Science-Metrix

Assessment of the Scientific Output of the Members of the Canadian Faculties of Agriculture and Veterinary Medicine

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Authors:
Guillaume Roberge
Grégoire Côté

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Science-Metrix Inc.
1335 Mont-Royal E. ▪ Montréal ▪ Québec ▪ Canada ▪ H2J 1Y6
1.514.495.6505 ▪ 1.800.299.8061
info@science-metrix.com ▪ www.science-metrix.com

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1 Introduction

Science-Metrix was commissioned by the Canadian Faculties of Agriculture and Veterinary Medicine (CFAVM) to provide bibliometric data in order to gain a general overview of CFAVM's research activity over the last eight years and to compare its performance with that of other Canadian institutions, including Agriculture and Agri-Food Canada (AAFC). The study includes all 13 faculties that are part of CFAVM:

CFAVM Agricultural Faculties

- College of Agriculture and Bioresources, University of Saskatchewan
- Faculté des Sciences de l'Agriculture et de l'Alimentation, Université Laval
- Faculty of Agricultural and Environmental Sciences, McGill University
- Faculty of Agricultural and Food Sciences, University of Manitoba
- Faculty of Agricultural, Life & Environmental Sciences, University of Alberta
- Faculty of Land and Food Systems, University of British Columbia
- Nova Scotia Agricultural College
- Ontario Agricultural College, University of Guelph

CFAVM Veterinary Faculties

- Atlantic Veterinary College, University of Prince Edward Island
- Faculté de Médecine Vétérinaire, Université de Montréal
- Faculty of Veterinary Medicine, University of Calgary
- Ontario Veterinary College, University of Guelph
- Western College of Veterinary Medicine, University of Saskatchewan

For this project, the scientific production of CFAVM as a whole and of each of its members was compared to that of AAFC and the most productive Canadian institutions in a benchmark dataset of publications relevant to Agricultural and Veterinary Sciences, as well as to their overall scientific production in the Scopus database which includes all publications indexed in the database from all fields of science. Statistics were produced and aggregated for the 2003–2010 period, with scientific productions also computed per year to assess their evolution over time.

Figure 1 presents a Venn diagram of the two datasets for which statistics were computed in this project. The largest dataset on the left (grey circle) represents all publications indexed in the Scopus database which encompasses publications from all fields of science (Medicine, Physics, Chemistry, Agriculture, etc.). Science-Metrix built a benchmark dataset of Agricultural and Veterinary Sciences publications (green circle on the left) which represents a fraction of all publications indexed in Scopus. CFAVM's total output in Scopus (orange circle on the left) is encompassed in Scopus, with most of CVFAVM's publications falling in the benchmark dataset of Agricultural and Veterinary Sciences, but with also a fraction of this output outside the benchmark dataset for mostly two reasons; these are papers not directly relevant to the benchmark dataset that were rightfully not captured by the keywords approach, or these are papers relevant to the benchmark dataset that were missed by the keywords approach. It is important to mention the difficulty of building a

dataset which encompass all publications relevant to a specific subfield. First of all, there are no definitive effective definitions of the fields of sciences, which makes it difficult to delineate the limits of a dataset. Moreover, even if these definitions existed, it is almost impossible to obtain a 100% recall of publications relevant to a field without highly increasing the rate of false positive (precision) results in the dataset. False positive results, which define precision of the dataset, are defined as publications not relevant to the dataset which are captured by the keywords approach because they share similar vocabularies (e.g., the term "milky" retrieves publications relevant to Agricultural and Veterinary Sciences, but also Astrophysics publications because of publications mentioning the Milky Way). If it is easy to increase the recall up to a certain threshold without adding a large quantity of false positive results, it becomes increasingly hard to improve the recall at a certain point without highly affecting the precision of the dataset. This threshold is different for each disciplines because of the different specification levels of the vocabulary used in each field of sciences (i.e., it is easier to build a dataset in Nanotechnologies where the term "nano" recalls a high level of publications without adding much false positives results than in Clinical Medicine for instance). At the end of the process, it becomes almost impossible to try to increase further the recall as only new false positives results gets captured by the added keywords, which can highly affect the analyses. Consequently, in this project, a fraction of CFAVM's output was not captured by the keywords approach because of two reasons mentioned above (not relevant or missed). However, given that this is a statistical analysis based on a high number of publications, the results obtained should be highly representative of CFAVM's performance in Agricultural and Veterinary Sciences. Furthermore, as we also provide an analysis based on all of CFAVM's publications indexed in the Scopus database (Section 4.1), all the information needed is available to get a full picture of CFAVM's performance.

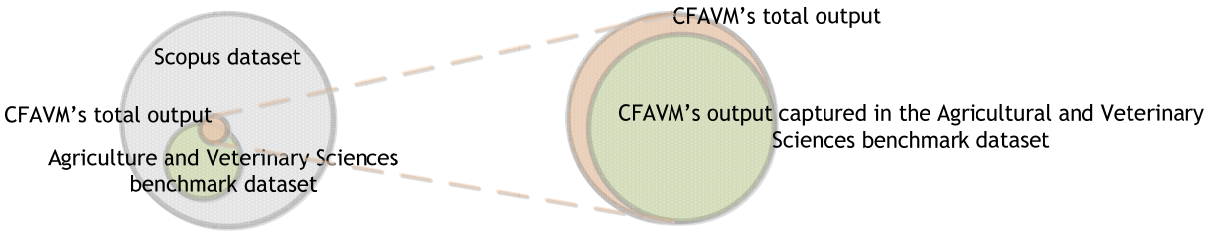


Figure 1 Venn diagram of CFAVM's total outputs in Scopus and in the benchmark dataset of Agricultural and Veterinary Sciences

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

This report is divided into the following sections in order to cover all relevant subjects from the bibliometric analysis. Section 2 describes the benchmark dataset of Agricultural and Veterinary Sciences that was produced for this analysis, providing details on its content (Section 2.1) and on its coverage of CFAVM's research activities (Section 2.2). Section 3 is dedicated to the scientific performance of leading countries in the benchmark dataset of Agricultural and Veterinary Sciences. Section 4 analyzes the scientific performance of CFAVM and AAFC using their total outputs indexed in Scopus (Section 4.1) and using the benchmark dataset of Agricultural and Veterinary Sciences (Section 4.2). Finally, Section 5 presents an analysis of CFAVM's performance within the

context of leading Canadian institutions in the benchmark dataset of Agricultural and Veterinary Sciences, supported by bibliometric data and a collaboration network.

2 Benchmark dataset

This section of the report is dedicated to the benchmark dataset on Agricultural and Veterinary Sciences used in this study. Section 2.1 is concerned with the steps involved in its creation and the final content delineating the dataset, while Section 2.2 presents statistics about the coverage of CFAVM's output in the benchmark dataset.

2.1 Content

Following discussions with the client, a benchmark dataset with a strong emphasis on Agricultural and Veterinary Sciences was built using specialized journals and keyword queries in titles, abstracts and author keyword lists. Special effort was made to include the following areas of research in the dataset:

- Agriculture (farms, crops, etc.)
- Veterinary Medicine (animal welfare)
- Food Sciences and Nutrition (cereals, dietetics, etc.)
- Renewable Bioresources (mostly biofuels)

More details on the content of the dataset by subfields of science are presented at Section 2.2 (Table III) A detailed list of keywords was tested and used to retrieve publications to build the benchmark dataset as well as specialized journals from each of these four sub-disciplines. Following a special request by CFAVM, articles in Veterinary Sciences related to companion animals, mostly cats and dogs, were manually removed from the benchmark dataset, which artificially increased the number of publications from the Veterinary Sciences field that are not included in the benchmark dataset (see Section 2.2 for more details). **No other exclusions were made to the benchmark dataset.** In the end, a total of close to 808,000 documents were retrieved from the Scopus database for the 2003–2010 to form the benchmark dataset on Agricultural and Veterinary Sciences for this project.

2.2 Coverage of the benchmark dataset

In order to evaluate the relevance of the benchmark dataset, Science-Metrix performed a multitude of validation tests. Each keyword was tested, and those that were found to retrieve a high level of false positives results (documents unrelated to Agricultural and Veterinary Sciences which are captured by the keyword approach) were removed from the list. Also, false negative results (documents relevant to the topic that were not captured in the dataset) were also deeply analyzed to ensure that the benchmark dataset covered the topic of Agricultural and Veterinary Sciences in a satisfactory manner. Table I presents statistics on the coverage of CFAVM and AAFC's outputs in the benchmark dataset of Agricultural and Veterinary Sciences. As can be observed, 64% of all CFAVM publications were included in the benchmark dataset. This number rises to 82% in the case of AAFC. This discrepancy can be explained by many factors. The first factor is the exclusion of companion animals from the benchmark dataset, which had a much higher impact on CFAVM than AAFC, considering their respective fields of expertise. In fact, after verification, almost 600

CFAVM papers were removed from the benchmark dataset because of that exclusion, which represents 3.3% of CFAVM's total output overall in Scopus and would already increase the effective recall to 67% if these publications were not removed. Another important factor is the wider diversity of the subjects covered by CFAVM, which led to the non-inclusion of some domains of interest for certain faculties because of the effective definition of Agricultural and Veterinary Sciences which was defined by Science-Metrix according to CFAVM's output on which domains should be included or not. Among the disciplines which were not at all covered with the keyword and journal approach after discussion with CFAMV, Forestry and Environmental Sciences are by far the largest. Statistics on the distribution of CFAVM members' non-included papers by subfields of science are presented in the accompanying data book (See Table VIII in data book).

