An Overview of the **Canadian Agricultural Innovation System**

Agricultural Institute of Canada

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Institut agricole du Canada

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Mapping Investments to Impacts

This document was prepared by the Agricultural Institute of Canada (AIC) with financial and logistical support from the Canada Foundation for Innovation (CFI). It aims to provide an overview of the Canadian agricultural research landscape in order to contextualize the work done by CFI in their *Pathways to Impact* initiative, a national study designed to capture the downstream benefits to Canadians from research infrastructure funding.

You are here

An Overview of the Canadian Agricultural Innovation System

Description of the Canadian agricultural research landscape to help assess the overall performance of agricultural research in Canada and the impact of innovation in the sector.

Pathways to Impact: Agricultural Research

Mapping Investments to Impacts is an approach used by the Canada Foundation for Innovation to explore its contribution to the national research landscape in a given thematic area – in this case agricultural research. The approach seeks to examine the economic, social and environmental benefits achieved but places an emphasis on identifying the pathways to impact.

Included are five areas of study selected in consultations with an advisory group composed of representatives from 20 organizations. The areas of study include dairy farming, grain storage, greenhouse gas emission, antimicrobial resistance in livestock, and improved resistance to stress in crops. Areas of study represent significant CFI and partner investments. Case study reports have been prepared for three of the 5 areas of study.

Dairy Farming

Grain Storage

Greenhouse Gases

Contents

Highlights

From farmers and ranchers to food and beverage processors, retailers and the Canadian consumer, the agriculture and agri-food system is rich and diverse and plays a critical role in an economy increasingly dominated by manufacturing and service industries.

Agricultural innovation is the key driver of economic and productivity growth in the agricultural sector, enabling greater competitiveness as well as opportunities to meet food security and sustainability goals in Canada and around the world. Sustainable production intensification, however, requires an inclusive, interactive and participatory demand-driven agricultural innovation system supported by evidence-based policy frameworks, institutional settings and governance structures that promote continuous technological progress and the creation of new knowledge by facilitating the sharing, access, and exchange of information.

- The Canadian agricultural innovation system has a diversity of stakeholders that play crucial roles in the innovation continuum.

  Multiple stakeholders interact to enable, create, fund, perform, implement, inform and disseminate innovation across the sector. Although governments provide strategic direction to guide agricultural innovation in Canada, other stakeholders actively participate in various consultative and networking mechanisms to guide policy development and priority setting.

- The public sector continues to be the largest source of funding for agriculture R&D whether performed in the public or private setting.

  Despite the increased participation of industry and the private sector in cross-sectoral partnerships and matching investment strategies, federal and provincial governments are the key funders of research, infrastructure, commercialization, development and extension activities in the sector. Although agriculture R&D reports very high rates of return, Canada's private sector appears to under-invest or decrease its investments due to insufficient incentives and a reduced number of successful agri-entrepreneurs willing to invest in innovation.

- Canada's strong scientific and infrastructure base plays a prominent role in the production of high-quality agricultural research across the country.

  Canada ranks 8th worldwide in the production of academic papers related to agriculture with 90,606 academic papers published between 1997 and 2014. Major research hubs in crop, livestock, and biotechnology are found in Edmonton (AB), Guelph (ON), Halifax (NS), Quebec (QC), Saskatoon (SK), Vancouver (BC) and Winnipeg (MB).

- Skilled labour shortages in primary agriculture over the last ten years have an impact on all stages of the innovation continuum, particularly research dissemination activities that promote farm-level adoption of innovation.

  A lack of skilled human resources in the primary sector can potentially undermine Canada's research capacity, but may also affect other stages of the innovation continuum such as the farm-level adoption of research outputs. Industry associations and commodity groups have increasingly taken the leading role in extension initiatives due to major organizational and operational changes in the delivery of public extension and knowledge transfer services.

Canada's Agricultural Research at a Glance

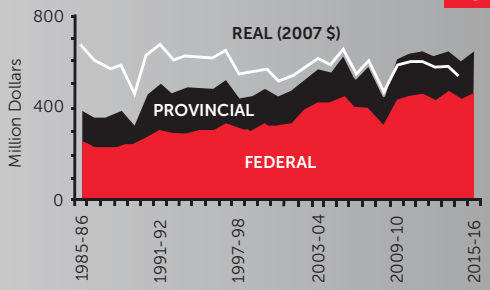
Investment

Public Agriculture R&D Spending

Provincial & Federal (AAFC Estimates)

Primary Agriculture & Food Processing

$649 million 2015-16

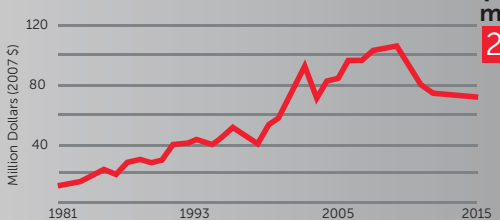


Source: AAFC

Private Agriculture R&D Spending

Primary Agriculture

$73[1] **million** 2015



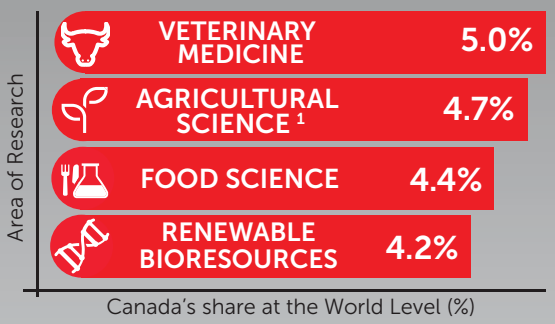
Source: Statistics Canada

[1] Agriculture only. Agriculture, forestry, fishing and hunting amounted $83M

Scientific Production

6,878 academic **papers published** 2014

8th place in **scientific production** of agricultural research **worldwide**



29,937 **students enrolled** in agricultural programs 2014-15

Sources: Science-Metrix, Statistic Canada

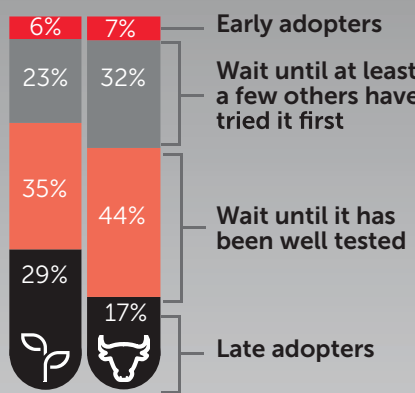
[1] Includes Agronomy, Agricultural Engineering, Irrigation, Weed and Pest Control, Agroforestry, Agricultural Economics & Policy, Plant Sciences, and Land Resource & Soil Science

Farm-Level Adoption

48% Canadian **farms** adopted agricultural innovations in 2013

Source: AAFC

Speed of adoption



Agricultural innovations are more likely to be adopted by **large farms** with revenues of over one million dollars.

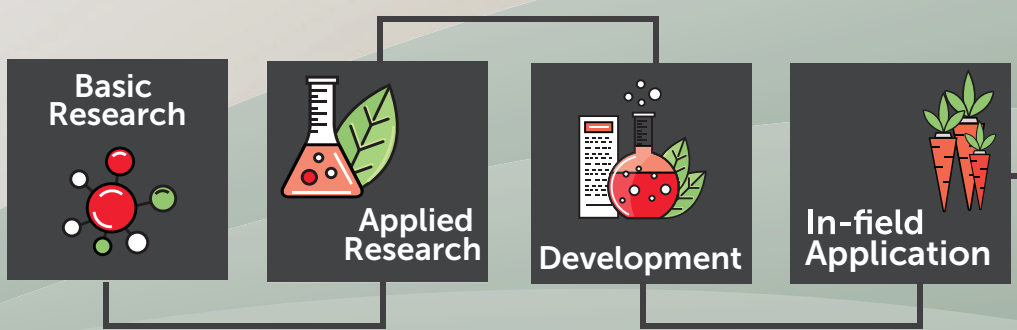
Source: AAFC

Actors

- Governments
- Academia
- Private Sector
- Industry
- Non-Profits
- Extension Providers
- Farmers
- Consumers
- International Partners

Why does agricultural research matter?

