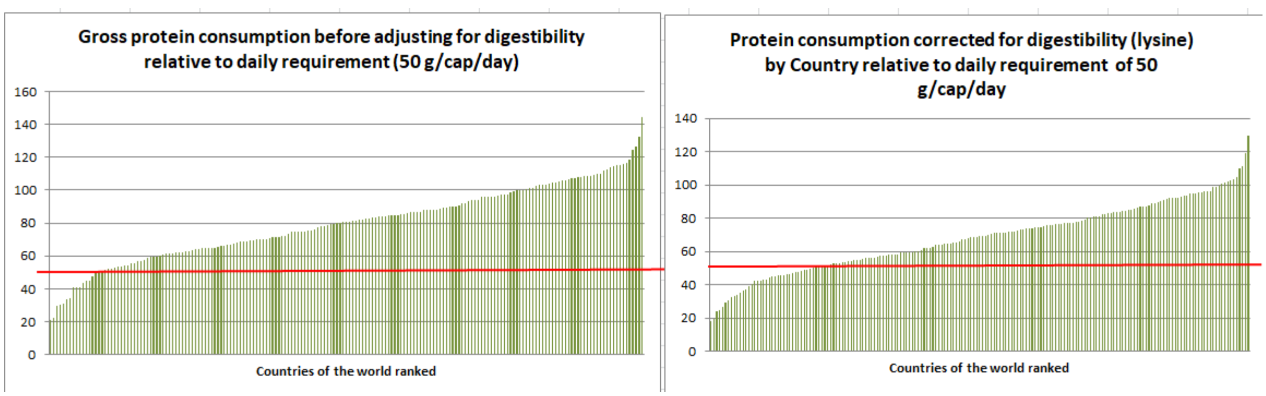


Source: IFPRI, Ranganathan *et al.* 2016 and Moughan, 2021 and FAO.

However, more recent research has demonstrated that the use of "gross" protein, such as shown above, does not adequately reflect the fact that animal-based protein tends to be more readily absorbed by individuals than plant-based protein. Moughan (2021) showed how average daily protein consumption adjusted for "quality," as measured by protein digestibility and amino acids (lysine), was lower than average daily protein requirements in more countries (Figure 7.14 B). This is primarily because plant-based proteins are of a lower quality given their incomplete amino acid profiles and lower digestibility (Moughan, p. 1). By re-estimating these numbers based on "quality" protein, Moughan was able to show how indeed insufficient protein is being consumed by citizens of more countries and particularly in countries that have greater nutrient deficiency and food security issues (*i.e.*, India, Sub-Saharan Africa (SSA) and China) (Figure 7.15). Adjusted for "quality" (amount of lysine), average daily protein consumption in SSA was below daily requirements. He also estimated the change in the impacts of animal-based proteins on GHG emissions, water use, and land use relative to plant-based proteins by using the quality-adjusted proteins in his calculations, shown in Figure 7.16 and Figure 7.17.

Figure 7.14. Protein consumption vs. requirement (g protein/capita/day) for 103 countries based on gross protein (A), or corrected for protein utilizability (B)

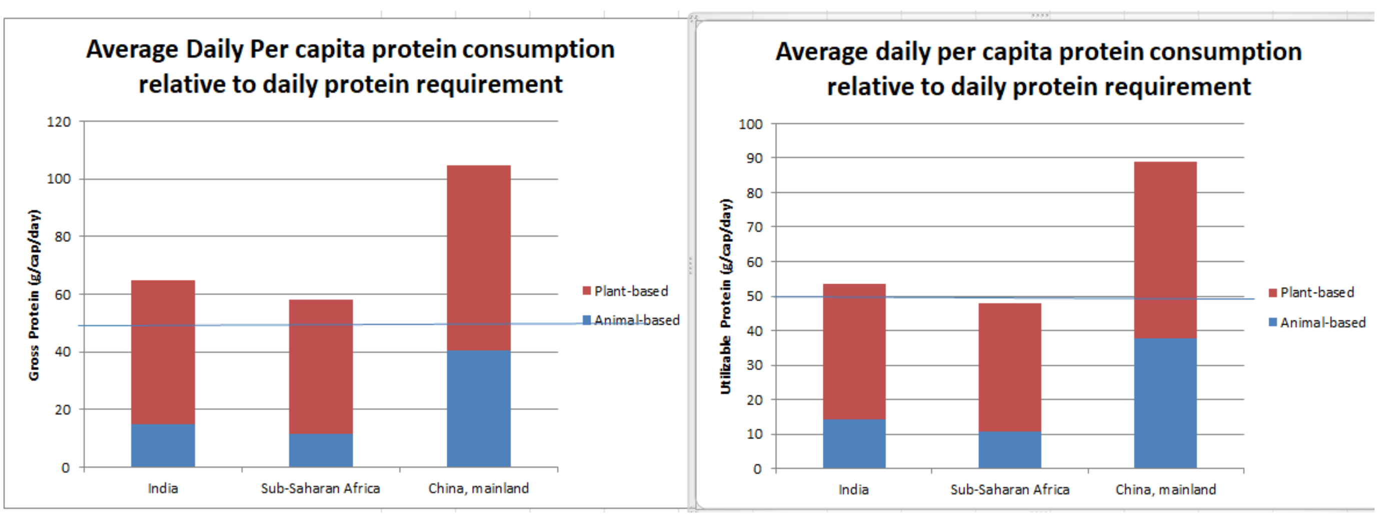
(A) **(B)**



Source: Moughan, 2021 and FAO

Figure 7.15. Protein consumption vs. requirement (g protein/capita/day) for India, SSA and China based on gross protein (A), or corrected for protein utilizability (B)

(A) **(B)**



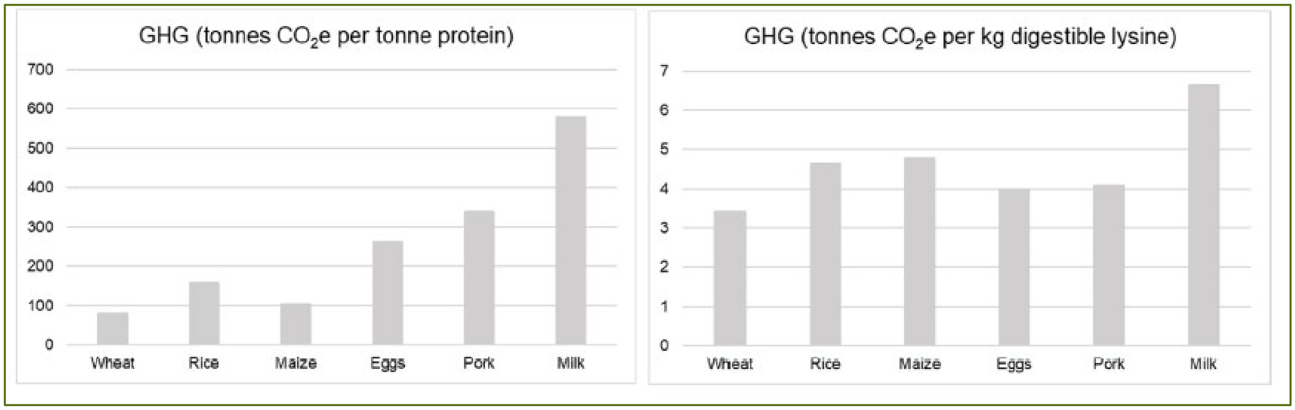
Source: Moughan, 2021.

The relative impact on GHG emissions (Figure 7.16B) shows how wheat, rice, and maize's relative carbon footprints were higher than eggs and pork after adjusting for protein quality. So for example, after quality adjustment, the carbon footprint of rice and maize was higher at 4.6 t and 4.7 t of CO_2e per kg of digestible lysine than for eggs (4 t) and pork (4.1t). This was similarly the case for water use and land use impacts (Figure 7.17 and Figure 7.18) where wheat, rice, and corn were more intensive users of land and water when reporting per kg of digestible protein. Hence, as Moughan argues, "the metrics matter," and actually can make a difference in estimating nutrient availability and environmental impacts of animal products.

Figure 7.16. GHG emissions of adjusting protein from animal- and plant-based foods for quality

(A)
Using “gross” protein

(B)
Using “quality” protein

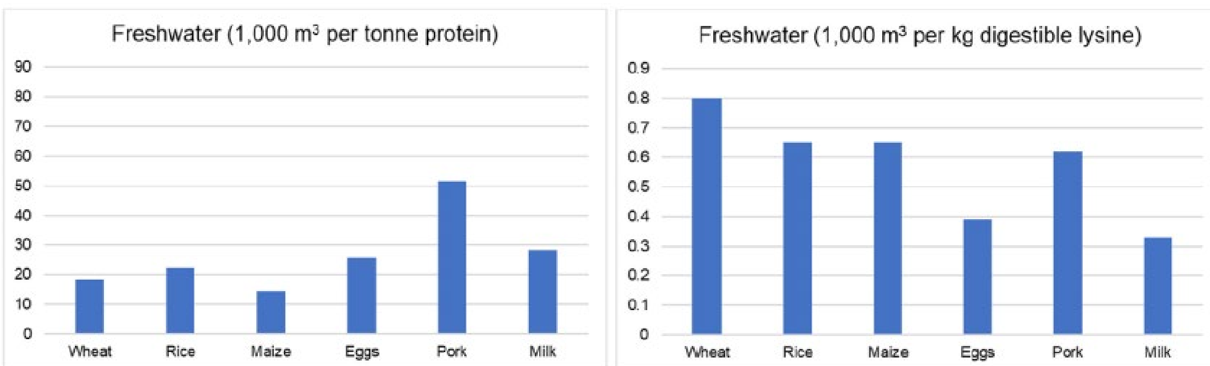


Source: Moughan, 2021.

Figure 7.17. Estimates of impacts on water use of adjusting protein from animal- and plant-based foods for quality

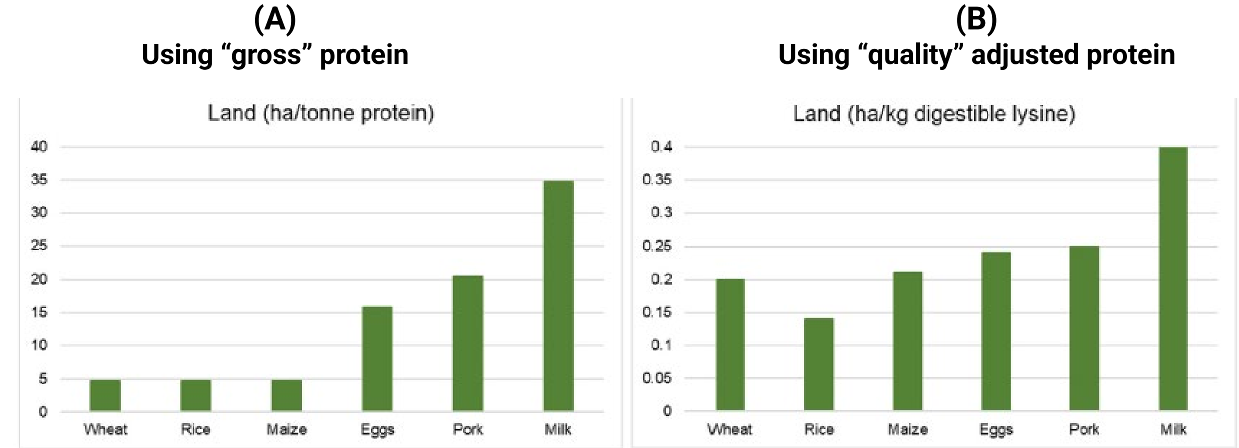
(A)
Using “gross” protein

(B)
Using “quality” adjusted protein



Source: Moughan, 2021.

Figure 7.18. Impacts on land use of adjusting protein from animal- and plant-based foods for quality



Source: Moughan, 2021.

Thus, when estimates include the impact of the "quality" of protein from animal-based products, the conclusions change to reflect the greater digestibility and nutrient content of animal- based versus plant-based proteins in feeding the world and for determining environmental impacts. Metrics matter and attempts to reduce animal-based food products in the diets of the world's population will have serious implications, beyond what has up until now been presented. It is therefore important to continue to evaluate the role of animal agriculture for global food security and human health for a more sustainable future.

The role of animal agriculture in the US: A case study

White and Hall (2017) estimated the nutritional and GHG emissions impacts of removing animals from U.S. agriculture in a scenario modelling exercise. By eliminating animals from US agriculture, they found that indeed GHG emissions were reduced by 28%, but this did not fully counterbalance the animal contribution of GHGs (49%) in their model. This is because of the important role livestock plays in disposing of a large amount of feed processing by-products. Also, N, P, K and S fertilizer previously sourced from manure would need to be synthesized for crop needs. And additional crops would need to be produced on land previously used by animals, where possible.

They found that while a plant-only US agriculture produced 23% more food, it met fewer of the US population's requirements for essential nutrients including calcium, protein, vitamin A and vitamin D, as well as iron and zinc (White & Hall, 2017). At the same time, removing animals from US animal agriculture resulted in the US having a greater exportable surplus in foods (and therefore nutrients) which could help with food security in other countries. Increases in exportable food energy would be of use in developing countries where calories are often a limiting factor in achieving food security. Based on these mixed results, they concluded that modifications to agriculture systems (such as shifting away from animal agriculture in certain countries) must be based on the direct and indirect effects on the complete diet, rather than focussing on a specific nutrient (White & Hall, 2017).

8. Research and innovation

Research and innovation has helped the livestock sector in Canada to find the optimal use of scarce resources, all while combatting animal disease and responding to the rising global demand for protein. This section outlines some of the ways that livestock R&D has advanced in North America in terms of production and yield of animal products, as well as improved animal welfare and environmental sustainability.

8.1 Challenges in Animal Agriculture Confronting Innovation

The livestock industry in Canada has made substantial progress over the past two decades in responding to the challenges it faces on all fronts from the environment, from human and animal health and welfare concerns, on the trade and consumer demand front and from society as a whole. We present here the Dublin Declaration as a summary of the challenges for livestock and the importance of meeting these challenges through research and innovation.

8.1.1 The Dublin Declaration of Scientists and the Societal Role of Livestock

The Dublin Declaration (2023) was the result of an agreement that was made at the International Summit on the Societal Role of Meat in Dublin, Ireland in the fall of 2022. The goal of this initiative was to provide the latest evidence and developments in knowledge around the societal role of meat. As of September 25, 2023, 1,145 persons have signed the Dublin Declaration (The Dublin Declaration, 2023), with the purpose of giving a voice to scientists around the world who do research in various disciplines to improve and innovate for the future of animal agriculture. Findings from the symposium have been published in the April 2023 volume of the journal *Animal Frontiers*, providing up-to-date evidence on meat as it relates to human nutrition and health, culture, socio-economic factors, the environment, and ethics.

The Dublin Declaration focused its objectives around five themes in an effort to prioritize the research around five issues:

Challenges for livestock. This theme focuses on the dual challenge for livestock: to increase supply in response to rising global demand for animal-sourced foods that address nutritional gaps, while doing so within the constraints of climate change, biodiversity, nutrient flows, and animal health and welfare to secure livestock-dependent livelihoods and address sustainability challenges through evidence-based solutions.

Livestock and human health. This theme draws out the critical dietary and health role for livestock products, to counter some of the negative press around its link to cardio-vascular diseases and cancer, drawing on bio-evolutionary, anthropological, physiological, and epidemiological research that underscores the importance of regular consumption of meat, dairy, and eggs as part of a well-balanced diet that is advantageous for human beings.

Livestock and the environment. This theme researches the benefits of farmed and herded animals for maintaining a circular flow of materials in agriculture, through the recycling of inedible biomass generated as by-products of plant-based foods in the human diet. Livestock also play a role valorising marginal lands not suitable for growing crops for human consumption. It is also important for generating environmental benefits, including biodiversity, carbon sequestration, improved soil health, and watershed protection as important ecosystem services. There is no doubt that more research and action is needed to reduce climate change impacts of livestock production. It is also important to communicate those findings effectively to a broader audience. This is to inform one-size-fits-all agendas which are currently calling for drastic reductions in livestock numbers and more serious environmental problems globally.

Livestock and socioeconomics. This theme addresses the historical and future role of livestock for providing food, clothing, power, manure, employment, and income as well as assets, collateral insurance, and social status to millions around the world in both developed and developing countries. In some communities, livestock is one of the few assets women can own as an entry point to gender equality, family and community welfare, and food security. Livestock is a long-proven method to create healthy nutrition and secure livelihoods deeply embedded in cultural values everywhere.

Outlook for livestock. This final theme argues that livestock will continue to provide solutions for remaining a critical bedrock of societies for staying within the Earth's safe operating zone of planetary boundaries well into the future.

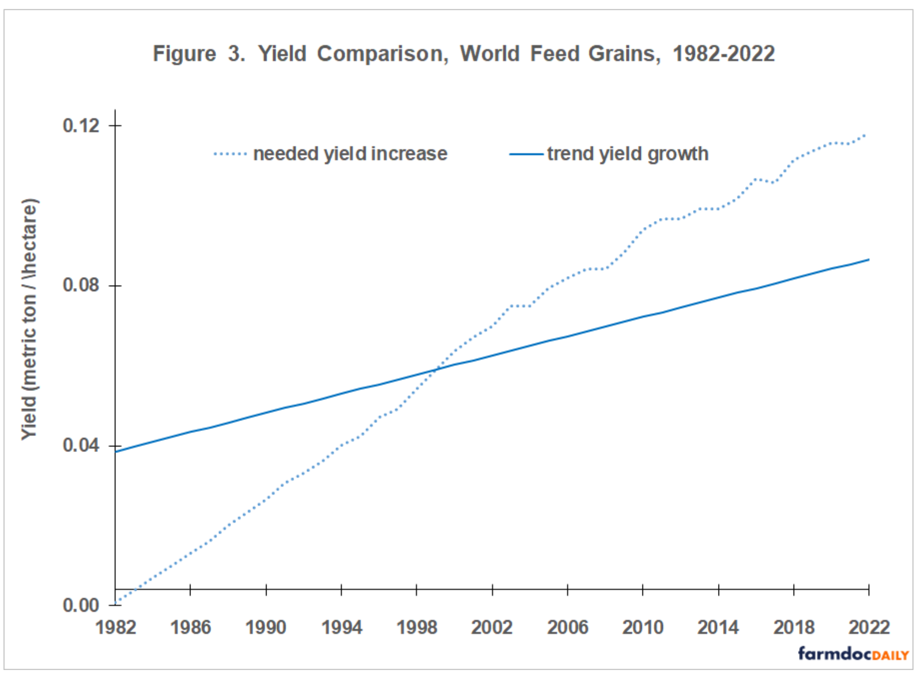
8.1.2 Efficiency and Sustainability in Resource Use

In the introduction of his 2002 article, Vaclav Smil remarked that "Von Liebig noted in his most famous book [published in 1840] that agriculture's principal objective is the production of digestible N" (Smil, 2002, p. 126). Digestible nitrogen would be referred to today as protein or amino acids. Under this conception of agriculture, field crops and horticulture are somewhat limited with key gaps in the supply of amino acids; animal agriculture is the element that converts feedstuffs from products either inedible for humans or low/deficient in protein/amino acids, to animal products higher or more complete in protein/amino acids. The efficiency of conversion – from the land base to feedstuffs, and from feedstuffs to animal proteins – is of paramount importance.

This is especially important because efficiency in animal conversion of feedstuffs interfaces with crop feedstuff yields. In this regard, Zulauf (2022) analyzed the problem of global yield drag: the proportion of growth feedstuff demand that cannot be satisfied by crop yield growth, and must instead be met by introducing new land into production. Figure 8.1 below, reprinted from Zulauf, shows that, starting from the early 1980's, for global feed grains (corn, barley, oats, and sorghum), yield growth in these crops was only able to keep up with demand up until 2000; since then, additional land has been needed to supplement yield growth in order to provide the production to meet demand.

Feed grains are intermediate products, primarily supplying animal agriculture as an end use. As such, efficiency in animal conversion of these feedstuffs has a direct effect on demand for feedstuffs, and influences yield drag and the associated need to bring additional acreage into cultivation to meet animal protein demand.

Figure 8.1. Trend Yields, Actual Yields, and Yield Drag: Global Feed Grains*



*Feed grains are barley, corn, millet, oats, and sorghum.
Reprinted from: Zulauf, C. (2022). The World's Increasing Need for Cropped Land. Farmdoc Daily, 12(173). https://farmdocdaily.illinois.edu/2022/11/the-worlds-increasing-need-for-cropped-land.html.

8.1.3 Access and Expense of Workforce

A significant problem across agricultural segments is access and cost of labour, and animal agriculture is affected along with other segments. Technology and innovation has developed to substitute for labour on farms, and this remains an ongoing process driving innovation in animal agriculture. Examples include robotic milking, cameras, and other precision technologies (see section 8.3).

8.1.4 Extreme Weather and Climate Change

Animal agriculture is subject to the effects of extreme weather and climate change. This is the case in a variety of respects. There are at least three distinct aspects. Extreme weather and climate change can impact the nature and feasibility of feed crops that support animal agriculture. Changes in temperature and extreme weather events causing adverse situations such as flooding directly impact the growth and welfare of farm animals. Animal pathogens can fluctuate in response to climate change, and foreign animal diseases can become a greater threat as a result.

For example, a review Thornton *et al.* (2014) observed "Changes in climate variability and in the frequency of extreme [climate] events may have substantial impacts on the prevalence and distribution of pests, weeds, and crop and livestock diseases" (Thornton et al., 2014, p. 3319).

A recent study of vulnerability to climate change in Ontario drew from the scientific literature in arriving at the following illustration of the effect extreme weather on dairy cows:

> *Dairy cows are particularly sensitive to high air temperatures due to additional metabolic heat generated during lactation. Exposure to heat over 32°C results in heat stress causing impacts such as reduced feed intake, lower milk yields (12 kg/day per cow), and reproductive problems (e.g. 26% lower conception rate), impacting farm revenue and timing of operations such as calving… Additionally, heat stress compromises cows' immune systems, making them vulnerable to disease, while extreme levels of heat stress result in an increased likelihood of mortality (27% greater mortality rate compared to a period with no heat stress) … Carryover effects of stress are known to persist even after the heatwave ends" (Ontario Ministry of the Environment, Conservation and Parks, 2023, p. 114).*

Significant adverse effects were also observed for beef cattle, swine, and poultry, and each of dairy, beef, swine, and poultry were classed as high climate risk by 2050 (Ontario Ministry of the Environment, Conservation and Parks, 2023)

8.1.5 Disease Threats

Animal agriculture in Canada faces ongoing threat of disease, in multiple dimensions. Animal diseases cause morbidity or death of animals are a source of reduced growth, increased costs, decreased revenue, and decreased welfare for affected animals. Many of these are production limiting diseases that are left to the individual producer and veterinarian to bring under control, and can undermine the financial viability of producers affected. A subset of these diseases must be immediately notified to the Canadian Food Inspection Agency, as they "are diseases exotic to Canada for which there are no control or eradication programs"[1] and CFIA can undertake control measures.

[1] For a list of immediately notifiable diseases, see https://inspection.canada.ca/animal-health/terrestrial-animals/diseases/immediately-notifiable/eng/1305670991321/1305671848331.

Another subset are Reportable Animal Diseases under the federal Health of Animals Act and are reported internationally to the World Animal Health Organization[2]. For these diseases, CFIA immediately takes responsibility to bring the disease under control, and other countries can limit imports in response to the disease. As a result of the limitations on trade, it is not only the affected producer that is adversely impacted by the disease – whole industries can be greatly impacted.

With Canada's overwhelming exporting interest in pork and also in beef, the occurrence of a reportable disease could be disastrous on affected industries. Canada had this experience following the discovery of Bovine Spongiform Encephalopathy (BSE) in 2003. The key threats today are African Swine Fever (ASF-pork), and Foot and Mouth Disease (pork, beef, and dairy). African Swine Fever poses an especially ominous threat, exacerbated by the presence of wild pigs, not native to Canada, that present a vessel of infectious agent in the wild if ASF were to occur in Canada- making eradication of the disease much more difficult. Avian influenza also poses a major threat to poultry industries.

8.1.6 Environmental Sustainability

Productivity and efficiency in the output of animal products relative to the land base are essential for environmental sustainability. There are also specific aspects that are issues for animal agriculture and the target for research and innovation. Livestock are large components of agricultural greenhouse gases, especially methane. Livestock manure is an important source of nitrogen and phosphorus deposition, and can be a source of runoff and pollution of waterways. Livestock manure can also be associated with nitrogen leaching into ground water. Manure-borne pathogens, notably coliforms and *E. coli*, can also contaminate waterways and ground water.

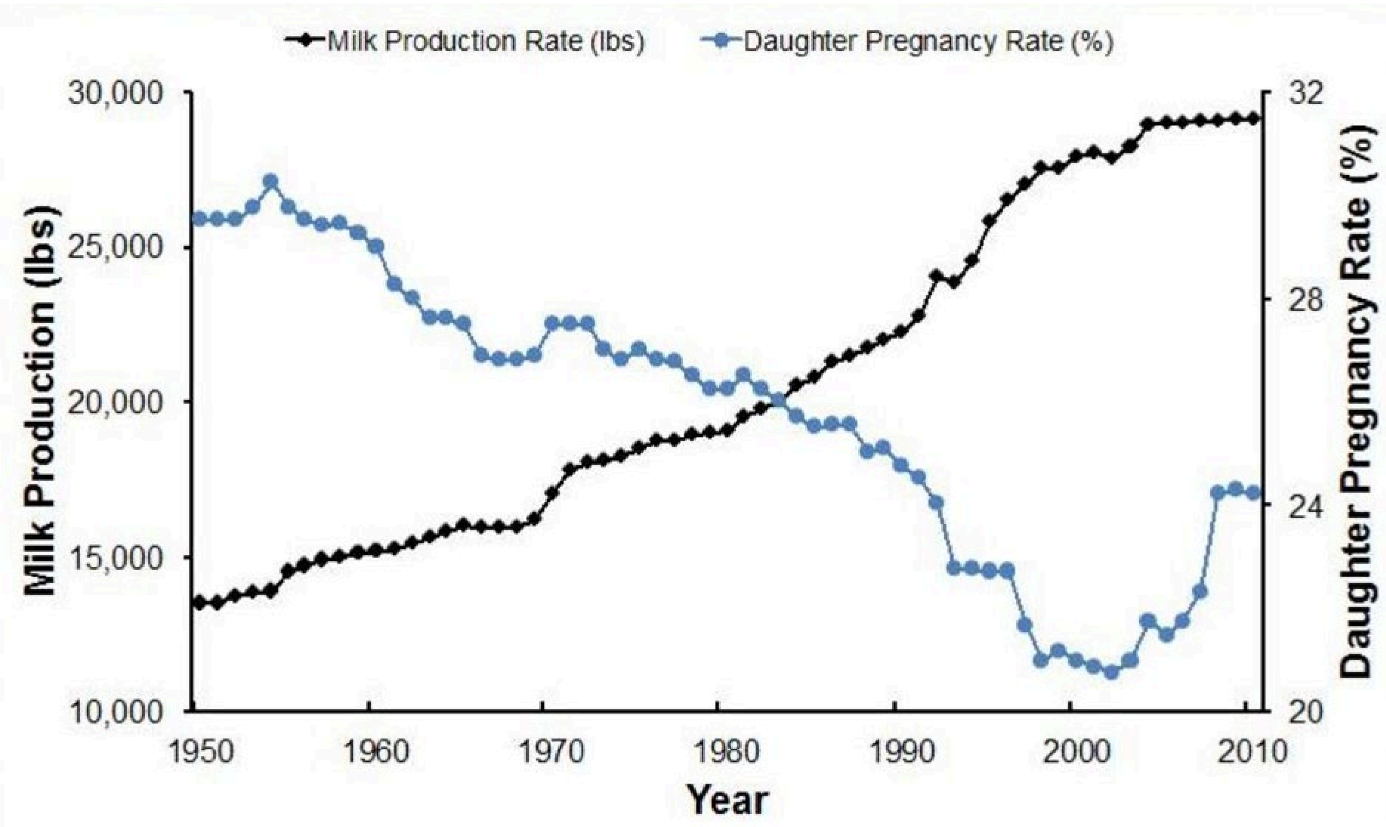
8.1.7 Animal Welfare

Grandin (2014) identified two types of animal welfare issues: "abuse or neglect of animals, caused by direct action by humans, and welfare issues where either a process or equipment has to be changed to improve animal welfare" (2014, p. 461). In the latter case, she specifically identified the problem of "biological system overload," defined as "concern that pushing the animal to produce more meat, eggs, or milk will cause both increasing welfare problems and a decline of functionality" (p. 466).

An illustration highlighted by Grandin and appearing in Spencer (2013) is provided below in Figure 8.2. The figure plots US milk production per cow vs daughter pregnancy rate, defined as the share of cows eligible to become pregnant in a 21-day period that actually become pregnant. The inference is that by focusing breeding traits related directly to milk production, US milk production per cow has increased impressively; however, this focus has come at the exclusion of reproductive rate, borne out in decreasing daughter pregnancy rate. Grandin provides other examples in poultry and swine. Grandin observes, "Both producers and scientists may think that we have to keep increasing production to feed a growing population. The author fears that an over emphasis on production may lower disease resistance. A new disease, Porcine Epidemic Diarrhea, is killing many piglets and the virus is very virulent and it can survive in manure and feed for seven to twenty-eight days. Dead piglets do not feed people" (p. 467).

[2] For a list of reportable diseases, see https://animalhealth.ca/disease-response/.

Figure 8.2 US Milk Production per Cow vs. Daughter Pregnancy Rate



Source: Reprinted from Spencer, T.E. (2013). Early pregnancy: Concepts, challenges, and potential solutions. *Animal Frontiers*, 3(4), 48–55.

8.1.8 Antimicrobial Resistance

Livestock are confronted by pathogens in their growth cycle which threaten to slow growth, cause morbidity and mortality, and compromise welfare. Both in anticipation of disease pathogen threats and in response to them, multiple refinements in nutrition, housing, ventilation, and both acute and therapeutic pharmaceutical treatments are deployed. Pharmaceutical treatments have met with stunning successes with regard to animal growth, health maintenance, prevented suffering, and decreased mortality. However, they are subject to other risks which must be addressed: the development of resistant pathogens within the target species, and pathogen resistance that spills over to impact other species, notably into human medicine.

With regard to the first issue, coccidiosis in poultry provides an illustration. Poultry are subject to infection by intestinal parasites that have significant negative impacts of their growth and health. The development of a modern commercial poultry industry in North America and around the world has been shaped in part by the constraint imposed by these diseases.

The development of treatments for intestinal parasites in poultry accelerated after the Second World War. One of the significant chemical products launched at this time was the sulphur-based feed additive sulphaquinoxaline in 1948, and many others followed (De Gussem, 2007). This included the "arsenical" group of medicated feed additives, such as roxarsone as both growth promotant and anti-coccidial, and nitarsone, a preventative treatment for blackhead in turkey.

The use of these products allowed the poultry industry to grow and expand more quickly (De Gussem, 2007). This is illustrated in Figure 8.3 for anti-coccidial treatments, from Reid (1990). US broiler production literally tripled between 1950 and 1970; this was coincident with a proliferation in available chemical treatments as medicated feed additives. It also allowed for a decrease in the consumer cost of chicken; Campbell (2008) notes that

“Following the commercial introduction of SQ [sulphaquinoxaline] in 1948, the price of broiler chickens in the United States declined sharply, and continued to decline over many years, during which sulphaquinoxaline was succeeded by other coccidiostats” (p. 941) (Figure 8.4).

