Collaboration results in higher impact research: Case study of the Canadian Forest Service

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ABSTRACT

The Canadian Forest Service (CFS) has a mandate to share its full breadth of scientific knowledge concerning Canada's forests broadly, with citizens, as well as narrowly, with organizations responsible for managing forests. Measuring the impact of CFS research in policy-making both nationally and internationally can be challenging, as policies may not reference research contributing to decisions. This paper presents an analysis of how collaboration with different partners impacts the reach of CFS research, as measured by published citation databases. We found that CFS publications authored or co-authored with a U.S. or Canadian federal government author had significantly higher research impact. University co-authorship also increased impact, in part through the quality of publication journals.

Keywords: citation analysis, collaboration, co-authorship, research impact, forestry

RÉSUMÉ

Le Service canadien des forêts (SCF) a pour mandat de diffuser l'ensemble des connaissances scientifiques sur les forêts canadiennes auprès de la population en général et, plus particulièrement, auprès des organismes responsables de la gestion des forêts. Il peut être difficile de mesurer l'impact qu'a la recherche du SCF sur l'élaboration des politiques à l'échelle nationale et internationale, car les politiques ne mentionnent pas nécessairement les travaux de recherche qui ont mené aux décisions. Cet article analyse comment la collaboration avec les différents partenaires affecte la portée des travaux de recherche menés par le SCF à partir des bases de données de citations publiées. Nous avons constaté que les publications du SCF en collaboration avec un auteur américain ou du Gouvernement fédéral canadien avaient un poids scientifique nettement plus important. Une publication corédigée avec un universitaire avait également plus de poids, en raison notamment de la qualité des revues scientifiques.

Mots-clés: analyse des citations, collaboration, corédaction, impact de la recherche, foresterie

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Introduction

The Canadian Forest Service (CFS) is a sector within Natural Resources Canada (NRCAN), a federal government department. The CFS is responsible for: "environmental leadership in Canada's forest sector; a visionary approach to sustainable forest management planning and policies; and a science and research-based understanding of the forests" (NRCAN 2019). A core mandate of the CFS is to conduct scientific research about Canada's forests to inform forest management planning and policy decisions. Specific issues that the CFS addresses include forest pest infestations and disease, forest fires, biodiversity, conservation, climate change, and industry innovation. At the core of CFS' mandate is collaboration: in national and international arenas, as well as with provinces and territories to provide scientifically based guidance on forest issues.

Dating back over 100 years when the Canadian Department of the Interior apportioned a modest budget for a new agency to protect western Canadian forest resources, what is now the CFS is one of Canada's oldest government research organizations (Simpson 2000). Currently, the CFS has research programs that address many forest-related issues ranging from pest management to climate change to wildfire. The CFS research mandate is

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national in scope, supporting Canadian provinces and territories that manage forests. Forest management challenges and hence research questions are often jointly experienced across provincial and international borders (see Bowes and Krutilla 1989). Consequently, the CFS participates in international research consortia such as the North American Forest Commission (NAFC consists of representatives from Canada, the United States and Mexico). The NAFC establishes working groups that have over time reported on mutual research interests such as climate and atmospheric change, migratory species, forest insects and disease, among others (North American Forest Commission 2019).

Canadian federal departments engaged in research

Science-based departments and agencies (SBDA) were defined by the Canadian federal government in 2019 as those that exchange scientific information on a regular basis (Houle 2019). Besides NRCAN, other federal SBDAs include Industry Canada, Agriculture and Agri-Food Canada (AAFC), Environment and Climate Change Canada (ECCC), Fisheries and Oceans Canada (DFO), and Health Canada (GLFC 2018). As of 2022, there were 199 research centres in Canada across thirteen federal departments (Government of Canada 2022), including NRCAN (57 facilities), ECCC (29 centres), National Research Council (NRC 25 centres), and AAFC (20).