INNOVATION CONTINUUM



- Agricultural Productivity
- Food Security
- Rural Development
- Economic Growth
- Sustainability

A. Introduction

A.1. The Agriculture and Agri-Food System in the Canadian Economy

Canada's agriculture sector is rich and diverse with a strong history in a wide range of production ranging from grains, oilseeds, red meat and pulses, to dairy, poultry, egg products and potatoes, with an almost equal share of crop and livestock products. The agriculture and agri-food system plays a crucial and integral role in the Canadian economy, employing one in eight Canadians and in 2014 generating $113.8 billion – 6.6% of GDP (Statistics Canada, 2017) and $55 billion in export sales, making Canada the fifth largest exporter of agri-food products globally (AAFC, 2016, 2016b).

A.2. The Agricultural Innovation System (AIS)

Agricultural innovations[1] such as new crop varieties, livestock breeds, nutrient management practices, tilling methods and farm machinery, as well as advancements in biotechnology, precision agriculture, communication and information technologies and alternative energy sources have significantly contributed to the transformation of the Canadian agriculture sector over the last 50 years, enabling greater competitiveness and productivity as well as demonstrating significant potential to contribute to national and global sustainability goals.

Agricultural productivity growth demands continuous technological progress. *Sustainable* growth, however, requires a paradigm shift from the traditional supply driven innovation model, to a more inclusive, interactive and participatory demand-driven *Agricultural Innovation System*[2] (AIS) that involves a wide range of actors who guide, support, create, transfer and adopt innovation (OECD, 2013). This dynamic network-based model requires continuous collaboration, strong stakeholder relationships and knowledge exchange, and thus demands a supportive institutional, policy and governance environment.

Using an approach consistent with AIS, this document aims to describe the Canadian agricultural research landscape to help assess the impact of innovation in the sector.

B. Canadian Agricultural Research Landscape

B.1. Structure of Agricultural Research in Canada

B.1.1. Innovation Actors: Funders, Performers, Intermediaries and International Partners

Multiple stakeholders interact within the research value chain to enable, create, fund, perform, implement, inform and disseminate innovation across the agriculture sector (Image B.1):

Federal and provincial governments are significant investors and performers of agricultural R&D and public extension, catalyzing partnerships across sectors as well as establishing policies and programs to support research and innovation activities.

The private sector – agri-businesses – also play a dual role as funders and performers of agricultural R&D that is mostly geared towards applied research and commercialization.

[1] As defined in the Oslo Manual innovation is the implementation of a new or significantly improved product (good or service), a new marketing method, or a new organizational method in business practices, workplace organization or external relations (OECD, 2005). Innovation encompasses science and technology (S&T), research and development (R&D) as well as the adoption of scientific research outputs such as new production techniques or improved farming practices.

[2] The concept of innovation systems provides a framework to understand the process of innovation – from the lab to the marketplace – emphasizing how the interaction and relationships between multiple actors determines the overall performance, impact and scope of innovation processes. This conceptual framework has been increasingly used to understand the process of innovation in agriculture – from S&T and R&D to knowledge transfer and extension.

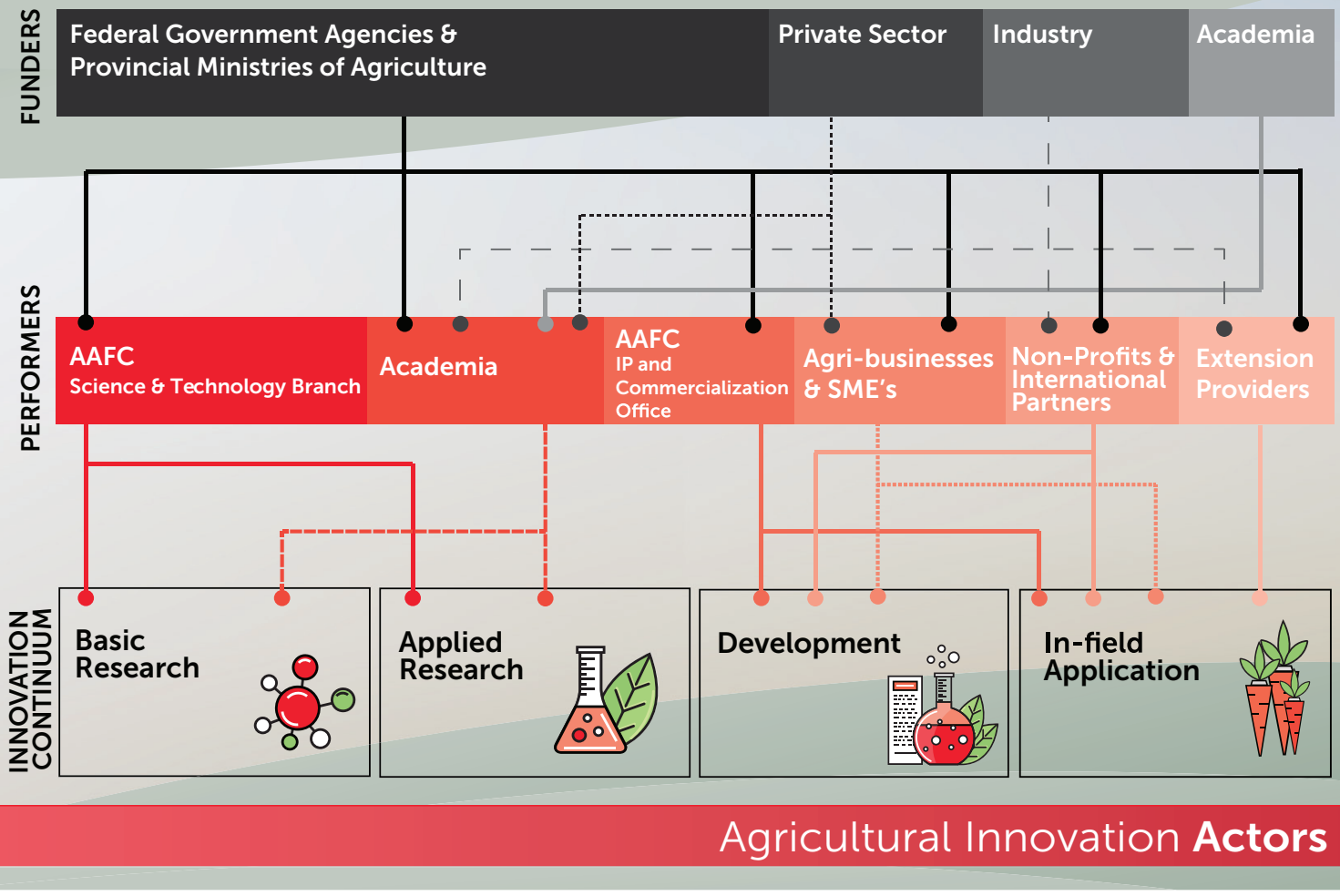


Image B.1. Agricultural Innovation Actors

Industry groups – commodity-specific and industry associations representing farmers, ranchers, and producers – help coordinate and direct funds for research efforts and act as intermediaries by supporting extension and knowledge transfer activities.

Post-secondary education institutions – universities, colleges, CEGEPs and polytechnics – are key providers of technical knowledge, performing a broad range of R&D and innovation activities as well as training highly qualified personnel (HQP).

Extension and advisory service providers facilitate the transfer of new scientific discoveries to end-users and the public and involve a wide range of intermediary actors in both the public and private sectors (i.e. agrologists, input manufacturers, private consultants and industry-led initiatives).

Non-profits and international partners create valuable opportunities for international cooperation with multi-national companies and post-secondary institutions working to solve global challenges.

B.1.2. Policy and Governance

Through the *Federal Science, Technology and Innovation (ST&I) Strategy*, the Government of Canada sets out strategic direction for the development of innovation activities and various research initiatives across all sectors of the economy including agriculture.

Innovation, Science and Economic Development Canada (ISED) is responsible for setting Canada's Innovation Agenda and the Ministry of Science oversees and supports scientific research and integration of evidence-based policy-making.

Agriculture and Agri-Food Canada (AAFC) leads federal efforts in the growth and development of the agriculture sector, with the National Research Council of Canada (NRC) and the federal research funding organizations (NSERC, SSHRC, CIHR, Genome Canada and CFI) (Image B.3) playing an important supporting role for R&D and innovation.

Provincial governments similarly guide their own agricultural innovation systems and provide support alongside the federal government for post-

secondary institutions and regional research centres concentrating on provincial agricultural research priorities.