However, the efforts to combat intestinal parasites has met with the problem of resistance. As a result, many of the chemical feed additive products introduced in the 1950’s, 60’s, and 70’s were withdrawn or declined in use due to resistance problems (De Gussem, 2007; Reid, 1990). As chemical feed additives declined in popularity due to pest resistance, these were replaced by a new category of control products: ionophores. The first ionophores were introduced in the early 1970’s (De Gussem, 2007); this can be identified as monensin in Figure 8.3. The period following the early 1970’s shown in Figure 8.3 is one in which broiler production again increased very rapidly. There are surely a number of reasons for this, including rapid increases in chicken demand, but it is consistent with the increased availability of ionophore anti-coccidials that were less prone to resistance than chemical additives (De Gussem, 2007). Today, ionophores are facing pressure as part of a broader concern regarding use of drugs in livestock production, which in turn drives the demand for alternative solutions to the issue of intestinal parasites in poultry.

Figure 8.3. Anticoccidial Products Introduced in the US vs. Broiler Chicken Production 1930-1990

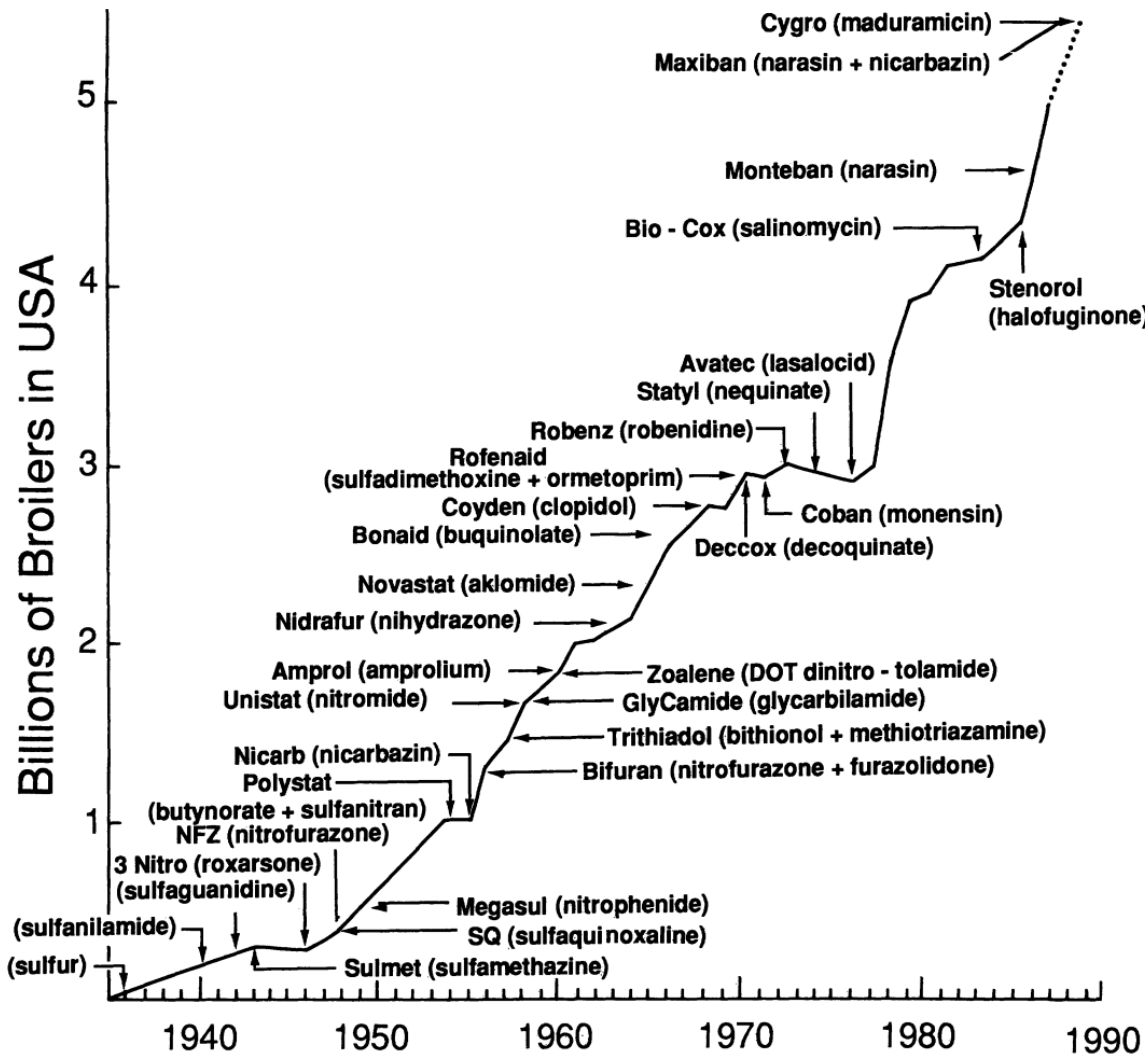


Fig. 1. Anticoccidial drugs introduced in the United States during 1936–89 plotted on USDA estimates of numbers of broilers produced. Registered trade names begin with a capital letter and generic names are shown in lower case.

Source: Reprinted from Reid, W. M. (1990). History of avian medicine in the United States. X. Control of coccidiosis. *Avian Diseases*, *34*(3), 509–525.

Figure 8.4. US Chicken Prices through time (2003 USD)

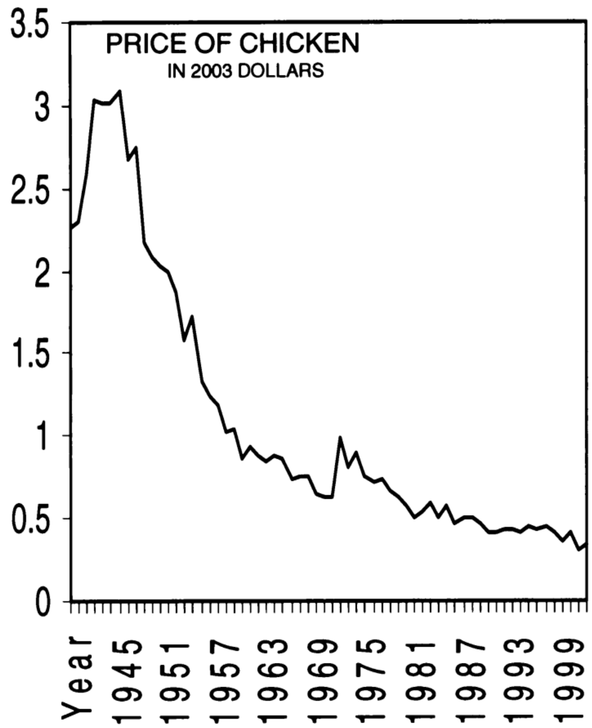


FIGURE 7. Decline in price of poultry meat following introduction of coccidiostats in 1948. Annual average of monthly live-weight price of chicken per pound received by farmers (expressed in 2003 dollars calculated from data of the Federal Reserve Bank of Minneapolis, Minnesota, 2006). The decline reflects an increase in the use of intensive production methods, which were made practicable by the introduction of the drugs. No attempt is made to disentangle the causative contributions of the methods and the drugs.

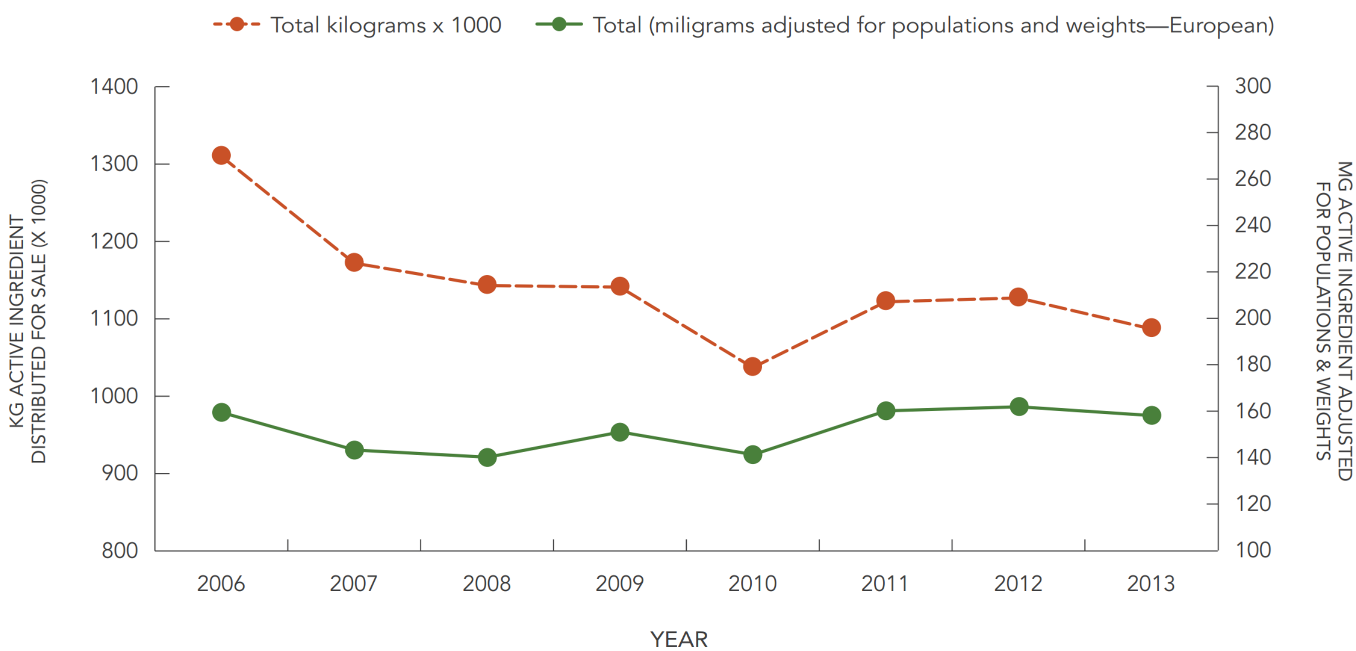
Source: Reprinted from Campbell, W. C. (2008). History of the discovery of sulfaquinoxaline as a coccidiostat. *Journal of Parasitology*, *94*(4), 934–945.

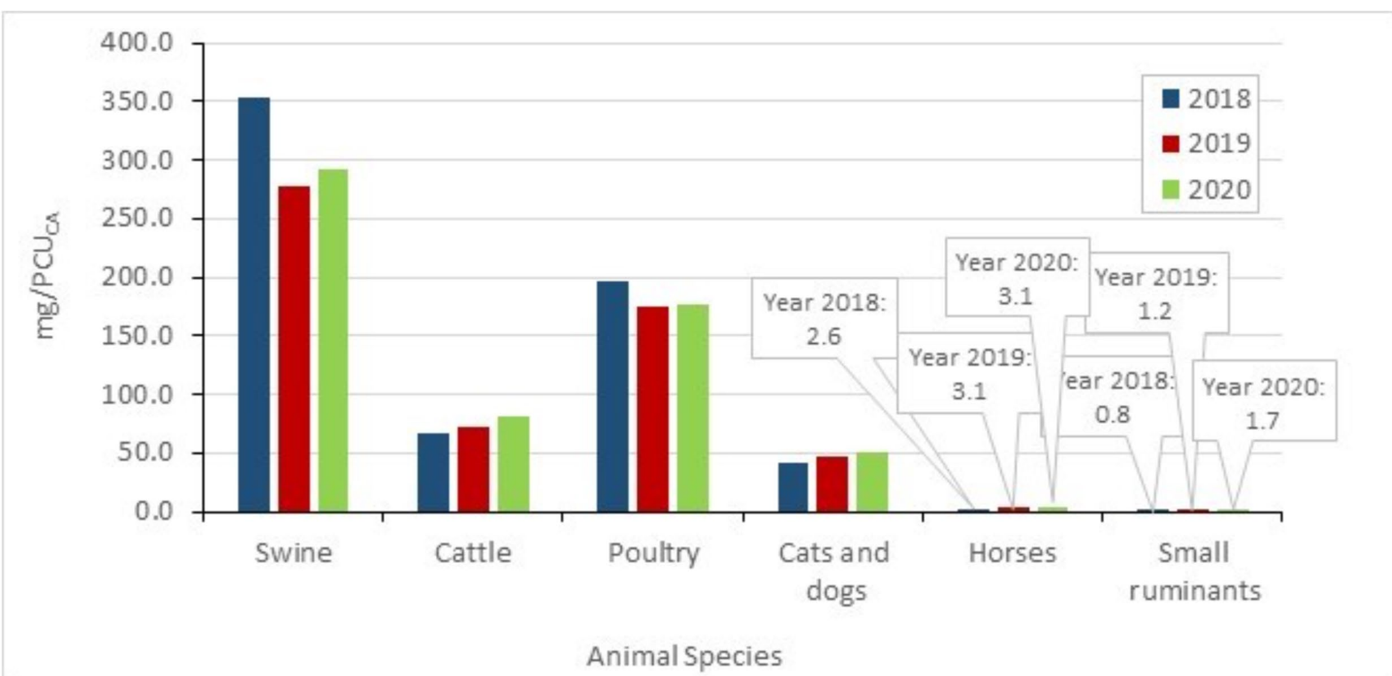
The decline in Figure 8.4 reflects an increase in the use of intensive production methods, which were made practicable by the introduction of the drugs. No attempt is made to disentangle the causative contributions of the methods and the drugs.

The second and related issue of risk is of antimicrobial resistance across species. This has been a matter of critical focus for innovation in animal industries, both in terms of data collection and monitoring, and judicious (and generally reduced) use of sub-therapeutic treatments. This is especially the case for medically important antimicrobial products. Figure 8.5. below presents data collected under the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS). The data shows that, comparing 2006-2013 with 2018-2021, total use of medically important antimicrobials in animals has decreased. When this is adjusted for livestock populations and animal weights, usage of these antimicrobials has been steady at around 160 mg/PCUEU (Public Health Agency of Canada, 2015, 2022). The challenge has been to maintain satisfactory levels of animal health and welfare and decrease the use of antimicrobials, and thus minimize the contribution of animal medications to the broader problem of pathogen resistance in human medicine.

Figure 8.5. Medically-important antimicrobials (adjusted for population and weights, mg/PCUCA) by animal species, CIPARS, 2006-2013 and 2018-2020

FIGURE 4: Medically-important antimicrobials distributed for use in animals over time; measured as kg active ingredient and mg active ingredient, adjusted for population and weight[h]





Source: Canadian Antimicrobial Resistance Surveillance System Reports, 2015 and 2022.

8.2 Breaches and Erosion in Social Capital

Significant responsibility and public trust is devolved to the institutions of animal agriculture and to the producers/businesses engaged in animal production, handling, and processing. In effect, they are charged with maintaining the integrity of the public image of the product category, quite apart from their own production processes, marketing, and profitability. Gaps in this public trust are an important source of risk to animal industries, and a source of increased scrutiny. This is complicated by public perceptions and expectations of animal welfare and the food system that fluctuate over time.

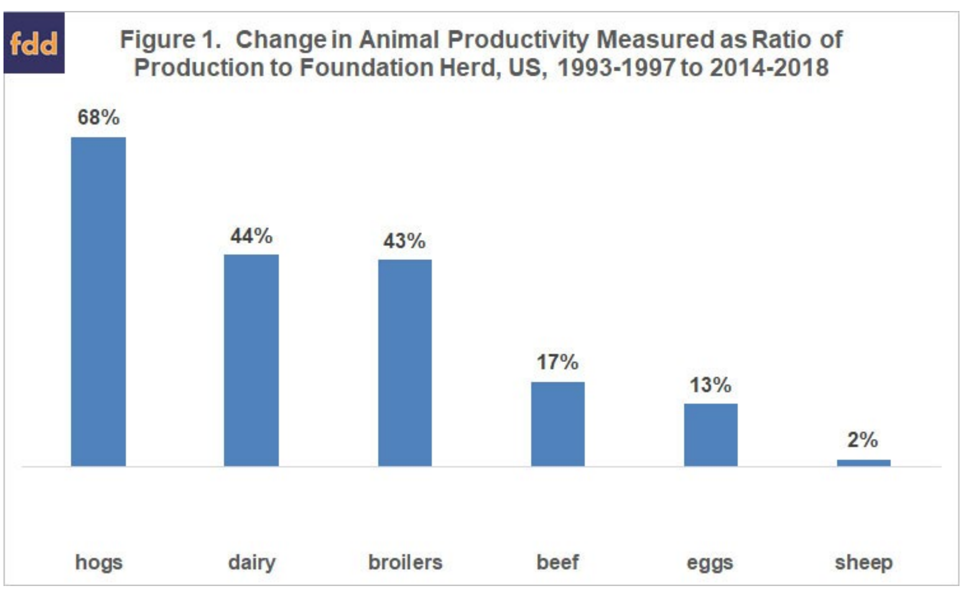
The most egregious example is animal activism seeking to discredit animal agriculture and carries the risk of swaying broader public opinion, amplified through the release of covert videos of incidences of animal abuse or suffering, and legal action taken against animal industries. The perception that animal facilities are excessively crowded; use processes viewed by some as wasteful, polluting, or inappropriate; or fail to treat its human resource stock fairly or safely are factors potentially undermining the legitimacy of animal agriculture institutions. This risks broader actions by governments and consumers against animal industries.

Trust can also erode from within animal agriculture. Changes in structure and interests can weaken institutions and make changes in collective standards more difficult to make. Conversely, if institutions are only seen as serving the interests of a subset, they can become frail.

8.3 Innovation and Progress in Animal Agriculture

Most indicators of efficiency progress and innovation in animal agriculture are compiled on a species-specific basis and deal with conversion efficiency, and are discussed elsewhere in this paper. Zulauf (2019) considers an alternative approach, in which efficiency is measured by taking animal production relative to the "foundation herd," and comparisons can be made across species. Essentially it views the breeding herd as the overhead that enables production of meat, milk, and eggs, and then indicates how the share of production relative to breeding animal overhead has changed over time. Zulauf (2019) compiles this measure for US animal agriculture and applies it in comparing the change from 1993-1997 (average) with 2014-18 (average) to measure progress. He finds that hogs had a 68% increase in productivity over the 20-year time period. Dairy and poultry (broilers) had approximately the same gains in productivity (44% and 43%). Beef had the lowest gain in productivity of the four, at an increase of 17% between the two time periods.

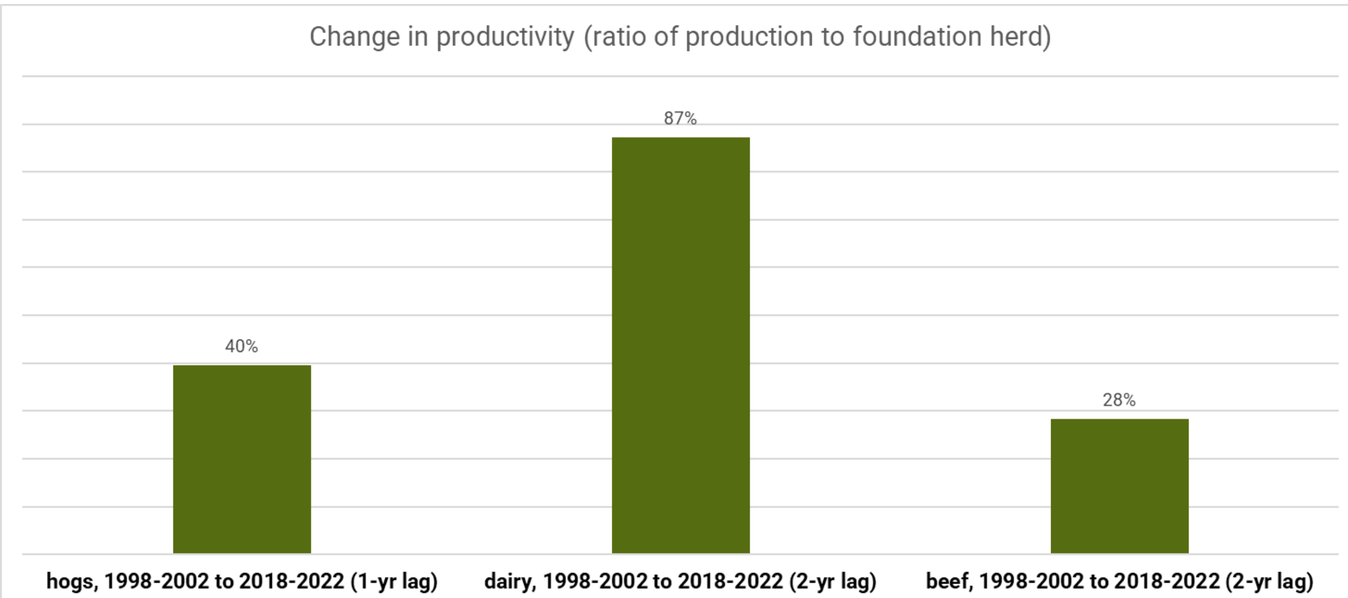
Figure 8.6. Change in animal productivity (ratio of production to foundation herd, USA).



Reprinted from Zulauf, C. (2019). Comparing Livestock Productivity Since 1993. *Farmdoc Daily*, *9*(96). https://farmdocdaily.illinois.edu/2019/05/comparing-livestock-productivity-since-1993.html

A similar analysis is undertaken for Canada here. Figure 8.7. compares hogs, dairy, and beef for the most recent five-year average available (2018-2022) for period 2, and approximately 20 years prior for period 1. In keeping with Zulauf, the foundation herd is lagged by two years for beef and dairy and one year for hogs. Like the results obtained in the US, output relative to the foundation herd has increased markedly in Canada over a relatively short period. The figure shows that in Canada, milk production increased the most relative to the foundation herd between the two periods (87%). In the case of broilers, historical data were not available on the broiler breeder population therefore broilers were left out of the Canadian analysis.

Figure 8.7. Productivity relative to foundation herds, Canada



Sources of data: Statistics Canada Tables 32-10-0126 (pig meat), 32-10-0160 (gilts and sows); 32-10-0130 (dairy cows and beef cows), 32-10-0053 (food supply, beef); Statistics Canada Hog Statistics reports, 1997-2001 (sows and bred gilts); Canadian Dairy Commission (milk production).

Figure 8.8 provides a snapshot of livestock productivity through the decades. In the seventies, the average broiler weight at 56 days old was 1.8kg; by 2005, it had more than doubled to 4.2kg per broiler. Feed efficiency in beef has improved over time: in 1950, it required 10 pounds of feed to produce one pound of beef; in 2010, this was down to 6 pounds of feed. Milk productivity in Canada has more than tripled in 50 years: in 1961, the average dairy cow produced 2,787kg milk per year; in 2021, it was 9,647 kg/cow/year (see Figure 10.4 for international comparisons of milk productivity through time).

Figure 8.8. Livestock productivity, then and now

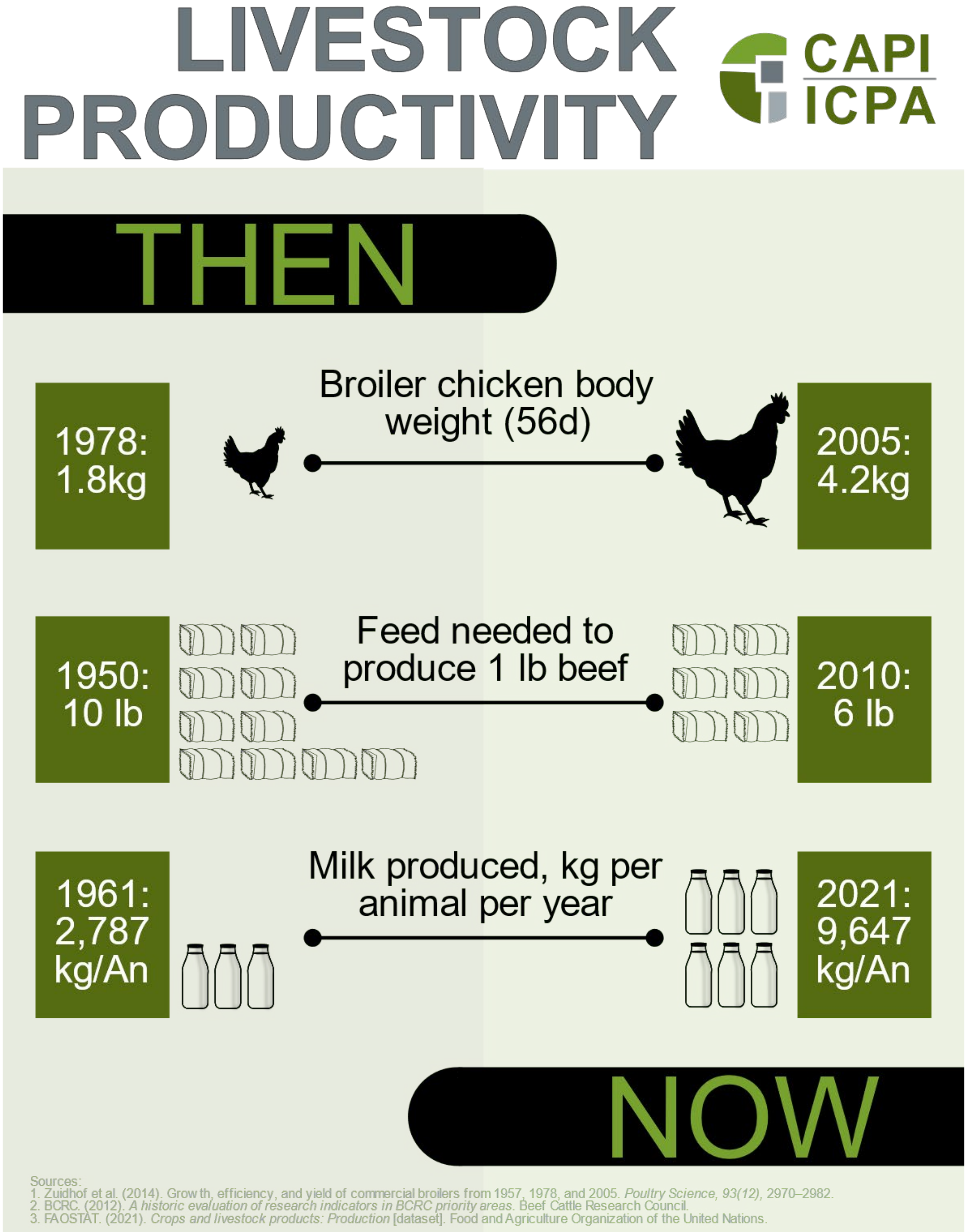


Image created internally.

8.3.1 Precision Technologies in Animal Agriculture

Aquilani *et al.* (2022) defined precision livestock farming as "the combined application of single technologies or multiple tools in integrated systems for real-time and individual monitoring of livestock" (p. 1). These technologies are deployed in a variety of applications, both in confined animal production and in grazing systems. They are also commonly connected to or combined with decision support systems.

Gómez *et al.* (2021) assessed precision technologies for use in monitoring pig welfare. Their review considered the following precision technologies in a review of advanced approaches to swine welfare:

- camera-based technologies
- load cells and flow meters
- accelerometers
- microphones
- thermal cameras
- photoelectric sensors
- RFID technologies for animal identification
- non-contact body sensors

They observed that "a variety of animal-based welfare indicators can be monitored on an individual scale, continuously and in real time" using these tools (p. 16).

Aquilani *et al* (2022) reviewed precision technologies in pasture-based systems. They explored many of the technologies above, mostly with grazing cattle, and also examined virtual fencing to implement intensive grazing management. They observed that "positive outcomes in terms of rangeland conservation, animal welfare, and labour optimization are expected from the spread of precision livestock farming in grazing systems" (p. 1).

Zuidhof (2020) discussed the prospects for precision feeding technologies in poultry to better match feeding with the dietary needs of individual animals. Individual tailored feeding could greatly improve retention of nitrogen, phosphorus and other nutrients in poultry diets; systems have been developed to implement individual feeding for broiler breeder operations, and are being developed for more general application in poultry (M. Zuidhof, 2020). In swine, Andretta *et al.* (2016) found that precision feeding reduced digestible lysine intake by 26%, and reduced nitrogen excretion by 30% and feeding costs by about 10% relative to group feeding.

Precision systems are also employed to identify disease and support decision making, and to increase labour productivity and gaps in labour supply. For example, Casella *et al.* (2023) investigated the use of precision technologies based on the Internet of Things (IoT), such as automatic feeders, scales, and accelerometers, to help detect behavioural changes before outward clinical signs of Bovine Respiratory Disease. Their results showed an accuracy of 88% for labelling sick and healthy calves, with 70% of sick calves predicted 4 days prior to diagnosis, and 80% of persistency status calves are detected within the first five days of sickness – an improvement relative to other approaches (Casella *et al.*, 2023).

Malacco (2022) developed an overview of the effect of automated milking systems using robotics in the dairy industry. His overview noted important advantages of spared labour in milking, but also remarkable data and information that is collected on individual cow health, welfare, behaviour, and nutrition that is valuable for management decisions. Malacco notes studies observing a milk production increase of 5 to 10 percent with automatic milking systems versus conventional twice-daily milking systems, and a 20 percent decrease in the number of employees (Malacco, 2022). Robotic milking systems also have an important social sustainability aspect. Vik *et al.* (2019) analyzed the adoption of robotic milking systems in Norway and observed that, while the economic returns were mixed, "Norwegian farmers invest in milking robots to improve their everyday life – socially and professionally – and they increase the production to finance their investment" (p. 1).

8.3.2 Reproductive Technologies

Georges *et al.* (2019) reviewed studies of genomic applications in livestock. They observed that "Over the past 10 years, genomic selection has been introduced in several major livestock species, and has more than doubled genetic progress in some" (p. 1). One illustration is that the process for obtaining estimated breeding values for individual animals for individual animals can be dramatically shortened using genomic methods, provided that sufficient data exists for a background reference. For example, Georges *et al.* observe that in cattle, genomic methods allow genetic data to be made available 5 years sooner, and with much greater accuracy on low heritability traits.

Holden and Butler (2018) review the evidence of effects of sexed semen technology applied in the dairy and beef cattle production. They found that "Sex-sorted semen is a revolutionary technology for cattle breeding. Greater utilization of sexed semen can increase the efficiency of both dairy and beef production, increase farm profitability and improve environmental sustainability of cattle agriculture" (p. s97). More specifically they observed "increased genetic gain in dairy herd, increased value of beef output from the dairy herd, and reduced greenhouse gas emissions from beef" (p. s97). However, Holden and Butler worry that even small reductions in fertility with sexed semen could negate the economic benefit.

8.4 Observations

Canadian animal agriculture has made impressive gains in productivity and output, distributed across animal industries. These have occurred as research effort and innovation has occurred targeting critical bottlenecks. The fundamental bottleneck is conversion efficiency, which ultimately maps back to the agricultural land base that supplies animal feedstuffs. It also relates to the foundation breeding herd/flock, and also to the use and availability of human resources in livestock agriculture. Progress is ongoing addressing these fundamental bottlenecks, which involves a broad spectrum of factors: nutrition, epidemiology, housing, animal husbandry, and management/economics. Impressive developments in animal genetics and breed, along with precision data capture and automation, have supported this progress.

There are also specific challenges and problems of animal agriculture, much of which falls within the purview of conversion efficiency. For example, manure emissions can readily result in offsite losses of nitrogen and phosphorus, which (in addition to offsite damages) implies a loss of plant nutrients and growth potential, and ultimately a loss of animal feedstuffs; this connects animal emissions with land use efficiency. Animal diseases also impact conversion efficiency, but with potentially much greater impacts related to export market access.

In many cases, the challenges and problems of animal agriculture cannot be readily contained within the farm or the industry value chain, nor focused solely on conversion efficiency – and research and innovation must target these explicitly. Work is well established and ongoing to measure, understand pathways, and develop innovations that will reduce the unintended effects of emissions from livestock agriculture. Thorough data is collected and shared on the use of animal health products, with industry initiatives for judicious use of the products most of concern for resistance, and alternatives to certain antimicrobial products actively pursued, such as through vaccines and phage animal health products.