The Canadian Forest Service has a relatively modest size compared to other federal departments. The employee directory for CFS lists 1012 personnel (CFS 2022b), up from 817 in 2020 (CFS 2020), not all of whom are engaged in research. In comparison, the NRC, with a mandate to convert research to industrial uses, employs 3700 scientists, engineers, technicians, technology advisors, and other staff. It is important to note that not all of CFS's staff work in research realms. Programs such as the recently announced 2 Billion Trees (2BT) and Investments in Forest Industry Transformation (IFIT) are reinforced by intramural (within government) research components. Other significant science-based research departments federally include AAFC (5495 staff), and ECCC (7616 employees; Treasury Board of Canada Secretariat 2022).

History of collaboration at the CFS

Cooperation between Canada and the United States on forest-related management has occurred for over a century. Early examples include research and control work coordinated with the U.S. Bureau of Entomology on such pests as the brown-tail and gypsy moths, forest tent caterpillar (Malacosoma disstria Hubner), and fall webworm (Hyphantria cunea Drury). As early as 1917, there was a cross-border effort with respect to spruce budworm (Simpson 2000).

Collaboration between federal, provincial, and international governments, industry, and universities has also been a feature of Canadian forestry research historically. Interprovincial collaboration was required to address the White Pine Blister Rust in Quebec and Ontario during the first world war. Universities have been engaged in the study of forests since the early part of the 20th century: Forestry schools were established at the University of Toronto in 1907 and at the University of New Brunswick in 1908. The Forest Products Laboratories of Canada represented a partnership with McGill University in 1913 (Simpson 2000).

Research objectives

Because CFS research supports other organizations and individuals, several of the performance metrics for the organization relate to use of CFS research. The CFS tracks a number of indicators related to how often publications and tools are used by stakeholders. One indicator in NRCAN's departmental plan which presents substantial measurement challenges, is the number of times stakeholders use NRCAN's scientific and technical products in making decisions (NRCAN 2018). Use of science in policy making is difficult to measure, as policy documents may not specifically reference underlying influential research.

The purpose of this study was to examine whether articles co-authored by a government agency with policy authority are more highly cited than those without such collaboration. Such organizations arguably set research agendas both implicitly and explicitly, thus affecting the academic peer-reviewed literature. In turn, policy-making organizations can be impacted by changes in scientific understanding. For the purpose of this study, we utilize citation indices as measures of impact. While not all encompassing, citation-related impacts are commonly used as a measure of impact (e.g., Breugelmans et al. 2018). In general, benefits of collaboration may include greater sharing of work linked to multiple authors, as well as cross-fertilization of ideas from different disciplines (Leahey 2016; Breugelmans et al. 2018).

We use as our example CFS collaborations with a particular focus on Canadian and other government agencies in North America with research interests related to the CFS. According to the Forestry Act (1985), the CFS has a mandate to collaborate with provincial/territorial, other federal, and international stakeholders, reflected in the authority of the Minister to enter into agreements with external organizations. However, such a mandate should be reinforced with evidence for the benefits of collaboration. This paper examines how collaboration affects research impact of articles (co)authored by one or more representatives of the Canadian Forest Service.

Methods

Data description

The indicators in this article were extracted from the Web of Science (WoS) database by Clarivate Analytics (2020) and Elsevier (2019) Scopus scientific literature citation database in 2020. We retrieved publications identified by the citation databases as authored by the Canadian Forest Service. The analysis presented also relies on the Canadian Forest Service Publications Database, an online repository of publications authored or co-authored by CFS employees (CFS 2022a). The publication history of the CFS as recorded in the bookstore extends to the 1960s; however, our primary interest for the current study was the impact of relatively recent, but still historical, collaboration on research impact, so we have restricted the impact analysis to a period from 2002 to 2017. Previous research has also validated the data coverage of external citations databases for these years (MacDonald et al. 2020).