Growing Forward 2 (GF2), the current five-year policy framework for the food and agriculture industry developed and implemented by AAFC and governed by a joint federal-provincial-territorial (FPT) agreement, guides innovation and collaborative initiatives in the sector (Image B.2).

Research priority setting

The *Environment and Agriculture* section of the Government of Canada's ST&I Strategy, outlines seven sub-areas of particular focus to agriculture including water security, biotechnology, aquaculture, food & food systems, and climate change research. Scientific research and analysis are also identified as key strategies to support improvements in sustainable farming practices in the *Federal Sustainable Development Strategy* (FSDS).

In line with the FSDS and the ST&I Strategy, four main strategic objectives guide AAFC's in-house science activities through its Science and Technology Branch (STB) in 20 research stations across the country namely: increasing agricultural productivity, enhancing environmental performance, improving attributes for food and non-food uses, and addressing threats to the value chain.

Agricultural industry groups also have an important impact on the strategic direction of public research through their own advocacy efforts and by providing their views at the House of Commons Committee on Agriculture and Agri-Food and the Senate Committee on Agriculture and Forestry.

They also participate in various consultative and networking mechanisms at both the provincial and national levels that bring policy makers and industry stakeholders together to provide strategic guidance for agricultural research program development and priority setting. Value Chain Roundtables (VCRTs), working groups facilitated by AAFC, have been good examples helping to ensure research priorities and long-term strategies reflect industry needs in key commodity sectors at the national level.

Post-secondary education institutions, largely autonomous and responsible for setting their own research priorities, seek to build strength in areas of importance to Canada taking into account provincial and federal research priorities.

B.2. Investments in Agricultural Innovation

B.2.1. Funding Mechanisms for Agricultural R&D and Innovation

The public sector supports the direct costs of research, infrastructure, commercialization activities and the development of R&D networks through a variety of funding programs at the federal and provincial levels, as well as indirectly through tax incentives for business investment in R&D.

The private sector also plays a role in private R&D and business-oriented applied research, while industry stakeholders and producer-led associations contribute funds through various mechanisms such as mandatory levy and/or check-off systems and targeted investments in R&D, partnerships, and extension activities (Image B.3).

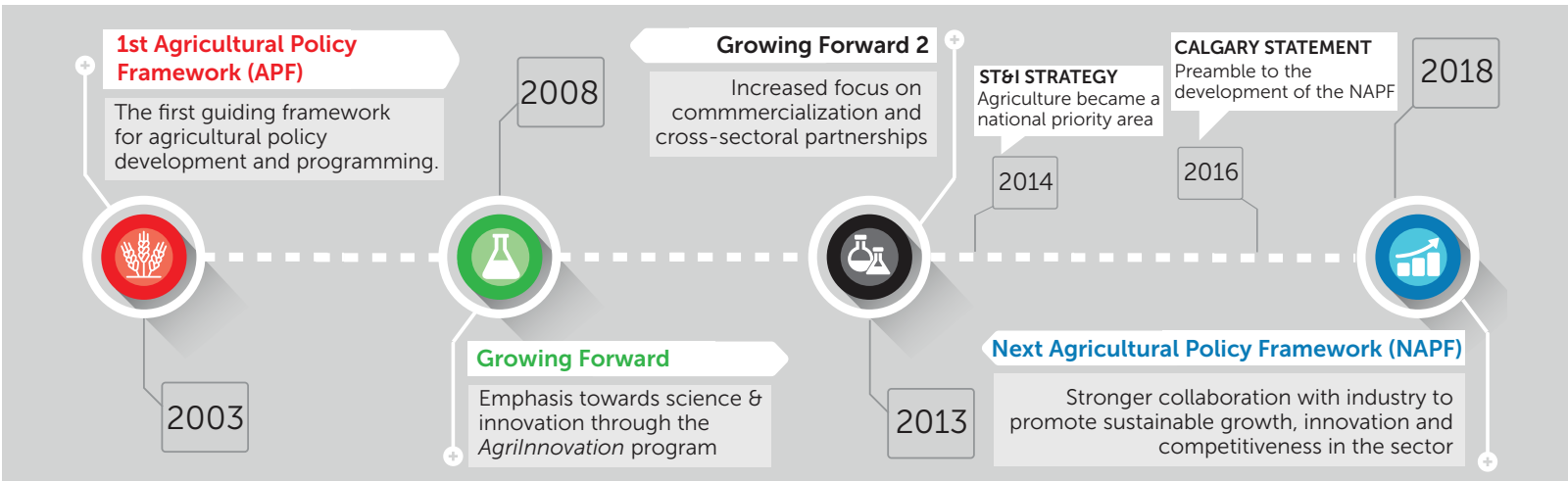


Image B.2. Canadian Agricultural Policies (2003-2018)

Image B.3. Funding mechanisms for agricultural research

B.2.2. Funding Trends in Agriculture R&D

Public Sector

Total expenditures by the federal and provincial ministries of agriculture in support of the agriculture and agri-food sector as a whole have slowly declined over the past decade, both in dollars and as a share of the agriculture GDP (Chart B.1).

Budgetary expenditures[3] financing the agricultural knowledge and innovation system (AKIS) represented 0.046% of Canada's total GDP in 2015, ranking 7th worldwide (Image B.4). This investment as a portion of total country GDP has steadily declined over the past three decades (Chart B.2).

Image B.4 summarizes Canada's funding trends in agricultural research nationally, provincially and relative to the rest of the world.

In 2015-16, the total federal expenditure across all departments in agriculture[4] S&T was $705 million, a decrease of 11.7% from 2010 (Statistics Canada, 2017b).

Based on AAFC's annual estimates, in 2015-16, $649.5 million of total federal S&T investment went through the federal ministry of agriculture toward agriculture and agri-food R&D (primary agriculture and food manufacturing R&D) – an increase from $643 million in 2014-15 (AAFC, 2016).

In 2015-16, overall reported expenditures by provincial ministries of agriculture – including capital, program, and operating expenses supporting both agricultural research and its associated activities (education and extension) – collectively accounted for $440 million (Image B.4).

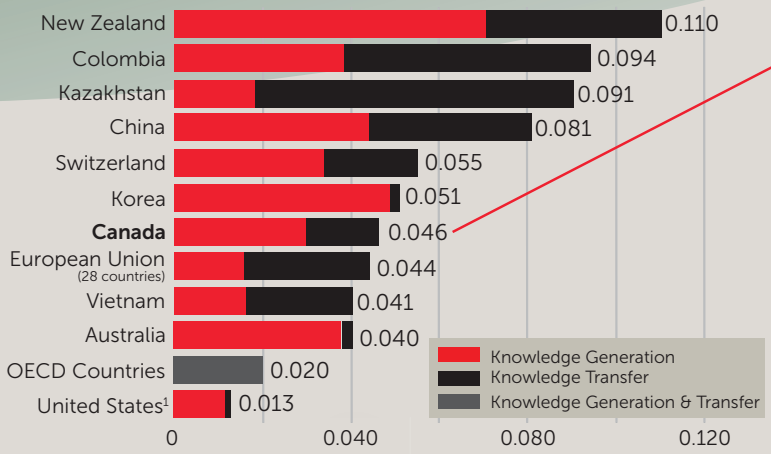
Nevertheless, after accounting for inflation, both AAFC and provincial estimates for real agriculture R&D expenditures (2007$) have demonstrated a slow downward trend (Image B.4).

[3] Budgetary expenditures include real budgetary payments and other transfers which do not require actual monetary disbursements (tax credits, interest rates or input prices) provided through policies that support producers collectively (General Services Support Estimate).

[4] This category includes: scientific research on chemical fertilizers, biocides, biological pest control and the mechanization of agriculture as well as research on the impact of scientific activities in the field of developing food productivity and technology (NABS Nomenclature).