Perhaps the most challenging problem is biological system overload, and the unintended pursuit of conversion efficiency at the exclusion of animal function, and ultimately of animal resilience. As discussed above, conversion efficiency is fundamental to sustainable land use, and ambition in animal development focused on conversion efficiency is critical. The extent to which this can or should be traded off with non-productive aspects is the subject of development, consistent with some aspects of improved animal welfare and with resilience to prospective future challenges such as new diseases and extreme weather.

9. Valuation of animal agriculture stocks and flows

9.1 Economic impact of animal agriculture in Canada and the regions

With about $90 billion in farm cash receipts and manufacturing shipments, employment of over 150,000, and GDP of $14.7 billion in 2022, Canada's meat, poultry and egg and dairy producers and processors contributed significantly to Canada's and the provinces' economies, to the profitability of Canadian farmers, ranchers and other players in the chain, as well as to the health and well-being of rural communities and Canadian and international consumers (Table 9.1).

Table 9.1. Economic contribution of animal agriculture and meat, dairy, and poultry and egg product manufacturing, 2021-2022

2022 economic contribution	Farm cash receipts ($B), 2022[1, 2]	Employment (salaried employees, persons), 2021[3]	Farm operators, persons), 2021[4]	GDP ($B), 2022[5]
Primary animal production[1]	**33.6**	**72,553**	**82,370**	**5.7**
Beef cattle & calves	11.9	14,642	49,730	
Dairy (unprocessed milk)	8.2	31,717	16,510	
Hogs	6.5	11,031	3,715	
Sheep/lambs	0.2		4,875	
Total poultry & eggs	6.0	15,163	7,540	
Chicken	3.8			
Turkey	0.4			
Eggs	1.6			
Chick hatcheries	0.1			
Meat, poultry, & dairy products manufacturing[2]	**55.9**	**91,483**		**9.0**
Meat & poultry manufacturing	38.5	64,059		6.1
Poultry manufacturing	9.7			
Animal slaughtering except poultry	*	*	*	*
Rendering & meat processing from carcasses	10.7	27,424		
Dairy product manufacturing	17.4	10,479		2.9
Animal food/feed manufacturing	11.9			1.6
Total animal production and manufacturing (excluding feed)	**89.5**	**164,036**		**14.7**

* Data suppressed due to confidentiality (too few plants).

Sources:
(1) (Statistics Canada, 2023b). *Farm cash receipts, annual (x 1,000)* (Table 32-10-0045-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210004501
(2) (Monthly Survey of Manufacturing, 2023). *Manufacturers' sales, inventories, orders and inventory to sales ratios, by industry* (Table 16-10-0047-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1610004701
(3) (Agriculture and Agri-Food Labour Statistics Program, 2023a). *Employees in the agriculture sector, and agricultural operations with at least one employee, by industry* (Table 32-10-0215-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210021501
(4) (Statistics Canada, 2023c). *Farm operators classified by farm type and operator income class, Agriculture–Population Linkage, 2021* (Table 32-10-0400-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210040001
(5) **(Statistics Canada, 2023e)**. *Gross domestic product (GDP) at basic prices, by industry, annual average* (Table 36-10-0434-03) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610043403

Given the fact that livestock farms are distributed across the country in all provinces and territories, they support rural economies and livelihoods in regions that might not otherwise attract large industry, but may support grazing and food access where these products might be otherwise less accessible and hence unaffordable, such as in northern communities, in areas of marginal or environmentally sensitive habitat such as grasslands, or on

Indigenous reserves. Table 9.2Table 9.2 shows how livestock farms were distributed across Canada, by farm type in 2021 (Statistics Canada, 2022a).

Table 9.2. Distribution of livestock farms by farm type and province, 2021

Geog.	Beef ranching and farming, including feedlots	Dairy cattle and milk production	Hog and pig farming	Poultry and egg production	Sheep and goat farming	Other animal	Total livestock farms
Canada	39,633	9,403	3,016	5,296	3,575	15,873	**76,796**
NFL & Lab.	44	27	1	19	21	19	131
PEI	269	157	7	22	24	62	541
NS	526	202	10	154	72	281	1,245
NB	344	162	9	53	33	139	740
Quebec	2,395	4,422	1,276	913	628	1,789	11,423
Ontario	7,986	3,188	1,189	2,061	1,309	4,556	20,289
MB	3,574	238	245	263	174	1,015	5,509
SK	7,610	122	50	145	205	1,488	9,620
Alberta	14,601	393	136	400	473	4,174	20,177
BC	2,284	492	93	1,266	636	2,350	7,121

Source: (Statistics Canada, 2022a). *Farms classified by farm type, Census of Agriculture, 2021* (Table 32-10-0231-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210023101

When looking at the total economic impacts, it is important to look beyond the ***direct*** **impacts,** such as those described in Table 9.1, and consider the ***indirect impacts***, such as backward and forward linkages and interdependencies across other sectors of the Canadian economy. This includes input suppliers and agribusinesses who generate economic activity when supplying the inputs and services to livestock producers (i.e. backward linkages). It also includes the impacts from the economic activity of processors, retailers, transporters and distributors who add value after purchasing the primary products, which are then sold to consumers (i.e. forward linkages). There are strong interdependencies between animal agriculture and the crop sector, which provides feed and bedding as inputs. Farms that supply eggs for hatching, chicks and calves from the breeding flock or herds, also have strong linkages with livestock producers as do other players in the economy. Clearly, decisions taken by one producer or firm in animal agriculture affect many other individuals or enterprises. These secondary impacts can be estimated using multipliers to determine the overall economic impact of animal agriculture in Canada and the regions.

Secondary impacts are generated based on two components: 1) ***indirect impacts*** created through purchases of inputs from other industries (that would not otherwise have occurred) or by adding value along the value chain; and through 2***) induced impacts*** when workers in animal agriculture and related industries spend the income they earned from wages and salaries on other consumer goods and services, thereby generating further economic activity (Kulshreshtha, 2012, p. xiv). Hence, total impacts are estimated from the sum of the three impacts- direct, indirect and induced. Multipliers provided by Statistics Canada's Input-Output model can be used to estimate these economic impacts for animal industries. However, several of the industry associations have estimated these impacts using other methods as described in various reports that are discussed below.

9.1.1 Statistics Canada's multipliers for animal agriculture and its total impacts

The latest multipliers for the Canadian economy were published by Statistics Canada for 2019. Table 9.3 shows the direct and total economic impact multipliers for animal production, dairy, and meat and poultry product manufacturing. Presented in the table are the direct impact multipliers, as well as the total economic multipliers, which account for the direct, indirect, and induced impacts of a change in economic activity, as measured by farm cash receipts or manufacturing shipments. Additional multipliers, called Type II multipliers are also presented in Table 9.3. These multipliers measure the ratio of the direct, indirect and induced impact multiplier to the direct multiplier and allow us to determine how much GDP, output or jobs are generated from every additional dollar of income or sales or for every job created. As an example, with a Type II multiplier of 4.129 for meat product manufacturing, we know that for every dollar of sales generated in meat product manufacturing, an additional 3.129 dollars (4.129 — 1) of GDP is generated in the overall economy. Similarly, for every job created in dairy product manufacturing, an additional 5.3 jobs are created in the overall economy.

Table 9.3. Statistics Canada's economic impact multipliers for animal production and manufacturing, 2019

	Animal production			Dairy product manufacturing			Meat and poultry product manufacturing		
	Direct	Total economic multiplier	Type II	Direct	Total economic multiplier	Type II	Direct	Total economic multiplier	Type II
Farm cash receipts or manufacturing sales ($B)[1]	**$33.6**	**-**	**-**	**$17.4**	**-**	**-**	**$38.5**	**-**	**-**
Multipliers[2]									
Output	1	2.75	-	1	2.924	-	1	2.978	-
GDP at basic prices	0.192	0.965	5.019	0.228	0.982	4.3	0.243	1.003	4.129
Labour income	0.124	0.491	3.949	0.143	0.538	3.758	0.149	0.546	3.654
Taxes on production	0.008	0.05	-	0.003	0.041	-	0.003	0.042	-
Jobs per $M of output	4.854	11.718	2.414	1.554	9.81	6.311	2.064	10.5	5.088

Sources:
(1) (Statistics Canada, 2023b). *Farm cash receipts, annual (x 1,000)* (Table 32-10-0045-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210004501
(2) (Supply, Use and Input-Output Tables, 2022). *Input-output multipliers, detail level* (Table 36-10-0594-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610059401

Multipliers are a basic tool of economic analysis that quantify the linkages between a change in output in one industry and its ripple effects on other industries in terms of jobs or output. They are derived from the Input-Output tables developed by Statistics Canada to measure economic activity in Canada. These multipliers, applied to farm cash receipts from livestock production and/or shipments from animal food, dairy and meat and poultry product manufacturing provide an estimate of the contribution of animal agriculture to the Canadian economy, as measured by output, GDP, labour income, tax revenues and jobs. The results are shown in Table 9.4. As an example, farm cash receipts from animal production were $33.6B in 2022 (Statistics Canada, 2023a; see Table 9.1). As a result of this activity, the direct, indirect, and induced impacts were estimated at an additional $32.4B generated in the economy ($33.6 × 0.965; see Table 9.3). Based on the Type II multipliers, we can see that for every dollar of sales generated by livestock producers, an additional $168.6 dollars of GDP are generated in the overall economy ($33.6 × 5.019; see Table 9.3). Similarly, an additional 81,110 jobs are created as a result of the $33.6B in farm cash receipts generated in animal agriculture ($33.6 × 2.414 jobs per $M; see Table 9.3), leading to 393,725 jobs (FTE), $16.5B in labour income ($33.6 ×, 0.491; see Table 9.3) and $1.7B in tax revenues ($33.6 × 0.05; see Table 9.3) from the direct, indirect, and induced effects of this economic activity throughout the economy.

Table 9.4. Total economic impacts using Statistics Canada multipliers for animal production and manufacturing, 2019

	Cplo cn'rtqfwevkqp			Fckt{"rtqfwev'o cpwhcewtkpi			Ogcv'rtqfwev'o cpwhcewtkpi		
	Fktgev	Vqvcn' geqpqo ke" o wnkr nkgt	V{r g'KK	Fktgev	Vqvcn' geqpqo ke" o wnkr nkgt	V{r g'KK	Fktgev	Vqvcn' geqpqo ke" o wnkr nkgt	V{r g'KK
Hcto "ecuj "tgegkr vu"qt" o cpwhcewtkpi "ucngu"*&D+	&5508	/	/	&3906	/	/	&5: 07	/	/
Qwr w'*&D+	&5508	&; 406	/	&3906	&720,	/	&5: 07	&33609	/
I FR'cv'dcuke'r tkegu	&807	&5406	&38: 08	&602	&3903	&960	&; 06	&5: 08	&37; 02
Ncdqwt'kpeqo g'*&D+	&604	&3807	&35409	&407	&; 06	&8706	&709	&4302	&36209
Vczgu'qp'r tqf wevkqp'*&D+	&205	&309	/	&203	&209	/	&203	&308	/
Lqdu'r gt"&O "qh'qwr w'	385.2; 6	5; 5.947	: 3.332	74.436	54; .838	434.572	8; .572	574.: 22	392.; 79

9.1.2 Figures are the products of the farm cash receipts, multiplied by the various multipliers listed in Table 9.3.Estimates of the Economic Impact of the Beef Cattle Sector in Canada

Several industry associations have developed their own estimates of the economic impact of the various animal agriculture commodities. As an example, the Canadian Cattle Association (CCA) estimated that the beef industry contributed about $22 billion to Canada's GDP based on market prices (2019-2021), and generated 347,000 jobs, either directly or indirectly, with every job in the sector yielding another 3.9 jobs elsewhere in the economy (Beef Cattle Research Council, 2021). The CCA explains that for every $1 of income received by workers and farm owners, another $6.22 is created elsewhere (Canadian Cattle Association, 2023a). Hence, the beef sector is a major driver of Canadian economic activity through the strong backward and forward linkages across the entire beef value chain.

Earlier work by Kulshreshtha (2012) for the CCA provided a detailed analysis of the economic impacts of cattle production in Canada. Making use of both Statistics Canada Input-Output multipliers and estimates from his own model of the cow-calf, backgrounding, feedlot and meat processing industries, he was able to estimate multipliers and economic impacts for the Canadian economy, Eastern Canada, Western Canada and the Province of Alberta in 2011. His model was called the Canadian Regional Cattle Sector Input-Output (CRECSIO) model. Table 9.5 shows how sales of goods and services from the cow-calf, backgrounding and feeder/feedlots industries have led to an overall economic impact of $19.8 B in additional sales in 2011, They also contributed to GDP of $7.9 B and employment of 165,164 in the Canadian economy, with the feeder/feedlot sector contributing the most.

Table 9.5. The economic impact of the Canadian cattle sector, 2011

Total Economic Impact (Type II) of the Canadian Cattle Sector,2011				
Indicator	Cow-calf	Backgrounding	Feeder/Feedlots	Total Farm Level
Sales of Goods & Services ($M)	$1,686	$8,255	$9,868	$19,809
GDP at Market Prices ($M)	$714	$3,039	$4,164	$7,917
Labour Income ($M)	$440	$1,853	$2,699	$4,992
Employment (PY)	14,259	68,218	82,687	165,164

Source: Kulshreshtha *et al.* (2012)

When Kulshreshtha (2012) considered both the cattle production and processing sectors together, he estimated that they contributed to an additional $33 B in sales, $13.2B in GDP, of which $8.1 was labour income, and 228,811 jobs in 2011, demonstrating the importance of the Canadian cattle industry (both farm level and processing) to the Canadian economy (Table 9.6).

He also estimated the impacts for Eastern Canada, Western Canada and Alberta's cattle industries. Alberta is home to the majority of beef producers and processors along with the other Western provinces. This is evident from the share of beef cattle farms and feedlots and animal slaughtering establishments that are found there (see Table 9.2 above and Table 7.4). However, Eastern Canada has its own cattle industry with abundant corn and forages available for feed, and there is significant movement of cattle, primarily feeder cattle from Western Canada to Ontario and Quebec to be fed and slaughtered in meat plants there. As a result, Alberta's cattle industry generated $5.9B in GDP and 62,612 jobs in Alberta, compared to Eastern Canada where GDP was $2.6B higher as a result, and 63,907 jobs were created (Table 9.6). This compares to Western Canada as a whole, where GDP was $8.9B higher and 127,677 jobs were created as a result of the cattle industry in Western Canada, almost double Eastern Canada's impacts.

Table 9.6. The Economic Impacts of Both Farm Level Cattle and Processing Sectors, 2011

Total Net Economic Impacts (Type II) of Canadian Cattle and Processing Sector, 2011				
Indicator	Canada	Eastern Canada	Western Canada	Alberta
Production of Goods and Services($M)	$32,724	$8,096	$ 24,138	$16,942
GDP at Market Prices ($M)	$13,200	$2,552	$ 8,858	$5,875
Labour Income ($M)	$8,065	$1,524	$ 5,529	$3,640
Employment (Person years)	228,811	63,907	127,677	62,612

Source: Kulshreshtha *et al.* 2012.

9.1.3 Economic Impact of the Canadian Dairy Industry

The Dairy Farmers of Canada have published economic impact studies of the Canadian dairy industry in previous years, but recently updated this information for 2021 (Dairy Farmers of Canada, 2021).

The Dairy Farmers of Canada estimated multipliers in order to determine the contribution and impact of the Canadian dairy industry to the Canadian economy, measured by GDP, jobs and tax revenues. They made use of multipliers for both dairy production at farm level and dairy product manufacturing, for Canada and for each of the provinces. According to the most recent study, the Canadian dairy industry (both farm level and processing) generated 195,115 jobs, $19.1 billion in GDP, and $3.3 B in tax revenues in 2021 (Table 9.7). This was based on the fact that dairy production by the 11,212 dairy farms across the country, reported farm cash receipts of $7.3 billion from milk and cream in 2021. At the same time, 406 dairy processing plants in Canada reported manufacturing shipments of $17.4 billion for dairy products, including fluid and powdered milk, cream, cheese, yogurt and other dairy products (see section 7.4.2).

Dairy farms and processing plants are distributed across the country in each province, but have different degrees of impact, depending on the size and importance of the dairy industry in that province. For example, the GDP impact of the dairy industry is greatest in Ontario at $6.3 billion because there are more dairy processing plants in this province where the population is greatest (Table 9.7). Quebec shows the second highest GDP impacts of any province and the highest farm cash receipts from dairy production, primarily because Quebec reports the largest number of dairy farms in Canada. The impact on jobs was greatest in Quebec, with 65,998 jobs generated by dairy industry activity and the linkages to other industries. Ontario's industry had the next largest impact on jobs of any province with 64,725 out of the total number of jobs generated for Canada of 195,115 jobs in 2021 (Dairy Farmers of Canada, 2021).

Table 9.7. Economic impacts of dairy industry across Canada, 2021

Total economic impact of the Canadian dairy industry including direct, indirect, and induced effects, 2021			
	GDP at Market Prices ($M)	Total Tax Revenues ($M)	Jobs (FTEs)
Canada	19,111.1	3,252.7	195,115
NL & Labrador	101.8	15.5	911
PEI	154.4	24.4	2,026
Nova Scotia	353.1	62.6	4,336
New Brunswick	263.9	46.5	3,325
Quebec	6,124.9	1,034.0	65,998
Ontario	6,284.5	1,054.1	64,725
Manitoba	1,042.2	196.9	10,557

Saskatchewan	663.2	91.8	5,835
Alberta	2,006.4	345.7	16,373
British Columbia	2,110.2	380.7	20,992

Source: (Dairy Farmers of Canada, 2021). *Highlights of Report on the Canadian Dairy Industry in 2021.* [Personal communication, unpublished]

Table 9.8. Economic impact of Canadian dairy industry: production and processing, 2021

Total economic impact (direct, indirect and induced) of Canadian dairy production and processing industries									
	Dairy production					Dairy processing			
	# farms reporting dairy cows	Farm cash receipts ($M)	GDP* ($M)	Total tax revenues ($M)	Jobs (FTEs)	Manu-facturing sales ($M)	GDP* (M)	Total tax revenues ($M)	Jobs (FTEs)
Canada	11,212	7,386.1	10,683.4	1810.9	111,564	18,633.6	8427.7	1441.8	83,552
NL / Lab.	31	46.9	50.0	6.9	405	x	51.8	8.6	506
PEI	172	95.8	94.5	15.7	1,509	x	59.9	8.7	517
NS	240	159.2	201.7	34.0	2,672	x	151.4	28.6	1,664
NB	175	129.0	155.9	28.0	2,226	x	108	18.5	1,099
Quebec	4,679	2,661.2	3,480.6	598.1	39,657	5739.4	2644.3	435.9	26,341
Ontario	3,793	2,340.0	3,675.5	629.2	38,325	5110.2	2609	424.9	26,400
Manitoba	363	325.8	500.1	89.0	4,581	913.9	542.1	107.9	5,976
SK	330	226.2	434.4	62.4	3,763	x	228.8	29.3	2,072
Alberta	815	681.2	1,191.3	199.7	9,823	1455.3	815.1	145.9	6,550
BC	614	720.9	895.9	147.5	8,582	1885.2	1214.4	233.2	12,410

* GDP is at market prices.
x suppressed to meet the confidentiality requirements of the *Statistics Act*.

Table created internally.
Data sources:

(1) (Dairy Farmers of Canada, 2021). Highlights of Report on the Canadian Dairy Industry in 2021. [Personal communication, unpublished]
(2) (Statistics Canada, 2023b). Farm cash receipts, annual (x 1,000) (Table 32-10-0045-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210004501.
(3) (Census of Agriculture, 2022a). *Cattle inventory on farms* (Table 32-10-0370-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210037001.
(4) (Monthly Survey of Manufacturing, 2023). *Manufacturers' sales, inventories, orders and inventory to sales ratios, by industry* (Table 16-10-0047-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1610004701.

9.1.4 Economic Impact of the Canadian Chicken Industry

According to the 2022 Annual Report of the Chicken Farmers of Canada, the 2,823 Canadian chicken farmers who raise the fastest growing protein source are responsible stewards of the land, and are key contributors to Canada's urban and rural economies (Chicken Farmers of Canada, 2022a). These farmers play a significant role in the value chain by creating jobs and stimulating the economy in each of the ten provinces, thereby strengthening both urban and rural economic health and the vitality of farm families across the country.

The annual report made use of 2018 estimates from an economic impact study of the Canadian poultry and egg industry by Kevin Grier Marketing Analysis and Consulting Inc. (Chicken Farmers of Canada, 2020). Using Statistics Canada multipliers and industry statistics from 2018, he measured the economic contribution of the chicken and egg production and processing industry to the Canadian and provincial economies. Results are shown in Figure 9.2 and 9.3 below. He reported that in 2018, 2,877 farmers earning $4.3 B in farm cash receipts, together with 185 poultry and egg processors who had sales of $9.7 B in manufacturing shipments, contributed to an additional $8 B in GDP, $1.9 B in taxes and 101,900 jobs through direct, indirect and induced impacts.

Figure 9.1. Economic impact of Canada's chicken sector with provincial breakdown

	BC	AB	SK	MB	ON	QC	NB	NS	PEI	NL	CANADA
total jobs	14,353	9,745	4,914	4,203	36,093	25,193	3,248	2,625	383	1,026	101,900
to GDP	$1.1 billion	$958 million	$471 million	$325 million	$2.8 billion	$1.8 billion	$226 million	$158 million	$24 million	$80 million	$8 billion
in taxes	$243 million	$205 million	$94 million	$79 million	$659 million	$529 million	$59 million	$43 million	$6 million	$20 million	$1.9 billion

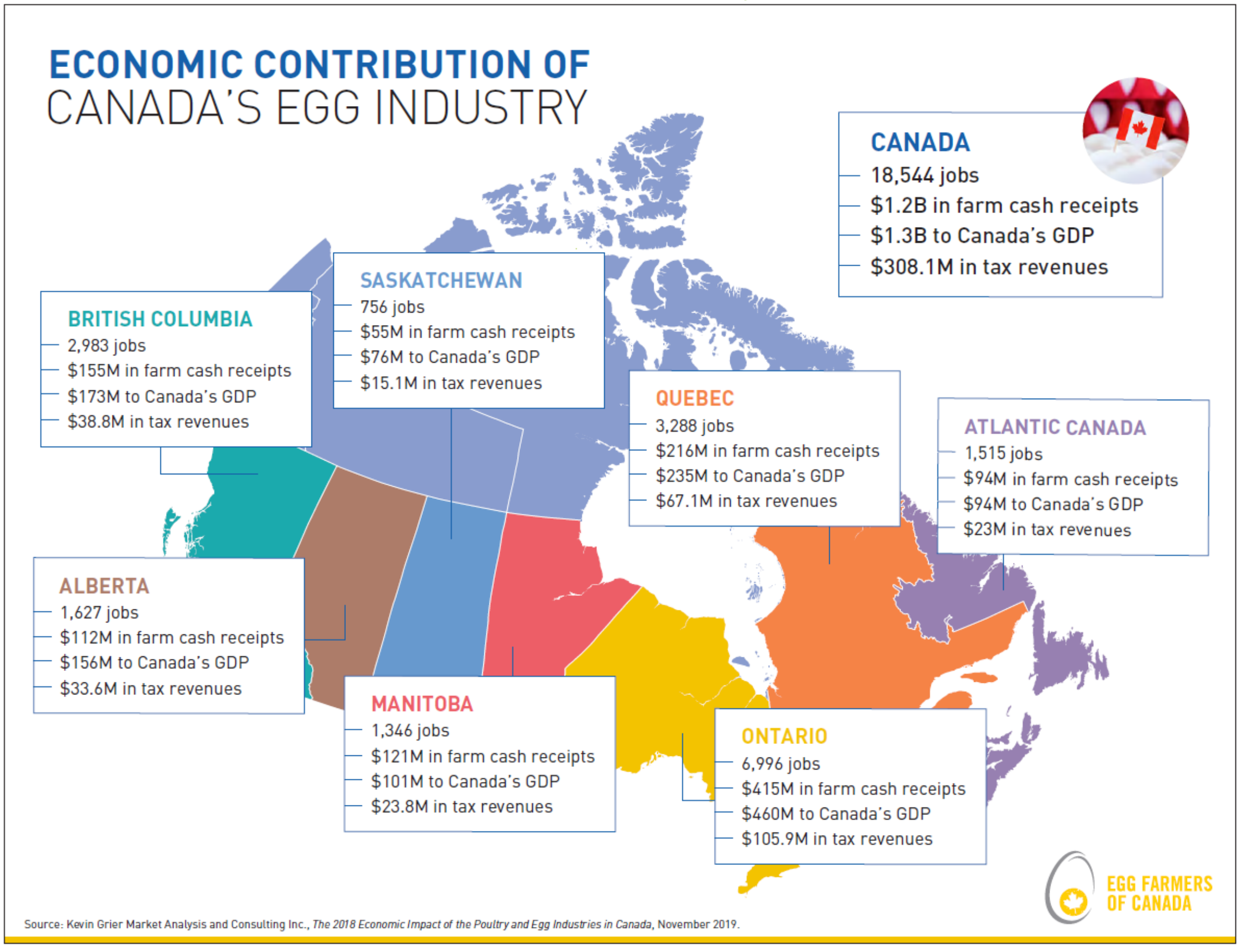
Source: Kevin Grier Marketing Analysis and Consulting Inc., The 2018 Economic Impact of the Poultry and Egg Industries in Canada, November 2019.
Adapted from Statistics Canada, Input-Output Model Simulations, 2019-05-22.

Reprinted from (Chicken Farmers of Canada, 2020). Canada's dairy, poultry & egg sectors. https://www.chickenfarmers.ca/wp-content/uploads/2021/07/SM5-2018-Economic-Contribution-Infographic-2021_E.pdf.

9.1.5 Economic Impact of the Canadian Egg Industry

Kevin Grier also estimated the impact of the Canadian egg industry on the Canadian economy in 2018. His analysis showed how the 2,197 chicken farms producing eggs for consumption and hatching generated $1.2 billion in farm cash receipts, an additional $1.3 B in Canadian GDP, 18,544 jobs and $308 million in tax revenues (Chicken Farmers of Canada, 2020). Figure 9.3 below shows how these impacts were distributed across the country. For example, British Columbia, with the most farms producing eggs (788 farms) (Table 9.2) generated farm cash receipts of $155 million, an additional $173 M in GDP, $39 M in tax revenues and 2,983 jobs. This was followed by Ontario, with 712 farms, and Quebec with 220 farms. Ontario and Quebec also generated significant farm receipts, GDP, tax revenues and jobs as a result of egg production in their provinces. Figure 9.2 shows that Ontario generated $415 million in farm cash receipts, and contributed $460 million to Canada's GDP, 6,996 jobs and $106 million in tax revenues. This compares with the next largest province, Quebec which generated $216 million in farm cash receipts, $235 M to Canada's GDP, an additional 3,288 jobs and $67.1 million in tax revenues.

Figure 9.2. Economic contribution of Canada's egg industry, 2018



Reprinted from (Egg Farmers of Alberta, 2018). *Economic Contribution.* https://eggs.ab.ca/healthy-farms/economic-contribution/.

9.1.6 Economic Impact of the Manitoba Pork Industry

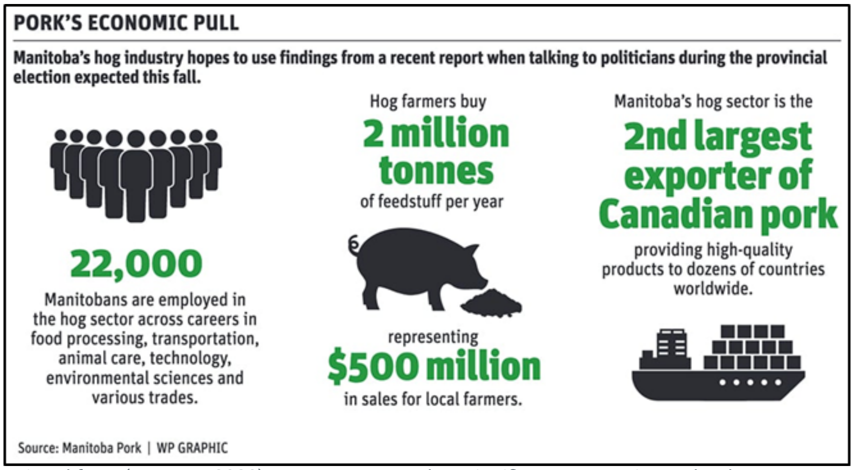
Manitoba Pork recently had Serecon Inc. undertake an economic impact of the Manitoba pork industry. According to their news release, with only 566 hog farms (number of farms reporting pigs), the Manitoba pork industry has a significant impact on the economy (Arnason, 2023). The report found that Manitoba's pork industry contributes $2.3 billion to the province's GDP, which represents about 3.5 percent of Manitoba GDP (Figure 9.3). The industry also employs 22,000 people and handles 55 percent of the agri-food manufacturing jobs in Manitoba.

Serecon looked at the history of the pork industry and how it developed in Manitoba. In 1951, 33,007 farms in Manitoba reported having pigs, but by 2021, that number was 566. The average number of pigs per farm reached its highest point in 2021 at 3,455. The number of hog farms has shrunk over time as farms have gotten bigger, but the farm cash receipts from those farms have grown to more than receipts from cattle in Manitoba, and are a close second behind wheat. In 2022, farm cash receipts from hog farming rose to $1.5 billion, up 25% from the five-year average (2018-22) of $1.2 billion.

Manitoba has two large slaughter plants for hogs — HyLife Foods in Neepawa and the Maple Leaf plant in Brandon. There are smaller plants in Winkler and near Steinbach, but 90 percent of pigs are processed in Brandon and Neepawa. Manitoba accounted for 23 percent of the hogs slaughtered in Canada, at 4.96 million, compared to Ontario at 5.4 million and Quebec at 7.19 million. The number of hogs processed in Manitoba increased from 3.68 million in 2007 to 4.96 million in 2022, a 35 percent increase. A percentage of that pork from those plants is consumed in Canada, but a sizable share is exported. In 2022, Manitoba's exports of fresh, chilled or frozen meat were $1.2 billion and cured meat exports were $87.5 million. The main export destinations were Japan (40.3

percent), the United States (27.4 percent), China (9.6 percent) and Mexico (9.5 percent). The province also exported $256 million worth of live hogs in 2022. In light of Winkler Meats partnering with Johnsonville, a major sausage maker in the U.S where the two companies are spending $52 million to expand the Winkler Meats processing plant, the number of sows slaughtered in Canada is expected to increase. For an indicator of the economic contribution of the pork industry in Canada as a whole, the Canadian Pork Council reported that given the 7,000 hog farms and farm cash receipts of $4.1 B in Canada, the industry supports 31,000 farm jobs which, in turn, contribute to 103,000 direct, indirect and induced jobs across the country. The total economic activity or output of these jobs generates $23.8 billion when farms, inputs, processing and pork exports are included (Canadian Pork Council, 2023b).

Figure 9.3. The economic impact of Manitoba's pork industry, 2022



Reprinted from (Arnason, 2023). Man. Hog sector has significant economic reach. *The Western Producer*. https://www.producer.com/markets/man-hog-sector-has-significant-economic-reach-2/.