Table I Coverage of CFAVM members' total output in the benchmark dataset of Agricultural and Veterinary Sciences (2003–2010)

Institution	Coverage in Dataset
Nova Scotia Agricultural College	83%
AAFC - Agriculture and Agri-Food Canada	82%
Faculty of Agricultural and Food Sciences, University of Manitoba	81%
College of Agriculture and Bioresources, University of Saskatchewan	78%
Ontario Agricultural College, University of Guelph	72%
CFAVM	64%
Ontario Veterinary College, University of Guelph	64%
Faculté de Médecine Vétérinaire, Université de Montréal	62%
Faculté des Sciences de l'Agriculture et de l'Alimentation, Université Laval	62%
Faculty of Agricultural, Life & Environmental Sciences, University of Alberta	61%
Western College of Veterinary Medicine, University of Saskatchewan	57%
Faculty of Agricultural and Environmental Sciences, McGill University	56%
Faculty of Land and Food Systems, University of British Columbia	53%
Atlantic Veterinary College, University of Prince Edward Island	51%
Faculty of Veterinary Medicine, University of Calgary	49%
World	**6.6%**

Note: Institutions are ordered based on the coverage of their papers in the dataset.
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

Table II presents the distribution of CFAVM publications not included in the benchmark dataset based on the keywords and journals approach by subfields of science according to Science-Metrix taxonomy of science which classifies all Scopus publication in 176 mutually exclusive subfields of science. As could be expected, the largest number of CFAVM's non-included publications fall in the subfield of Veterinary Sciences, with an overwhelming majority of these papers being excluded because of their focus on the care of companion animals (As mentioned at Section 2.1). As a counterpart, 1,730 CFAVM's publications (9.4% of CFAVM's total output in Scopus) are included in the benchmark dataset, which is a clear indication that this topic is wildly covered in the benchmark dataset. The second topic is Microbiology with about 430 CFAVM publications from this subfield not being captured in the benchmark dataset on Agricultural and Veterinary Sciences by the keywords approach, which represents about half of CFAVM's total number of publications

classified in this subfield (about 400 Microbiology publications included). The third field is Ecology, which is also not surprising considering that environmental sciences were not directly included in the dataset with the keywords approach, which results in only about a quarter of all CFAVM's publication classified in this subfield being included in the dataset. In fifth place is the topic of Environmental Sciences, also not included in the benchmark dataset. Finally, in seventh place is the subfield of Forestry, also not specifically included in the benchmark dataset (except for Agro-Forestry publications which could have been captured by keywords and journals related to Agriculture Sciences). It is interesting to note that while about 340 CFAVM publications classified in Plant Biology & Botany were not captured in the benchmark dataset, 72.7% of all CFAVM publications in this subfield were included using the keyword and journal approach, which is a high recall for a subfield which is not as specific to Agricultural and Veterinary Sciences as other subfields (Agronomy & Agriculture, Veterinary Sciences, Food Sciences, etc.).

Table II Distribution of CFAVM's scientific production not captured by the keywords and journals approaches to build the benchmark dataset on Agricultural and Veterinary Sciences by subfields of science (2003–2010)

Subfield*	CFAVM papers outside the benchmark dataset on Agriculture and Veterinary Sciences		CFAVM papers included the benchmark dataset on Agriculture and Veterinary Sciences		CFAVM total number of papers classified in the subfield	
	Papers	% of CFAVM's total in Scopus	Papers	% of CFAVM's total in Scopus	Papers	% included in the benchmark dataset
Veterinary Sciences	600	3.3%	1,730	9.5%	2,330	74.2%
Microbiology	432	2.4%	401	2.2%	833	48.1%
Ecology	399	2.2%	140	0.8%	539	26.0%
Plant Biology & Botany	343	1.9%	915	5.0%	1,258	72.7%
Environmental Sciences	308	1.7%	112	0.6%	420	26.7%
Endocrinology & Metabolism	258	1.4%	70	0.4%	328	21.3%
Forestry	256	1.4%	89	0.5%	345	25.8%
Biochemistry & Molecular Biology	223	1.2%	101	0.6%	324	31.2%
Fisheries	205	1.1%	89	0.5%	294	30.3%
Entomology	203	1.1%	305	1.7%	508	60.0%
All subfields	**6,656**	**36.4%**	**11,628**	**63.6%**	**18,284**	**63.6%**

Note: *Only the top 10 subfields based on non-included publications are presented here.
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

On the other hand, Table III presents the distribution of CFAVM's publications captured in the benchmark dataset on Agricultural and Veterinary Sciences based on the keywords and journals approach by subfields of science according to the same taxonomy. Most of these subfields have a high recall with the subfields of Agronomy & Agriculture (99.9%), Dairy & Animal Sciences (99.6%), Food Science (99.8%) and Nutrition & Dietetics (87.8%) having the highest recalls among the 15 subfields with the largest numbers of CFAVM publications captured in the benchmark dataset. The score for the subfield of Veterinary Sciences is a little lower with 74.2% of CFAVM's publication classified in this subfield being included in the benchmark dataset, but as this was already explained, exclusion of companion animals from the benchmark dataset on Agricultural and Veterinary Sciences resulted in a lower coverage in this subfield. Otherwise, the recall would have been close to 100%.

Table III Distribution of CFAVM's scientific production captured by the keywords and journals approaches to build the benchmark dataset on Agricultural and Veterinary Sciences by subfields of science (2003–2010)

Subfield*	CFAVM papers included in the benchmark dataset on Agriculture and Veterinary Sciences		CFAVM papers outside the benchmark dataset on Agriculture and Veterinary Sciences		CFAVM total number of papers classified in the subfield	
	Papers	% of CFAVM's total in Scopus	Papers	% of CFAVM's total in Scopus	Papers	% included in the benchmark dataset
Agronomy & Agriculture	1,972	10.8%	2	0.0%	1,974	99.9%
Dairy & Animal Science	1,945	10.6%	8	0.0%	1,953	99.6%
Veterinary Sciences	1,730	9.5%	600	3.3%	2,330	74.2%
Food Science	1,137	6.2%	2	0.0%	1,139	99.8%
Plant Biology & Botany	915	5.0%	343	1.9%	1,258	72.7%
Nutrition & Dietetics	503	2.8%	70	0.4%	573	87.8%
Microbiology	401	2.2%	432	2.4%	833	48.1%
Entomology	305	1.7%	203	1.1%	508	60.0%
Agricultural Economics & Policy	213	1.2%	0	0.0%	213	100.0%
Obstetrics & Reproductive Medicine	191	1.0%	118	0.6%	309	61.8%
Biotechnology	160	0.9%	123	0.7%	283	56.5%
Horticulture	159	0.9%	40	0.2%	199	79.9%
Virology	146	0.8%	109	0.6%	255	57.3%
Ecology	140	0.8%	399	2.2%	539	26.0%
Behavioral Science & Comparative Psychology	131	0.7%	69	0.4%	200	65.5%
All subfields	**11,628**	**63.6%**	**6,656**	**36.4%**	**18,284**	**63.6%**

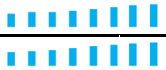
Note: Subfields highly connected to Agricultural and Veterinary Sciences are highlighted.
*Only the top 15 subfields based on included publications are presented here.

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

3 Scientific performance of leading countries in the benchmark dataset on Agricultural and Veterinary Sciences

This section of the report presents the results of the bibliometric study performed at the country level based on publication captured in the benchmark dataset on Agricultural and Veterinary Sciences. As can be observed in Table IV, the United States was the leading country in Agricultural and Veterinary Sciences over the 2003–2010 period, with almost 200,000 scientific papers indexed in the Scopus database. It was followed by China, with around 86,000 papers. The United Kingdom rounds out the top three, with about 51,000 papers. Canada is in the eighth spot, with a little more than 36,000 papers.