Funding Trends in Agriculture R&D

Expenditures in Agriculture R&D and Extension
% of Total Country GDP, 2015[1]

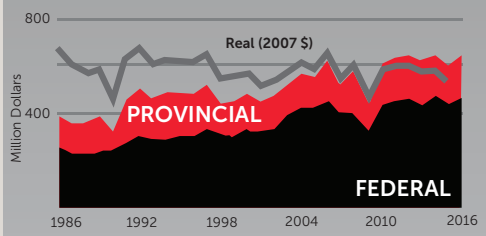


Source: OECD, Producer and Consumer Support Database (2016)

0.046% of GDP
0.030% **Knowledge Generation**
0.016% **Knowledge Transfer**

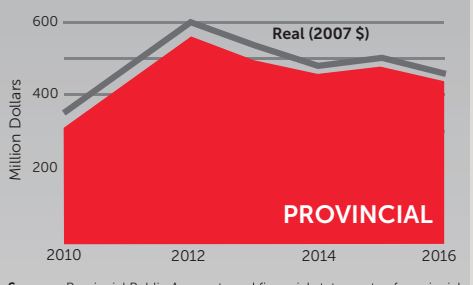
Governments

Public Research Spending in Support of the Agriculture & Agri-Food Sector[2]
Primary Agriculture & Food Processing
AAFC's Estimates



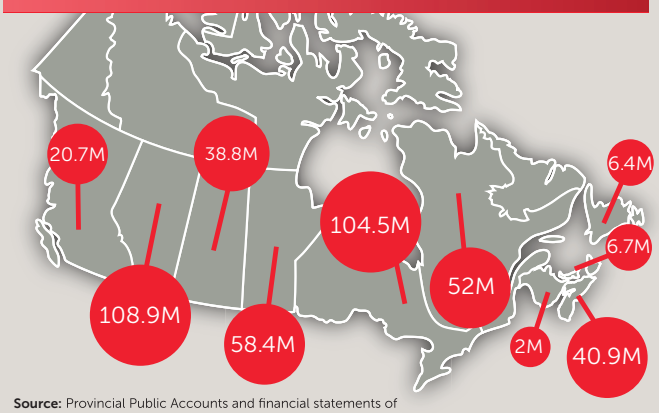
Source: AAFC Estimates. Chart extracted from *An Overview of the Canadian Agriculture and Agri-Food System*, AAFC 2016.

Public Provincial Expenditures in Agricultural Research, Education & Extension[3]
Overall Provincial Expenditures



Sources: Provincial Public Accounts and financial statements of provincial ministries of agriculture, 2010-2016.

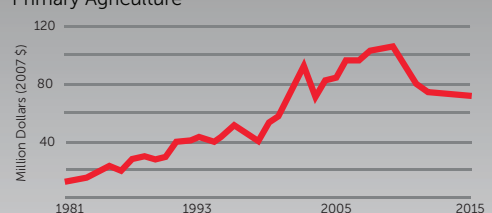
Provincial Expenditures in Agriculture R&D and Extension 2015-2016[4]



Source: Provincial Public Accounts and financial statements of provincial ministries of agriculture, 2015-2016.

Private Sector

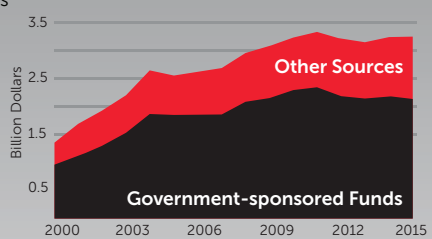
Real Private Sector R&D Expenditures[5]
Primary Agriculture



Source: Statistics Canada

Academia

Total sponsored expenditures (all fields)[6]
supporting research at post-secondary institutions with agricultural programs



Source: Canadian Association of University Business Officers, *Financial Information of Universities and Colleges*, Report 3.1, 2000-2015

Image B.4. Funding Trends in Agriculture R&D

1 Agricultural knowledge generation includes budgetary expenditure to finance agricultural research (institutes, grants) and gene banks. Agricultural knowledge transfer includes agricultural education and generic training and extension services provided to farmers. The U.S.A. ranked 18th among 33 countries and the European Union.

2 AAFC Estimates. Federal research values correspond to operating, capital and program expenditures.

3 AIC Estimates. Sources for provincial expenditures: Provincial Public Accounts and financial statements of provincial ministries of agriculture, 2010-2016. Real values (2007 $) based on StatCan Price Indexes.

4 For a more detailed description of the data and sources used in this map, see the References section at the end of this report.

5 Data includes all R&D expenditures (intramural) made by private industry regardless of whether the sources of funds were self-financing but does not include investments from the agricultural input sector.

6 Post-secondary institutions with agricultural programs included in this chart are members of the Canadian Faculties of Agriculture and Veterinary Medicine. Government-sponsored funds include federal, provincial, municipal, intra-provincial & foreign governments. Other sources of funding include donations, non-government grants and contracts, investment, sale of services and products, and miscellaneous. None of the listed institutions allocated resources from tuition and other fees towards research.

Since 2008, the federal funding agencies (NSERC, SSHRC, CIHR and Genome Canada) collectively provided in excess of $337 million to support agricultural research in academia. During the same period, the CFI invested approximately $42M to build and improve research infrastructure used by academic researchers and their partners in fields related to agriculture.

The National Research Council (NRC) reported total expenditures of $36.6 million for Aquatic and Crop Research Development (ACRD) in 2014-15 with approximately 10% of these expenditures being funded through earned revenues ($3.5M) – one-third of which has been generated through industry partnerships since 2012 (NRC, 2016).

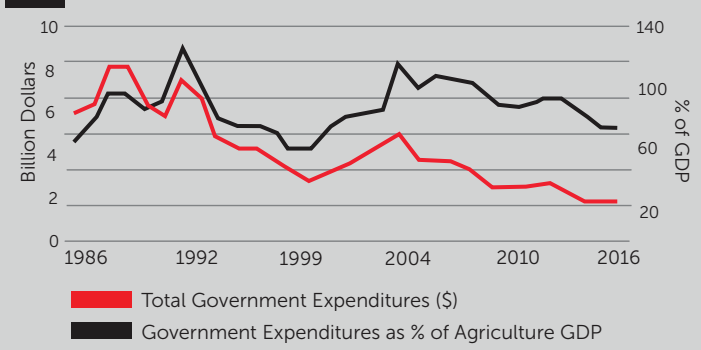
Private Sector

Business R&D performance is a critical factor in the creation of a competitive and innovative environment in all sectors of the Canadian economy.

Nevertheless, Canada's private sector invested less in R&D as a share of GDP than many other advanced economies, falling from 18th position in 2006 to 25th in 2014 (OECD, 2014).

In the 2016-17 World Economic Forum's Competitiveness Survey, Canada ranked 29th in BERD – Business Enterprise Expenditures of Research and Development (World Economic Forum, 2017).

Real private sector spending on primary agriculture R&D amounted to $74.2 million in 2013, down from a peak of $102 million in 2008 (AAFC, 2015). Despite the introduction of intellectual property protection on new crop varieties and an important increase in spending between 1998 and 2002, private sector investment in agriculture R&D has slowed in recent years (Image B.4).



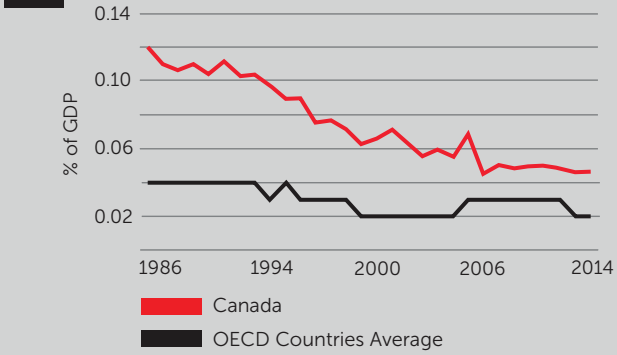


Chart B.1. Total government expenditures in support of the agriculture and agri-food sector as a share of agriculture GDP, 1985-2016 Source: AAFC

Chart B.2. Public expenditure for the agricultural knowledge and innovation system, as a share of total GDP, 1986-2015. Source: OECD

B.2.3. Human Capital

Production of Highly Qualified Personnel (HQP)

Enrollment in Agriculture, Natural Resources and Conservation programs at Canadian post-secondary institutions has steadily increased from 2009 to 2015. The Canadian Faculties of Agriculture and Veterinary Medicine has noted a 50% rise in foreign enrolment in Canadian postgraduate programs in recent years as well as increased demand for Food Science programs (CFAVM, 2013). In 2014, 8,880 students graduated in this field, with Ontario accounting for the highest share of graduates (36%) (Chart B.3).

Labour Force Deployment

Over 10,000 people work in professional occupations related to natural and applied sciences[5] in the agriculture sector (Statistics Canada, 2016).