9.1.7 Economic Impact of Quebec Supply Management Industries

According to *le Mouvement pour la gestion de l'offre*, Quebec's supply managed industries play an important role in Quebec, supplying a stable supply of high quality, healthy and sustainable animal protein products, which contribute to the province's jobs, rural economic activity, farm family livelihoods and affordable locally-supplied food (Le mouvement pour la gestion de l'offre, 2023). They recently published their own estimates of the economic impact of these industries in Quebec. Accordingly, based on the economic activity of 6,513 supply managed farms in Quebec, including dairy, poultry and eggs, 116,000 jobs are generated as a result, with a contribution of $8.7 B to provincial GDP, and $2.1 B in tax revenues generated for the government. More specifically, the 4,753 dairy farms generate 83,000 direct, indirect and induced jobs, $ 2.5 B in farm cash receipts, $6.2 B in provincial GDP, and $1.3 B in tax revenues. The Quebec poultry sector, of which there are 889 farms, generate 27,300 direct, indirect and induced jobs, as well as $726 million in farm cash receipts, $2.1 B in GDP, and $689 million in tax revenues. Finally, the Quebec egg industry supplied by 114 farms, generated 3,300 direct, indirect and induced jobs, at the same time that farm cash receipts were $168 million, and provincial GDP was an additional $255 million, with $83 M in tax revenues as a result. Finally, 37 farms that raise hatching eggs generated 210 jobs, $80 million in farm cash receipts, $120 million in GDP and $46 Million in tax revenues. Together these sectors play a role in Quebec's vibrant agriculture sector that contributes to positive rural economic activity and high quality safe and healthy local food for Quebecers.

9.1.8 Economic Impact of Ontario Agri-businesses – Feed Manufacturers, Grain Elevators, and Crop Input Suppliers

The Ontario Agri-business Association commissioned a study by MNP to estimate the economic impact of Ontario's Agri-business industry in 2021 (MNP LLP, 2023). This industry includes crop Input suppliers, feed manufacturers and grain elevators. Making use of Statistics Canada's multipliers and other financial and sales data, MNP was able to describe how this sector contributes to the Ontario economy. They concluded that the Ontario Agri-business as a whole generated $8.2 billion in output, a total GDP of $3.6 billion, total employment of 24,650 full time equivalents and total government revenues of $1 billion (Table 9.9). Feed manufacturers which are a component of this industry, had the largest impact of the three sub-sectors, generating 11,100 jobs and GDP of $1.7 billion. This was followed by grain elevators with $1.1 B in GDP, and 6,700 jobs (MNP LLP, 2023, p. 36).

Table 9.9. Economic impacts of Ontario's agri-businesses

Economic Impacts for Ontario Agri-businesses, 2022	Feed Manufacturers			Agri-food Businesses (Feed manufacturers, grain elevators and crop input suppliers)		
	Output ($M)	GDP($M)	Employment (FTEs)	Output ($M)	GDP($M)	Employment (FTEs)
Direct	$ 2,524	$ 580	2,400	$ 4,370	$ 1,637	9,150
Indirect	$ 1,918	$ 835	6,700	$ 2,771	$ 1,312	10,800
Induced	$ 433	$ 253	2,000	$ 1,030	$ 604	4,700
Total	$ 4,875	$ 1,668	11,100	$ 8,171	$ 3,553	24,650

Table created internally. Data source: (MNP LLP, 2023). Economic Impact Study of the Ontario Agri-business Industry (Updated). Ontario Agri Business Association. https://oaba.on.ca/newsFiles/1684936079--Economic_Study_-_2023.pdf.

A summary of the various economic impact studies that have been described above are provided in Table 9.10 below. The results show that animal agriculture has substantial linkages across the Canadian and provincial economies and hence contribute significantly to the health and vitality of Canada's economy.

Table 9.10. Summary of literature on the economic impact of animal agriculture in Canada

Summary of Economic Impacts of Animal Agriculture in Canada	Cattle (Grant 2022)	Cattle (Kulshreshtha 2012)	Chicken (Grier 2018)	Eggs (Grier 2018)	Dairy (DFC & EcoRessources 2015)	Ontario Agri-business (MNP 2022)	Manitoba Pork (Serecon 2021)	Quebec Supply Managed Industries (le mouvement 2022)
Farm Cash Receipts ($M)	$ 11,900	$ 6,564	$ 4,300	$1,200	$ 6,000		$ 1,500	$ 3,474
Manufacturing Shipments ($M)	$ 28,800	24,874	$ 9,700		$ 17,000	$ 4,400		
Output ($M)		$ 32,724				$ 8,171		
GDP ($M)	$ 22,000	$ 13,200	$ 8,000	$1,300	$ 19,900	$ 3,553	$ 2,300	$ 8,700
Labour Income ($M)		$ 8,065						
Tax Revenues ($M)			$ 1,900	$ 308	3,800			$ 2,100
Jobs (FTE)	347,000	22,881	101,900	18,544	220,936	24,650	22,000	116,000

Table created internally based on a scan of the literature.

9.2 Externalities

Externalities are the effects (positive or negative) on agents not involved in a particular transaction, such as the production and consumption of goods and services in the marketplace. A simple example of a positive externality is the protection of wildlife habitat as a result of maintaining a pasture. A negative externality example is the pollution of water by runoff of excess nutrients from agricultural lands. These externalities are not taken into account when the price is set for the goods and services which generated the externalities.

Understanding externalities is important for many reasons. Firstly, as members of a larger value chain, livestock farmers have a responsibility to consider the costs and benefits of their agricultural activities as they extend beyond conventional markets. Secondly, externalities can help inform policy by indicating the total costs and total benefits (explicit and implicit) of a particular intervention. The valuation of externalities can also help farmers adjust by bearing the costs of negative externalities (and reap the benefits of positive externalities) and modifying their practices. Finally, understanding the true effects of animal agriculture can help inform the dialogue as new markets are increasingly being considered (Zafiriou, 2022, p. 1). Examples of these markets include carbon pollution pricing systems and water markets (see Council of Canadian Academies, 2013, p. xvii).

9.2.1 Positive externalities

Ecological goods and services (EG&S) are the environmental benefits resulting from healthy ecosystems (Province of Manitoba, n.d.) and are a common form of positive externalities resulting from animal agriculture. Specifically, one of the well-documented positive externalities from animal agriculture is the protection and upkeep of pasture, especially native grasslands, because of these lands' abilities to sequester and store carbon from the atmosphere and preserve wildlife habitat and biodiversity. Marginal lands are often used as grazing land for cattle, which in turn convert the low-quality forage into high-quality food products for human consumption (Munch, 2023). Pastures contain valuable ecosystems such as wetlands which foster biodiversity and store and filter water, and other plant communities which help support and protect endangered species (Derner *et al.*, 2009).

Community pastures are a livestock grazing model used in Canada and the United States wherein the land is owned by the state rather than by private individuals. Also called "public lands," these pastures provide additional benefits such as lowering the feed costs for farmers, easing the pressure on other lands to produce hay and forage, and easy access for rural and remote communities (Munch, 2023). The habitats within community pastures are sometimes more protected than those on private lands (through prohibition of land alteration and hunting, for example). The open spaces in community pastures can also provide recreation opportunities (Munch, 2023). If farmers and ranchers could be rewarded for the EG&Ss they produce on their pastures and marginal lands, there would be more incentive for them to preserve these lands rather than convert them and lose the EG&S.

EG&Ss provided by pastures are rarely assigned a dollar value and therefore can go unrecognized. However, some researchers and economists have attempted to evaluate these services. The community pastures in the United States, for example, have been estimated to produce $3.7 billion worth of EG&S per year, translating to $20.15 per public acre grazed (Munch, 2023). Compared to the $0.30 per acre per taxpayer required to maintain these lands, the cost-benefit analysis of community pastures is extremely favourable.

9.2.2 Negative externalities

While EG&Ss are an example of positive externalities, there are also negative externalities that result from animal agriculture. A common example is water pollution that can result from fertilizers and manure. Another often-cited externality is GHG emissions. Research is ongoing to find ways to signal and allocate the costs of these negative externalities from the persons suffering them (such as neighbours of livestock farmers who value clean water) to the source. The first step, though, in passing on the costs to the agents involved in the transaction, is the measurement of the externalities.

9.2.3 Estimates of externalities

Externalities are difficult to value. Notwithstanding the lack of data and price signals, much work has been done to estimate, in dollars, the value of both positive and negative externalities. Table 9.11 summarizes work done by Skolrud *et al.* (2020). Using publicly available data from Agriculture and Agri-Food Canada's Agri-Environmental Indicators Report, 2016, the authors use different research-based methodologies for each metric. The table shows that in the Prairie provinces, agriculture (both crop and animal) produce net positive externalities (measured in 2012 Canadian dollars). Taken in aggregate, Canada's agriculture sector produces a net of $284,780,000 in externalities. This is the sum of both positive externalities (wildlife habitat and landscape aesthetics) and negative externalities (water pollution by nitrogen, phosphorus, pesticides, and coliforms; soil erosion; and wildlife and biodiversity loss). Two positive externalities were identified but not quantified: strength of rural communities and wetlands (Skolrud *et al.*, 2020).

Table 9.11. The costs and benefits of positive and negative externalities, 2011 (millions of 2012 $)

		AB	SK	MB	ON	QB
Positive externalities	Wildlife habitat	0.40	2.90	0.35	28.39	0.45
	Landscape aesthetics	1,505	1,839	538	378	246
	Strength of rural communities	*	*	*	*	*
	Wetlands	*	*	*	*	*
Subtotal		*1,505.40*	*1,841.90*	*538.35*	*406.39*	*246.45*
Negative externalities	Nitrogen water pollution	28	85	75	368	429
	Phosphorus water pollution	15.61	23.57	6.96	5.78	3.00
	Pesticide water pollution	116	34	38	404	277
	Coliform water pollution	19.93	15.86	4.30	1.51	0.61
	Soil erosion	497	768	249	424	112
	Wildlife and biodiversity loss	21.12	19.23	6.96	156.69	48.58
Subtotal		*697.66*	*945.66*	*380.22*	*1359.98*	*870.19*
Net		**807.74**	**896.24**	**158.13**	**-953.59**	**-623.74**
Grand total, Canada		**---------------284.78---------------**				

*Not estimated due to lack of sufficient data and/or methodology.
Source: Skolrud, T., Belcher, K., Lloyd-Smith, P., Slade, P., Weersink, A., Abayateye, F., & Prescott, S. (2020). Measuring externalities in Canadian agriculture: Understanding the impact of agricultural production on the environment. Canadian Agri-Food Policy Institute. https://capi-icpa.ca/wp-content/uploads/2020/01/2020-01-15-CAPI-ag-externalities-Skolrud-paper_WEB-2.pdf.

10. International comparisons

To help contextualize the elements of animal agriculture in Canada, this section compares Canada's animal agriculture sector with those in other countries. Firstly, the regulatory costs of registering and maintaining food animal drugs is discussed. Section 10.2 provides measures of competitiveness related to primary production. This includes yields (meat or product per animal) for beef, pork, and dairy and costs of production for cow-calf operations, feedlots, pork, and the cost of feed grain. Section 10.3 compares the production and trade quantities around the world and shows that Canada is a material beef and pork net exporter, which has implications related to global food security as well as international and domestic policy. An example of such policy is emissions policy, which is treated in section 10.4, showing that Canada is a low-emissions intensity producer of beef and pork, relative to other countries.

10.1 Regulatory costs of livestock animal health products

Animal health products are designed to optimize animal health and welfare. Products range from dewormers to vitamins to antibiotics and vaccines and can be administered orally (such as a pill, liquid, or feed additive), injected into the muscle, or applied topically. Each country has its own regulatory framework for authorizing the development (i.e., research and commercialization), sale, and use of livestock pharmaceuticals.

This section compares the costs of registering new pharmaceutical products and presents focused results from the Global Benchmarking Survey (HealthforAnimals, 2020a). The analysis shows that Canada has a comparative disadvantage in the regulatory burden for bringing veterinary drugs to market and maintaining them post-approval. This disadvantage is borne out through a relatively small market in Canada, more drug establishment requirements, higher post-approval costs, and a lack of recognition of drugs already approved and proven effective in other jurisdictions such as the United States and Europe.

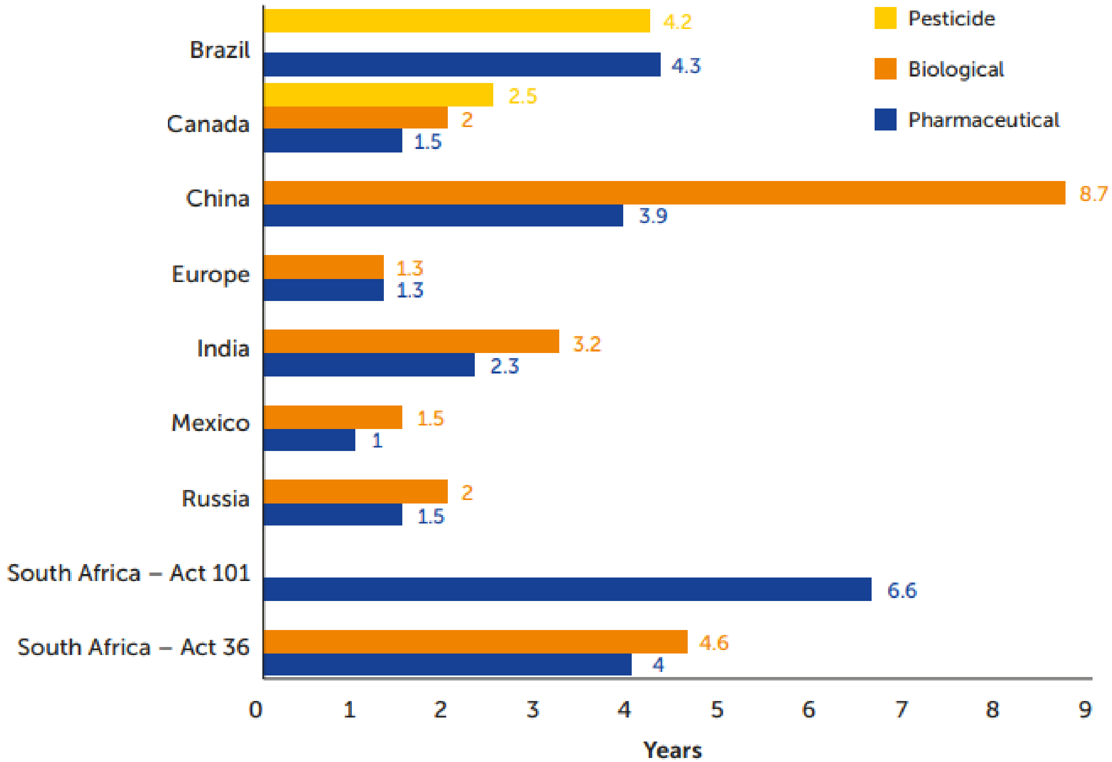
10.1.1 Global Benchmarking Survey

HealthforAnimals is a non-profit NGO which represents manufacturers of animal health products (including livestock pharmaceuticals) and associations (HealthforAnimals, 2020b, p. 1) which publishes a benchmarking survey every five years. It reports on six areas: 1) the impact of regulations on innovation; 2) commercialisation of existing products; 3) regulatory trends; 4) hopes and expectations for the next five years; and 6) regulatory cooperation and special product categories.

The latest Global Benchmarking Survey report was published in 2020 and shows that in Canada, the average time to approval for new pharmaceuticals for major food animals is 1.5 years (dark blue bars, Figure 10.1). The wait time is lowest in Mexico (1 year) and highest in South Africa (6.6 years). The United States is not shown because it uses a phased process which is not comparable with other countries. However, an internal survey of US companies showed that it takes an average of seven years from the time of opening an investigational new animal drug to the time of approval (HealthforAnimals, 2020b, p. 18).

The Global Benchmarking Survey report reveals that animal health companies perceive that the cost of new product development increased 10 to 25% from 2015 to 2020 in Canada. In comparison, some companies feel that costs have risen in the United States by 26 to 50%. The majority of respondents feel that in Brazil, the rise was 26 to 50%, and some companies state it has risen by more than 50%. In the European market, the perceived rise in cost ranges from 26-50%, 10-25%, or "little change" (HealthforAnimals, 2020b, fig. 12).

Figure 10.1. Average times-to-approval for new product for major food animals



Source: Reprinted from HealthforAnimals. (2020b). Global Benchmarking Survey 2020: Overview Report. [Figure 9]. https://www.healthforanimals.org/wp-content/uploads/2021/06/2020-global-benchmarking-survey-overview.pdf.

10.1.2 Regulatory fees

The fees to register new veterinary drugs in Canada are set by the Minister of Health pursuant to the Food and Drugs Act (Fees in Respect of Drugs and Medical Devices Order, 2019). New fee schedules for veterinary drugs were established by the Treasury Board of Canada on a cost recovery basis in 2019, showing significant fee increases spread over seven fiscal years (2020-2021 through 2026-2027) (Fees in Respect of Drugs and Medical Devices Order, 2019 Schedules 2 & 4). For example, the fee for a new food animal drug submission was $20,375 in 2020-2021 and will be $54,333 in 2026-2027 (Fees in Respect of Drugs and Medical Devices Order, 2019 Schedule 2). Beyond 2026, the fees are set to increase in alignment with the CPI (consumer price index) – an inflation adjustment which had not been done for several decades.

When comparing across various countries, Canada's new drug submission costs are higher (up to $179,000 for a new livestock product dossier) than Japan ($5,500), Australia ($58,000 to $95,000), and the United Kingdom (approximately $48,000), but are lower than those in the US (approximately $903,000) and central Europe ($250,000 to $1,003,000) (Toni Bothwell, personal communication, 2023). With the new fee schedule described above, as of 2026, the cost of registering a novel, non-compendial active pharmaceutical ingredient (API) (one claim, one dosage form, one species) for food animals will be $161,331 in Canada; in Australia (which has a similar market size to Canada's), it was $94,915 as of February 2018 (Canadian Animal Health Institute, 2019, tbl. 1).

Post-approval changes and renewals are more expensive in Canada than in many other countries. For instance, to add a claim for a new active pharmaceutical ingredient, the cost is $13,000 in Canada, compared with $240 in Japan, $4,800 in the UK, $4,700 in Australia, and $13,000 to $60,000 in central Europe (which includes the EU) (Toni Bothwell, personal communication, 2023). Costs may be offset in Canada if drugs have already been approved in other jurisdictions including the United States (HealthforAnimals, 2020b, p. 18).

Compared to other markets, Canada is the only country which requires good manufacturing practise evidence to be less than three years old. This means that inspections are required every few years by Health Canada, a mutually recognized agency (MRA), or a Pharmaceutical Inspection Co-operation Scheme (PIC/S) participating authority in one of its 53 member countries (The Pharmaceutical Inspection Co-operation Scheme, n.d.; Toni Bothwell, personal communication, 2023).

10.1.3 Changes in veterinarian drug fee policy

Two of the main regulatory bodies for veterinary drugs in Canada are the Veterinary Drugs Directorate (VDD) (a part of Health Canada's Health Products and Food Branch), and the Regulatory Operations and Enforcement Branch (ROEB), which carries out inspections and enforcement activities on behalf of Health Canada (Health Canada, 2019b, 2021; HealthforAnimals, 2020a, p. 34). The Global Benchmarking Survey (Canadian overview) lists the perceived gaps that respondents would like to see addressed going forward within these two entities. Notably, greater harmonization with international drug requirements and approvals is desired from the VDD (HealthforAnimals, 2020a, p. 29).

Table 10.1. Perceived gaps and changes desired in Canadian regulatory approach to vet drugs by animal health product firms

Regulatory body	Perceived gaps and mitigation
VDD	• Move to greater use of benefit-risk assessment approaches • Updating of guidance documents (GLs) to support single review passes for products • Increased use and acceptance of foreign reviews and decisions • Move to dose ranges and alignment in maximum residue assessments • Elimination of redundant need for endotoxin testing in favour of alignment with the EU requirement • Alignment over the interpretation of VICH guidelines
ROEB	• Robust triaging of foreign site assessments • Improved timeliness of reviews using modern system approach • Working with manufacturer on observations before going public • Better understanding of veterinary requirements by inspectors • Better oversight and more inspection of compounding facilities to ensure a level playing field, as well as the safety and efficacy of compounded products

Table reproduced from HealthforAnimals. (2020a). Global Benchmarking Survey 2020: Canada. https://healthforanimals.publishingbureau.co.uk/wp-content/uploads/2021/05/global-benchmarking-survey-2020-canada.pdf, Table 15.

When considering registration costs, renewal fees, and regulatory burden, veterinary drug companies in Canada have a comparative disadvantage relative to similar markets in the world. With innovation costs of approximately $39 million per food animal drug and no returns on investment for the first three to seven years, (Canadian Animal Health Institute, 2019, p. 1), the development of food animal health products in Canada risks lagging behind other jurisdictions.

Overall, the HealthforAnimals' Global Benchmarking Survey summarized the challenges in the Canadian market as follows. As discussed, Canada's market for animal health products is relatively small, and yet, fees are disproportionately large in Canada, with ongoing fee increases through 2026; this may result in the removal of some products from the Canadian market, and will almost certainly hamper private investment in research and development (HealthforAnimals, 2020b, p. 8). While joint and parallel reviews with other regulatory authorities have improved the innovation environment in Canada, mandatory defensive R&D costs have increased due to new regulatory requirements. Canada's existing regulatory framework is in need of modernization and increased transparency, including harmonization with products approved in the European Union and the United States (HealthforAnimals, 2020b, p. 8, 2020a, p. 3). Another factor affecting the innovation environment is a lack of financial resources, which are diverted in large part to fees for new product development as well as product maintenance (HealthforAnimals, 2020a, pp. 10, 21). In terms of non-financial burden, the time to gain registration for a major new product for major feed animals has generally decreased since 2011, ranging anywhere from one to three years, but there is a one-year backlog of submissions with the Canadian Food Inspection Agency (HealthforAnimals, 2020a, p. 13).

10.2 Measures of competitiveness

Economic competitiveness is a concept fundamental to the profitability and success of a country, industry, or firm. It is defined by the OECD as "the degree to which a country can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the long term" (OECD, n.d., as cited in Oginskyy et al., 2011, p. 2). In general, competitiveness (of a farm, region, or country) relates to output generated relative to inputs, accounting for economic values, relative to others. A range of measures exist, each of which can capture specific aspects of competitiveness. Physical measures, such as feed conversion, can be an indicator of a country's ability to convert feedstuffs into livestock outputs versus others; however, it lacks measures of price/value for inputs and outputs. Comparative cost can rank production costs across countries, but it obscures the value of the output, recognizing that proportionately higher output values can justify higher production costs. Comparative profit margins overcome this, but it is important that the measures be entirely comparable, and subsidies also obscure the meaning of the comparisons.

Many measures of competitiveness by country are available but this section is particularly focused on the competitiveness of Canada's animal agriculture sector. Indicators are presented based on available data shown in various tables and charts in this section. To provide a snapshot of competitiveness in the international landscape, yields are presented in section 10.2.1, followed by costs of production of cow-calf operations, feedlots, and pork production in section 10.2.2.

10.2.1 Yields

Beef and pork yields

FAO publishes yields (meat per animal) for beef and pork, pictured below. Of the net-exporting countries, Canada has the highest yields: 418kg/cow and 103kg/pig in 2021. Canada has also seen marked growth in yield per animal on both beef and pork since 1961. Gains in yield per beef cow have been relatively stable in other net-exporting countries except Brazil, with an uptick beginning in 2017. In pork (bottom panel), the Netherlands, USA, and Denmark have also seen steady gains in yields over time. Brazil's yield improvements have occurred in fits and starts, with a decline from 2020 to 2021. Spain's yields in pork decreased from 1963 to 1985, but have increased since then. Germany's pork yields have been relatively stable.

Figure 10.2. Beef production yields by country (2021)

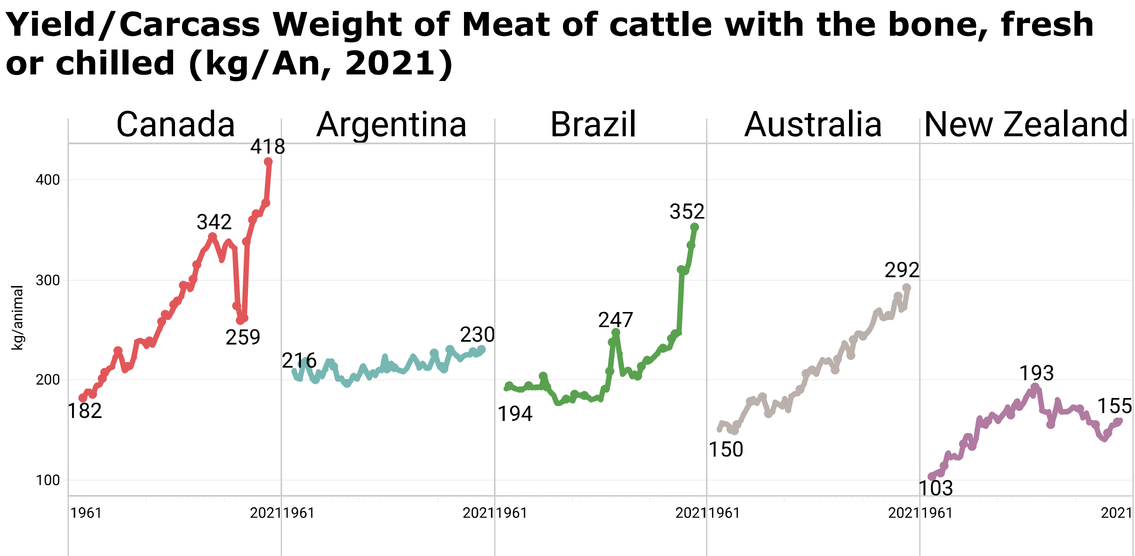


Image created internally. Data source: FAOSTAT. (2021). Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL.

Figure 10.3. Pork production yields by country (2021)

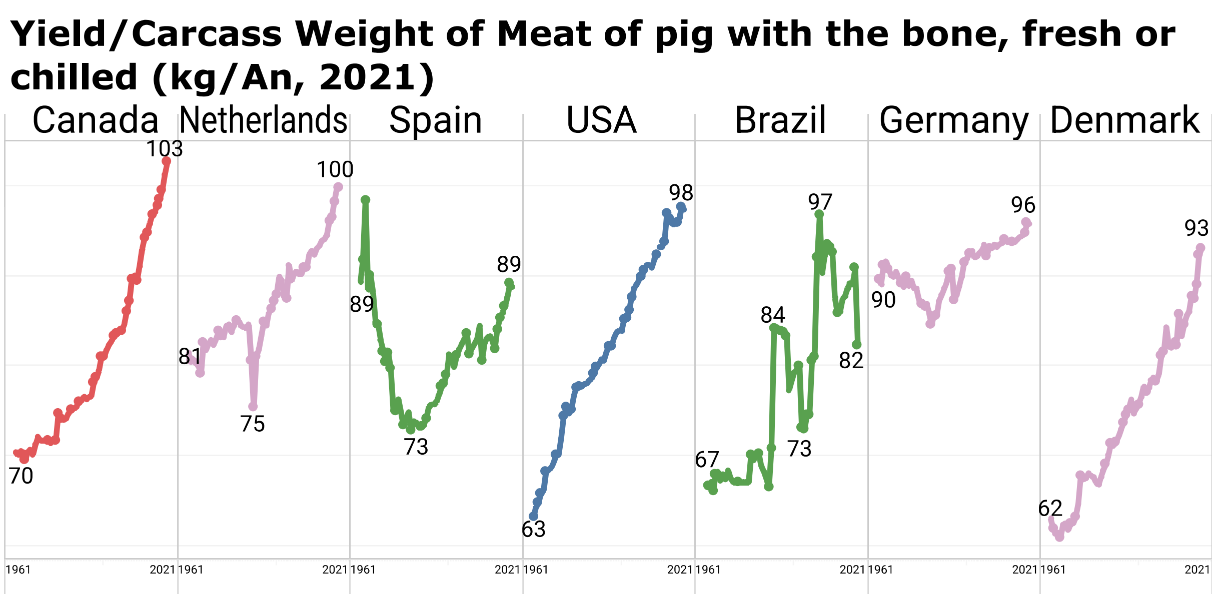


Image created internally. Data source: FAOSTAT. (2021). Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL.

Milk yields

The dairy industry in Canada is focussed on the domestic market and so has not been included in the discussion of global production and trade. However, FAO publishes yields in terms of kg of raw milk per cow per year. The top 10 net exporters are shown in Figure 10.4. New Zealand, the largest net exporter of all dairy products (7.4M tonnes in 2021), had the lowest yield, at 4,555 kg/cow/year. The US, the 2nd largest net exporter of dairy (6.6M tonnes), had the highest yield: 10,869 kg/cow/year. Canada's yield was 9,647/cow/year, higher than all the top 10 dairy net exporters except USA and Denmark (FAOSTAT, 2021a). These figures align with the 2018 estimates from *agri benchmark* for USA, Germany, France, and New Zealand (AHDB, 2020) as well as with the 2022 weighted averages gathered from Lactanet (Canada) and from the International Committee for Animal Recording for the Netherlands, Denmark, and Germany (Agriculture and Agri-Food Canada, 2023f).

Figure 10.4. Milk yields, top 10 net exporters, 2021.

Image created internally. Source of data: FAOSTAT. (2021). Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL.

10.2.2 Costs of production

Cow-calf costs of production

The cost of production is the main factor in determining competitiveness with other businesses or jurisdictions. Data from benchmark farms around the world are gathered by *agri benchmark*. Based on average total profit margins from 2016 to 2021, Canada had the 12th lowest total cost and the 14th highest profit margin (Canfax Research Services, 2023b). The lowest total cost was in Kazakhstan (<$100 USD per 100kg liveweight). The lowest total profit margin was in Brazil at approximately $125 USD/100 kg liveweight (Canfax Research Services, 2023b). The important net-exporting countries in 2021 are shown in Figure 10.5.

Figure 10.5. Cow-calf costs of production and profit margins, 2021

	Net exporter rank	Total cost (rank, 1=lowest)	Total profit margins (rank, 1=highest)
Canada	8	~$360 (12th)	~$300 (14th)
Brazil	1	~$175 (4th)	~$125 (lowest, 24th)
Australia	2	~$200 (7th)	~$280 (18th)
Argentina	4	~$190 (6th)	~$290 (15th)
Paraguay	7	~$180 (5th)	~$175 (21st)
Uruguay	5	~$210 (9th)	~$300 (9th)
Dollar values are in USD per 100kg liveweight			

Table created internally. Data source: (Canfax Research Services, 2023b). International Comparison, Cow-calf, 2016-2020 [Unpublished].

Canfax also publishes results from case studies, which are in-depth analyses of individual operations which are thought to be representative of typical farm structures in the area. Figure 10.6 summarizes some key measurements of competitiveness from farms in Alberta, Manitoba, Quebec, New Mexico (USA), and Australia, measured in 2021. The calves weaned per cow was lowest in Australia (83 head) and highest in New Mexico (93). Total costs were lowest in Australia ($588 CAD per cow) and highest in New Mexico ($1,613 CAD) due to high opportunity costs of land, labour. A theme from all these case studies was that when on-farm labour is unpaid, the opportunity cost of that labour is high (Canfax Research Services, 2021c, 2021a, 2021b).

Figure 10.6. Case studies, cow-calf, 2021 costs of production

	Calves weaned per 100 cows	Cash costs	Depreciation	OC of land	OC of labour	OC of capital	Total cost
Alberta	85	587	95	46	88	49	864
New Mexico	93 (highest)	833	107	360	240	74	1,613
Manitoba	92	614	12	38	160	0	824
Quebec	91	587	182	82	214	86	1,151
Australia	83 (lowest)	268	29	164	91	36	588
Cost units: $CAD per cow on cow-calf operations.							