Table IV Scientific performance of leading countries in Agricultural and Veterinary Sciences (2003–2010)

Country	Papers		ARC	ARIF	SI
	Score	Trend*			
United States	197,189		1.30	1.19	0.87
China	86,313		0.79	0.85	0.70
United Kingdom	51,424		1.46	1.25	0.86
India	45,530		0.53	0.62	1.89
Japan	44,989		0.90	0.95	0.77
Germany	43,487		1.28	1.09	0.77
Brazil	38,542		0.67	0.80	2.29
Canada	36,076		1.25	1.17	1.07
France	35,536		1.24	1.14	0.85
Spain	34,316		1.28	1.19	1.34
Italy	30,165		1.09	1.09	0.95
Australia	29,232		1.33	1.16	1.29
Turkey	28,484		0.68	0.72	2.45
Netherlands	19,162		1.59	1.27	1.07
Rep. of Korea	17,761		0.94	1.01	0.82
Poland	14,183		0.63	0.69	1.16
Belgium	11,824		1.44	1.22	1.18
Sweden	11,381		1.49	1.26	0.95
Switzerland	11,287		1.64	1.27	0.87
Iran	10,692		0.58	0.82	1.48
Denmark	10,205		1.51	1.27	1.52
Mexico	9,994		0.80	0.93	1.68
New Zealand	9,106		1.34	1.15	2.16
Argentina	8,331		0.86	1.03	2.12
South Africa	7,938		0.89	0.90	1.94
World	**808,036**		**1.00**	**1.00**	**1.00**

Note: *The scale is not the same across countries.
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

Canada's output in Agricultural and Veterinary Sciences, while on the rise for most of the period, has been steadily decreasing in terms of its share of the world's scientific output (Figure 2). Indeed, while Canada's output increased from around 3,700 papers in 2003 to more than 5,000 in 2010, its share of world papers fell from 5.0% to 4.0% in the same period.

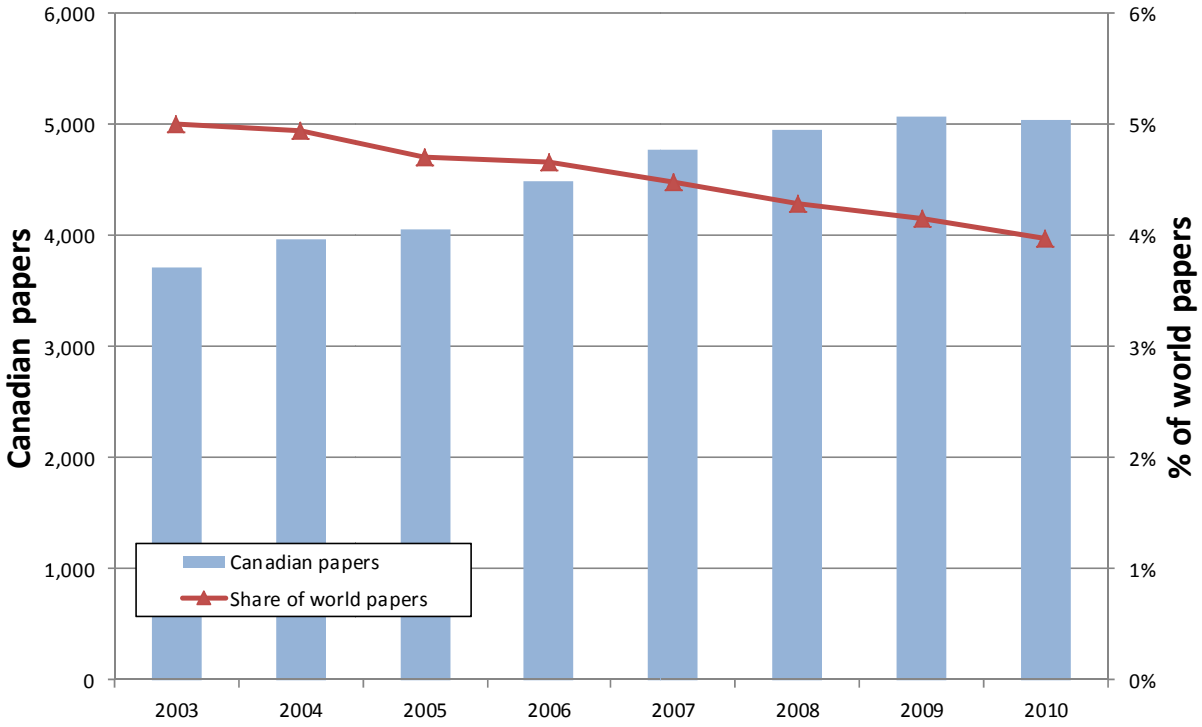


Figure 2 Trends in Canadian output and share of world papers in Agricultural and Veterinary Sciences, 2003–2010

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

This situation is not exceptional, as most industrialized countries lost some ground to developing countries. Figure 3 presents the trends in the shares of world papers of leading countries over the 2003–2010 period. The first graph on the left is dedicated to the case of China and the US. While the US was still the global leader in this field in 2010 with more than 21,000 papers[1], its share of world papers dropped 6 percentage points from 28% to 22%. In contrast, China experienced tremendous growth over the same period, going from about 4,200 papers per year in 2003 (6%) to more than 17,000 papers per year in 2010 (14%).

[1] Data not presented in the report. See the data book accompanying this report for details on the trends of number of papers

It is difficult to ascertain if China will eventually overtake the US as there is still a large gap between these two countries, but if these trends are maintained in the coming years, it would be possible for China to pass the US somewhere in the next decade. While China's growth is impressive, other countries also presented strong growth over the period, with Brazil increasing its share of world papers from 3.0% to 5.9% and Iran going from 0.4% to 2.2%. In most case, it could be hypothesized that developing countries with large and still quickly growing populations (China, Brazil, India, etc.) need to find solutions to feed their citizens, which is probably no stranger to these strong increases towards agricultural sciences. Of course, these gains in shares must come at the expense of some other countries, which explains why most industrialized countries, while still increasing their output, saw their predominance decrease, with the largest decreases being experienced by the US (28% to 22%), the UK (7.9% to 5.4%), Japan (6.8% to 4.6%), Germany (6.4% to 4.7%), France (5.1% to 4.0%) and Canada (5.0% to 4.0%).

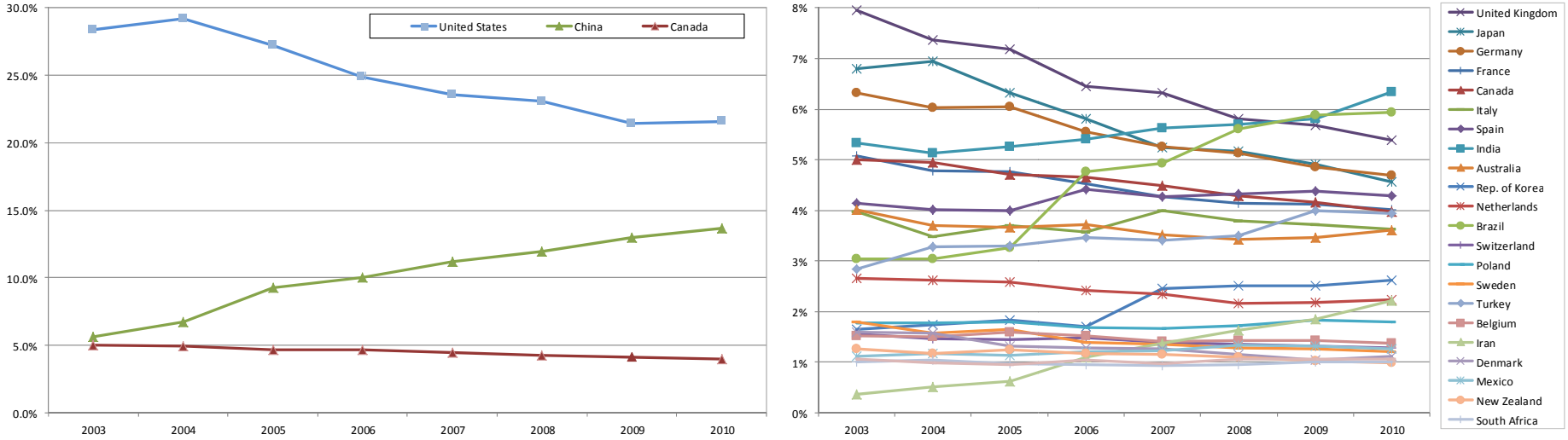


Figure 3 Share of world papers from leading countries in Agricultural and Veterinary Sciences, 2003–2010

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

While the size of scientific production is an important factor, scientific impact is also important. In this category, Switzerland ranked 1st among leading countries, with an average of relative citations (ARC) of 1.64, above the Netherlands at 1.59 and Denmark with 1.51. The US ranked 9th, with a score of 1.30. In comparison, China, which is challenging the US in the size of its scientific output in this field, scored 0.79, which indicates scientific impact lower than that of the world on average. Nevertheless, China's ARC has been increasing over the years, starting at 0.77 in 2003 and reaching 0.88 in 2008[2], the last individual year for which this indicator could be computed. China is slowly increasing its scientific impact, and with its blooming scientific output, it should be considered a strong future contender.

Canada achieved an ARC of 1.25 for the global period, putting it in 12th position among leading countries. However, Canada lost one position from 2003 to 2010, even after it increased its ARC from 1.18 to 1.31. While Canada overtook the US in 2008, Spain and France both surpassed Canada between 2003 and 2010, resulting in the loss of one rank.