Separate queries were run in Clarivate Analytics' Incites (2020) and Elsevier (2019) Scopus scientific literature citation database interface to retrieve publication records for documents co-authored by the CFS singly as well as articles also

co-authored by other major research partners. The queries used to extract data are reproduced in Technical Appendix 1. We also downloaded SJR journal category data by SCImago (2022), which categorizes journals into 313 subject categories. The process to create the dataset containing Scopus, SJR and CFS bookstore records is described in MacDonald *et al.* (2020).

SAS software, Version 9.4 of the SAS System for Windows was used to merge the data from different queries by article title (see T1 for the methodology used to link data). PROC UNIVARIATE was used to assess the skewness of each dependent variable. We implemented a GLM using the gamma distribution and the log link to accommodate the right skewedness of the normalized citation indices. The SAS code used for this analysis is available at available at DOI 10.17605/OSF.IO/MWV2T. The regression models included the following independent variables: number of authors, and presence of a U.S. or Canadian federal government author/co-author. We explored inclusion of Mexican government agencies, but there was only one unique Comision Nacional Forestal (CNF)– CFS publication, as well as three other articles jointly co-authored with the CNF and the U.S. Forest Service (USFS). Regression analyses were implemented for documents classified as "articles".

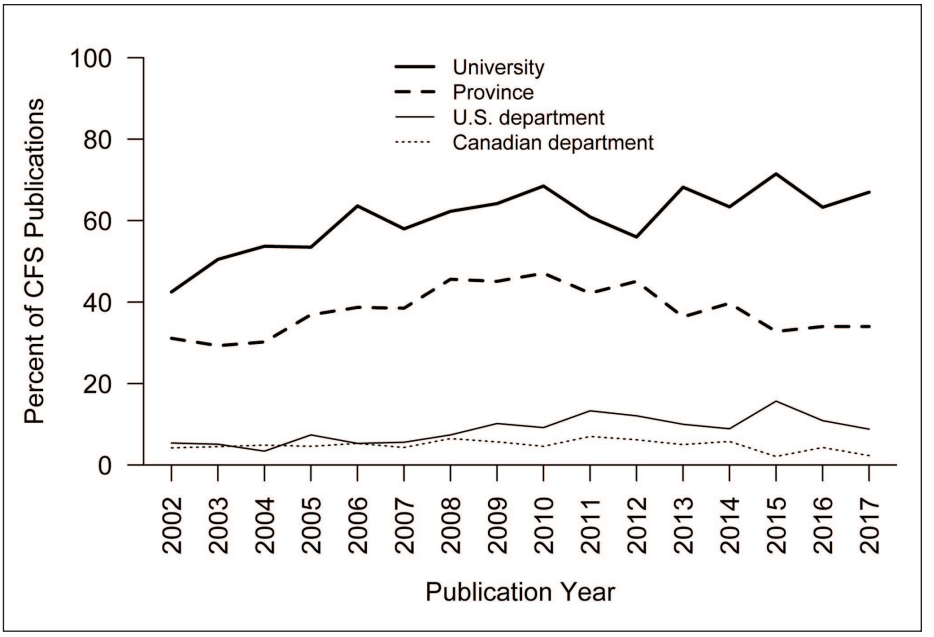

Fig. 1 Percent of CFS publications by partner type, 2002–2017

The independence of co-author categories (U.S. versus federal Canadian) was assessed using a chi-square test. We also computed Pearson's correlation coefficient during preliminary data analysis to assess the relationship between dependent variables and number of authors. Journal category (subject area) are analysed using SAS CROSSTAB by co-author type. Figures were produced in R Core Team (2017).