Table created internally. Data source: Canfax case studies, available at https://www.canfax.ca/resources/cost-of-production/cop-analysis.html.

Feedlots

An international comparison using 2011 data showed that the Canadian total feedlot cost was $487/100kg of carcass weight (CW) sold. Brazil, the world's largest net exporter of beef, had a feedlot cost of approximately $380/100kg CW. Argentina, the 4th largest net exporter, had a feedlot cost of $411/100kg CW. Mexico, the 10th largest net exporter, had the lowest feedlot costs, at $330/100kg CW (Canfax Research Services, 2011).

In terms of productivity, Canada's average daily gain in 2011 was 3.3 lb/day. Brazil had the highest average daily gain at ~3.97 lb/day. Among important net exporters, Mexico had the lowest, at ~2.92 lb/day.

Figure 10.7. Feedlot comparisons, 2011

	Net exporter rank	Feedlot cost of production	Feed costs	Average daily gain
Canada	8	$487/100kg CW	$164/100kg CW	3.3 lb/day
Brazil	1	~$380/100kg CW	$185/100kg CW	~3.97 lb/day
Australia	2	$425/100kg CW	~$100/100kg CW	3.96 lb/day
Argentina	4	$411/100kg CW	~$65/100kg CW	~3.11 lb/day
Mexico	10	$330/100kg CW	$194/100kg CW	~2.92 lb/day
~ indicates that values were estimated by reading a bar graph without value labels.				

Table created internally. Data source: Canfax Research Services. (2011). *International cost of production analysis*. https://www.albertabeef.org/files/site-content/c0pxE8h4SFhuKpP8P8zFgNpouPgQtCgrzk4R1h6l.pdf.

Feedlot cost comparisons were updated based on a five-year average (2016 to 2020) and found that again, Canada had the second highest labour costs, second to Spain. However, Canada also had the second highest number of animals per labour unit, second to Brazil. Among the important net exporters studied, Brazil had the lowest total feedlot cost in 2020. The United States had lower total costs than Canada, but the US are not large net exporters of beef, despite being the largest producer in the world. Land, labour, and capital were more costly in Canada than other countries, putting Canada at a comparative disadvantage for these production costs (Canfax Research Services, 2023a).

Pork costs of production

International comparisons in the cost of production of pork are compiled by *agri benchmark* (the same source of data used by Canfax for beef cost of production analyses). Costs of production from the 2020 comparison report, published by the United Kingdom's Agriculture and Horticulture and Development Board, are pictured in Figure 10.8. The top 10 countries are listed in order of net exports of pork in 2021: Spain first, Ireland last, and Canada in 5th place. Canada has the second-lowest total cost of pork production, at 0.96 £/kg cold deadweight, tied with the United States, and behind Brazil at 0.925 £/kg. Brazil, Canada, and the US have low costs across the board, from fixed costs (depreciation/finance and labour) to variable costs (feed and other). Ireland, the 10th largest net exporter, has some of the highest costs of production. Spain, despite being the largest net exporter of pork, has the 6th largest total cost of production, at 1.27£/kg cold deadweight (AHDB, 2021, tbl. 3).

Figure 10.8. Pork cost of production (2020), top 10 pork net exporters

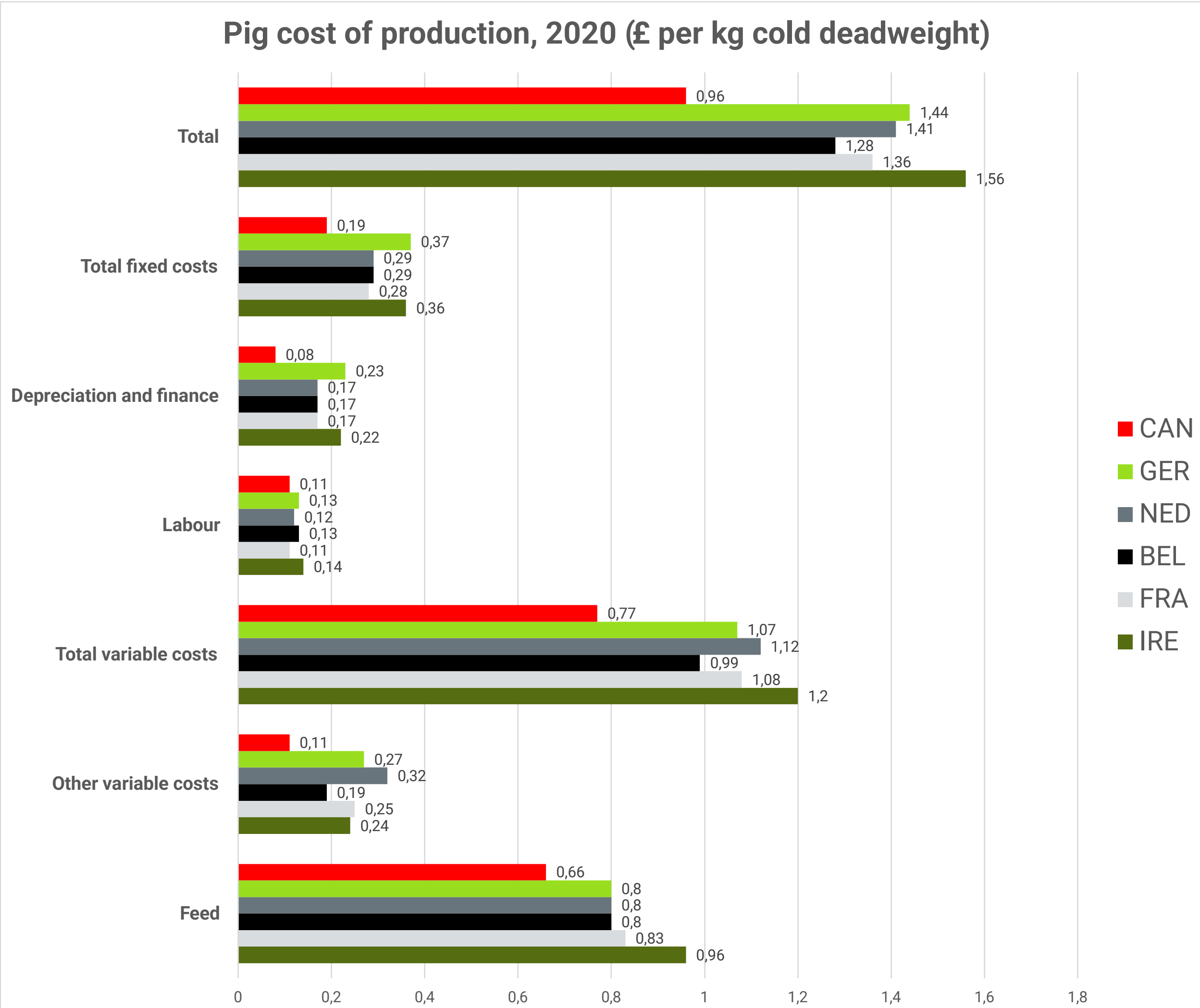


Image created internally. Data source: Agriculture and Horticulture Development Board. (2021). *2020 pig cost of production in selected countries.* https://projectblue.blob.core.windows.net/media/Default/Pork/CostOfPigProduction_2020_4568_161121_WEB.pdf.

The important measures of competitiveness in pork production are cost of feed, feed conversion ratio, number of pigs weaned per sow, and average daily gain. Feed costs are in Figure 10.8 above and show that Canada and the USA had the lowest feed costs in 2020, at 0.66 and 0.64 £/kg cold deadweight. Spain, the largest net exporter of pork, had the second highest feed cost, at 0.84 £/kg, only behind Ireland (the 10th largest net exporter) at 0.96 £/kg cold deadweight (AHDB, 2021, tbl. 3).

Figure 10.9 shows the number of pigs weaned per sow per year in 2020. The top 10 net-exporting countries are shown, beginning with Ireland in 10th place, and ending with Spain, the largest net exporter in terms of tonnes according to FAOSTAT (2021 trade values). Canada, the 5th largest net exporter of pork, had the lowest number of pigs weaned per sow per year, 25.34. Denmark, the 3rd largest net exporter, had the highest, at 33.89 pigs weaned per sow per year (AHDB, 2021, tbl. 7)

Figure 10.9. Pigs weaned per sow per year, 2020

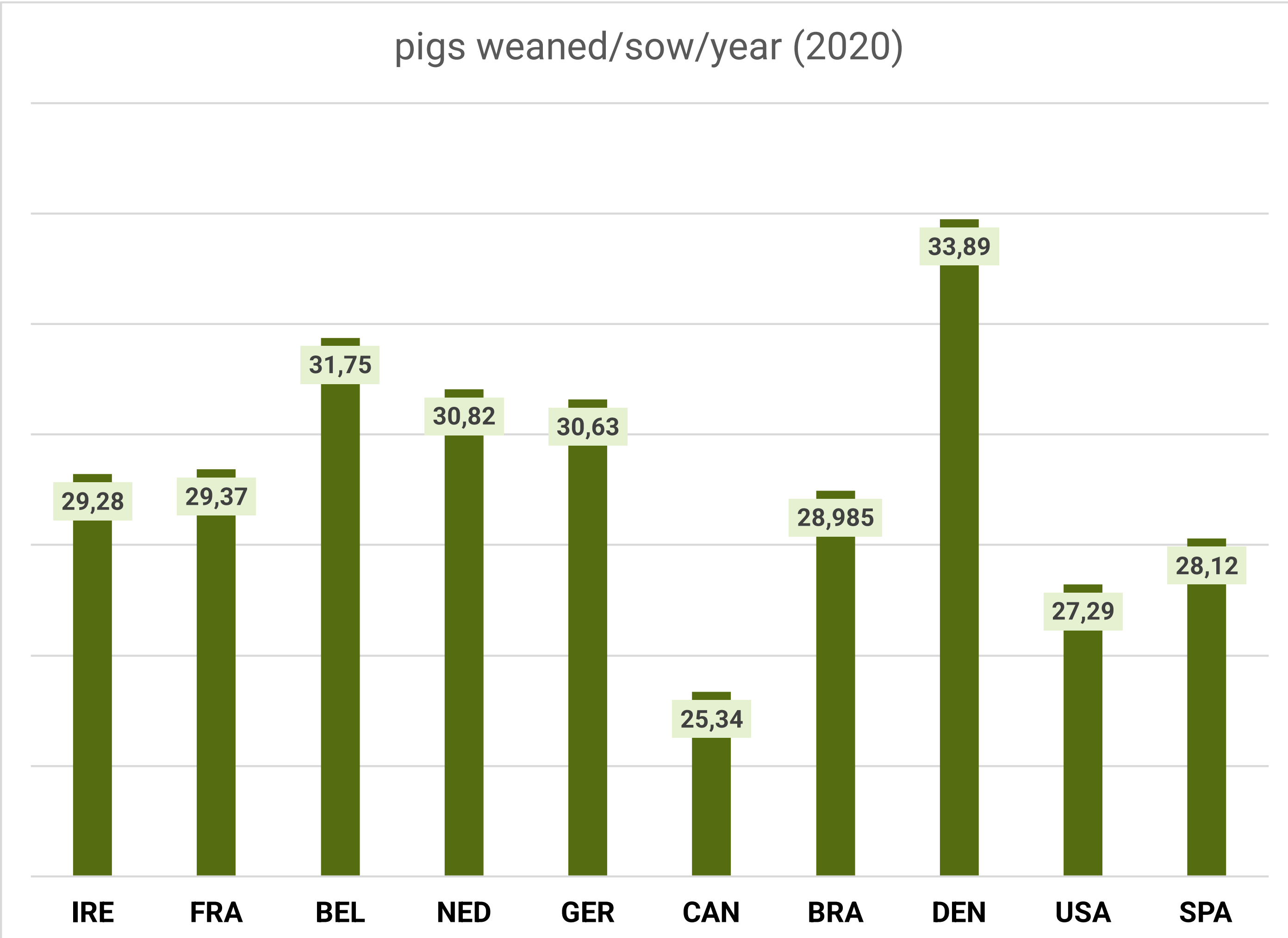


Image created internally. Data source: Agriculture and Horticulture Development Board. (2021). *2020 pig cost of production in selected countries.* https://projectblue.blob.core.windows.net/media/Default/Pork/CostOfPigProduction_2020_4568_161121_WEB.pdf.

The finishing feed conversion ratios for the top ten net exporters of pork are shown in Figure 10.10. Again, the figure shows Ireland first (the 10th largest net exporter), and Spain last, the largest net exporter of pork in 2021 (FAOSTAT). Canada has the largest finishing feed conversion ratio, demonstrating low competitiveness. Brazil, the 4th largest net exporter, had the lowest feed conversion ratio in 2020, giving it an advantage in the amount of food it requires to fatten its hogs.

Figure 10.10. Finishing feed conversion ratio, 2020

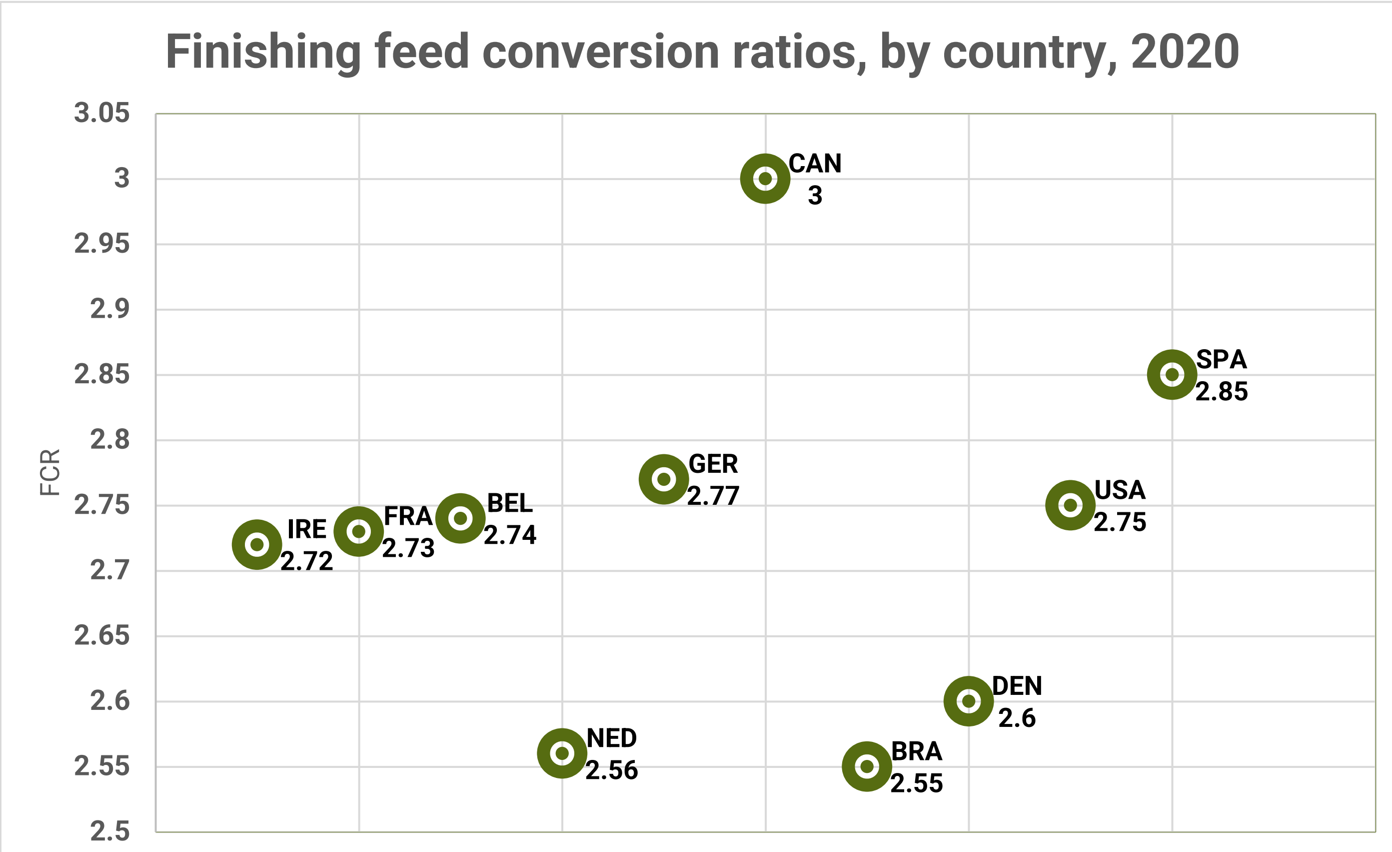


Image created internally. Data source: Agriculture and Horticulture Development Board. (2021). *2020 pig cost of production in selected countries.* https://projectblue.blob.core.windows.net/media/Default/Pork/CostOfPigProduction_2020_4568_161121_WEB.pdf.

Figure 10.11 shows the finishing daily liveweight gain in 2020 of the top 10 net exporters of pork (by tonnes according to trade data from FAO, 2021). Spain, the largest net exporter of pork, had a daily liveweight gain of 754 grams per day in 2020, the second lowest of the ten countries. The highest gain was Denmark (the 3rd largest net exporter) at 1,030 grams per day. Canada had the 4th highest gain, at 876 grams per day. Ireland, the 10th largest net exporter of pork, had the second highest gain, at 921 grams per day (AHDB, 2021).

Figure 10.11. Finishing daily liveweight gain, 2020

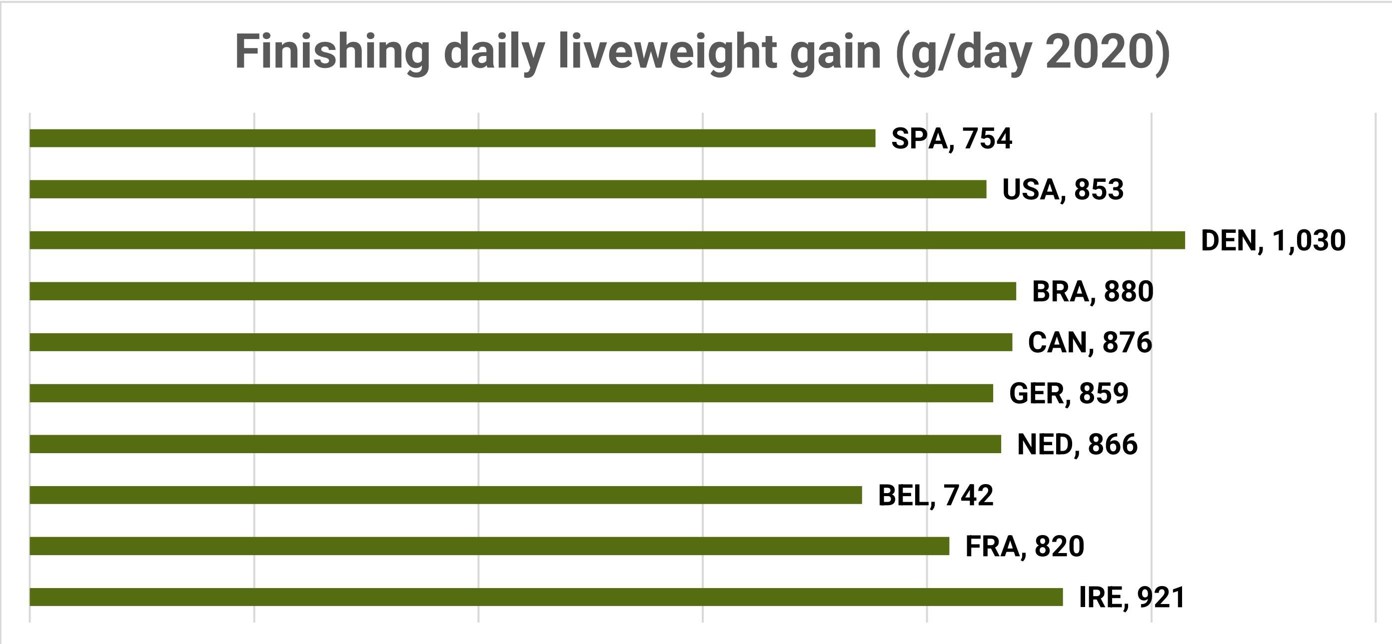


Image created internally. Data source: Agriculture and Horticulture Development Board. (2021). *2020 pig cost of production in selected countries.* https://projectblue.blob.core.windows.net/media/Default/Pork/CostOfPigProduction_2020_4568_161121_WEB.pdf.]

Cost of feed grain

Figure 10.12 and Figure 10.13 provide a summary of producer prices for corn and barley in countries which are significant producers and exporters of animal agriculture products. The data are producer prices from FAOSTAT; benchmark prices for China, India, and Argentina were unavailable.

The figures show that for corn, Canada (bright green bar) is among the low-price countries presented, along with the United States (patterned bar) and Brazil (dark bar; data not available for 2017 or 2021). France, Germany, and Mexico (producers of both corn and animal products) have corn prices broadly higher than Canada, the US, and Brazil. New Zealand (thick line) and Australia have the highest prices displayed here and are not significant corn producers, and corn is not a major feed grain in these countries.

Figure 10.12. Cross-Country Comparison of Corn Prices

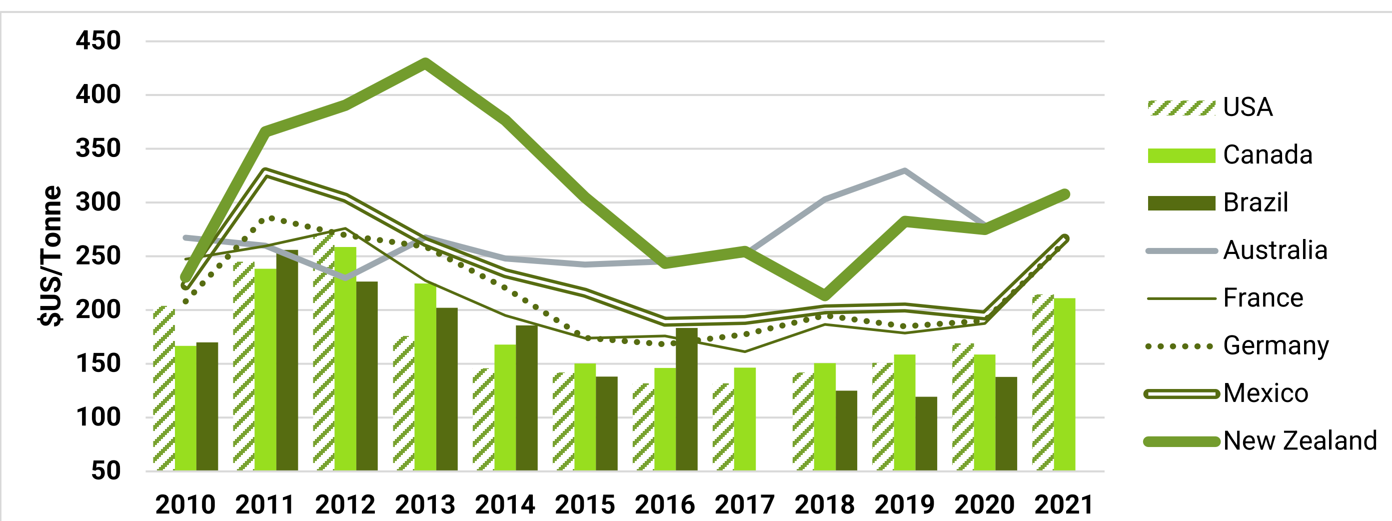


Image created internally. Data source: (FAOSTAT, 2021b). *Producer prices* [dataset]. https://www.fao.org/faostat/en/#data/PP.

Figure 10.13 presents a cross-country comparison of barley prices, a common substitute for corn as a feedstuff, especially in colder or drier areas less amenable to corn production. The figure shows that Canada (bright green bar) is typically the low price point among countries, at a similar price level as Australia (grey bar), with Canada and Australia two of the principal barley exporters. European countries have usually had somewhat higher-priced barley, but that appeared to narrow between 2015-19. Barley prices are higher in the US (dashed line), but barley is not the principal feed grain for livestock in the US. Barley prices are much higher in New Zealand (thick line) than in Canada.

In grain feeding systems, globally ubiquitous in poultry and hogs and also common in beef and dairy, cereal grains[3] are the principal component of animal production cost. In turn, they form the principal element of comparative advantage and the key element of competition for feeder livestock. Canada is clearly among the low-priced feed grain countries, and forms the basis for cost-competitive livestock feeding industries.

Figure 10.13. Cross-Country Comparison of Barley Prices

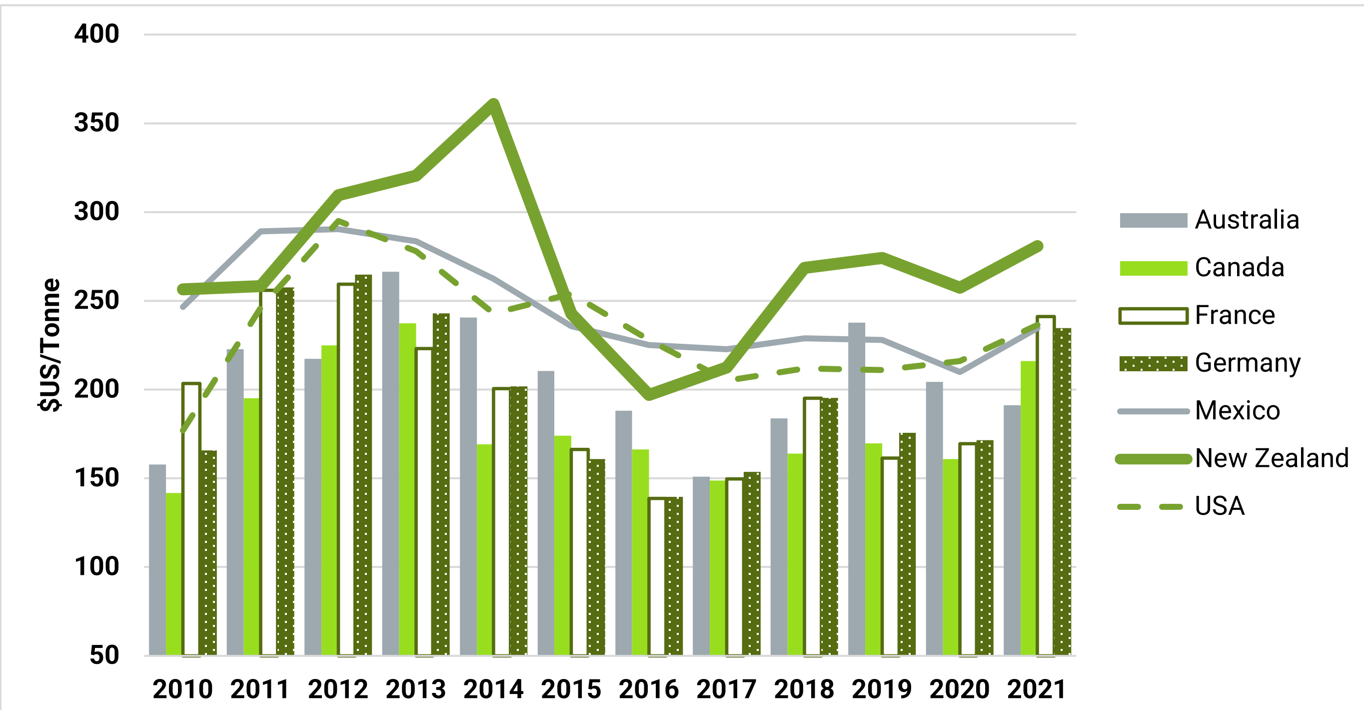


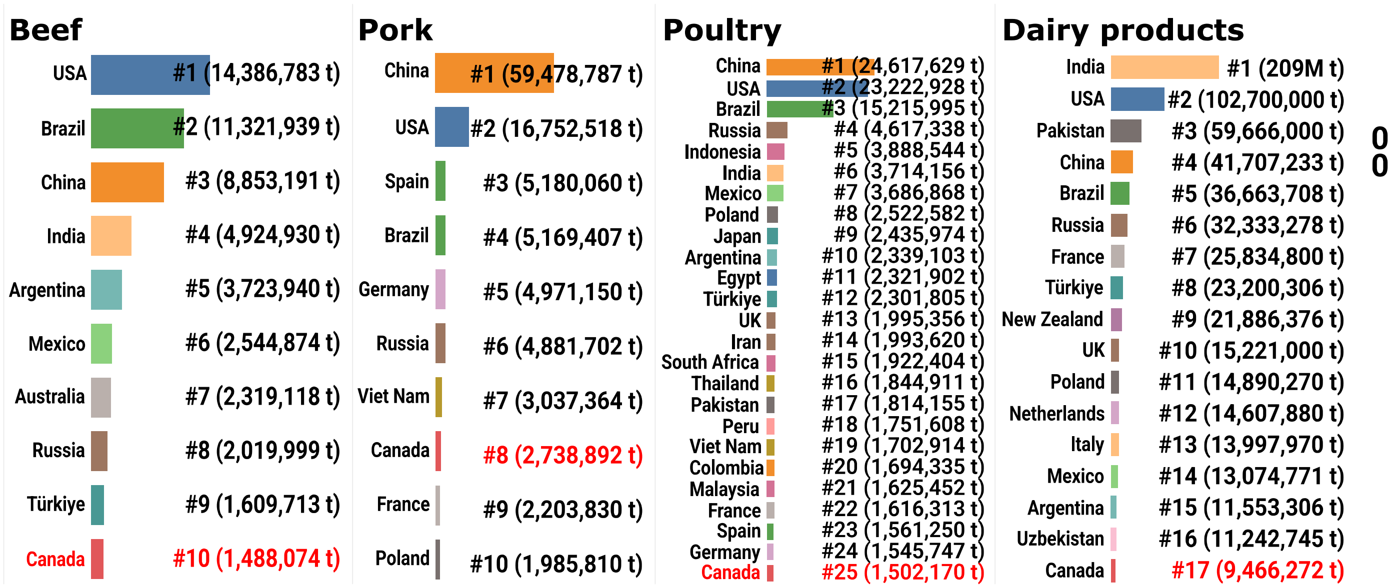
Image created internally. Data source: (FAOSTAT, 2021b). *Producer prices* [dataset]. https://www.fao.org/faostat/en/#data/PP.

10.3 Production and trade

In terms of production, Canada was the 11th largest producer of beef and the 8th largest producer of pork at 1.5M tonnes and 2.7M tonnes in 2021, respectively. The largest producer of beef was the USA (14M tonnes), and China was the largest producer of pork (59M tonnes). Canada exported 34% of its beef production in 2021 and 52% of its pork. Canada was the 25th largest producer of poultry (1.5M tonnes) and the 17th largest producer of dairy products (9.5M tonnes). The largest producer of poultry was China (25M tonnes), and of dairy, India (209M tonnes).

[3] corn and barley, but also downgraded or damaged wheat, corn distillers' grains, oats, sorghum, and downgraded or damaged rice

Figure 10.14. Production by country, 2021



Source of data: FAOSTAT. (2021). Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL. Image produced internally.

Table 10.2. Trade in beef and pork

Trade	Exports, tonnes	Exports, $US	Net exports, tonnes	Net exports, $US
Beef	506,942 (9th)	$3.6B (6th)	328,314 (9th)	$2.3B (8th)
Pork	1,437,262 (6th)	$3.9B (6th)	1,185,395 (6th)	$2.7B (7th)
Data source: FAOSTAT, 2021				

Beef and pork are the principal animal agriculture exports for Canada. In 2021, Canada was the 9th largest exporter of beef in terms of tonnes (506,942) and the 6th largest exporter in terms of value ($3.6B USD) (FAOSTAT, 2021a). Canada was the 6th largest exporter of pork in terms of both volume and value: 1.437,262 tonnes or $3.9B USD (Table 10.2).