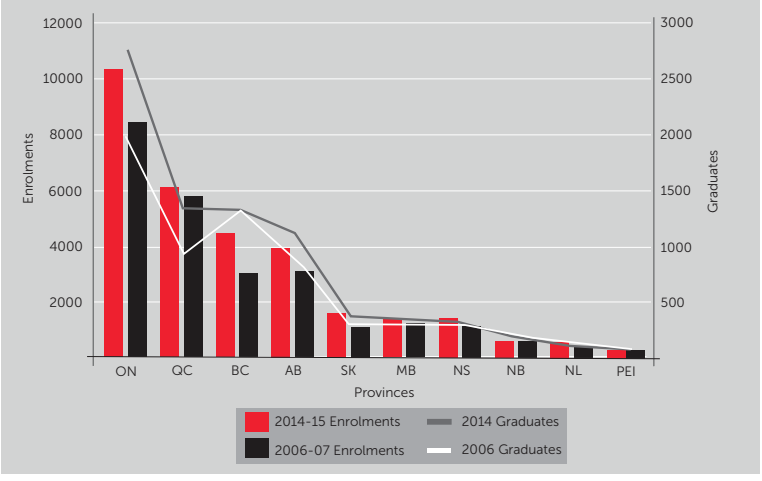


Chart B.3. Postsecondary enrollments and graduates in Agriculture, Natural Resources and Conservation programmes by province, 2006-07 and 2014-15. (Statistics Canada. Table 477-0019 and 477-0020)

[5] Physical science professionals, life science professionals and civil, mechanical, electrical and chemical engineers.

A 6.2% share of total scientific and technical personnel in all federal departments and agencies work in AAFC research centres across Canada with 1,629 research scientists and technicians performing agriculture R&D (Statistics Canada, 2017c).

In the private sector, the latest data indicates 2,607 full-time personnel engaged in agriculture R&D activities (Statistics Canada, 2016b), 1.9% of the total BERD labour force in all sectors of the economy.

B.2.4. Knowledge Infrastructure

The distribution of major agricultural research centres and facilities across Canada is outlined in images B.5 and B.6 according to their institutional setting and areas of research. Federal and regional research centres as well as post-secondary institutions play a prominent role in research production across the country.

B.3. Dissemination of Agricultural Research

B.3.1. Trends in Scientific Production: Quantity and Quality of Canadian Research Publications

Canada ranks 8th worldwide in scientific production of agricultural research[6] between 1997 and 2014, generating 90,606 academic papers[7], demonstrating a marked growth of 64% in papers published over the course of this period (Science Metrix, 2015). Image B.7 summarizes Canada's scientific production performance in agricultural research nationally and relative to the rest of the world.

B.3.2. Knowledge Management and Commercialization of Agricultural Research

Intellectual property rights (IPR) affect nearly every step of the research process – from initial development to the sharing of results with other researchers. Increased participation by the private sector in agricultural research and an increased focus on commercialization by governments and post-secondary institutions in the last two decades has led to an increased level of intellectual property protection (IPP) in the agriculture sector.

Patents

Patents provide an important mechanism for agricultural research dissemination. They require full public disclosure of research and encourage partnerships between academia, industry groups and the private sector, helping to more efficiently commercialize research into marketable products, protect investments and generate revenue for further innovations.

Since 1999, Canadian inventors[8] have filed 371 patents through the PCT (Patent Cooperation Treaty) procedure[9], a unified worldwide patent application system administered nationally by the Canadian Intellectual Property Office (CIPO) – a growth rate of 88% from 1999 to 2013 (OECD, 2016).

The technological strength and quality of a country's patented innovations are commonly indicated by *triadic patent families*[10] (OECD, 2009). The number of triadic patents filed by Canadian inventors in the agriculture sector has dropped progressively from the 1999-2012 period, filing an average of six triadic patents annually (OECD, 2016).

Plant Breeders' Rights

Plant breeders' rights (PBRs) are another form of IPR by which plant breeders can protect new varieties. Since Canada's plant breeders' rights laws were updated in 2015 to bring them in line with the *International Union for the Protection of New Varieties of Plants (UPOV) 1991*, providing stronger protection and better access to improved varieties from other countries, there has been a 25% increase in new applications and 5000 different varieties protected under the Plant Breeders Rights Act (PBRA) over the 1999-2012 period (Roch, 2016).

[6] Agricultural research includes the following subfields: Agricultural Science (Agronomy, Agricultural Engineering, Irrigation, Weed and Pest Control, Agroforestry, Agricultural Economics & Policy, Plant Sciences, and Land Resource & Soil Science), Veterinary Sciences (animal welfare), Food Sciences (cereals, dietetics, etc.), Renewable Bioresources (mostly biofuels) and Aquaculture.

[7] Papers indexed in the Scopus database.

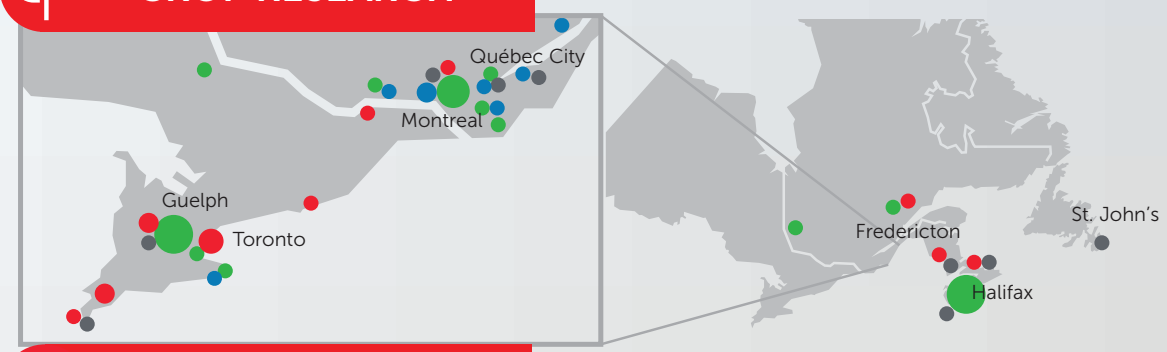
[8] Patents filed by inventors residing in Canada.

[9] Applicants file a single international application (PCT application) with the Canadian Intellectual Property Office and then, begin the application process in other countries – the preferred patenting route among inventors targeting worldwide markets.

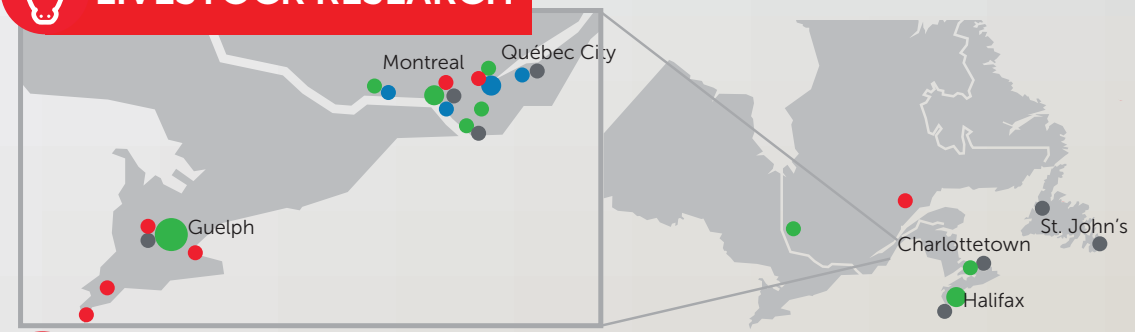
[10] The number of patent applications filed at the European Patent Office (EPO) and the Japan Patent Office (JPO), and granted by the US Patent Trademark Office (USPTO).