The three leading countries in ARC (Switzerland, the Netherlands and Denmark) also led the rankings in average of relative impact factors (ARIF), an indicator of the quality of the journals in which an entity published its papers; all were tied with a score of 1.27. Canada ranked 9th with an ARIF of 1.17, an increase from 1.15 in 2003. In fact, Canada tied the US in 2010, as the US saw its ARIF steadily decrease from 1.21 in 2003 to 1.17. However, Canada still lost one position in the ranking from 2003 to 2010 (from 8th to 9th) because of impressive performances by Spain (from 1.13 to 1.24) and Australia (from 1.11 to 1.20) during this period.

Finally, among leading countries, Turkey was the most specialized, with a specialization index (SI) of 2.45, ahead of Brazil at 2.29, New Zealand at 2.16 and Argentina at 2.12. Canada ranked 14th in this category with an SI of 1.07, indicating that Canada was slightly specialized in this field.

In order to assess the overall performance of leading countries, a positional analysis combining the scientific production, the SI and the ARC was produced and is presented in Figure 4. Seven countries, including Canada, appear in the upper right quadrant, which is an indication of specialization and high scientific impact. This is the most desirable situation for a country, as it indicates that its particular effort in a specific field produced a scientific output that had a high impact on the scientific community.

[2] Trends in ARC and ARIF scores are not presented in this report nor in the accompanying data book and are provided as supplementary data for the analysis.

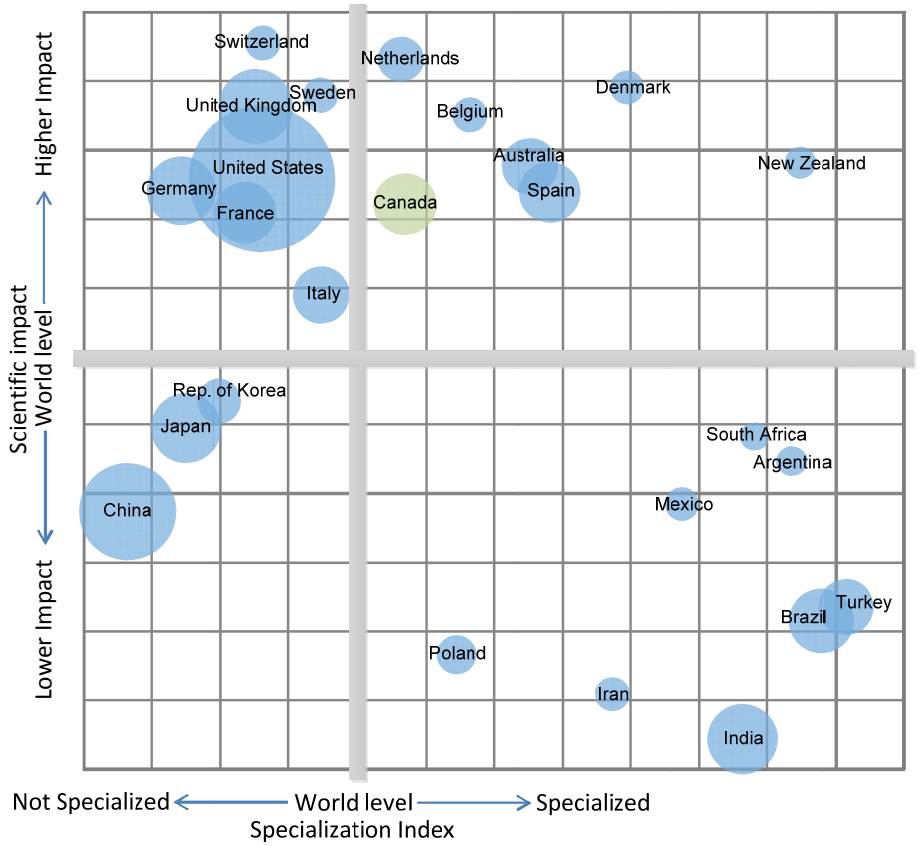


Figure 4 Positional analysis of leading countries in Agricultural and Veterinary Sciences (2003–2010)

Note: Number of papers (area of circles), scientific impact (ARC), specialization index (SI)
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

Interestingly, Canada had the largest scientific output of these countries, which is important considering that it is more difficult to maintain a high scientific impact as scientific output increases. Nevertheless, even if their scientific production was smaller, it is important to mention the performance of countries like New Zealand and Denmark, which have some of the highest SI and ARC among leading countries. Australia, Spain, Belgium and the Netherlands also performed well, all combining strong SI and ARC. Many European countries (Switzerland, Sweden, UK, Germany, France and Italy) are gathered in the upper left quadrant, which is not surprising considering that most of these countries tend to have high scientific impact. Their presence in this quadrant indicates that they have high scientific impact but are not specialized in Agricultural and Veterinary Sciences. The US also belongs to this group. The lower right quadrant contains many highly specialized countries (Turkey, Brazil, Argentina, South Africa, India, Mexico and Iran) that have scientific impact lower than the world average. However, most of these countries are far below the world level in terms of impact, which demonstrates the difficulty of increasing specialization while increasing or even maintaining level of scientific impact. Finally, the lower left quadrant contains only three countries, all from Asia (China, Japan and the Republic of Korea). These countries are not specialized in the field and had low scientific impact for the 2003–2010 period.

4 Scientific performance of CFAVM and AAFC

This section of the report focuses on the performance of CFAVM, its members and AAFC. The first section (Section 4.1) presents the performance of these institutions based on all publications indexed in Scopu, while Section 4.2 is dedicated to their scientific performance using the benchmark dataset of publications in Agricultural and Veterinary Sciences.

4.1 Scientific performance of CFAVM and AAFC in Scopus

Overall, close to 18,300 papers associated with one of the 13 faculties of CFAVM are indexed in the Scopus database over the 2003–2010 period (Table V). This represents about 10,000 more papers than AAFC, which published close to 7,800 papers over the same period. The Ontario Agricultural College (University of Guelph) ranked 1st among CFAVM members with about 3,200 papers, followed by the Faculty of Agricultural and Environmental Sciences of McGill University with around 2,500 papers. The smallest output came from the recently founded Faculty of Veterinary Medicine (University of Calgary), with 230 papers.

Table V Scientific performance of CFAVM members and AAFC in the Scopus database (all publications) (2003–2010)

Institution	Papers		ARC	ARIF
	Score	Trend*		
CFAVM	**18,284**		**1.23**	**1.17**
AAFC - Agriculture and Agri-Food Canada	**7,783**		**1.16**	**1.06**
Ontario Agricultural College, University of Guelph	3,222		1.25	1.15
Faculty of Agricultural and Environmental Sciences, McGill University	2,495		1.16	1.15
Faculty of Agricultural, Life & Environmental Sciences, University of Alberta	2,349		1.32	1.23
Ontario Veterinary College, University of Guelph	1,920		1.41	1.23
Western College of Veterinary Medicine, University of Saskatchewan	1,597		1.25	1.23
Faculté des Sciences de l'Agriculture et de l'Alimentation, Université Laval	1,541		1.20	1.22
College of Agriculture and Bioresources, University of Saskatchewan	1,448		1.09	1.10
Faculty of Agricultural and Food Sciences, University of Manitoba	1,345		1.22	1.09
Faculté de Médecine Vétérinaire, Université de Montréal	1,106		1.20	1.21
Faculty of Land and Food Systems, University of British Columbia	938		1.63	1.21
Atlantic Veterinary College, University of Prince Edward Island	690		1.21	1.16
Nova Scotia Agricultural College	507		0.94	1.04
Faculty of Veterinary Medicine, University of Calgary	230		1.57	1.18
World	**12,249,221**		**1.00**	**1.00**

Note: *The scale is not the same across institutions.
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

CFAVM as a whole also had a higher scientific impact than AAFC according to the ARC for the 2003–2010 period, with scores of 1.23 and 1.16, respectively. Among CFAVM members, 11 of the 13 faculties scored on par or higher than AAFC over the whole period. The Faculty of Land and Food Systems of the University of British Columbia was in the 1st position, with a score of 1.63 based on close to 940 papers. The Faculty of Veterinary Medicine of the University of Calgary came in 2nd at 1.57, based on 230 papers, and was followed by the Ontario Veterinary College in 3rd place, at 1.41 for approximately 1,920 papers. It is important to note that AAFC greatly improved its

scientific impact to catch up to CFAVM's increasing scientific impact—it surpassed CFAVM in 2007, going from 0.96 in 2003 to 1.33 in 2008, while CFAVM went from 1.12 in 2003 to 1.31 in 2008[3]. AAFC could move further ahead if this trend is maintained, though maintaining this level of growth will be no easy task for AAFC. It will be interesting to see whether its ARC will continue to rise in the coming years or will level off.