At the provincial level, in 2022, 79% of Canada's beef exports (fresh or chilled; HS heading 0201) originated from Alberta, followed by 19% from Quebec. In terms of frozen beef exports (including veal; HS heading 0202), 72% originated from Alberta, followed by 24% from Ontario (Figure 10.15). In 2022, the leading pork exporting province (HS heading 0203) was Quebec at 42% (451,641 tonnes) followed by Manitoba with 308,703 tonnes exported (Statistics Canada, 2023a).

Figure 10.15. Beef exports by province (fresh or chilled, and frozen)

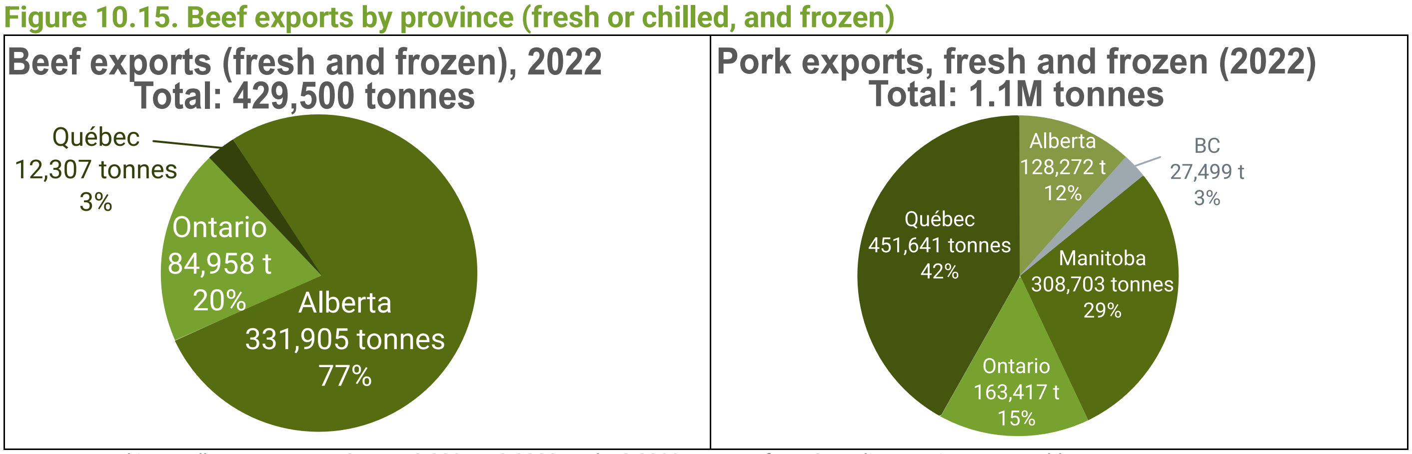


Image created internally. Data source: CIMT, HS 0201, HS 0202, and HS 0203: exports from Canadian provinces to world.

The leading exporter in 2022 of sausages and similar products of meat, offal, or blood (HS heading 1601) was Ontario, with 79% (14,000 tonnes) of Canada's exports (not pictured here). The second largest was Quebec with 10% (1,741 tonnes) of exports to the world (Statistics Canada, 2023a).

10.3.1 Net exports

The concept of net exports is richer than exports alone because net exports show which countries in the world truly have a food surplus, accounting for imports and re-exports of imported products. For instance, the USA is the #1 producer of beef (Figure 10.14), but is not even in the top 10 net exporters. However, looking at net exports reveals that Canada is one among a handful of countries with a meaningful surplus in meat products (Figure 10.16). In fact, in the case of both beef and pork, the top three countries make up 50% of global net exports for each commodity: Brazil, Australia, and New Zealand for beef; and Spain, USA, and Denmark for pork (FAOSTAT, 2021a).

There are a few implications of having only a few material net exporters of meat products in the world. Firstly, if production or exports were severely limited in just one country, the effects would be felt around the world. Secondly, the net exporters may hold a certain degree of power over countries which are in need of their product. Finally, the material net exporters have an interest in collaboration to ensure global food security, especially amid population growth estimates.

Figure 10.16. Net exports of beef and pork, 2021

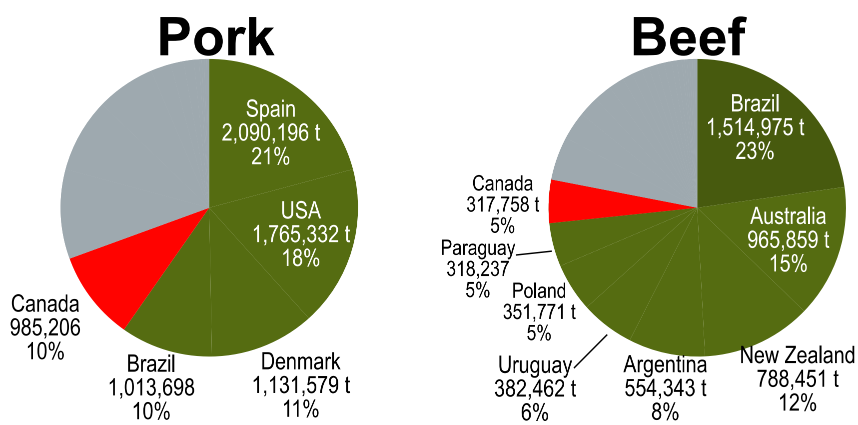


Image created internally. Data source: FAOSTAT. (2021). Crops and livestock products. Available at https://www.fao.org/faostat/en/#data/TCL.

10.4 Emissions policies

As of 2023, 198 countries have ratified the United Nations Framework Convention on Climate Change (United Nations Climate Change, 2023c); 195 of these are signatories of the Paris Agreement (United Nations Climate Change, 2023b). Table 10.3 shows the countries who have adopted laws which commit them to "net zero" (or "climate neutral" or "carbon neutral"; see note below table) by 2050, and who also have interim GHG reduction targets by 2030 (Net Zero Tracker, 2023).

Table 10.3. Countries with emissions targets by 2030 and net zero by 2050 enshrined in law

Country/region	Target by 2050	Interim target (% reduction from baseline)	Interim target baseline year	GHG emissions (Mt CO_2e), 2019
1. USA	Net zero	52	2005	5,771
2. EU	Climate neutral	55	1990	3,330
3. Japan	Carbon neutral	46	2013	1,134

4. Canada	Net zero	45	2005	774
5. South Korea	Net zero	40	2018	653
6. Australia	Net zero	43	2005	609
7. UK	Net zero	68	1990	429
8. France	Net zero	55	1990	352
9. Spain	Climate neutral	23	1990	293
10. Greece	Climate neutral	55	1990	80
11. New Zealand	Net zero	50	2005	73
12. Hungary	Net zero	40	1990	62
13. Portugal	Carbon neutral	40	2020	62
14. Ireland	Net zero	55	1990	59
15. Switzerland	Net zero	50	1990	44
16. Denmark	Net zero	70	1990	44
17. Luxembourg	Net zero	55	2005	10

Net zero: GHG atmospheric emissions are balanced by removal from the atmosphere. Considered the "best" target.
Climate neutral: Activities result in no net effect on the climate system. Includes non-GHG effects such as land use changes with albedo effects (reflecting the sun). Considered an intermediate step toward net zero.
Carbon neutral: Only balances CO2 emissions with CO2 reductions or removals. Considered an intermediate step toward net zero because it does not consider any other GHGs.
Source: Net Zero Tracker, 2023. *Data explorer* [Microsoft Excel]. https://zerotracker.net/.

These commitments are translating into policies which impact animal agriculture for some of the world's most important agri-food producers and net exporters. The EU – with the world's 5th largest cattle herd – has committed to reducing its GHG emissions by 40% from 1999 to 2030 (see Table 10.3). Ireland, one of the EU members (albeit with a special status), is targeting a 25% reduction in emissions specifically from farming by 2030 (Abrahams, 2023). This has engendered a proposed culling of the Irish cow herd by 10%; that's 65,000 cows per year for three years (Abrahams, 2023). In the Netherlands, a buy-out program was begun by the government in 2021 which could reduce livestock numbers by a third over 13 years (Levitt, 2021). Nitrogen emissions targets in the EU have prompted farmers to visibly protest, for instance, by driving convoys of tractors into Brussels (the seat of the EU) and The Hague (the Dutch capital) (Biesemans & Rossignol, 2023; Sterling, 2023). New Zealand had announced a tax on agricultural methane beginning in 2025 (Craymer, 2023); however, the new prime minister as of October 2023 is not in favour of the Government's previous plan and prefers an approach that includes industry (Neilson, 2023).

Farmers in the United Kingdom, despite no longer belonging to the EU, have expressed fears that similar culling policies will be enacted (Blackett, 2023). A reduction in meat consumption has been recommended for environmental reasons: 20%-50% by the Climate Change Committee (an independent, statutory group which advises the U.K. Government on targets and progress) to reach net zero by 2050 (Climate Change Committee, 2021, p. 11); and a 30% reduction in meat consumption (from 2019 to 2032) by the country's National Food Strategy (Climate Change Committee, 2021, p. 142). The new Conservative prime minister, Rishi Sunak (appointed in October 2022), has "scrapped" the idea of taxing meat, conceding that it would "harm British farmers" (Prime Minister's Office, 2023). Other emissions-related proposals rejected by Prime Minister Sunak were: new taxes on flying, compulsory car sharing, and upgrading home heating systems.

The Paris Agreement requires each party to track *nationally determined contributions* (NDCs), or post-2020 "climate actions" (United Nations Climate Change, 2023a). There are two ways to reduce emissions from livestock: reduce the number of animals; or reduce the emissions output per animal through technologies such as feed additives. The first option (culling) would necessarily lead to lower global production of meat, dairy products and eggs. With a growing global population, this option does not seem feasible. The only way to maintain production levels of meat and dairy products, and simultaneously reduce global emissions from animal agriculture, is to reduce the *emissions intensity* of animal agriculture. This can be achieved by: (1) reducing the emissions per animal (for example, through feed additives and genetics; see Nickel, 2023); (2) increasing the productivity of each animal; or a combination of these two options. Regardless which option is favoured, the outcome is the same: a reduction in the emissions intensity (kg of CO_2 emitted per unit of food produced).

Table 10.4 lists the emissions intensities (Gerber et al., 2013, figs. 8, 19) and herd sizes of beef and pork by country (FAOSTAT, 2020a). The top 20 countries with the largest cattle herds are displayed, as well as material net exporters of beef and pork (recall Figure 10.16, Net exports of beef and pork, 2021). Note that some countries – such as Brazil and India – have some of the largest cattle herds (152M and 97M cattle), but have the highest emissions intensities (72 and 48 kg of CO_2 per kg of carcass weight, respectively). If global emissions from animal agriculture are to be reduced, one prospective strategy is to reduce production in these high-intensity regions, and concomitantly shift production of beef and pork to low-intensity regions, such as North America (30 kg CO_2e/kg CW beef, and 4.6 for pork compared with 7.1 for pork in Latin America and 6.7 in West Europe). However, the implied shift toward developed countries that are large net exporters and prospective dependence of importing countries for food security could create discomfort.

Table 10.4. Emissions intensity and herd size by country, 2015-2020

Geography§	Cattle, 2020[1]	Emissions intensity (kg CO2e/kg product beef), 2015[3]	Net exporter rank, beef, 2021[2]	Swine / pigs, 2020[1]	Emissions intensity (kg CO2e/kg product pork), 2015[4]	Net exporter rank, pork, 2021[2]
1. Brazil	152,705,209	58.97 (C&S.Am.*)	1st	10,281,058	5.36 (C&S.Am.)	4th
2. India	97,241,178	105.63 (S. Asia)	-	1,770,422	10.09 (S.Asia)	-
3. USA	93,793,300	17.42 (N.Am.)	-	19,328,000	4.95 (N.Am.)	2nd
4. China	39,733,748	52.74 (E. Asia)	-	103,043,069	6.59 (E.Asia)	-
5. Argentina	38,122,559	58.97 (C&S.Am.*)	4th	1,344,240	5.36 (C&S.Am.)	-
6. Ethiopia	35,145,888	106.97 (SSA*)	-	7,283	6.66 (SSA*)	-
7. Mexico	24,947,446	58.97 (C&S.Am.*)	10th	4,697,001	5.36 (C&S.Am.)	-
8. Pakistan	24,812,000	105.63 (S. Asia)	-	-	10.09 (S.Asia)	-
9. Australia	21,152,914	27.37 (Oceania)	2nd	564,512	7.89 (Oceania)	-
10. Colombia	19,771,683	58.97 (C&S.Am.*)	-	1,677,667	5.36 (C&S.Am.)	-
11. Chad	16,118,605	106.97 (SSA*)	-	22,312	6.66 (SSA*)	-
12. France	16,010,325	24.09 (W.Eur.)	-	3,434,250	4.97 (W.Eur.)	9th
13. Sudan	15,878,633	46.25 (WANA*)	-	-	6.57 (WANA*)	-
14. Tanzania	14,167,525	106.97 (SSA*)	-	104,177	6.66 (SSA*)	-
15. Türkiye	12,575,837	46.25 (WANA*)	-	198	6.57 (WANA*)	-
16. Myanmar	12,275,771	52.74 (E. Asia)	-	4,798,160	6.59 (E.Asia)	-
17. Bangladesh	12,195,500	52.74 (E. Asia)	-	-	6.59 (E.Asia)	-
18. Venezuela	11,367,456	58.97 (C&S.Am.*)	-	750,037	5.36 (C&S.Am.)	-
19. Indonesia	11,353,415	52.74 (E. Asia)	-	2,267,473	6.59 (E.Asia)	-
20. Canada	11,265,000	17.42 (N.Am.)	8th	3,492,500	4.95 (N.Am.)	5th
21. New Zealand	9,074,509	27.37 (Oceania)	3rd	58,633	7.89 (Oceania)	-
22. Spain	5,972,787	24.09 (W.Eur.)	-	8,199,018	4.97 (W.Eur.)	1st
23. Ireland	5,876,496	24.09 (W.Eur.)	9th	419,643	4.97 (W.Eur.)	-
24. Netherlands	3,321,900	24.09 (W.Eur.)	-	2,885,250	4.97 (W.Eur.)	7th
25. Denmark	1,350,000	24.09 (W.Eur.)	-	3,347,750	4.97 (W.Eur.)	3rd

*Acronyms and abbreviations
C&S.Am.: Central and South America
SSA: Sub-Saharan Africa
WANA: West Asia and Northern Africa

§Regions defined according to GLEAM. See appendix 15.5 for map.

Image produced internally. Data sources:

(1) (FAOSTAT, 2020b). *Livestock patterns.* https://www.fao.org/faostat/en/#data/EK
(2) (FAOSTAT, 2021a). *Crops and livestock products.* https://www.fao.org/faostat/en/#data/TCL (calculations performed internally)
(3) (FAO, 2022b). FAO. (2022). *GLEAM v3 Dashboard [2015 data]. In: Shiny Apps.* Global Livestock Environmental Assessment Model. https://foodandagricultureorganization.shinyapps.io/GLEAMV3_Public/

11. Eastern and western Canada

Material differences exist in eastern and western Canada in terms of topography, climate, and infrastructure related to animal agriculture. We present here a series of data and a set of infographics to highlight the differences in the livestock sectors between eastern and western Canada.

11.1 Beef

Figure 11.1 shows that the majority of beef cattle are raised, marketed, and slaughtered in western Canada: Alberta has 45% of all beef cows and 37% of all beef cattle farms; Saskatchewan has 29% of all beef cows on 19% of all beef farms (Livestock Survey, 2023b; Statistics Canada, 2022a). In total, Alberta and Saskatchewan together have 56% of all beef cattle farms in Canada, and 74% of all beef cows in Canada (see Table 11.1 for full list of provinces). Alberta has, by far and away, the majority of fed cattle marketings in Canada: 2,317,100 or 71% of the Canadian total; the second largest is Ontario with 586,600 or 18% of the Canadian total (Canfax Research Services, personal communication, September 13, 2023). The majority (63%) of all cattle slaughtering in Canada takes place in Alberta, followed by Ontario, at 18%, and Québec has 8% (Statistics Canada, 2023h). Table 11.2 shows that Canada had 19 federally inspected cattle slaughtering plants in 2022, with 7 in Alberta, 1 in British Columbia, 1 in Manitoba, 6 in Ontario, 3 in Quebec, and 1 in Prince Edward Island (Agriculture and Agri-Food Canada, 2021b). (For the time series from 2013 to 2022, see Table 7.4 in section 7.2.2, "Meat Processing").

Figure 11.1. Beef cattle by province

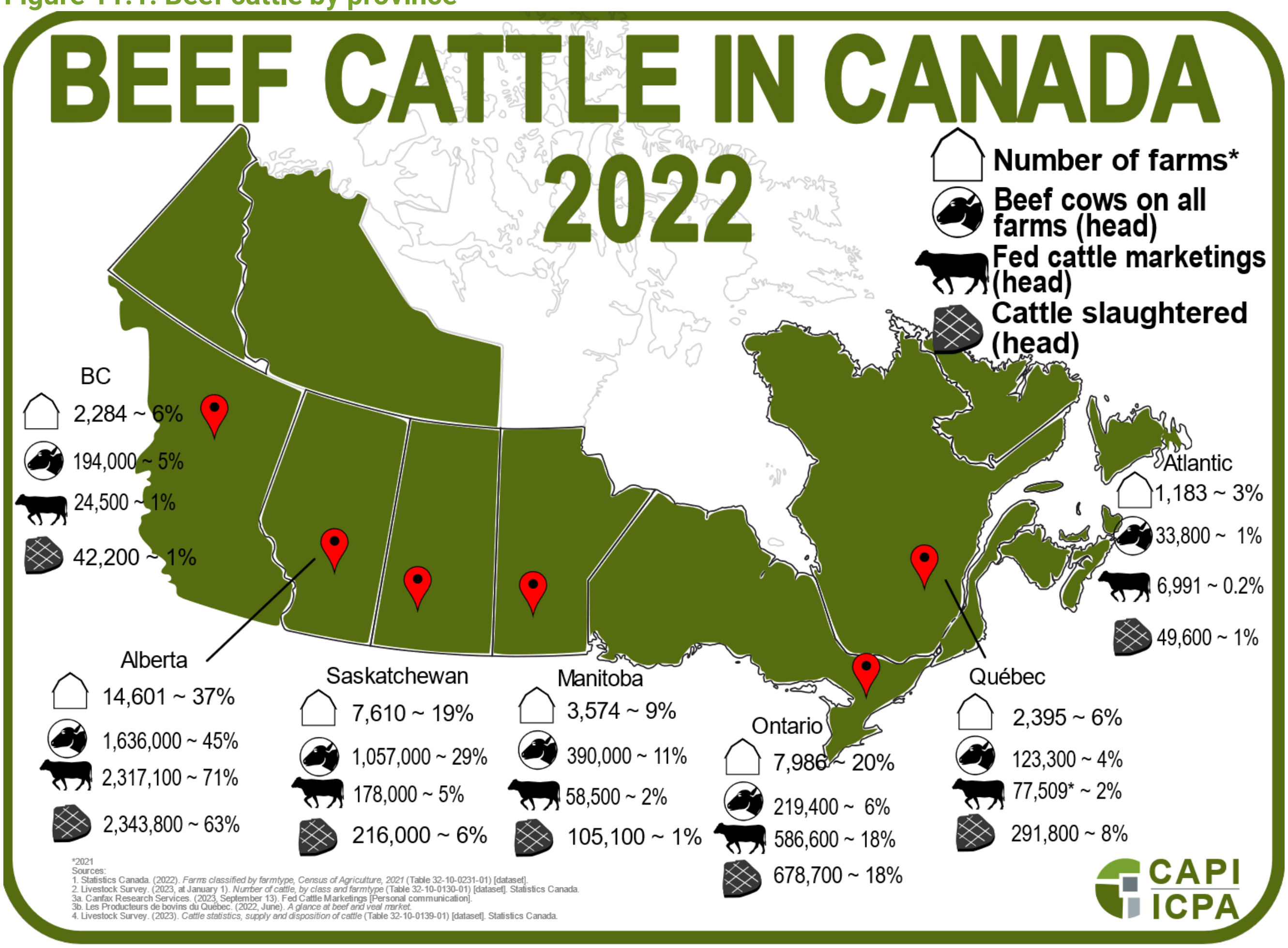


Image created internally.

Table 11.1. Beef ranching and farming operations, including feedlots, 2021

	Beef ranching and farming, including feedlots
Canada	**39,633**
NFL & Lab.	44
PEI	269
NS	526
NB	344
Quebec	2,395
Ontario	7,986
MB	3,574
SK	7,610
Alberta	14,601
BC	2,284

Table created internally. Data source: (Statistics Canada, 2022a). *Farms classified by farm type, Census of Agriculture, 2021* (Table 32-10-0231-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210023101

Table 11.2. Cattle slaughtering plants by province, 2022

Alberta	7	37%
British Columbia	1	5%
Manitoba	1	5%
Ontario	6	32%
Quebec	3	16%
Prince Edward Island	1	5%
Canada	**19**	**100%**

Source: Agriculture and Agri-Food Canada. (2021b, June 15). Distribution of Slaughtering Activity. Red Meat and Livestock Market Information. https://agriculture.canada.ca/en/sector/animal-industry/red-meat-and-livestock-market-information/slaughter-and-carcass-weights/distribution-slaughtering-activity.

In terms of beef exports, Alberta is by far and away the leader, exporting over $2.6B of chilled beef and $528M of frozen beef (includes veal; Table 11.3), for a total of $3.2B; this represents 78% of the total value ($4.0B) of Canada's beef and veal exports (Statistics Canada, 2023a).

Table 11.3. Beef exports by province, value and quantity, 2022

Province	Value ($CAD)	Quantity (kg)	Meat type
Alberta	$2,656,579,359	264,320,381	Beef, chilled*
Alberta	$528,635,783	67,585,105	Beef, frozen§
British Columbia	$1,181,385	38,918	Beef, chilled*
British Columbia	$1,468,486	221,169	Beef, frozen§
Newfoundland and Labrador	$300	28	Beef, frozen§
Nova Scotia	$110,892	7,227	Beef, chilled*
Nova Scotia	$650,983	22,643	Beef, frozen§
Ontario	$537,550,593	62,675,686	Beef, chilled*
Ontario	$175,482,140	22,282,737	Beef, frozen§
Prince Edward Island	$15,291	4,764	Beef, frozen§
Quebec	$119,306,230	8,492,450	Beef, chilled*
Quebec	$37,360,229	3,814,933	Beef, frozen§
Saskatchewan	$436,509	37,533	Beef, frozen§
Canada	**$4,058,778,180**	**429,503,574**	**Beef, fresh and frozen**

*HS code 0201 – Meat of bovine animals, fresh or chilled
§HS code 0202 – Meat of bovine animals, frozen

Table created internally. Data source: (Statistics Canada, 2023a). *Canadian International Merchandise Trade (CIMT) Web Application* (71-607–X) [dataset]. https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2021004-eng.htm.

11.2 Dairy

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Figure 11.2 shows that approximately 90% of the farms with dairy cows are in eastern Canada: Quebec had 4,422 dairy farms in 2021, 47% of the Canadian total of 9,403 farms; Ontario has 3,188 farms, or 34% of the national total (Statistics Canada, 2022a). Table 11.4 shows the number of farms by province.

The number of dairy cows is also highest in eastern Canada. At January 1, 2023, Quebec had the greatest number of dairy cows: 354,000, or 37% of Canada's total dairy cows (969,100) (Livestock Survey, 2023b). Ontario had the second highest number, at 325,500 dairy cows, or 34% of the national total (Livestock Survey, 2023b). These two provinces' milk production values are perfectly aligned with the share of total dairy cows: Quebec produces 37% of all milk in Canada, and Ontario, 33% (Agricultural Industry Market Information System (AIMIS), 2023).

Figure 11.2. Dairy by province

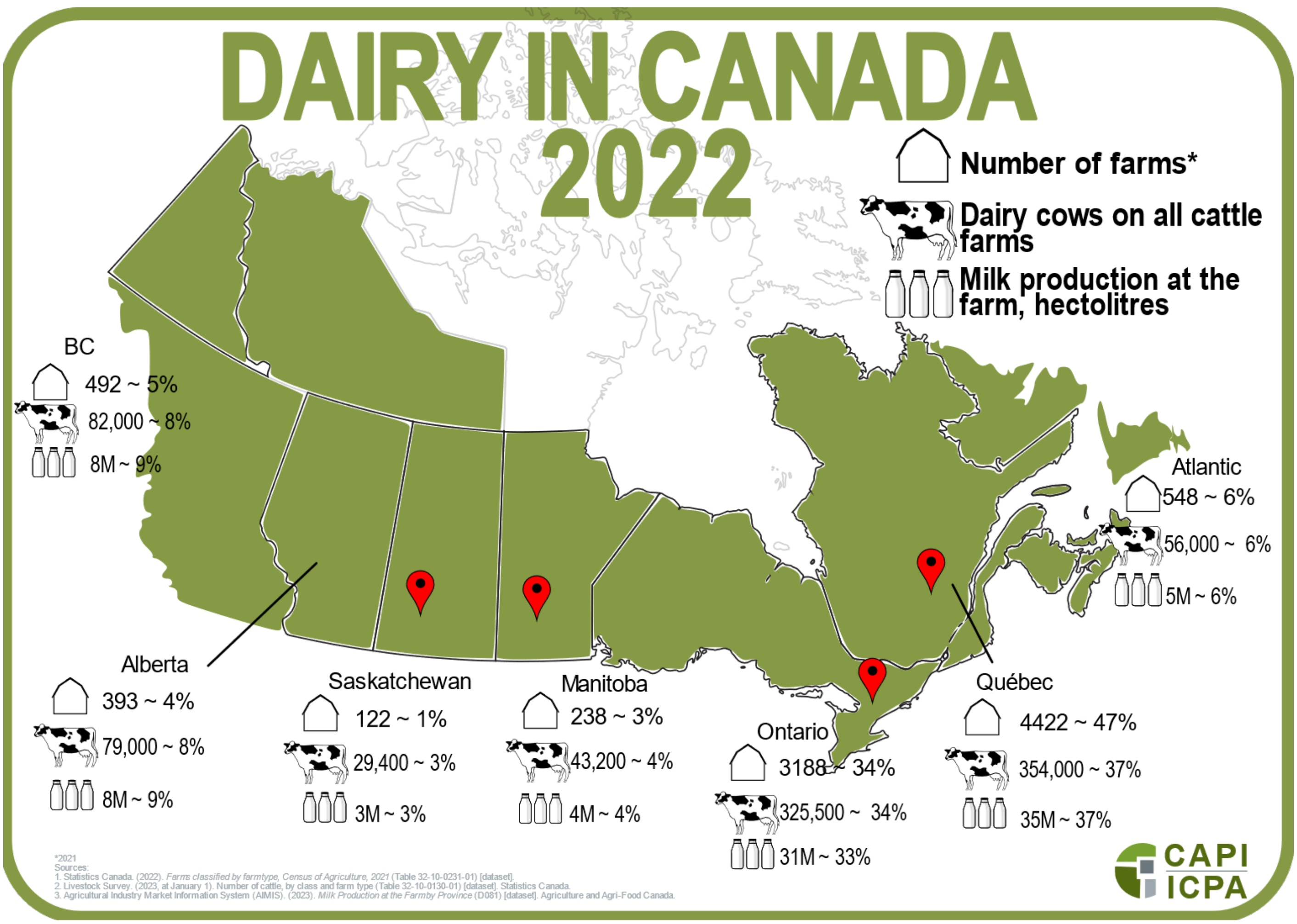

Image created internally.

Table 11.4. Dairy farms, by province, 2021

Geog.	Dairy cattle and milk production
Canada	9,403
Quebec	4,422
Ontario	3,188

BC	492
Alberta	393
MB	238
PEI	157
NS	202
NB	162
SK	122
NFL & Lab.	27

Table created internally. Data source: (Statistics Canada, 2022a). *Farms classified by farm type, Census of Agriculture, 2021* (Table 32-10-0231-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210023101

Economic impact studies have been conducted for Canada's dairy industry, broken down by province. Section 9.1.3, "Economic Impact of the Canadian Dairy Industry," has details broken down by the production and processing sectors, separately. Certain figures of the economic impact of Canadian dairy are summarized here in Table 11.5. As expected, the GDP contribution and number of jobs are highest in Ontario and Quebec. Notably, British Columbia has 20,992 jobs in the dairy sector, mostly from in the dairy processing sector.

Table 11.5. Summary of economic impact of Canadian dairy, 2021

	GDP	Jobs
Canada	$19,111M	195,115
Quebec	$6,124.9M	65,998
Ontario	$6,284.5M	64,725
BC	$2,110.2M	20,992
Alberta	$2,006.4M	16,373
MB	$1,042.2M	10,557
PEI	$154.4M	2,026
NS	$353.1M	4,336
NB	$263.9M	3,325
SK	$663.2M	5,835
NFL & Lab.	$101.8M	911

Table created internally. Data source: (Dairy Farmers of Canada, 2021). *Highlights of Report on the Canadian Dairy Industry in 2021.* [Personal communication, unpublished]

11.3 Pork

Figure 11.3 shows that in 2021, nearly 90% of all farms with hogs were located in eastern Canada: 1,189 in Ontario (39% of the total hog farms in Canada), and 1,276 in Quebec (39%) (Statistics Canada, 2022a). Ontario and Quebec also have the largest number of head of hogs, with 4.39M head in Quebec (31% of national) and 3.7M head in Ontario (26% of all hogs in Canada) (Livestock Survey, 2023a).

Figure 11.3. Pork by province

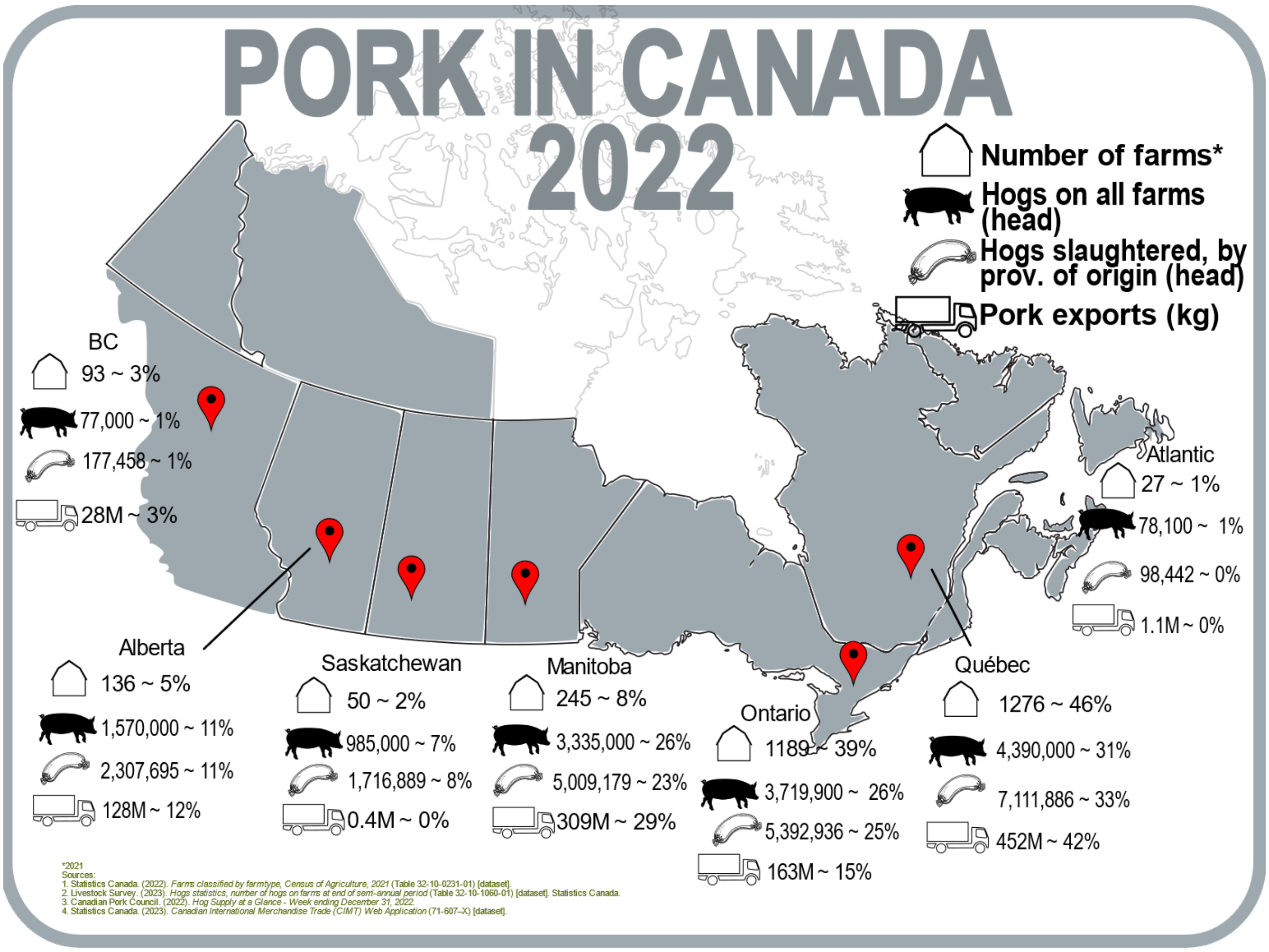

Image created internally.