Distribution and scope of
major agricultural research facilities
Eastern Canada

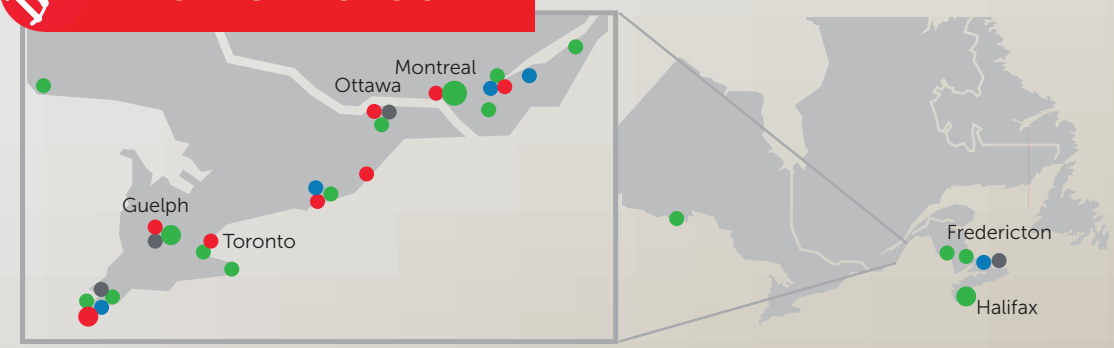
CROP RESEARCH



LIVESTOCK RESEARCH



BIOTECHNOLOGY



- Federal & Provincial Governments
- Post-secondary Institutions
- Private Sector
- Non-Profit & Partnerships

The size of each city's circle is proportional to the concentration of major research centres, institutes and facilities.

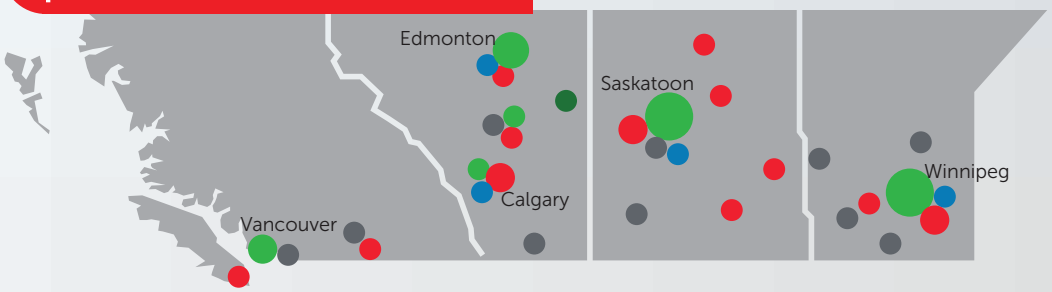
PROVINCIAL PRODUCTION [1]

[1]Statistics Canada - 2016 Farm Cash Receipts (Annual, dollars x 1,000)

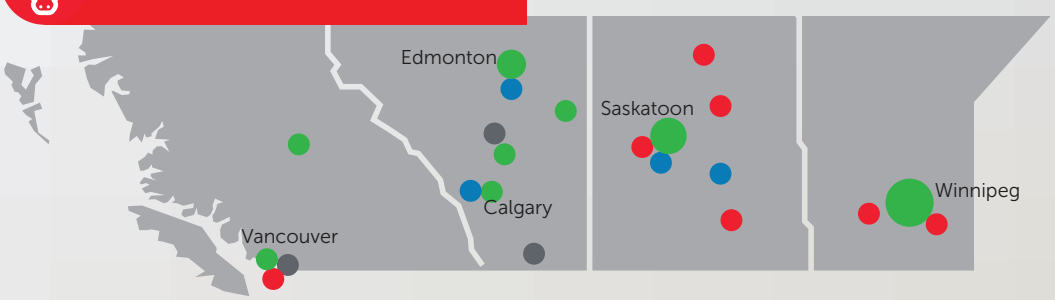
Image B.5. Knowledge infrastructure - Eastern Canada

Distribution and scope of
major agricultural research facilities
Western Canada

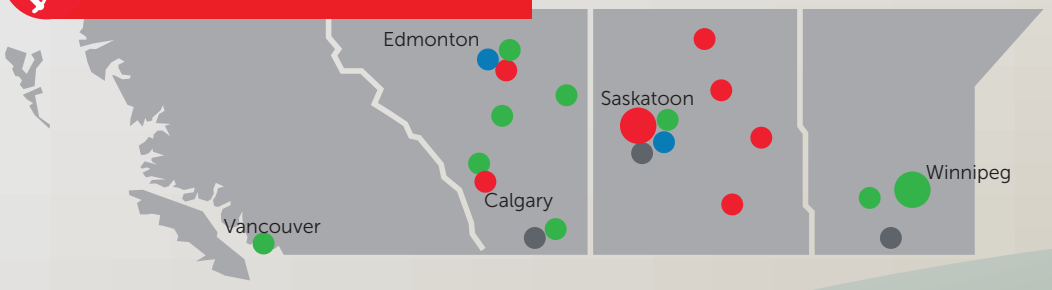
CROP RESEARCH



LIVESTOCK RESEARCH



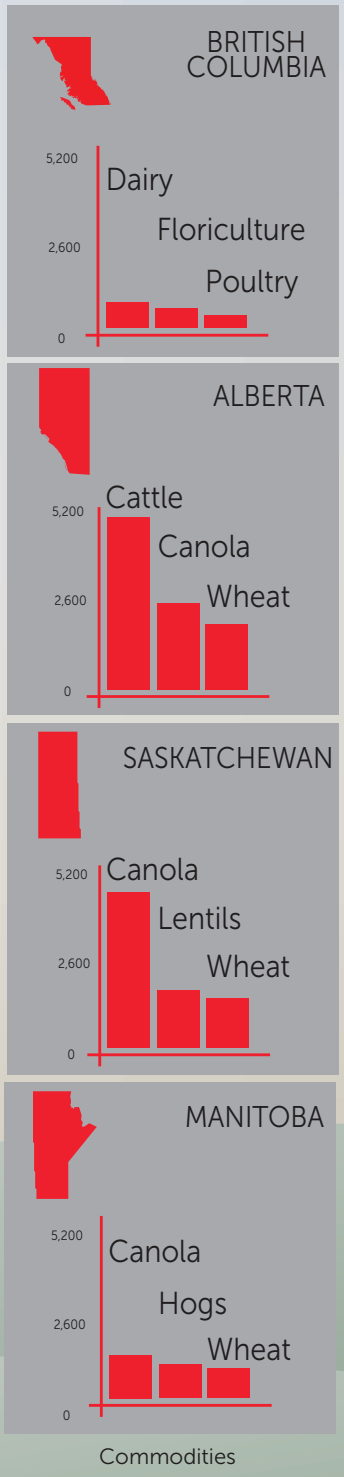
BIOTECHNOLOGY



- Federal & Provincial Governments
- Post-secondary Institutions
- Private Sector
- Non-Profit & Partnerships

The size of each city's circle is proportional to the concentration of major research centres, institutes and facilities.

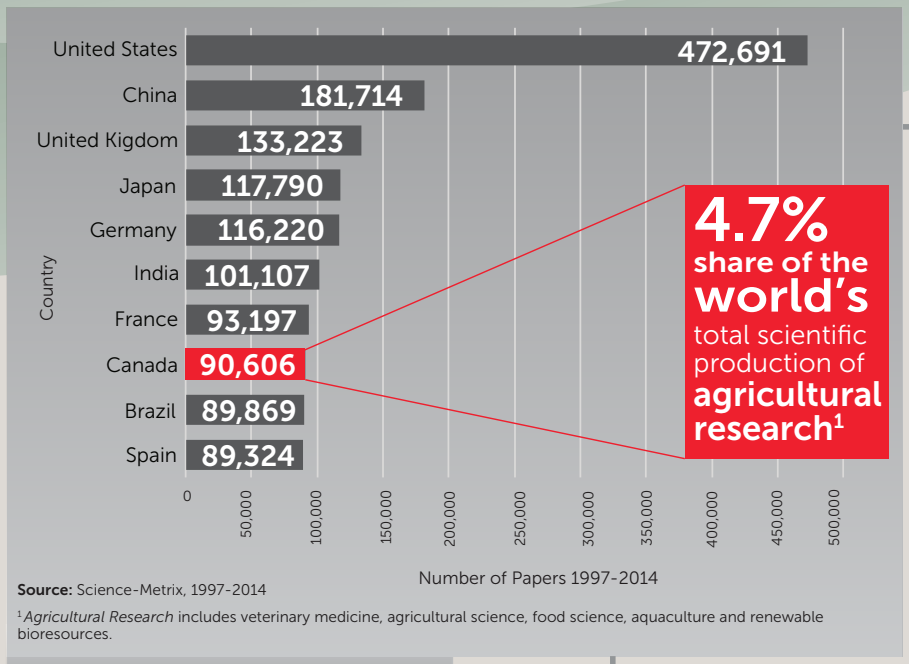
PROVINCIAL PRODUCTION [1]



[1]Statistics Canada - 2016 Farm Cash Receipts (Annual, dollars x 1,000)

Image B.6. Knowledge infrastructure - Western Canada

Scientific Production in Agricultural Research



Source: Science-Metrix, 1997-2014

[1] *Agricultural Research* includes veterinary medicine, agricultural science, food science, aquaculture and renewable bioresources.