In terms of ARIF, all but one faculty of CFAVM (the Nova Scotia Agricultural College) scored higher than AAFC, which resulted in CFAVM scoring 1.17 for the whole period on this indicator, higher than the score of 1.06 from AAFC. Also, all CFAVM members scored higher than the world on average. As opposed to what could be observed with the ARC, CFAVM's ARIF stayed stronger than AAFC's ARIF throughout 2003 and 2010, despite the fact that AAFC's score increased a little more overall, going from 1.03 to 1.10 (compared to CFAVM's, which rose from 1.14 to 1.17). Overall, leading CFAVM faculties according to the ARIF had almost identical results, which resulted in six faculties sharing the lead with similar performances: the Faculty of Agricultural, Life & Environmental Sciences of the University of Alberta (1.23), the Western College of Veterinary Sciences (University of Saskatchewan) (1.23), the Ontario Veterinary College (1.23), the Faculté des Sciences de l'Agriculture et de l'Alimentation of the Université Laval (1.22), the Faculté de Médecine Vétérinaire (Université de Montréal) (1.21) and the Faculty of Land and Food Systems (University of British Columbia) (1.21).

4.2 Scientific performance of CFAVM and AAFC in the benchmark dataset on Agricultural and Veterinary Sciences

Within the benchmark dataset of Agricultural and Veterinary Sciences, CFAVM as a whole was ahead of AAFC in terms of scientific production, but the margin between the two organizations' outputs was lower than in Scopus overall, with still more than 5,000 separating the two institutions (or approximately 11,600, compared to 6,400) (Table VI).

The Ontario Agricultural College (University of Guelph) was again the leading CFAVM member, with a little more than 2,300 papers, but the Faculty of Agricultural, Life & Environmental Sciences (University of Alberta) caught up to the Faculty of Agricultural and Environmental Sciences (McGill University) in second place, both having about 1,400 papers.

Regarding scientific impact, most institutions had an ARC around their overall score in Scopus. Only once faculty, the Faculty of Veterinary Medicine at the University of Calgary, had a noticeable discrepancy in its ARC, mostly because of a lower scientific production, as lower numbers of papers makes these scores more volatile. It had the highest ARC with a score of 2.12 for about 100 papers, compared to 1.57 for 230 papers in Scopus.

[3] Trends in ARCs and ARIFs for the overall productions in Scopus are not presented in the report or in the accompanying data book.

Table VI Scientific performance of CFAVM members and AAFC using the benchmark dataset on Agricultural and Veterinary Sciences (2003–2010)

Institution	Papers		ARC	ARIF	SI	Top 1% most cited	Top 10% most cited
	Score	Trend*				% of pub.	% of pub.
CFAVM	**11,628**		**1.23**	**1.18**	**9.6**	**1.14%**	**13.0%**
AAFC - Agriculture and Agri-Food Canada	**6,361**		**1.20**	**1.08**	**12.4**	**1.18%**	**13.0%**
Ontario Agricultural College, University of Guelph	2,310		1.25	1.17	10.9	1.02%	12.8%
Faculty of Agricultural, Life & Environmental Sciences, University of Alberta	1,428		1.31	1.21	9.2	1.67%	14.2%
Faculty of Agricultural and Environmental Sciences, McGill University	1,404		1.12	1.16	8.5	0.92%	10.9%
Ontario Veterinary College, University of Guelph	1,220		1.50	1.27	9.6	1.92%	16.1%
College of Agriculture and Bioresources, University of Saskatchewan	1,125		1.07	1.08	11.8	0.48%	11.2%
Faculty of Agricultural and Food Sciences, University of Manitoba	1,091		1.17	1.08	12.3	1.25%	13.1%
Faculté des Sciences de l'Agriculture et de l'Alimentation, Université Laval	958		1.23	1.24	9.4	1.01%	13.0%
Western College of Veterinary Medicine, University of Saskatchewan	914		1.29	1.29	8.7	1.17%	14.5%
Faculté de Médecine Vétérinaire, Université de Montréal	688		1.23	1.21	9.4	0.78%	12.8%
Faculty of Land and Food Systems, University of British Columbia	494		1.52	1.21	8.0	1.76%	18.8%
Nova Scotia Agricultural College	419		0.98	1.05	12.5	1.36%	10.1%
Atlantic Veterinary College, University of Prince Edward Island	353		1.29	1.23	7.8	1.05%	13.6%
Faculty of Veterinary Medicine, University of Calgary	113		2.12	1.26	7.4	5.00%	22.2%
World	**808,036**		**1.00**	**1.00**	**1.0**	**1.00%**	**10.0%**

Note: *The scale is not the same across institutions.
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

The Faculty of Land and Food Systems of the University of British Columbia came in second again with an ARC of 1.52, almost on par with the Ontario Veterinary College in third at 1.50. Nine CFAVM members scored higher than AAFC, whose ARC increased from 1.16 in Scopus to 1.20 in the dataset of Agricultural and Veterinary Sciences, while CFAVM's ARC stayed the same at 1.23 for both datasets. However, as was the case in Scopus overall, AAFC's ARC overtook that of CFAVM in 2007—its ARC increased from 1.04 in 2003 to 1.40 in 2008, while CFAVM's increased from 1.13 to 1.29.[4]. In terms of the ARIF, only one CFAVM members (the Nova Scotia Agricultural College) scored lower than AAFC, with CFAVM as a whole scoring 1.18 for the entire period on this indicator and higher than AAFC's 1.08 score.

[4] Trends in ARC and ARIF scores in the dataset of Agricultural and Veterinary science are presented in the accompanying data book (Table VI).

Again, all CFAVM members scored higher than the world on average. CFAVM's ARIF was also above that of AAFC between 2003 and 2010, but AAFC has slowly been closing the gap (CFAVM's ARIF was stable, ranging from 1.16 to 1.20, while AAFC's rose from 1.07 to 1.13). This time, the Western College of Veterinary Sciences ranked first with an ARIF of 1.29, closely followed by the Ontario Veterinary College (1.27) and the Faculty of Veterinary Medicine at University of Calgary (1.26).

As could be expected, all of these institutions were heavily specialized in Agricultural and Veterinary Sciences. Indeed, the lowest SI belonged to the Faculty of Veterinary Medicine (University of Calgary) (7.4) and the Atlantic Veterinary College (7.8). Given the specific exclusion that were made for publications in veterinary sciences (companion animals), it should not come as a surprise to observe these slightly smaller SIs for some veterinary sciences faculties. In comparison, CFAVM as a whole had a SI of 9.6 and AAFC achieved 12.4, slightly behind the Nova Scotia Agricultural College with the highest score at 12.5. Overall, with such large scores, it can be assessed that all CFAVM members as well as AAFC are heavily specialized in this area of research.

Finally, another good indicator of scientific impact is the number of papers among the most cited documents. Statistics on the percentage of papers among the 1% and 10% most cited documents in this field were produced to assess the scientific impact of CFAVM as well as AAFC. As presented in Table VI, ten CFAVM members had more or just about the expected number of papers in the 1% most cited documents (more than 1% of their documents). The leader in this category was the Faculty of Veterinary Medicine (University of Calgary), with 5.00% of its papers among the 1% most cited documents in Agricultural and Veterinary Sciences. This result helps to explain the high ARC achieved by this Faculty: because of its low number of papers and its high percentage of highly cited documents, the Faculty's ARC was likely boosted by a few highly cited documents. After verification, this hypothesis was confirmed: the ARC was computed with only 36 valid relative citation (RC) scores based on about 110 papers, as most of the Faculty's publications were published after 2008, which did not leave enough time for these papers to receive a valid RC score (77 papers in 2009 and 2010). Of these remaining 36 scores, some were extreme values, which were indeed among the most cited documents in the dataset. However, if the Faculty of Veterinary Medicine's ARC was recomputed after removing only its top cited document, it would drop to 1.73 based on the remaining 35 documents with a valid RC. By removing the next most cited document, the ARC would reach 1.57, which is a big difference from the overall 2.12 with only two supplementary documents. While this score would still be high enough for a first place finish overall among CFAVM, this example is highly representative of the caution that is needed when dealing with impact scores with low numbers, as extreme values can greatly impact these scores.

The Ontario Veterinary College came in 2nd for this indicator, with a score of 1.92%, ahead of the Faculty of Land and Food Systems (University of British Columbia) at 1.76%. Overall, 1.14% of CFAVM's papers were among the 1% most cited documents in Agricultural and Veterinary Sciences, slightly behind AAFC, with 1.18% of its papers falling into this category. In the case of the 10% most cited documents, all CFAVM members scored higher than the world average. The Faculty of Veterinary Medicine (University of Calgary) achieved the highest score again at 22.2%, followed by

the Faculty of Land and Food Systems (University of British Columbia) at 18.8%. Overall, CFAVM and AAFC were evenly matched in this category, with both 13.0% of their papers in the 10% most cited documents.