Table 11.6. Hog and pig farms, by province, 2021

	Number of farms
Canada	3,016
NFL & Lab.	1
PEI	7
NS	10
NB	9
Quebec	1,276
Ontario	1,189
MB	245
SK	50
Alberta	136

BC	93

Source: (Statistics Canada, 2022a). *Farms classified by farm type, Census of Agriculture, 2021* (Table 32-10-0231-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210023101

In terms of exports, Quebec is the leader in terms of value ($1.46B in 2022; Table 11.7), representing 38% of Canada's total exports in value ($3.8B). Manitoba is the second largest exporter of pork, at $1.1B in 2022, or 30% of Canada's total exports in value. In terms of quantity, Quebec and Manitoba are also the leaders, exporting 452,073 tonnes and 308,897 tonnes in 2022, or 42% and 29%, respectively, of Canada's total exports by weight (Statistics Canada, 2023a).

Table 11.7. Pork exports (HS chapter 0203*) by province, 2022

Province	Value	Share	Kilograms	Share
Quebec	$1,456,960,776	38%	452,072,796	42%
Manitoba	$1,138,270,540	30%	308,896,803	29%
Ontario	$621,772,873	16%	163,573,977	15%
Alberta	$508,700,318	13%	128,243,454	12%
British Columbia	$86,654,957	2%	27,578,352	3%
Nova Scotia	$2,657,181	0.1%	953,957	0.1%
Saskatchewan	$1,308,929	0.0%	457,682	0.0%
New Brunswick	$196,955	0.0%	95,039	0.0%
Prince Edward Island	$117,474	0.0%	39,973	0.0%
Newfoundland and Labrador	$289	0.0%	47	0.0%
Canada	**$3,816,640,292**	**100%**	**1,081,912,080 kg**	**100%**

*HS 2023 – Meat of swine, fresh, chilled or frozen

Table created internally. Data source: (Statistics Canada, 2023a). *Canadian International Merchandise Trade (CIMT) Web Application* (71-607–X) [dataset]. https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2021004-eng.htm.

The number of federally inspected hog slaughtering plants is highest in Quebec, the same province with the largest number of hog and pig farms, and the leading province in terms of exports of fresh and frozen pork. Table 11.8 shows that in 2022, 10 of Canada's 25 federally inspected hog slaughtering plants was in Quebec, representing 40% of the total number of plants in Canada.

Table 11.8. Hog slaughtering plants by province, 2022

Quebec	10	40%
Alberta	5	20%
Manitoba	4	16%
Ontario	4	16%
Saskatchewan	1	4%
British Columbia	1	4%
Canada	**25**	**100%**

Source: Agriculture and Agri-Food Canada. (2021b, June 15). *Distribution of Slaughtering Activity*. Red Meat and Livestock Market Information. https://agriculture.canada.ca/en/sector/animal-industry/red-meat-and-livestock-market-information/slaughter-and-carcass-weights/distribution-slaughtering-activity.

11.4 Chicken

Figure 11.4 shows that the majority of farms with broilers and other meat-type chicken production are in eastern Canada: In 2021, Ontario had 1,064 farms (45% of the national total), followed by Quebec with 546 farms (23% of all farms declaring broiler and meat-type chicken production) (Statistics Canada, 2022a). Table 11.9 shows the provincial breakdown of the number of farms producing broiler and other meat-type chicken production, as well as the number farms classified as poultry and egg production.

The number of broilers is also highest in eastern Canada, with 36M broilers in Ontario (33% of the 108M broilers in Canada) and 29M in Quebec (27% of the national total) (Census of Agriculture, 2022d). Ontario has 41% of all laying hens aged 19 weeks and over (Table 11.10), and Quebec has 15% (Census of Agriculture, 2022d).

Ontario and Quebec produce the largest quantities of eviscerated chicken: in 2022, Ontario produced 471M kg, or 35% of Canada's total (1,353M kg), and Quebec, 355M kg, or 26% of the national total (Chicken Farmers of Canada, 2022a, p. 66). British Columbia is third, with 191M kg of chicken eviscerated in 2022, or 14% of the national total (Chicken Farmers of Canada, 2022a, p. 66).

British Columbia has the largest number of chicken slaughter plants: 34, or 42% of Canada's total of 81 plants in 2022 (Agriculture and Agri-Food Canada, 2021c). Although Ontario and Quebec have the largest number of broilers and produce the greatest amounts of eviscerated chicken, these provinces combined have fewer chicken slaughter plants than British Columbia: 29 (19 in Ontario, 10 in Quebec) (Agriculture and Agri-Food Canada, 2021c). Table 11.11 shows the provincial breakdown of chicken slaughtering plants, including federally and provincially inspected plants.

Figure 11.4. Chicken by province

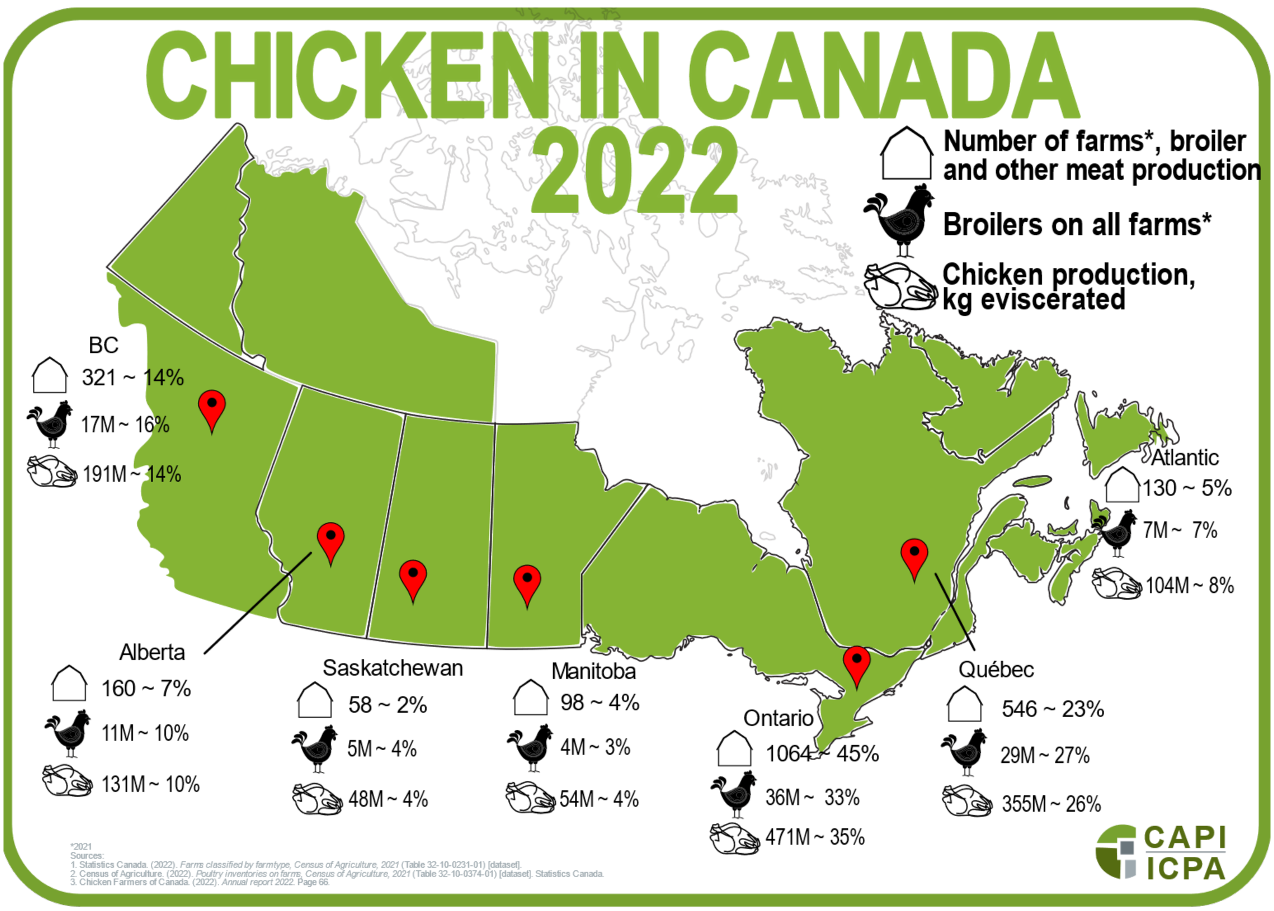

Image created internally.

Table 11.9. Number of farms by province: poultry/egg and broiler* production, 2021

Geog.	Broiler* production	Share	Poultry and egg production	Share
Canada	**2,377**	**100%**	**5,296**	**100%**
NFL & Lab.	5	0.2%	19	0.4%
PEI	14	0.6%	22	0.4%
NS	84	3%	154	3%
NB	27	1%	53	1%

Quebec	546	23%	913	17%
Ontario	1,064	45%	2,061	39%
MB	98	4%	263	5%
SK	58	2%	145	3%
Alberta	160	7%	400	8%
BC	321	14%	1,266	24%

*Broiler and other meat-type chicken production

Table created internally. Data source: (Statistics Canada, 2022a). *Farms classified by farm type, Census of Agriculture, 2021* (Table 32-10-0231-01) [dataset]. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210023101

Table 11.10. Number of broilers and laying hens by province, 2021

Geography	Number of broilers*	Share	Laying hens, 19 weeks and over	Share
Canada	**107,947,696**	**100%**	**24,779,689**	**100%**
ON	35,858,499	33%	10,120,114	41%
QB	29,275,405	27%	3,813,613	15%
BC	16,898,873	16%	3,377,744	14%
AB	10,564,935	10%	2,285,990	9%
SK	4,603,913	4%	2,193,974	9%
MB	3,661,876	3%	1,223,420	5%
NS	3,112,316	3%	780,452	3%
NB	2,053,008	2%	488,054	2%
NFL	1,643,065	2%	345,054	1%
PEI	275,806	0.3%	151,274	1%

*Broilers, roasters and Cornish

Table created internally. Data source: (Census of Agriculture, 2022d). *Poultry inventories on farms, Census of Agriculture, 2021* (Table 32-10-0374-01) [dataset]. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210037401.

Table 11.11. Chicken slaughtering plants by province, 2022

	Plants	Share	Federally inspected	Provincially inspected
Canada	**81**	100%	**42**	**39**
BC	34	42%	8	26
ON	19	23%	12	7
QB	10	12%	10	0
AB	6	7%	4	2
MB	5	6%	2	3
SK	3	4%	2	1
NB	2	2%	2	0
NS	1	1%	1	0
NFL	1	1%	1	0
PEI	0	0%	0	0

Table created internally. Data source: (Agriculture and Agri-Food Canada, 2021c). *Provincial poultry facts* [Industry profile]. https://agriculture.canada.ca/en/sector/animal-industry/poultry-and-egg-market-information/industry-profile/provincial-poultry-facts.

Economic impact studies have been done for both the chicken and egg industries in Canada. Table 11.12 presents a few of these figures. See section 9.1.4, "Economic Impact of the Canadian Chicken Industry," and section 9.1.5, "Economic Impact of the Canadian Egg Industry," for more details.

Table 11.12. Summary of economic impact of chicken and egg sectors, by province

	Chicken		Eggs	
	GDP	Jobs	GDP	Jobs
ON	$2.8B	36,093	$460M	6,996

QB	$1.1B	25,193	$235M	3,288
BC	$1.1B	14,353	$173M	2,983
AB	$958M	9,745	$156M	1,627
SK	$471M	4,914	$76M	756
MB	$325M	4,203	$101M	1,346
NS	$158M	2,625	Atlantic $94M	Atlantic 1,515
NB	$226M	3,248		
NFL	$80M	1,026		
PEI	$24M	383		

Table created internally. Data source:

(1) (Chicken Farmers of Canada, 2020). *Canada's dairy, poultry & egg sectors.* https://www.chickenfarmers.ca/wp-content/uploads/2021/07/SM5-2018-Economic-Contribution-Infographic-2021_E.pdf.

(2) (Egg Farmers of Alberta, 2018). *Economic Contribution.* https://eggs.ab.ca/healthy-farms/economic-contribution/.

12. SWOT analysis

Throughout the process of developing this livestock white paper, CAPI heard from experts from industry and government along with steering committee members in a series of consultations focused on the white paper and leading to a discussion of the strengths, weaknesses, opportunities, and threats (SWOT) of animal agriculture in Canada. The results from these discussions are presented in the tables below and aggregated in appendix 15.5.

Given the fact that animal agriculture in Canada is a complex, adaptive system, a framework was developed (see Figure 4.3. Framework for the white paper). The SWOT results presented in this section reflect this framework and will help us draw conclusions around where actions are needed.

12.1 Strengths

Clearly, Canada's strengths lie in its *abundant natural capital*, arable land, water, climate, and biodiversity which differ across the country, contributing to regional strengths based on the diversity of animal agriculture across Canada. *Past investments in human capital* through strong educational institutions, public laboratories, research centres, as well as hands-on knowledge around animal husbandry practices and technologies have evolved over time while being transmitted to farmers through active extension and advisory services, thereby contributing to Canada's strengths.

Also, with its *strong rule of law*, and participation in *international organizations* that promote fair trade, food safety, animal health standards and environmental commitments, Canada benefits from the enabling environment this creates. This contributes to *Canada's reputation on global markets* for safe, high-quality animal products and Canada's success as a major producer and exporter of high-quality animal products. In addition, *strong rural communities* and a history of industry associations operating at both provincial and federal levels add to the social cohesion and social capital upon which a strong animal agriculture community in Canada is based.

Finally, Canadian animal production has advanced to the stage that it produces and exports some of the *most GHG emissions efficient animal product*s in the world. The productivity and efficiency improvements that have been made over the past several decades have contributed to Canadian beef, pork, chicken, dairy and egg products reducing their GHG emissions on a per unit basis throughout their value chains. This provides strength in a global environment in which growing consumer demand for meat and protein from developing countries is expected to provide opportunities for Canadian animal product producers and exporters.

Table 12.1. Strengths from SWOT analysis

Strengths		
Natural capital	- Abundance: water, land, land base per capita	- Differing conditions allow varied production
Human capital	- Strong educational resources and institutions - Workforce is able, educated, knowledgeable - R&D, universities - Research, evidence - High education and knowledge level of stakeholders (producers, et cetera)	- Immigration & changing demographics → new ideas, new opportunities - Animal welfare from farm to slaughter
Created capital	- Excellent new livestock research facilities (especially in Ontario) - Stability through supply management → positive externalities - Genetics, breeding (especially poultry) - Food safety: high standards and modernized and outcome-based inspection system; industry exceeds regulatory requirements	- Biosecurity programs in primary production - Irrigation in Alberta and Saskatchewan, especially Palliser triangle
Social capital	- Farmers still generally trusted (see Figure 5.20. Trust in the Canadian agriculture and food system)	- On-farm food safety programs to ensure appropriate feed is

Strengths		
	- Cooperation (example: interdisciplinary approach in developing animal care codes of conduct) - Strong regulatory system → faith in system by producers and consumers - Traceability from farm to final product	supplied to animals, meat products are safe for human consumption, and animals are cared for - Strong animal disease surveillance and controls
Flows (outputs)	- Strong net exporter of key products	- Carcass and meat quality
Flows (emissions)	- Relative to other countries, we have low emissions per unit of product	

12.2 Weaknesses

Some of the weaknesses that are impacting animal agriculture in Canada stem from *labour* and worker shortages which limit production capacity and impede scale and the ability to compete. In addition, an *aging population* of farmers and ranchers does not bode well for the long-term sustainability of the sector, impacting rural communities and the future sustainability of Canada's natural grasslands and pastures. This problem is exacerbated by succession problems as future generations move into urban centres and are drawn toward other industries. Other weaknesses identified focused on Canada's *small domestic market* and *dependence on the U.S.* as a major export destination for our animals and animal products. At the same time, a lack of scale, capacity and competitiveness of our value-added industries here at home leads to an over reliance on bulk or live exports and low investment in processing facilities that would support a growing primary animal agriculture industry. Moreover, by virtue of its land mass and climate, Canada's animal agriculture depends on precipitation for livestock watering and feed, as most feed crops in Canada are rain-fed. This has implications on herd size, animal feed crops, and Canada's demand for imports, especially in times of drought.

On the trade front, weaknesses were identified related to certain *trade agreements* which have not been sufficiently enforced, including the Canada-EU Comprehensive Economic Trade Agreement (CETA), still prohibiting exports of Canadian beef on nontariff barrier grounds.

Finally, there are weaknesses related to Canada's fragmented markets and interprovincial trade barriers which increase the cost of inspection and end product and add regulatory barriers to trade. The regulatory environment is also seen as a weakness, especially with regard to the development and approval of innovative new vet drugs, feed additives and genetically engineered crops.

Table 12.2. Weaknesses from SWOT analysis

Weaknesses		
Natural capital	- Size of domestic market vs. international	- Dependent on precipitation → implications for herds, feed, crops, demand for imports into Canada
Human capital	- Research and innovation are sorely underfunded - GRIP (getting research into practice: extension, knowledge mobilization, et cetera) has been left in the wilderness	- Poor orientation for new hires into ag - Average age increasing - The "middle" is by and large gone as farm size increases
Created capital	- Funding to drive value from new research facilities is lacking	- Difficult for entrants, particularly into SM
Social capital	- Lack of collaboration across sectors on big issues - Most new hires (gov, academia and industry) lack any farm background	- Vet access - Regulatory burden
Flows (outputs)	- Highly concentrated processing and retail sectors	- Deadstock management plan
Flows (emissions)	- Society applies global numbers to Canada o livestock contributes 14% of all GHG globally; fact yet only 4% are for Ontario	

	Weaknesses
	70% of global freshwater withdrawals are for agriculture, but only 11% in Canada

12.3 Opportunities

Opportunities for Canada's animal agriculture come from the expected *growing global demand for meat* and dairy products around the world as developing countries become wealthier and their growing populations look to buy higher value, more nutritious foodstuffs, including those containing protein and calcium. The growing Asian market will be a particularly important market for these products. The fact that Europe's policy focus is currently on reducing domestic GHG emissions through reductions in meat production leaves the door open for Canadian animal product exports in this market. And since meat and dairy products are known to be highly nutrient dense products, Canadian exporters have the opportunity to help feed the world and combat global food insecurity.

Opportunities could also arise from the fact that Canadian meat and dairy products are some of the most *GHG emission efficient* products in the world, with few competitors. With growing consumer demand for more sustainable food products and interest by food manufacturers to market more sustainable food products and report to their shareholders on Environmental, Social and Governance (ESG) strengths, this is a great opportunity for Canadian producers to meet these new market demands for more sustainable animal products.

Table 12.3. Opportunities from SWOT analysis

	Opportunities	
Natural capital	- Agriculture feeds and captures CO_2	- Position livestock as good for soil health - Genomics
Human capital	- Automation, AI - Sharing perspectives of TFWs - Lifestyle of working in animal agriculture - Agriculture in the classroom, generating interest at a young age	- Automation, digitization of (more) practices - New collaborative governance emerging at the science interface
Created capital	- Industry work more closely with lending institutions	- Rules-based trade and comparative market access
Social capital	- Present a balanced scorecard (rather than 1-2 items/metrics of importance). Begin to add in: new entrants, HR, GDP; GHG intensity, water, other env. Food security: feeding Can, world, et cetera. World media want one-liners; livestock is suffering because it's a really big picture not suited to one-liners.	-
Flows (outputs)	-	-
Flows (emissions)	- Brand Canada as climate friendly producer	-

12.4 Threats

One of the major risks identified during consultations is related to *climate change* and the increasing extreme weather events that are impacting animal production, health and future sustainability. Some regions in the Prairies experienced drought again in 2023, after the devastatingly drought of 2021, contributing to the culling of cattle herds and shortages of hay and forage from drought and water shortages. Floods and wildfires in other regions of the country also have had serious impacts on livestock production, such as in B.C. and other parts of Canada.

At the same time that climate change is creating production risks, it is also increasingly linked to greater incidence of *animal disease*. Avian influenza, African swine fever and foot and mouth disease could prove disastrous for Canada's animal agriculture industry, impacting export market access exports and future production capacity. Fortunately, Canada has an excellent reputation in food safety and animal health, and has strong surveillance and prevention mechanisms in place to prevent or minimize disease incidence. Canada's access to veterinarian drugs and new vaccine research are all measures that are helping Canada address these risks.

Another important risk identified relates to the increasing *protectionism* and growing uncertainty around trade rules that are contributing to greater difficulty marketing Canadian animal products in export markets around the world. Given that Canada is a small trading nation with a small domestic market, trade is important and greater uncertainty creates difficulties for Canadian animal agriculture and adds to the risks.

Another risk lies with *consumer perceptions* and the potential reduction in demand for meat and dairy products based on their perceived environmental impacts. This could have repercussions for future Canadian production and prices. Many of the statistics used to describe meat and dairy products' environmental footprint are based on global averages rather than on Canadian statistics. Increased risks are also emerging from the growth in non-meat protein alternatives and non-dairy milk substitutes which risk displacing animal production. On the other hand, Canadian animal products have improved their environmental performance over time and tend to be less GHG intensive with lower carbon, water and land use footprints than animal products from many other countries in the world. There is a risk that if Canada produces less meat, poultry and dairy products, then other countries will pick up the slack, called "leakage." Many of these other countries have much higher GHG emissions from animal production and are less efficient than Canada. This risks leading to higher GHG emissions globally, which will ultimately be more harmful for the world.

Table 12.4. Threats from SWOT analysis

	Threats	
Natural capital	- Climate change impacts: not immune to weather extremes, could shift comparative advantage away from Canada	- New diseases - Genomics - AMR (and other products)
Human capital	- AI - Uncertainty in future global security - High labour costs in Canada relative to the rest of the world - Livestock may be seen as an unreliable partner → low investment incentive - Unreliable knowledge that is expensive; need for reliable and nimble research systems	- Institutions are ill equipped to respond - Immigration policy and related labour shortages which limit R&D
Created capital	- Shareholder influence -	- Size of domestic market is small relative to international
Social capital	- Canada's desire to follow EU Policy - Leadership in exporting Canadian - Unfriendly messaging and activity which is effective against animal agriculture	- Trade talks from which Canada is absent/not invited - Reliance on a handful of trade partners → risk is not diversified
Flows (outputs)	- Loss of markets - Growth of alternate proteins - Geopolitical tensions - Dependence on exports	- Disagreements in food safety - Trade restrictions based on things such as animal disease
Flows (emissions)	- Poor policy (e.g. GHG tax on farm fuels used to produce food - Growing mentality that food comes from the store and there are no related emissions - Trend of national commitments to net zero	- Policy "shove" to limiting Canada's absolute emissions, even at the peril of increasing global emissions as other countries produce more

13. Gaps, conclusions, and recommendations

Canada has a remarkable context for animal agriculture. Its capital stock is unique and important, allowing both extensive production systems and more intensive production systems, at a capacity that can produce output flows exceeding the demands of Canadians, on a sustainable basis. Animal agriculture in Canada entails an investment of almost $190 billion in assets, revenues of about $33.6 billion, and total economic impact of $92.4 billion.

However, its base of natural, human, physical, and social capital needs to be maintained, and it needs to provide economic returns that will sustain renewal of its capital bases. Land deployed in animal production, especially grasslands for grazing, needs to be maintained and prevented from conversion to other uses: annual crops and development into non-agricultural uses. The pool of talented individuals choosing animal agriculture as their preferred career must be first maintained and then expanded. Financial returns must support ongoing investments in animal production without overtly influencing asset values. A coherent community and business environment must be maintained that is robust to the shifting demands on animal agriculture and consolidation in farms and agri-businesses.

The capital stock in the breeding herd in animal agriculture reflects market and profitability expectations. The beef cow herd has been in decline for several years, recently motivated by droughts in western Canada. The dairy cow herd has been in decline as productivity per cow has grown relatively faster than Canadian dairy market growth. The sow herd has been roughly stable. Chicken has grown extensively, consistent with growth in the Canadian market.

Intensification has increased the flows of product output from animal production systems and has reduced unit emissions. Increasing efficiency in animal agriculture is an important aspect of land use efficiency, which builds upon crop yield efficiency into the next stage of conversion and helps to meet growing animal product demands without needing to bring additional land into production. At the same time, biological system overload – in which a pursuit of excessive focus on the most tangible or direct elements of animal efficiency comes at the expense of functional or welfare elements – must be avoided.

In relatively short order, the list of emissions to be concerned with from animal production systems has grown, from primarily a matter of macro-nutrient fertility balance with crops (especially nitrogen), to inclusion of atmospheric emissions of GHGs, phosphorus, coliforms, etc. There are inevitable lags in adjustment as these emissions become more tightly managed. There are also ongoing demands for knowledge given the breadth of emissions, and the prospect of trade-offs, in which the reduction in some emissions could exacerbate others.

The animal agriculture value chain is highly interrelated in a complex, adaptive system. This paper has taken an exceptionally broad view of animal agriculture, and as such has identified a multitude of interrelationships that exist:

- Animals are the dominant consumer of field crops: either directly, such as corn, barley, and alfalfa; indirectly, as consumers of damaged or below quality grade crops such as broken kernels of wheat and bakery wastes; or of byproducts such as canola meal resulting from canola crushing and processing operations.
- Nutrients consumed in animal feedstuffs are partially passed in manure and can be returned to the soil as a source of nutrients for future crops. Manure provides organic matter that contributes to soil health in a variety of respects.
- Farm animals are sources of GHG emissions, but they also support, or are essential to, crops and landscapes that sequester carbon. Many of these landscapes contribute to biodiversity, especially natural grasslands.
- Farm animals are also the source of manure nutrients that are recycled back as crop nutrients in soils; these can pose risks of offsite loss of nitrogen and phosphorus that must be prudently managed.

- Animal foods are appropriate and indeed essential elements of human diets; gaps in consumption of/access to animal-based foods are the subject of dietary deficiencies, both within the Canadian population, and globally.
- Animal agriculture is a critical source of employment and economic development in Canada, especially in rural areas where employment and business alternatives are more limited.
- The facilitation of animal agriculture entails collective action to promote, coordinate, and mitigate various aspects of animal production. This has generated important and robust institutions that serve a community that spans geography and commodity segments. But it can be vulnerable to industry concentration that reduces the number participants and fractures commonality of interests.

Animal agriculture is a major or dominant source of economic impact, especially in rural areas. It is a natural value addition to field crops, as evident in the total economic impact multiplier for animal production of 2.75 versus the economic impact multiplier for crop production of 1.938. However, due to its many interrelationships and complexity, the economic development from animal agriculture builds up slowly; conversely, it can be slow to recover from shocks.

The record of innovation and productivity improvement in Canadian animal agriculture is impressive. These efforts will need to be redoubled as Canadian animal agriculture deals with a host of focused challenges:

- Extreme weather/climate change
- Foreign animal disease
- Sustainability
- Animal welfare
- Anti-microbial resistance
- Losses of social capital
- Accessing and retaining a talented workforce

Trade is a critical element for the segments of animal agriculture scaled beyond the Canadian market, notably pork and beef. Without export markets, the revenue basis to facilitate production and processing in these industries would be greatly diminished. Canada is generally a low-cost producer and is competitive in export markets, where it has access through supportive trade policy.

Trade is expected to be increasingly important as a source of growth in demand. In its most recent market outlook for 2023-2032, the OECD/FAO notes that

> *"…it is expected that global average per capita demand for meat will increase by 2%, from the 2020-2022 base period to 2032. Consumption growth in middle-income countries will account for a significant share of this increase… disposable income in high-income countries is no longer a main determinant of changes in meat consumption. Instead, concerns about human health, environmental impacts and animal welfare are the main motivations prompting consumers in these countries to shift towards a diet that shifts demand among meat products (e.g. red vs white meat) or reduces overall meat demand. In middle-income countries, where economic growth, urbanization, and the growth of the fast-food industry progresses, more significant changes in the consumer meat choices are anticipated. In low-income countries, high population growth is expected to remain the key driver of higher meat consumption. However, limited access at relatively low income levels will continue to constrain growth in per capita meat consumption, which is only 15% of the average in high income countries" (OECD-FAO, 2023, p. 185).*

Thus, the growth in demand in the domestic market is essentially mature, not sensitive to income, and driven by perceptions and lifestyle choices. However, the income and population driven growth from middle- and lower-income countries is expected to be significant if existing global economic growth levels can be retained. Canada is among remarkably few countries with the natural resource base relative to domestic demand to produce significant exportable surpluses especially in pork and beef. It is ironic, then, that as global demand for meats is increasing, with few rival suppliers, Canada's export-oriented animal industries are retrenching.

As a low emissions intensity producer of animal products, any decrease in Canadian production will result in an increase in production from another country in order to pick up the unmet demand (all else equal). If geopolitical boundaries are erased, "net zero" pertains to global emissions, not emissions from any one country. To minimize the environmental impact of animal agriculture in the world, then, it makes most sense for low intensity emitters (such as Canada) to ramp up production, and for high intensity emitters to decrease their production.

13.1 Recommendations

Animal agriculture is highly significant – economically, environmentally, and socially – in Canada. While there are important differences, most of the issues of animal agriculture are in common across industries and species. This suggests an overall strategy for animal agriculture beyond its fragmentation across specific issues: disease and animal welfare, for example. As demonstrated in this paper, these issues are all connected. The task of such a strategy would be to establish broad objectives for animal industries that the differential needs of individual industries have, and acknowledge that many (or most) of the constraints and vulnerabilities are in common across industries, and that broader and deeper collaboration has value.

Consistent with this, the database on animal agriculture is highly fragmented, mostly at the species and farm levels. The existing database does not readily align along supply chains, acknowledging that some supply chain segments are in common across industries. The prospect that important shifts – whether evolutionary changes or sudden shocks – are not readily contained within the farm or isolated to other supply chain segments means that knowing the overall dimensions of supply chains would be of great benefit. These need to be constructed on an ad hoc basis today; this would be much better handled with a public database on supply chains and their individual segments.