Variables

In general, citation counts are known to be highly skewed (Bornmann and Leydesdorff 2018), with very few researchers achieving extremely high citation rates, while the majority of articles are typically not cited. As well, citation counts are dependent on type and year of publication. One accepted approach to address these issues is to normalize citation counts, both by year of publication, journal category/subject, or even journal (e.g., Breugelmans et al. 2018). Three standardized indicators from Clarivate Analytics (2020) include: a) journal normalized citation impact (JNCI), normalizes citation impact by each specific journal and year of publication; b) category normalized citation impact (CNCI), defined as the total citations received by the article since publication, divided by the average number of citations for articles in the same year of publication and subject area; and c) percentile in subject area, reflecting how highly cited an article is relative to the research category and year of publication (100=no citations).

Each of the indicators reflects a different focus. Whereas the CNCI also reflects the relative rank of each journal within the subject category, JNCI is specific to each journal, reflecting individual publication contributions to journal performance. For publication in journals that fall into multiple categories, the CNCI is the average of the CNCIs in each subject area.

Results and discussion

Number of publications by source

From 2002 to 2017, we identified 4168 WoS publications authored or co-authored by the CFS from 2002 to 2017, of which 3657 were articles and the remainder were biographical items, book reviews, discussions, editorials, meeting abstracts, notes, reprints, and reviews. In comparison, there were 4438 Scopus records containing CFS publications over the same period. Both WoS and Scopus records were found for 3404 CFS publications from 2002 to 2017, which formed the basis of the analysis.

Co-authorship

CFS publications showed a deep level of collaboration between multiple types of organizations. To begin, most CFS publications listed at least one university author (2249 articles, 66.1% overall); the percentage of CFS publications with a university author increased over the fifteen-year period of the study (Fig. 1). Co-authorship with representatives from provincial government co-authors was also common, accounting for 1402 articles over 15 years, or 41.2% of all CFS publications (see Table 1 for publications by province/territory). The Ontario Ministry of Natural Resources (OMNR, now Ministry of Natural Resources and Forestry) was the most common co-author at the provincial governmental level from 2002 to 2017, resulting in 112 articles co-authored

Table 1. CFS publications with a provincial or territorial government co-author

Province	Number of Publications	% of CFS Publications
British Columbia	79	2.0%
Alberta	10	0.3%
Ontario	118	2.9%
Quebec	56	5.1%
New Brunswick	14	0.4%
Nova Scotia	8	0.2%
Prince Edward Island	4	0.1%

with the CFS. The BC Ministry of Forests and Range (now Ministry of Forests) was a co-author for 79 articles, and the Quebec Ministère Des Ressources naturelles et de la Faune (now Ministère de l'Énergie et des Ressources naturelles) was associated with 56 articles co-written by the CFS. Fourteen and seven articles were co-produced with the New Brunswick and Nova Scotia Departments of Natural Resources respectively. Alberta provincial departments were less frequently affiliated with CFS research (Fig. 2).

Nine percent of CFS articles were co-authored by one or more U.S. government agencies (303 articles). CFS collaboration with U.S. government agencies was more common than with other Canadian federal agencies in all years, and the percentage of CFS-US publications rose over the period of this study (Fig 1). Collaboration with the US Forest Service (USFS) resulted in 252 articles recorded in Scopus between 2002 and 2017. The U.S. Geological Survey was the second most common U.S. government collaborator, with 41 articles, and NASA was a co-author in 36 CFS-affiliated papers. The U.S. Environment Protection Agency (EPA) co-authored 15 articles with CFS in Scopus between 2002 and 2017.

The CFS also produced 167 papers with other federal Canadian agencies and departments (4.9% of CFS publications). AAFC was the most frequent federal department co-author with the CFS, with 110 such articles identified from 2002 to 2017 (2.7% of all CFS-identified articles). ECCC was a co-author for 77 of CFS-affiliated articles from 2002 to 2017. The Canadian Food Inspection Agency (CFIA) was a co-author in 38 articles, the Meteorological Service of Canada in 21 articles, and the NRC in 9 articles over the 15-year period.