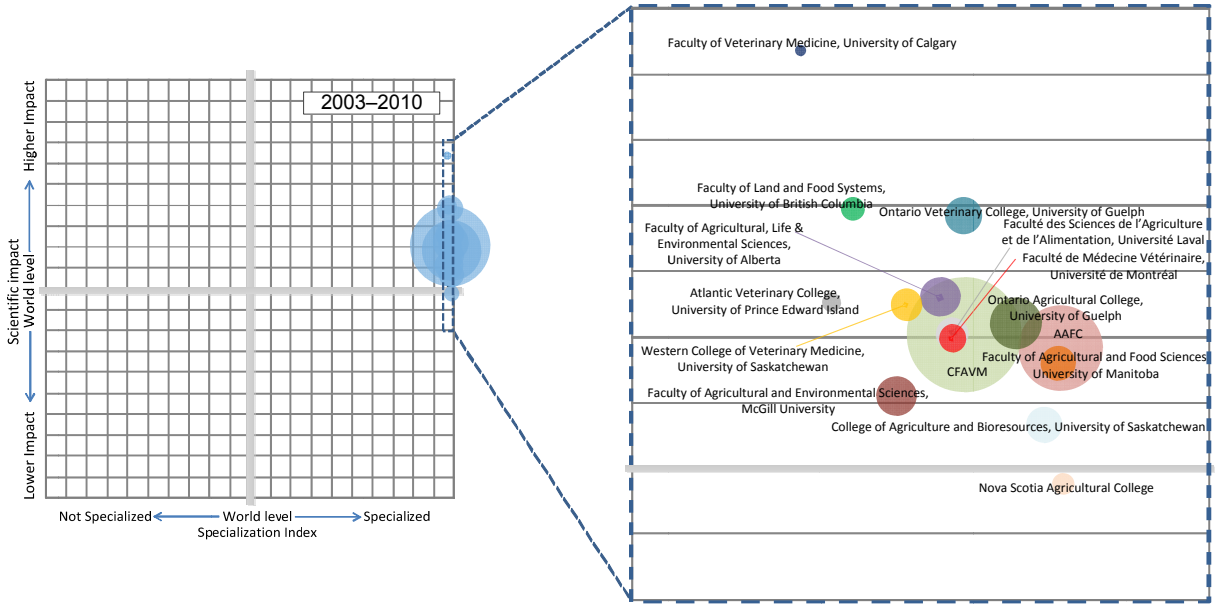


Figure 5 Positional analysis of CFAVM members and AAFC in Agricultural and Veterinary Sciences (2003–2010)

Note: Number of papers (area of circles), scientific impact (ARC), specialization index (SI)
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

As was presented for leading countries, a positional analysis was also produced for CFAVM members and AAFC to assess their scientific performance (Figure 5). However, little new information can be extracted from this graph, as all institutions are highly specialized and have high scientific impact; the only exception is the Nova Scotia Agricultural College, which is highly specialized but has an ARC slightly below (though almost on par with) the world level. Overall, CFAVM had a little more impact than AAFC, while being slightly less specialized for the period. However, as mentioned earlier, AAFC's ARC grew more quickly than that of CFAVM between 2003 and 2010, surpassing it in 2007[5]. Other notable performances are that of the Nova Scotia Agricultural College, which increased its ARC above the world level (from 0.84 in 2003–2006 to 1.14 in 2007–2010), the Faculté de Médecine Vétérinaire (Université de Montréal) (from 1.15 to 1.37), the College of Agriculture and Bioresources (University of Saskatchewan) (from 1.07 to 1.27) and the Atlantic Veterinary College (from 1.22 to 1.51). Overall, AAFC appears to have distanced itself from CFAVM over the last few years, based on the ARC score.

[5] See Figure 5 and Table VI in the accompanying data book for positional analyses for the 2003–2006 and 2007–2010 periods and trends in the ARC and ARIF of CFAVM and AAFC.

5 Scientific performance of leading Canadian institutions in the benchmark dataset on Agricultural and Veterinary Sciences

Table VII presents bibliometric data related to the top performing Canadian institutions based on number of publications. CFAVM as an organization would be the leading institution in Canada with more than 11,600 papers. Nevertheless, Agriculture and Agri-Food Canada was 1st with close to 6,400 papers, followed by the University of Guelph at almost 4,500 papers, with contributions from its two CFAVM faculties. The University of Saskatchewan ranked 4th with close to 2,800 papers with contributions from two CFAVM faculties, ahead of the University of Alberta with around 2,650 documents and McGill University in 6th with a little less than 2,300 papers. Among the top 10, eight organizations were CFAVM Universities (universities with at least one CFAVM faculty). Overall, all CFAVM faculties would take one spot in the top 40 if ranked individually of their respective university. The top non-CFAVM or -AAFC institution in the list was the University of Toronto, which ranked 7th with around 2,150 papers, followed by Environment Canada with about 790 papers.

Based on scientific impact, the Faculty of Veterinary Medicine (University of Calgary) ranked 1st in Canada with an ARC of 2.12; however, as presented earlier, this score was heavily influenced by extreme values and a low number of papers with RC scores. It was followed by the Public Health Agency of Canada with an ARC of 1.79 for 339 papers (195 papers with valid RC to compute the ARC). Trent University came in 3rd with 1.77, ahead of York University at 1.73.

Table VII Scientific performance of leading Canadian institutions in the benchmark dataset on Agricultural and Veterinary Sciences (2003–2010)

Institution	Papers		ARC
	Score	Trend*	
CFAVM	**11,628**		**1.23**
AAFC - Agriculture and Agri-Food Canada	6,361		1.20
University of Guelph	**4,456**		**1.34**
Ontario Agricultural College	*2,310*		*1.25*
Ontario Veterinary College	*1,220*		*1.50*
University of Saskatchewan	**2,797**		**1.17**
College of Agriculture and Bioresources	*1,125*		*1.07*
Western College of Veterinary Medicine	*914*		*1.29*
University of Alberta	**2,651**		**1.36**
Faculty of Agricultural, Life & Environmental Sciences	*1,428*		*1.31*
McGill University	**2,276**		**1.22**
Faculty of Agricultural and Environmental Sciences	*1,404*		*1.12*
University of British Columbia	**2,165**		**1.59**
Faculty of Land and Food Systems	*494*		*1.52*
University of Toronto	2,157		1.54
University of Manitoba	**1,671**		**1.15**
Faculty of Agricultural and Food Sciences	*1,091*		*1.17*
Université Laval	**1,652**		**1.26**
Faculté des Sciences de l'Agriculture et de l'Alimentation	*958*		*1.23*
Université de Montréal	**1,505**		**1.23**
Faculté de Médecine Vétérinaire	*688*		*1.23*
University of Calgary	**917**		**1.22**
Faculty of Veterinary Medicine	*113*		*2.12*
Environment Canada	788		1.64
University of Ottawa	775		1.43
University of Western Ontario	760		1.17
McMaster University	636		1.56
NRCan - Natural Resources Canada	600		1.51
University of Waterloo	572		1.26
CFIA - Canadian Food Inspection Agency	559		1.21
NRC Canada - National Research Council	559		1.24
Simon Fraser University	539		1.26
Queen's University	539		1.61
Dalhousie University	523		1.31
Governement of Alberta - Agriculture, Food and Rural Development	471		1.24
Memorial University of Newfoundland	466		1.26
Health Canada	426		1.58
Nova Scotia Agricultural College	**419**		**0.98**
University of Prince Edward Island	**398**		**1.23**
Atlantic Veterinary College	*353*		*1.29*
DFO - Fisheries and Oceans Canada	389		1.50
Université de Sherbrooke	389		1.35
Carleton University	341		1.55
Public Health Agency of Canada	335		1.79
UQAM - Université du Québec à Montréal	322		1.37
University of Victoria	321		1.44
University of New Brunswick	263		1.09
York University	245		1.73
Trent University	230		1.77
University of Lethbridge	224		1.08
INRS Armand-Frappier	178		1.59
University of Regina	169		1.03
Brock University	159		1.26
World	**808,036**		**1.00**

Note: *The scale is not the same across institutions.
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

In order to provide another angle to analyze CFAVM's performance in Agricultural and Veterinary Science, statistics for different aggregates were prepared and are presented in Table VIII. As can be observed, out of the more than 36,000 papers published in Canada, about 18,300 (51%) involved a Canadian university (not including contributions from CFAVM faculties). When taking into account all AAFC publications, as well as papers from all the other federal government institutions, more than 9,100 papers were retrieved, less than the total of more than 11,600 papers from CFAVM as a whole. Interestingly, this aggregate of federal institutions scored an ARC higher than that of CFAVM because of the strong ARC associated with federal institutions (1.38 as opposed to 1.20 for AAFC). However, differences are small between CFAVM and the aggregate of AAFC and all other federal institutions, as both have similar scientific outputs and scientific impacts. Finally, close to 2,600 papers had contributions from other types of institutions (provincial governments, companies, etc.)

Table VIII Scientific performance of aggregates of Canadian institutions in the benchmark dataset on Agricultural and Veterinary Sciences (2003–2010)

Institution	Papers		ARC
	Score	Trend*	
Other Canadian Universities	18,319		1.32
Federal Institutions with AAFC	9,124		1.26
CFAVM	**11,628**		**1.23**
CFAVM Agriculture Faculties	*8,827*		*1.18*
CFAVM Veterinary Faculties	*3,056*		*1.37*
AAFC - Agriculture and Agri-Food Canada	6,363		1.20
Federal Institutions without AAFC	3,028		1.38
Other Institutions	2,582		1.34
World	**808,036**		**1.00**

Note: *The scale is not the same across institutions.
Source: Computed by Science-Metrix using the Scopus database (Elsevier).