Top 5 Publishing Institutions in Agricultural Research

AAFC
U of Guelph
U of Saskatchewan
U of Alberta
U of British Columbia

Source: Science-Metrix

Scientific Production

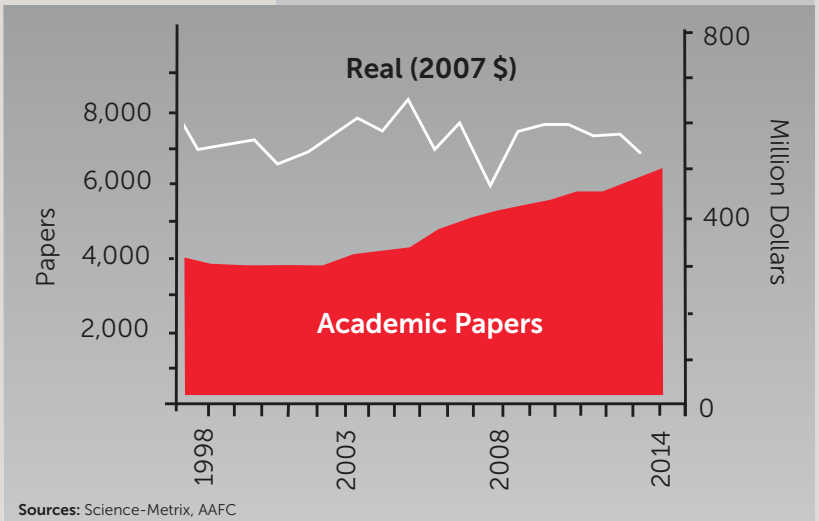
16th place in **scientific impact**[2] of agricultural research **worldwide**

Source: Science-Metrix
[2] Based on Canada's average of relative citations (ARC) score (2014).

21st place in **level of specialization**[3] in agricultural research **worldwide**

Source: Science-Metrix
[3] Based on Canada's specialization index (SI) score (2014).

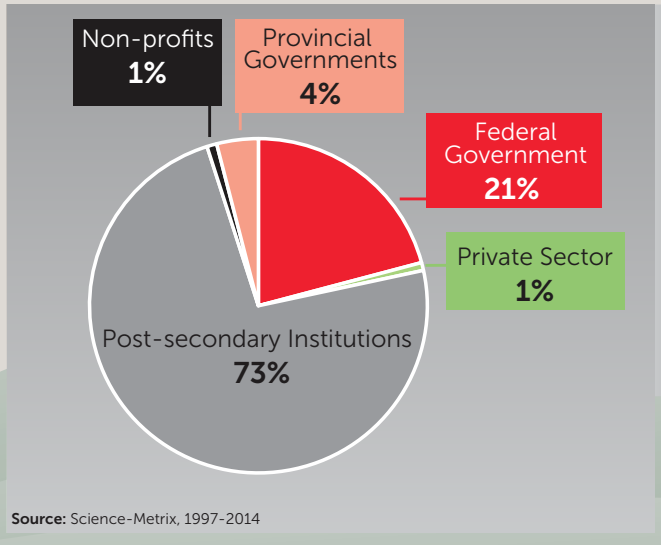
Scientific Production and Public Agriculture R&D Spending[4]



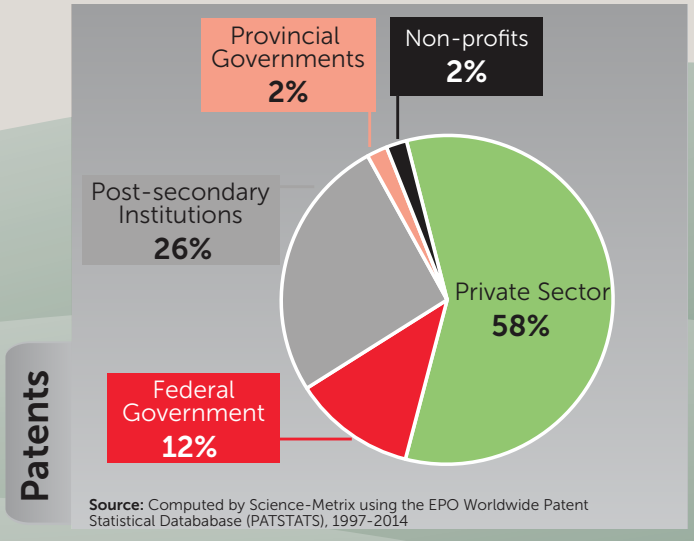
Sources: Science-Metrix, AAFC
[4] Includes agriculture R&D funding by AAFC and the provincial ministries of agriculture only.

Who are the key performers of agricultural research?

Share of Canada's Scientific Production in Agriculture by Sector



Source: Science-Metrix, 1997-2014



Source: Computed by Science-Metrix using the EPO Worldwide Patent Statistical Database (PATSTATS), 1997-2014

Image B.7. Canada's scientific production in agricultural research

B.3.3. Knowledge Transfer, Extension and Advisory Services

Traditional knowledge diffusion pathways such as the publication of research, academic conferences and the commercialization of intellectual assets remain a necessary condition and first step for disseminating agricultural research results. Nevertheless, additional dissemination channels are needed to ensure research results get into the hands of key stakeholders and incorporated into agricultural practices on the ground.

Extension and advisory services

Despite major organizational and operational changes in the delivery of advisory and knowledge transfer services during the last twenty years (OECD, 2015), public programs continue to play a role in Canadian agricultural extension.

Industry associations and commodity groups have increasingly taken the leading role in extension activities with the use of new electronic and online information sharing channels to provide data to farmers and producers, as well as coordinating continuing education, workshops and e-learning opportunities to facilitate stakeholders' understanding of technical knowledge. The majority of current federal and provincial government investments in extension services have been increasingly allocated to grants and contributions to support these industry-led initiatives (AAFC, 2016c).

The private sector is also increasingly active, offering extension and consulting services that vary in accordance to regional particularities – about half of Quebec's agrologists for example work in private extension (OECD, 2015) while in some other provinces, like Saskatchewan, there is still a strong government lead in the delivery of extension services.

Trends in farm-level adoption

Although the delivery of extension services has changed dramatically over the last decades, at least one type of agricultural innovation was adopted on about half of Canadian farms (48%) between 2011 and 2013 (AAFC, 2016).

Farm size and revenue have an important impact on the adoption of innovation, with larger farms (over $1-million annual revenue) being the most likely to implement agricultural innovation and seek advice from public or private extension specialists (AAFC, 2016).

Farmers' openness to innovation is also an important determinant. The great majority of farmers in Canada tend to adopt innovation only after they have been influenced by and made aware of others' experiences, while the rest will most likely wait until new products, processes and practices are fully tested and vetted (AAFC, 2016).

C. Analysis: Challenges and Opportunities for the Canadian Agricultural Innovation System

C.1. Return on Investment and Balanced Funding Models for Agricultural Research

Increased innovation in the agriculture sector boosts productivity while reducing commodity prices, improving competitiveness and economic growth, and thus benefits consumers and input suppliers along the entire length of the agriculture and agri-food value chain from farm inputs to food retail.

Worldwide estimates repeatedly report very high rates of return on agriculture R&D investments regardless of the type of research (basic or applied), area of research, or who performed the research (public or private sector) (Table C.1). Canadian and global benefit-cost ratios for public and private agricultural research are also reported to be high, estimated to range from 10:1 to 20:1 (Alston, Gray & Bolek, 2012).

Internal rate of return per year for agriculture R&D	
Applied Research	139.5%
Basic Research	42.9%
Extension	72.2%

Table C.1. Worldwide estimates for internal rate of return for agricultural R&D (Hurley, Pardey, Rao & Andrade, 2016)

Note: Internal Rate of Return is the interest rate that equates the present value of an investment's benefits to the present value of its costs (Hurley, Rao & Andrade, 2016). The IRR (the annual growth rate) exceeds and diverges from the total rate of return (ROI) as research investments become more profitable in the long-term.

Despite this evidence, public spending on agriculture R&D has gradually decreased, having an enormous impact on the Canadian AIS where the public sector continues to be the main source of funding for agriculture R&D whether performed in the public or private setting.