Establishment of an animal product supply chain database would reveal the shifting nature of risks in animal agriculture, and highlight opportunities and risks for expanded public policy. While the effects of many perils can be contained within the farm or other segments and effectively mitigated with business risk management programming and market adjustment, other perils that are more systemic, sudden, or large in magnitude cannot be contained in individual segments. As such they can pose a much larger threat to supply chains and with extensive interrelationships, animal product supply chains as a whole can be vulnerable. Agricultural policy in Canada has not targeted supply chain risks, and animal product supply chains could form a useful starting point.

An element of social capital is the trust placed by Canadians in animal agriculture through government agencies, farm/industry organizations, farms, and agribusinesses. But this social capital is vulnerable to decay from misinformation, fear, and innuendo. This has implications, for example, in how regulators make decisions on approvals of new products and processes used in animal agriculture. Canada should redouble its commitment to a science basis for dialogue, regulatory approvals, and broader decision making, with monitoring of system performance to make mid-course corrections, as evident. Appropriate public resources and staff will be required to do so.

Animal agriculture industries in Canada, both domestic-focused and export-oriented, have a fundamental interest in the integrity of a rules-based multilateral trade system, and in the enforcement of the terms of regional trade agreements that Canada has in place. As concerns build regarding the devolution of the rules-based international trading system, the federal government needs to act as a strong advocate for the multilateral system and the fulfilment of trade commitments. Alternatively, Canada may need to forge strong bilateral trade relationships that protect the interests of Canada's animal industries.

Animal agriculture represents a core trophic level in agricultural systems, and as such, an agricultural systems perspective – along the lines of the flows detailed in this white paper – is critical. This would better integrate farm animals with feed and crops, root farm animals in with sustainability and environmental goods and services, and orient research and development in agricultural systems that include animals rather than as more separable isolated topics. In turn, this would aid in the understanding of the broader contribution of animal agriculture at a systems level and the value of these contributions. For example, profitable grazing ruminants have the effect of maintaining land use in grasslands, but the ultimate value – understanding the pending pressure of land use change into annual crops and other uses – is distributed across a broad range of considerations, including GHG emissions/sequestration, biodiversity, and downstream grain feeding/grain production activities. This systems approach should be incorporated in government roundtable processes, research and development, and elsewhere in policy planning. It would better inform incentive-based programming and the value of payments for beneficial management practices that animal industries can adopt.

These observations lead into the following policy themes:

(1) The biggest issues in animal agriculture are in common across species

Much of the natural, human, created, and social capital, as well as the output flows and associated issues, are shared across animal industries. These capital stocks, and management of changes in stocks and flows, require constant attention. Markets, in conjunction with industry collective action supported by governments, have been fundamental in guiding adjustments. However, the need for renewal is ongoing, and perhaps increasing as the demands and expectations on the system are expanding – but with a thinning and concentrating of the community supporting industry collective action. Animal agriculture needs to operate – and be seen as operating – in harmony with its base of natural capital, to improve animal productivity but not at the expense of biological systems overload, and to manage complex supply chains that are resilient to a range of conditions and stresses.

Government policies that support industry communities, facilitate new industry organizations where they are needed, and enhance responsible industry freedom to operate, are consistent with this ongoing and shifting need. Also, government policies are needed that support industry competitiveness, such as: an enabling environment; regulatory modernization; investments in transportation infrastructure and in research and innovation; and data and information that can provide a balanced view of the role of animal agriculture in Canada's future economic, social and environmental sustainability.

(2) Major components of animal agriculture in Canada are at risk, and require more targeted supportive policy

The beef industry is anchored by a beef cow herd that continues to shrink. Taken to its logical extent, this will eventually undermine the grain feeding/finishing segment of beef production, and with it, the economics of beef processing. Moreover, the declining beef cow herd will undermine the use of land in pasture, motivating conversion to annual crops, and in turn risks the loss of biodiversity and the release of carbon stored in grasslands. Ultimately, a decline of Canadian beef cattle farming, together with a steady or growing demand for meat products, could result in greater demand for imports sourced from countries with relatively higher emissions intensities in animal agriculture. This shifting burden of production could have adverse effects such as loss of biodiversity in Canada and higher global emissions. The sow herd has not expanded to grow with international pork demand, even though Canada is a highly competitive supplier. The risk is that the sow herd will begin to take on the pattern of the Canadian beef cow herd, and that retention of existing supply chain capacity could be threatened. In turn, this would weaken the demand for feed grains that are the focus of competitiveness in pork (and beef) production.

This situation could be turned around with bold policy actions. A portfolio of beneficial attributes – especially biodiversity and carbon sequestration – are tied to grasslands, and grassland will readily flip into other land uses on a market basis that does not reflect the value of these attributes- and can be detrimental to them. Governments can explore policy measures that prevent the conversion of grasslands and the grazing sector, such as by facilitating conservation easements that retain land in pasture, or by providing payments for ecological goods and services (EG&S) such as carbon and biodiversity credits and management practices which increase the efficiency and profitability of beef cattle production.

The unique situation of Canadian pork relates to the shadow cast by African Swine Fever (ASF). If Canada were subject to infection by ASF, it would pose an existential threat to the industry, due to the extent to which pork depends upon export markets, and the near certainty of border closures by others in response, and resulting market isolation. This imminent threat has had the effect of chilling investment throughout the pork supply chain. Governments and industry associations have been very active on this issue, but the dimension of threat justifies greater action. In particular, public action on the problem of wild pigs as vessels of infection and a permanent reservoir of disease remains inadequate, apparently caught between jurisdictional restrictions in provincial departments with a wildlife mandate, and federal/provincial departments of agriculture. This presents an opportunity for coordinated federal-provincial-territorial action and policy implementation based on One Health principles.

Both pork and beef have suffered from the erosion of rules-based trade and gaps in bilateral trade agreements. Canada has led efforts to rejuvenate and strengthen multilateral rules-based trade, and these efforts should be redoubled. Enforcement efforts on market access provisions of trade agreements, notably the CETA between Canada and the EU, appear to have left gaps for Canadian beef and pork. The entry of the U.K. into the CPTPP agreement is another opportunity for Canada to more assertively position itself for beef and pork market access. In addition to market access, the federal government can provide enhanced market development support, especially in markets where Canada's presence in beef and pork has historically been small.

(3) Domestically focused industries can benefit from industry development

Export-oriented animal industries interface with a broader set of risk factors than domestically oriented industries, but domestic industries still face challenges. Much of the success of domestic-focused industries has been in their collaborative adaptation to changes in markets, technology, and policy. This needs the freedom to continue as, like all aspects of animal agriculture, there are problems to address and improvements to make.

Federal and provincial governments are key stakeholders and can act to support and encourage industry development within the existing regulated structure. For example, system and program changes have previously been developed to facilitate new entrants into supply managed industries, to better serve niche markets, and to facilitate further processing. This support and flexibility are essential for continued growth and evolution of domestically oriented industries.

(4) Climate change policy should be a growth opportunity for Canadian animal industries

The worries of climate change and food security should be on par as policy priorities. Animal agriculture has an impact on both carbon emissions and sequestration, and is a major contributor to food security. But the emissions intensities of countries vary considerably, with Canada at the very low end of the range. For example, Canada is the 5th highest net exporter of pork in the world (FAOSTAT, 2021a; internal calculations) and produces pork with an intensity of 4.43 kg CO2e/kg of pork (Groupe Agéco, 2018) compared with 6 kg CO2e/kg pork, world average (GLEAM, as cited in Gerber et al., 2013). If a high animal emissions country were to downsize its animal industry and import the equivalent output from production increases in Canada, net global emissions would fall.

Domestic climate change policy should bear this out. Moreover, it underscores the disadvantage of country-by-country emissions targets, and the cost of this policy approach as it applies to the necessities of life through food and food security. Canada has been active in discussion on climate change policy, taking a whole-of-economy approach to it domestically and being heavily engaged in the international dialogue, both climate change and sustainable development goals. Canada thus has the platform, and the interest, to apply a food security filter to both national and international climate change policy, and advocate for change. Canada's comparative advantage in sustainable animal agriculture creates alignment with UN sustainable development goals (SDGs) #2 (Zero Hunger) and #12 (Responsible Production and Consumption). However, downsizing or impairing the efficiency of Canadian animal agriculture with strict emissions constraints would run contrary to the advancement of these SDGs.

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15. Appendix

15.1 Steering Committee members

(1) Alltech
(2) Chicken Farmers of Canada
(3) Grand River Agricultural Society
(4) United Farmers of Alberta
(5) Dairy Farmers of Canada
(6) Canadian Cattle Association
(7) Livestock Research and Innovation Corporation

15.2 Participating institutions in consultations

(1)	All steering committee members	(15)	Canadian Meat Council
(2)	RBC	(16)	Turkey Farmers of Canada
(3)	Canfax	(17)	University of Alberta
(4)	Saskatchewan Stock Growers	(18)	Dairy Processors' Association of Canada
(5)	Lactanet	(19)	ANACAN
(6)	Agriculture and Agri-Food Canada	(20)	Grain Growers of Canada
(7)	Alta Genetics	(21)	Virginia Tech
(8)	Grand Valley Fortifiers	(22)	Ontario Ministry of Agriculture, Food and Rural Affairs
(9)	Ontario Vet College	(23)	University of Guelph
(10)	Alberta Ministry of Agriculture and Irrigation	(24)	Restaurants Canada
(11)	Canadian Pork Council	(25)	Banque nationale
(12)	Maple Leaf Foods	(26)	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation
(13)	Feedlot Health Management	(27)	Zoetis
(14)	Ducks Unlimited		

15.3 Institutions in animal agriculture

	Beef	Dairy	Pork	Poultry/eggs	General
Associations, national	Canadian Cattle Association Canadian Beef Cattle Check-Off	Dairy Farmers of Canada Lactanet (Canadian Dairy Network)	Canadian Pork Council Canada Pork	Chicken Farmers of Canada Egg Farmers of Canada	Academic institutions offering animal husbandry courses Canadian Society of Animal Science

	Beef	Dairy	Pork	Poultry/eggs	General
	Canadian Beef Breeds Council Canadian Meat Council Canadian Aberdeen Angus Association Canadian Beef Grading Agency Canadian Roundtable for Sustainable Beef		The Canadian Swine Exporters Association Canadian Swine Breeders Association	Turkey Farmers of Canada Canadian Hatching Egg Producers	The Canadian Livestock Records Company Animal Nutrition Association of Canada Canadian Veterinary Medical Association
Provincial and regional	Saskatchewan Stock Growers Association Saskatchewan Cattlemen's Association Alberta Beef Producers Alberta Cattle Feeders' Association Les Producteurs de bovins du Québec Beef Farmers of Ontario	Les producteurs de lait du Québec	Manitoba Pork Council Les Éleveurs de porcs du Québec	Les Éleveurs de volaille du Québec La Fédération des producteurs d' œufs du Québec Les Producteurs d' œufs d' incubation du Québec	United Farmers of Alberta Grand River Agricultural Society Ontario Agri Business Association
Research	Beef Cattle Research Council	Valacta, centre d'expertise en production laitière du Québec	Swine Innovation Porc Canadian Centre for Swine Improvement		Canadian Livestock Genetics Association Livestock Research and Innovation Corporation
Economic		Dairy Farmers of [Canada or province]			Firms: genetics and breeding, feed (e.g., Alltech), marketing, transportation and logistics, research (e.g., Beef Cattle Research Council), et cetera
Regulatory	Governments				

	Beef	Dairy	Pork	Poultry/eggs	General
	Canadian Council on Animal Care Animal Protection Party of Canada National Farm Animal Care Council Animal Health Canada				

15.4 Growing degree days

Figure 15.1. GDDs, PEI

Growing degree days, base=10 degrees (corn). HARRINGTON CDA CS & STANHOPE, PEI. Years eliminated due to missing data: 1993, 2000, 2018. May, June, July and 2 more

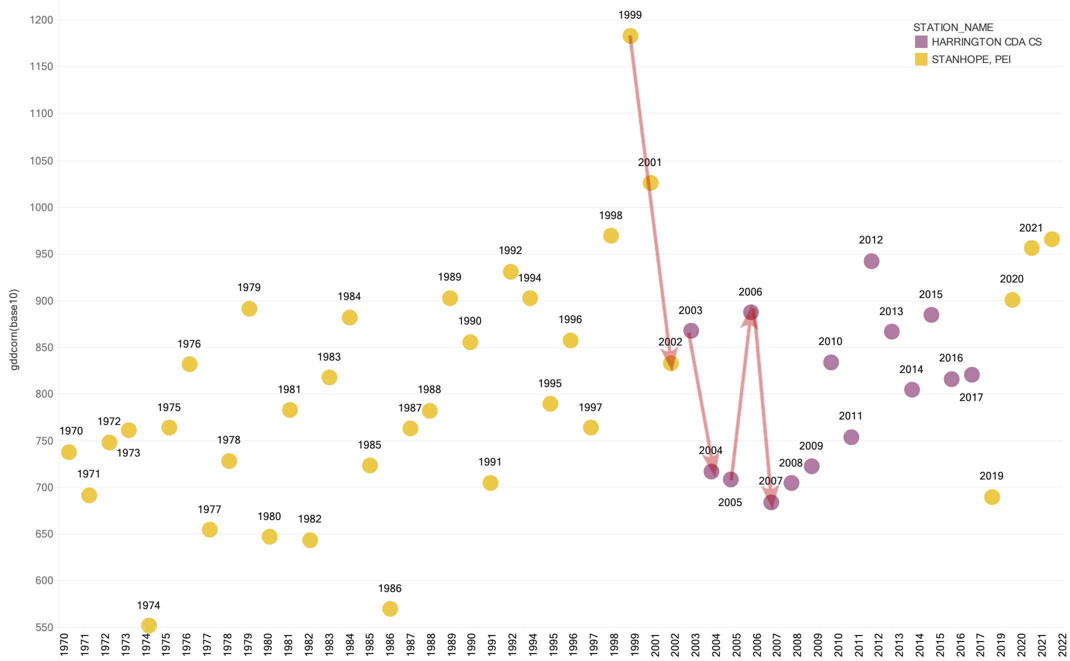

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Figure 15.2. GDDs, Lennoxville, QB

Growing degree days, base=0 degrees (wheat). LENNOXVILLE. Years eliminated due to missing data: 1973, 1996, 2003, 2006

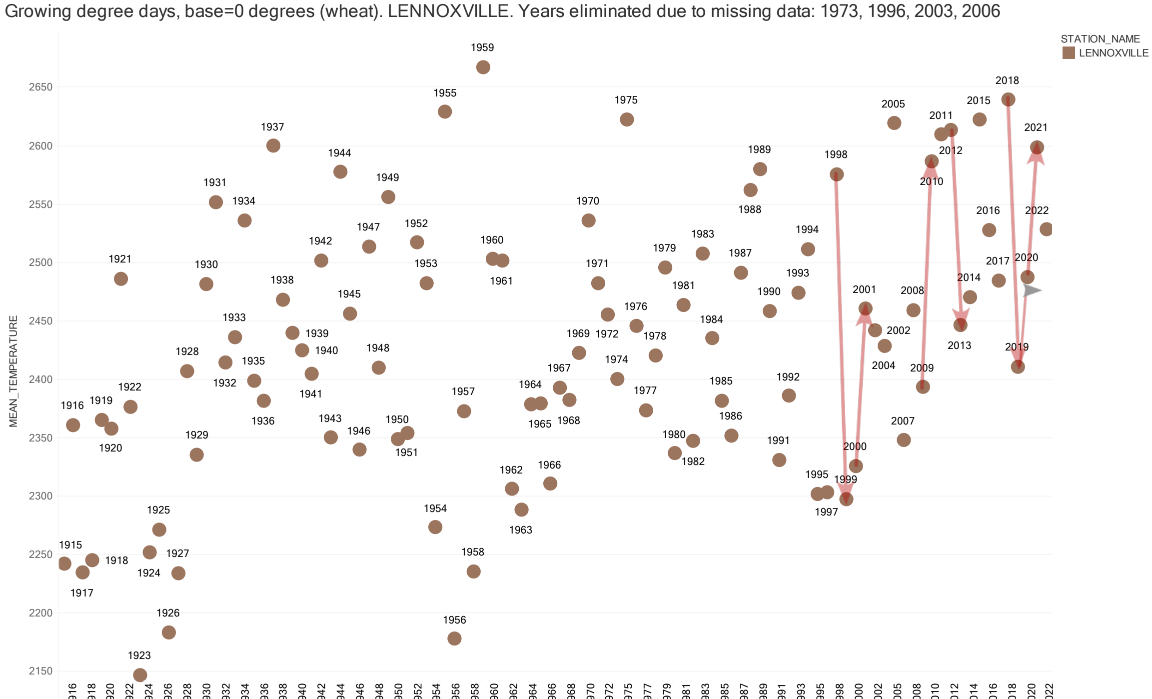

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Figure 15.3. GDDs, Baldur, MB

Growing degree days, base=0 degrees (wheat). BALDUR, MB. Years eliminated due to missing data: 1996, 2007, 2016, 2021. May, June, July and 2 more

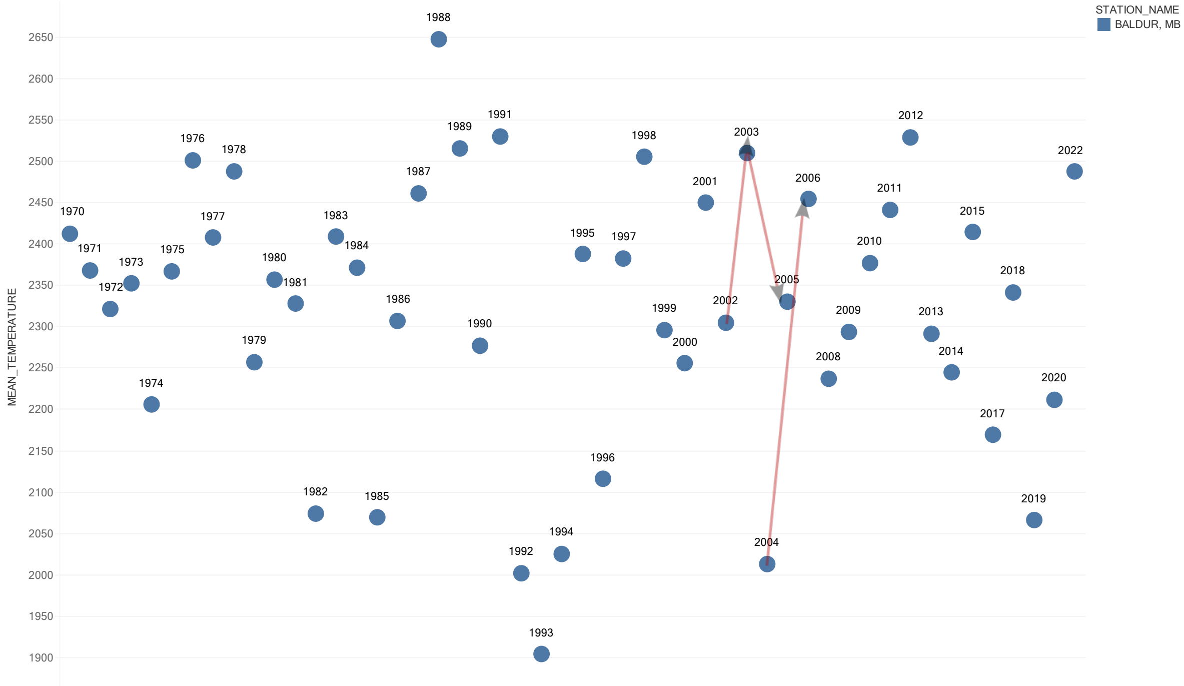

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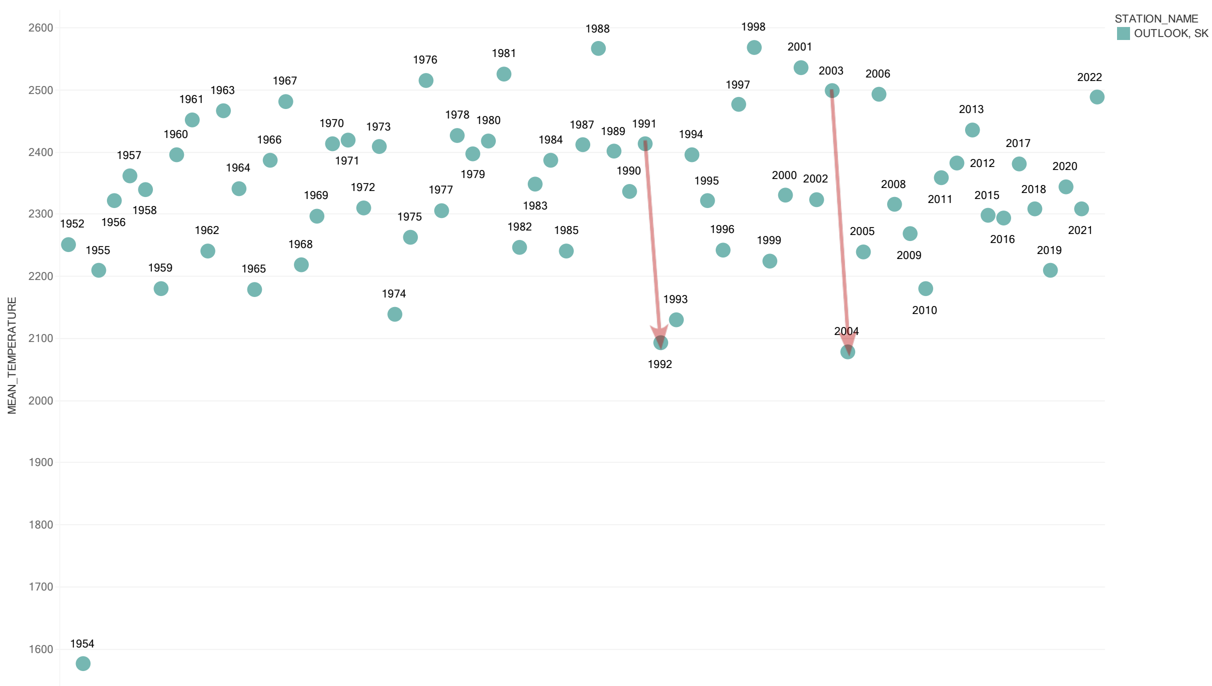
Figure 15.4. GDDs, Outlook, SK.

Growing degree days, base=0 degrees (wheat). OUTLOOK, SK. Years eliminated due to missing data: 1986, 2007, 2014. May, June, July and 2 more



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15.5 SWOT analysis

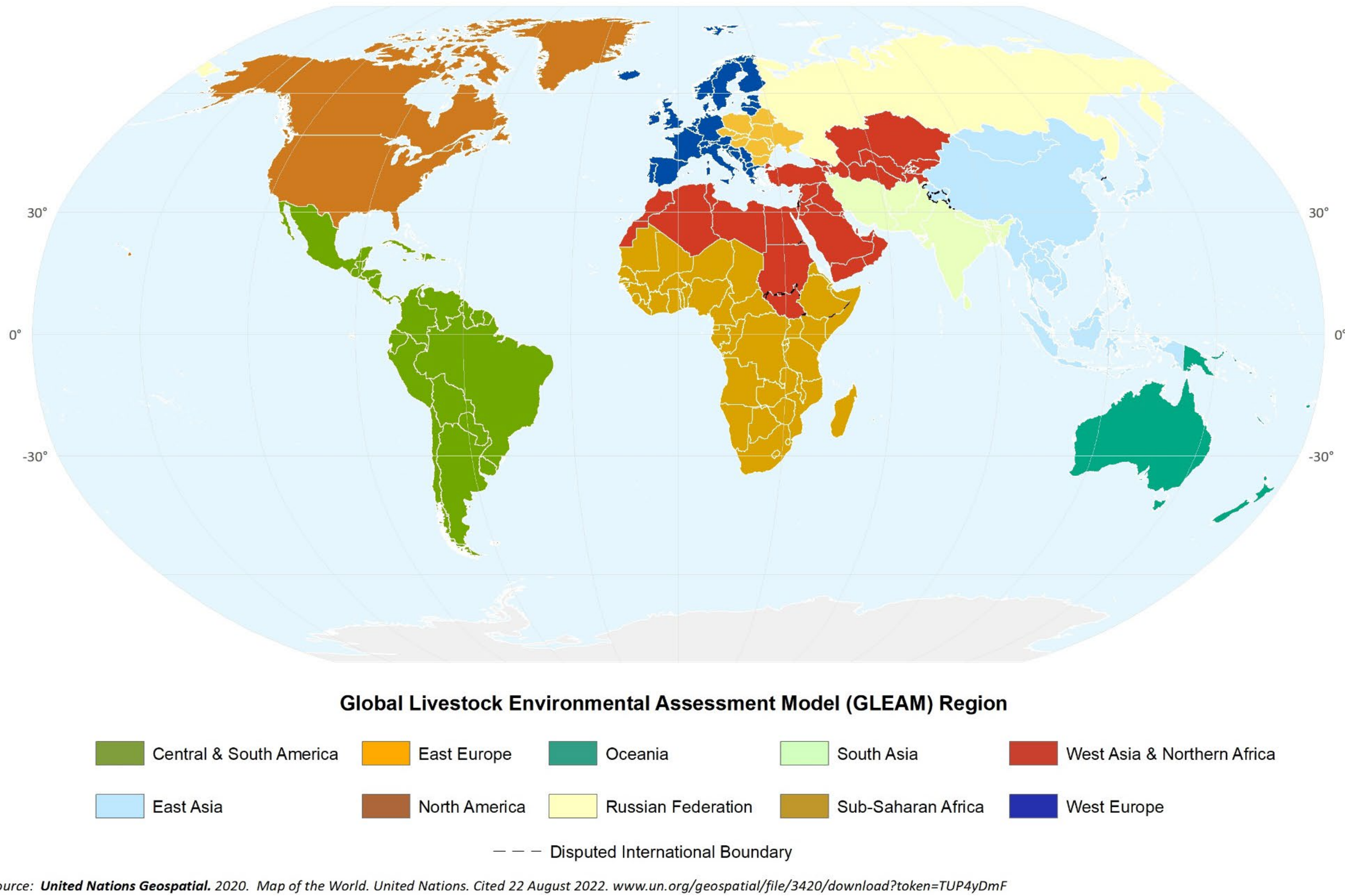
Table 15.1. SWOT analysis

	Strengths	Weaknesses	Opportunities	Threats
Natural capital	- Abundance: water, land, land base per capita - Differing conditions allow varied production	- Size of domestic market vs. international - Dependent on precipitation → implications for herds, feed, crops, demand for imports into Canada	- Agriculture feeds and captures CO_2 - Position livestock as good for soil health - Genomics - BMPs which improve soil health - Climate change will shift comparative advantage: more opportunities for Canada in the *longer term*	- Alternate proteins - Climate change impacts: not immune to weather extremes, could shift comparative advantage away from Canada - New diseases - Genomics - AMR (and other products)
Human capital	- Strong educational resources and institutions - Workforce is able, educated, knowledgeable - R&D, universities - Research, evidence - High education and knowledge level of stakeholders (producers, et cetera) - Immigration & changing demographics → new ideas, new opportunities - Animal welfare from farm to slaughter	- The "middle" is by and large gone as farm size (acres) increases and number of farms decreases - Research and innovation are sorely underfunded - GRIP (getting research into practice: extension, knowledge mobilization, et cetera) has been somewhat ignored - Poor orientation for new hires into agriculture - Average age of producers increasing - Inadequate farm succession especially due to urbanization - Reliance on TFWs - Low understanding of philosophy in animal ag - Low uptake and impact of scientific research - Labour shortage, especially in animal food vets	- Automation - AI - Sharing perspectives of TFWs - Lifestyle of working in animal agriculture - Agriculture in the classroom, generating interest at a young age - Automation, digitization of (more) practices - New collaborative governance emerging at the science interface	- AI - Uncertainty in future global security - High labour costs in Canada relative to the rest of the world - Livestock may be seen as an unreliable partner → low investment incentive - Unreliable knowledge that is expensive; need for reliable and nimble research systems - Institutions are ill equipped to respond - Immigration policy and related labour shortages which limit R&D

	Strengths	Weaknesses	Opportunities	Threats
Created capital	- Excellent new livestock research facilities (especially in Ontario) - Stability through supply management → positive externalities - Genetics, breeding (especially poultry) - Food safety: high standards and modernized and outcome-based inspection system; industry exceeds regulatory requirements - Biosecurity programs in primary production - Irrigation in Alberta and Saskatchewan, especially Palliser triangle	- Funding to drive value from new research facilities is lacking - Difficult for entrants, particularly into SM - Land use competition: urban vs. agriculture - Low incentive for investment - Logistics, especially transportation of livestock - Distance to market - Landlocked agricultural provinces: Alberta, Saskatchewan - Lack of value-add, irrigation; value-add is done elsewhere - Lack of competitiveness - Decline of beef herd	- Industry could work more closely with lending institutions - Rules-based trade and comparative market access - Low cost of feed	- Shareholder influence - Size of domestic market is small relative to international
Social capital	- Farmers still generally trusted (see Figure 5.20. Trust in the Canadian agriculture and food system) - Cooperation (example: interdisciplinary approach in developing animal care codes of conduct) - Strong regulatory system → faith in system by producers and consumers - Traceability from farm to final product - On-farm food safety programs to ensure appropriate feed is supplied to animals, meat products are safe for human consumption, and animals are cared for - Strong animal disease surveillance and controls	- Lack of collaboration across sectors on big issues - Most new hires (gov, academia and industry) lack any farm background - Vet access - Regulatory burden - Public perception, misperception about animal welfare, livestock emissions, et cetera - Incomplete messaging around emissions ("Cows are the new coal") vs. fact: animal agriculture is responsible for a small share of GHG emissions, and even smaller in net emissions - Beef meatpacking competitiveness is harmed by specified risk material (SRM) harmonization with US harms	- Present a balanced scorecard which reflects the complexity of animal agriculture: new entrants, HR, GDP, GHG emissions intensity, environmental indicators (water, et cetera), food security (feeding Canadians and the world). - Because of its complexity, animal agriculture is not well suited to media-friendly one-liners. - Messaging around the high standards of animal welfare - Diversifying trade partners - Communication with other sectors - Biogenic carbon cycle analyses (new work) -	- Canada's desire to follow EU Policy - Leadership in exporting Canadian - Unfriendly messaging and activity which is effective against animal agriculture - Trade talks from which Canada is absent/not invited - Reliance on a handful of trade partners → risk is not diversified

	Strengths	Weaknesses	Opportunities	Threats
Flows (outputs)	- Strong net exporter of key products - Carcass and meat quality	- Highly concentrated processing and retail sectors - Deadstock management plan - Loss of processing capacity - High concentration in processing → vulnerability to labour disruptions	- Leveraging the high quality of Canadian products which is recognized internationally - Reputation for high-quality meat products (especially beef/veal) and excellent genetics	- Loss of markets - Geopolitical tensions - Dependence on exports - Disagreements in food safety - Trade restrictions based on things such as animal disease
Flows (emissions)	- Relative to other countries, we have low emissions per unit of product	- Society applies global numbers to Canada ○ livestock contributes 14% of all GHG globally; fact yet only 4% are from Ontario ○ 70% of global freshwater withdrawals are for agriculture, but only 11% in Canada	- Brand Canada as climate friendly producer - Canada is expected to "do its part" in sustainable agriculture – and animal agriculture in Canada *is* doing its part	- Poor policy (e.g. GHG tax on farm fuels used to produce food - Growing mentality that food comes from the store and there are no related emissions - Trend of national commitments to net zero - Policy "shove" to limiting Canada's absolute emissions, even at the peril of increasing global emissions as other countries produce more

Figure 15.5. GLEAM regional map



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