Collaborations between leading Canadian institutions were also analyzed in this study, and the results are presented in Figure 6. This collaboration network presents collaboration behaviours between leaders in Agricultural and Veterinary Sciences in Canada. As can be observed, AAFC comes out as the main hub in this network, with collaboration ties with a large number of leading institutions, as well as strong ties with many others, including some CFAVM universities (University of Manitoba, University of Guelph, University of Saskatchewan, Université Laval and the University of Alberta).[6] Another interesting fact is that geographical proximity is apparent in the network, with Québec's institutions located in the lower right corner (Université de Montréal, McGill University, Université Laval, UQAM, Université de Sherbrooke and INRS Armand-Frappier), Ontario institutions are in the upper part of the network (University of Toronto, Queen's University, McMaster University, University of Western Ontario, York University, Brock University,

[6] A modified version without AAFC is available in the accompanying data book (Figure 9).

University of Waterloo and Trent University) and Atlantic Canada's institutions are in the lower part (University of New Brunswick, Dalhousie University, the Nova Scotia Agricultural College and Memorial University of Newfoundland). Overall, AAFC is central to this network, as are leading CFAVM universities.

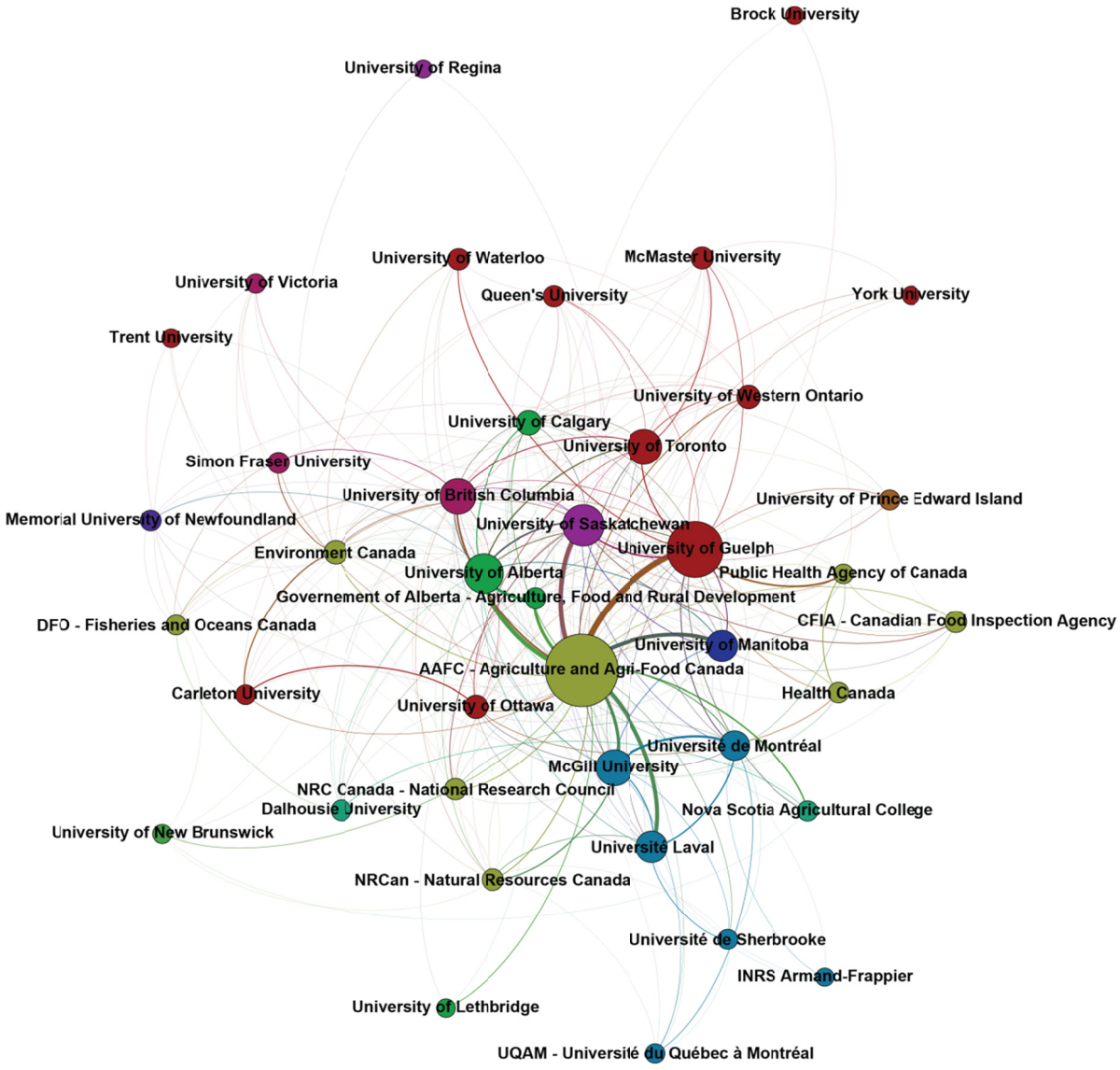


Figure 6 Collaboration network of 40 leading Canadian institutions in the benchmark dataset on Agricultural and Veterinary Sciences (2003–2010)

Note: Links representing less than 10 collaborations were filtered for readability purposes. The colours of the nodes are based on Canadian provinces. Institutions that are not located in only one province are dark yellow. The colors of the links are a mix of colors from nodes they link together.

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

6 Conclusion

Overall, Agricultural and Veterinary Sciences represents a large area of research, cumulating more than 800,000 papers from 2003 to 2010 in the Scopus database (Table IV). The United States published the most in the area, with almost 200,000 papers, followed by China with close to 86,000 papers and the United Kingdom with about 51,000 papers. Canada ranked 8th with around 36,000 papers. While industrialized countries saw their share of world papers decrease over the period, the shares of developing countries like China and Brazil sharply increased. In accordance with this trend, Canada's share declined from 5.0% to 4.0%, even while the country increased its yearly output. In terms of scientific impact, Switzerland ranked 1st among leading countries with an ARC of 1.64, above the Netherlands at 1.59 and Denmark at 1.51. These three countries also tied for 1st in ARIF, with a score of 1.27. Canada came in 12th for its ARC of 1.25 and 9th for its ARIF of 1.17. Turkey was the most specialized country with a SI of 2.45. Canada ranked 14th for this indicator (at 1.07), meaning that it is slightly specialized. Overall, Canada was one of seven countries that are specialized and that have a strong scientific impact in Agricultural and Veterinary Sciences, with particularly strong performances from New Zealand and Denmark.

Comparing the presence of CFAVM and AAFC in the Scopus database (all publications), CFAVM had a much higher scientific output with more than 18,300 papers, higher than AAFC's score of close to 7,800 papers (Table V). The difference was smaller in the dataset of Agricultural and Veterinary Sciences, but CFAVM still had almost twice as much papers as AAFC (respectively 11,600 (64% of total) and 6,400 papers (82% of total)). It appears that CFAVM has a more diversified output than AAFC, which is probably not unexpected considering that CFAVM is an organization that includes 13 faculties from 11 universities. The CFAVM members with the highest outputs in Agricultural and Veterinary Sciences were the Ontario Agricultural College with more than 2,300 papers, ahead of the Faculty of Agricultural, Life & Environmental Sciences (University of Alberta) and the Faculty of Agricultural and Environmental Sciences of McGill University with both about 1,400 papers. In terms of impact, CFAVM had a slight edge on AAFC for the overall period, with an ARC of 1.23 compared to AAFC's 1.20. However, AAFC has caught up to CFAVM in the last years and is now ahead in this indicator. While still fairly new, the Faculty of Veterinary Medicine of the University of Calgary had the highest ARC with a score of 2.12. However, because of its low number of publications before 2008, this result should be analyzed cautiously as only about a third of its papers could be used to compute this ARC score. As time goes by, more papers will reach the needed three-year citation window and it will be interesting to see whether this high ARC stands. Regarding the ARIF, CFAVM was firmly ahead of AAFC for the whole period (1.18 versus 1.08) and for each individual year. The Western College of Veterinary Medicine (University of Saskatchewan) ranked 1st with an ARIF of 1.29.

Overall, all CFAVM members performed well in Agricultural and Veterinary Sciences based on the benchmark dataset of publications from this domain, with a strong scientific impact and high specialization (Figure 5). The Nova Scotia Agricultural College was the only institution not in the top right quadrant of the positional analysis graph. CFAVM also had a strong performance in terms of its percentage of papers falling in the top most cited documents in the field, with 1.14%

and 13.0%, respectively, of its papers belonging to the 1% and 10% most cited documents. This performance resembles that of AAFC, which had 1.18% and 13.0%, respectively, of its papers belonging to the 1% and 10% most cited documents. The Faculty of Veterinary Medicine (University of Calgary) came first in both of these indicators, with 5.00% and 22.2% of its papers belonging to the 1% and 10% most cited documents, respectively, in the field.