Significant risks arise from a strong reliance on public funding, including a gradual reduction of Canada's capacity to innovate and the creation of economic disincentives and uncertainty for other actors to invest in agricultural research.

Furthermore, other key funders of agricultural research, such as producer groups and the private sector, appear to either under-invest or decrease their investments in agriculture R&D. Due to the time gap that exists between initial investment and in-field application of agricultural innovations, low short-term returns on investment, as well as a lack of strong IPR and an insufficient number of successful agri-entrepreneurs willing to invest in innovation, the private sector has not been incentivized to invest in agricultural research (OECD, 2015).

Evidence shows that certain types of agricultural R&D – crop breeding for example – have benefited from increased private and total investment due to characteristically strong IPR and potential for considerable research gains (Alston, Gray & Bolek, 2012). Nevertheless, an increased emphasis on private R&D and overly enforced IPR can hamper cross-sectoral research in the sector – collaboration that is crucial to efficient knowledge transfer and broad dissemination of information.

Matching investment strategies encouraging partnerships that leverage private and industry investments leading to applied research projects geared toward commercialization still have a key role to play in the Canadian agricultural policy framework. Scientific research that advances the state of knowledge (basic research) however is equally as valuable, as the key driver of innovation in the sector, and must continue to receive adequate support.

In this context, a diverse set and, most importantly, a combination of existing funding mechanisms – public, levy-based and private funding – that each serve a particular purpose in the innovation system should be adopted to suit the particular needs and characteristics of the Canadian AIS and ensure all types of research are properly supported.

C.2. Scientific Base Capacity and Deployment

Increasing specialization in science and technology has made Canada's strong scientific base and highly educated population – ranking 12th out of 34 countries in doctorate holders per 100,000 people (OECD, 2015b) – a cornerstone of the modern innovation system.

Nevertheless, Canada has been experiencing substantial labour shortages in primary agriculture (including commodity-specific research specialists and technicians) over the last ten years, with a labour gap expected to grow from 59,000 to 114,000 workers by 2025 (CAHRC, 2009; CAHRC, 2016).

Primary agriculture reports a high job vacancy rate (9%) relative to other Canadian economy sectors (CAHRC, 2009) and some provinces have reported significant growth in the demand for highly-skilled workers in the agriculture sector (OECD, 2015). An analysis of the food processing industry as well has reported that firms face obstacles to innovation due to skilled labour shortages (AAFC, 2015). Graduates from agri-food and agriculture programs at the University of Manitoba, for example, receive an average of 1.85 job offers by graduation (CFAVM, 2013).

Although agricultural post-secondary programs have been experiencing high to, in some cases, near-capacity enrollment (CFAVM, 2013), studies have noted that the agriculture sector has not effectively marketed itself to youth in order to attract enough students to meet the demand for skilled labour in the sector (CAHRC, 2009). Guidance and career counselling information for high school students interested in pursuing careers in research, as well as investments in education through grants, scholarships and infrastructure can potentially help address these human resource challenges.

Skilled labour shortages in particular have an important adverse impact on the innovation continuum, particularly on the dissemination of agricultural research. Almost all farmers (91%) report that they rely on their own knowledge, experience and experimentation in their decision to implement innovation (AAFC, 2016). Extension specialists and highly educated producers capable of understanding and transferring agricultural innovation are therefore needed to ensure that research is adopted in a timely manner on the ground.

Participatory research approaches bring valuable opportunities to engage science graduates in research projects, extension services and knowledge transfer (KT) activities that give them the opportunity to work alongside producers. It also helps ensure research responds more effectively to end-users' needs and that technologies can be adopted more widely on Canadian farms.

The private sector too has an important role to play, bringing increased opportunities to attract highly skilled personnel through internships and co-op programs that give post-secondary students valuable hands-on experience in R&D and business-led innovation.

The hiring and retention of a skilled labour force, however, demands the development of human resource plans aligned with strategic business planning. Business management training courses or programs focused on solutions to the human resource challenges in the agriculture sector are thus a significant priority (CAHRC, 2009).

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Statistics Canada (2017). Table 379-0031 - Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), monthly (dollars). CANSIM database (accessed: May 30, 2017).

Statistics Canada (2017b). *Table 358-0151 - Federal expenditures on science and technology and its components, by socio-economic objectives, annual (dollar)*. CANSIM database (accessed: 2017-05-29).

Statistics Canada (2017c). *Table 358-0165 - Federal personnel engaged in science and technological activities, by occupational category and major departments and agencies, annual (number)*. CANSIM database (accessed: 2017-05-30).

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Provincial Data Sources

Image B.4. Funding Trends in Agriculture R&D

Alberta

Expenditures in Livestock Development (Alberta Livestock and Meat Agency Ltd.), Agriculture and Food Innovation Endowment Account and Industry Development (Department of Agriculture and Forestry). *Source:* Financial Statements of the Alberta Livestock and Meat Agency Ltd., and Alberta's Department of Agriculture and Forestry (2010 -2016).

Note: Figures from 2010 to 2013 include Food Safety and Inspection expenditures.

British Columbia

Expenditures in Innovation and Adaptation Services (Innovation and Governance for 2013 and 2012), and Plant and Animal Health. *Source:* Public Accounts, Province of British Columbia (2010 - 2016).

Note: Figures for 2010 and 2011 include Food Safety and Inspection expenditures.

Manitoba

Expenditures in: Research and Market Intelligence, Grain Innovation Hub, Manitoba Biomass Energy Support Program, Farmland School Tax Rebate, Livestock Industry, Crop Industry, Agri-Resource, Growing Opportunities Centres, Food Development Centre, Food and Agri-Produc Processing (2016), Agri-Innovation and Adaptation, Agricultural Sustainability Initiative, Manitoba Biomass Energy Support Program, Farmland School Tax Rebate, Livestock Industry, Crop Industry, Agri-Environment, Growing Opportunities Centres, Food Development Centre, Food Commercialization and Marketing (2015). Agri-Innovation and Adaptation, Agricultural Sustainability Initiative, Farmland School Tax Rebate, Livestock Industry, Crop Industry, Agri-Environment, Growing Opportunities Centres, Food Development Centre, Food Commercialization and Marketing (2014 and 2013. *Source:* Annual Reports, Manitoba Agriculture, Food and Rural Development (2013 - 2016).

New Brunswick

Expenditures in Innovation and Market Development and Sector Specialist Services (for 2016 and 2015), Biosciences and Agriculture Specialist Services (2014), Crop and Livestock Development (2013, 2012, 2011 and 2010). *Source:* Public Accounts of the Province of New Brunswick, Department of Agriculture and Aquaculture (2010 - 2016).

Newfoundland and Labrador

Expenditures in Research and Development, Animal Health, and Production and Market Development (2010-2016). *Source:* Annual Report, Department of Forestry and Agrifoods (2010-2016)

Nova Scotia

Expenditures in Agriculture and Food Operations (AR), grants to Dalhousie University and Perennia Food and Agriculture (PA) for 2016, 2015 and 2014; Agriculture and Food Operations and N.S. Agricultural College(AR), grants to Dalhousie University and Perennia Food and Agriculture (PA) for 2013; Agriculture and Food. *Source:* Public Accounts (PA) of the Province of Nova Scotia (Vol. 3) and Annual Report (AR), Department of Agriculture (2011 - 2016).

Ontario

Expenditures in Research Program and Capital Expenses in Research and Education Infrastructure. *Source:* Public Accounts of the Province of Ontario, Ministry of Agriculture, Food and Rural Affairs (2010 - 2016).

Prince Edward Island

Expenditures in Agricultural Innovation, Sustainable Agriculture Resources, and P.E.I. Analytical Laboratories. *Source:* Public Accounts, Province of Prince Edward Island (2010 - 2016).

Quebec

Expenditures in Institut de technologie agroalimentaire expenditures, and transfer expenses to: Assistance for Research and Technology Transfer, Regional Development Assistance, and Support for Training. Regional Development Assistance consists of extension and commercialization programs. *Source:* Public Accounts of the Province of Quebec, Ministère de l'Agriculture, Pêcheries et Alimentation (2010 - 2016).

Saskatchewan

Expenditures in Agricultural R&D and demonstration of new practices and technologies at the farm level. Data directly provided by the Agriculture Research Branch, Ministry of Agriculture, Government of Saskatchewan.

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