When all federal institutions are considered together with AAFC, the performance of the group accounts for about 9,100 publications in Agricultural and Veterinary Sciences, less than CFAVM's total of close to 11,600 (Table VIII). However, both aggregates have similar impact as expressed by their respective ARC of 1.26 and 1.23. At the Canadian level, CFAVM would rank 1st (Table VII), ahead of AAFC. Overall, CFAVM Agricultural Faculties and the aggregate of federal institutions (including AAFC) had about the same output for the 2003–2010 period, with federal institutions having a slightly edge according to the ARC with its score of 1.26 compared to 1.18 for CFAVM's Agricultural Faculties.

CFAVM universities appear to be strong leaders in Canada. Eight out of the top ten institutions are CFAVM universities, the only exceptions being AAFC and the University of Toronto. All CFAVM universities appeared in the top 40 leading institutions in Canada, and all CFAVM faculties would also rank among them if ranked individually. Finally, collaborations between these leading institutions were analyzed using a collaboration network (Figure 6), which identified AAFC and CFAVM universities as being part of the main hub in Agricultural and Veterinary Sciences in Canada.

Methods

To perform this bibliometric assessment, Science-Metrix used the Scopus database, which contains close to 20 million documents indexed between 1996 and 2010. What follows are descriptions of the indicators that were computed for this project.

Number of publications

This is an analysis of the number of publications obtained using full-counting. In the full-counting method, each paper is counted once for each entity listed in the address field. For example, if a paper is authored by two researchers from the University of Calgary, one from the University of Washington and one from AAFC, the paper will be counted once for the University of Calgary, once for the University of Washington and once for AAFC. It will also be counted once for Canada and once for the US (double counting is avoided). Data were also presented based on shares of publications, where appropriate (e.g., Canada's share of world publications in Agricultural and Veterinary Sciences).

Average of Relative Citations (ARC)

This is an indicator of the scientific impact of papers produced by a given entity (e.g., the world, a country, an institution) relative to the world average (i.e., the expected number of citations). In this study, the number of citations received by each publication was counted for the year in which it was published and for the two subsequent years. For papers published in 2003, for example, citations received in the 2003–2005 period were counted. To account for different citation patterns across fields and subfields of science (e.g., there are more citations in biomedical research than in mathematics) and across the ages, each publication's citation count is divided by the average citation count of all publications of the corresponding document type (i.e., a review would be compared to other reviews, whereas an article would be compared to other articles) that were published the same year in the same subfield to obtain a Relative Citation count (RC). Since a three-year citation window was used in this study, computation of the ARC was possible up until 2008. Science-Metrix only computes scores with at least 30 publications. In the case of the ARC, at least 30 publications with a valid RC score are needed for computation. Otherwise, the score is not calculated, which is indicated by "n.c." in tables. If no score is computed because there were no papers at all, the cell is left empty.

The ARC of a given entity is the average of the RCs of the papers belonging to it. An ARC value above 1 means that a given entity is cited more frequently than the world average, while a value below 1 means the reverse.

6.1.1.1 Average of Relative Impact Factors (ARIF)

The ARIF is a measure of the expected scientific impact of publications produced by a given entity (e.g., the world, a country), based on the impact factors of the journals in which they were published. The IF of publications is calculated by ascribing to them the IF of the journal in which they are published, for the year in which they are published. Subsequently, to account for different

citation patterns across fields and subfields of science (e.g., there are more citations in biomedical research than mathematics), each publication's IF is divided by the average IF of all papers of the corresponding document type (i.e., a review would be compared to other reviews, whereas an article would be compared to other articles) that were published the same year in the same subfield to obtain a Relative Impact Factor (RIF). In this study, the IF of journals was computed over five years. For example, in 2007, the IF of a journal would be equal to the number of citations to articles published in 2006 (8), 2005 (15), 2004 (9), 2003 (5) and 2002 (13) divided by the number of articles published in 2006 (15), 2005 (23), 2004 (12), 2003 (10) and 2002 (16) (i.e., IF = numerator [23] / denominator [38] = 0.658). This indicator was computed for the whole 2003–2010 period, as the Scopus database starts in 1996. Science-Metrix only computes scores with at least 30 publications. In the case of the ARIF at least 30 publications with a valid RIF score are needed for computation. Otherwise, the score is not calculated, which is indicated by "n.c." in tables. If no score is computed because there were no papers at all, the cell is left empty.

The ARIF of a given entity is the average of its RIFs (i.e., if an institution has 50 publications, the ARIF is the average of 50 RIFs, one per publication). When the ARIF is above 1, it means that an entity scores better than the world average; when it is below 1, it means that on average, an entity publishes in journals that are not cited as often as the world level.

6.1.1.2 Specialization Index (SI)

The SI is an indicator of research intensity in a given entity (e.g., a country, an institution) for a given research area (e.g., Agricultural and Veterinary Sciences), relative to the intensity in a reference entity (e.g., the world, or the entire output as measured by the database) for the same research area. In other words, when a country is specialized in a field, it places more emphasis on that field at the expense of other research areas. Specialization is therefore said to be a zero sum game: the more one specializes somewhere, the less it does elsewhere. The SI is formulated as follows:

$$SI = \frac{(X_S/X_T)}{(N_S/N_T)}$$

Where:

X_S = Publications from entity X in a given research area (e.g., papers by Canada in Agricultural and Veterinary Sciences);

X_T = Publications from entity X in a reference set of papers (e.g., total papers by Canada);

N_S = Publications from reference entity N in a given research area (e.g., world papers in Agricultural and Veterinary Sciences);

N_T = Publications from reference entity N in a reference set of papers (e.g., total world papers).

An index value above 1 means that a given entity is specialized relative to the reference entity, whereas an index value below 1 means the reverse.

Percentage of papers in top 1% and 10% most cited papers

The percentage of papers of an institution in the top most cited documents is the ratio of the number of papers from an institution which fall in the top most cited documents in a particular field (e.g., Agricultural and Veterinary Sciences). In this analysis, only documents with a valid relative citation count are considered. For instance, if an institution has 100 documents in the top 10% most cited documents in Agricultural and Veterinary Sciences and has a total of 1,000 documents with a valid RC count (not an overall total of 1,000), it will have 10% of its publications in the top 10% most cited documents.

Collaboration network

A collaboration network involving the top Canadian institutions in Agricultural and Veterinary Sciences was produced for this project. Collaboration networks are used to help illustrate the scientific collaboration between entities (e.g., institutions). Based on matrix (either a symmetric or asymmetric matrix in full or sparse format) cross-linking the number of co-publications by the relevant entities, the software program GEPHI is used to produce a visual representation of the strength of the relationships between top entities. More specifically, a "force atlas" algorithm (similar to a "spring-embedding" algorithm with node repulsion and equal edge length) is used to establish the relative locations of the entities in the graphic representation.

Each node corresponds to an institution represented by a circle of a size proportional to the total number of publications. Edges (i.e., links or lines) between nodes represent co-publications between institutions. The width of each link is proportional to the number of co-publications between two institutions. The colour of the nodes was determined using a modularity score implemented in Gephi and is based on the Louvain algorithm (*Fast unfolding of communities in large networks (2008)*). This modularity score identifies communities within the network.

The advantage of the collaboration network is that it allows for the rapid visualization of major "hubs" in the network (i.e., institutions for which the number and/or width of links is the highest). In collaboration networks, the "force atlas" algorithm brings together the entities that share the most co-publications relative to entities that have fewer co-publications, thus creating visual "clusters" of entities.

Positional analysis

To visualize the composite performance of countries and CFAVM institutions, positional analysis graphs were also produced. To more easily interpret the strengths and weaknesses of a country through the use of several separate indicators, Science-Metrix uses a graphical representation called positional analysis. This graphical representation logically combines three of the previously mentioned indicators (number of papers, SI and ARC).

The horizontal axis of this positional graph corresponds to the SI and the vertical axis to the ARC. These data are transformed to obtain a symmetrical distribution of possible values between -100 and +100, with zero representing the world level. The size of the bubbles is proportional to the number of papers produced by the country or institution.

The position of a country or institution in one of four quadrants can therefore be interpreted as follows:

- **Quadrant 1:** Located at the top right of the graph, this quadrant is synonymous with excellence. Countries in this quadrant specialize in the given domain and their activities have a high impact, meaning that their papers are more frequently cited than the world average in this domain.
- **Quadrant 2:** Located at the top left of the graph, this quadrant is synonymous with high impact scientific production, but the countries are not specialized in the domain.
- **Quadrant 3:** Located at the bottom right of the graph, this quadrant signals specialization in the domain, whereas output impact is below the world average.
- **Quadrant 4:** Located at the bottom left of the graph, this quadrant represents the worst case scenario, as both the intensity of activity and its impact are below the world average in the domain.