Publication category

Using the SJR categories, CFS authors were most likely to publish in a forestry-related journal (33%), as illustrated in Fig. 3. Other common journal subjects included ecology (25%), global and planetary change (12%), insect science (11%), and plant science (9%). Interestingly, SJR categorized 9% of CFS articles as falling into "Medicine". Follow-up analysis indicated that medicine tended to be a secondary classification for all but two of the publications. For instance, the Journal Ambio is classified as falling into Environmental Science, as well as Medicine, and Social Sciences by SJR.

Looking at articles co-published with the USFS, the most common journal subject was ecology (34%) compared to forestry (28%), insect science (14%), and global and planetary change (14%). In comparison, papers produced with AAFC were more likely to be published in an insect science journal (27%), followed by plant science (20%), and agronomy (19.1%) journals. While not displayed in Fig. 3, animal science, structural biology, and genetics were also common journal subject categories for papers published with AAFC (8%, 7% and 6% respectively). For papers written with ECCC, nearly 20% of articles were published in forestry-related journals, 17% in atmospheric science, 15.8% in global and planetary change, 13% in ecology, and almost 10% were published in water science and technology journals and the same percent in earth surface journals.

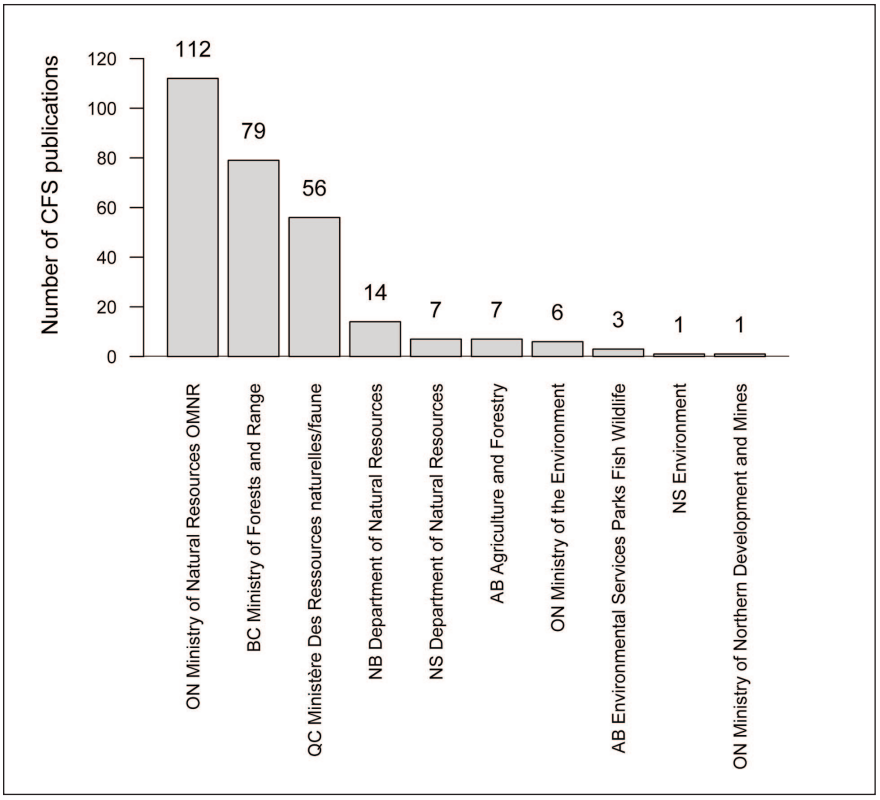

Fig. 2 Number of CFS articles by provincial governmental collaborator, 2002 to 2017 (BC=British Columbia, AB=Alberta, ON=Ontario, QC=Québec, NB=New Brunswick, NS=Nova Scotia).

Statistical distribution of research impact (dependent) variables

Journal normalized impact for CFS authored or coauthored articles from 2002 to 2017 was highly skewed (19.41), as was the category normalized citation impact (29.69). In contrast, subject area percentile was not skewed (see S2). Consequently, an OLS regression model was fitted for this variable.

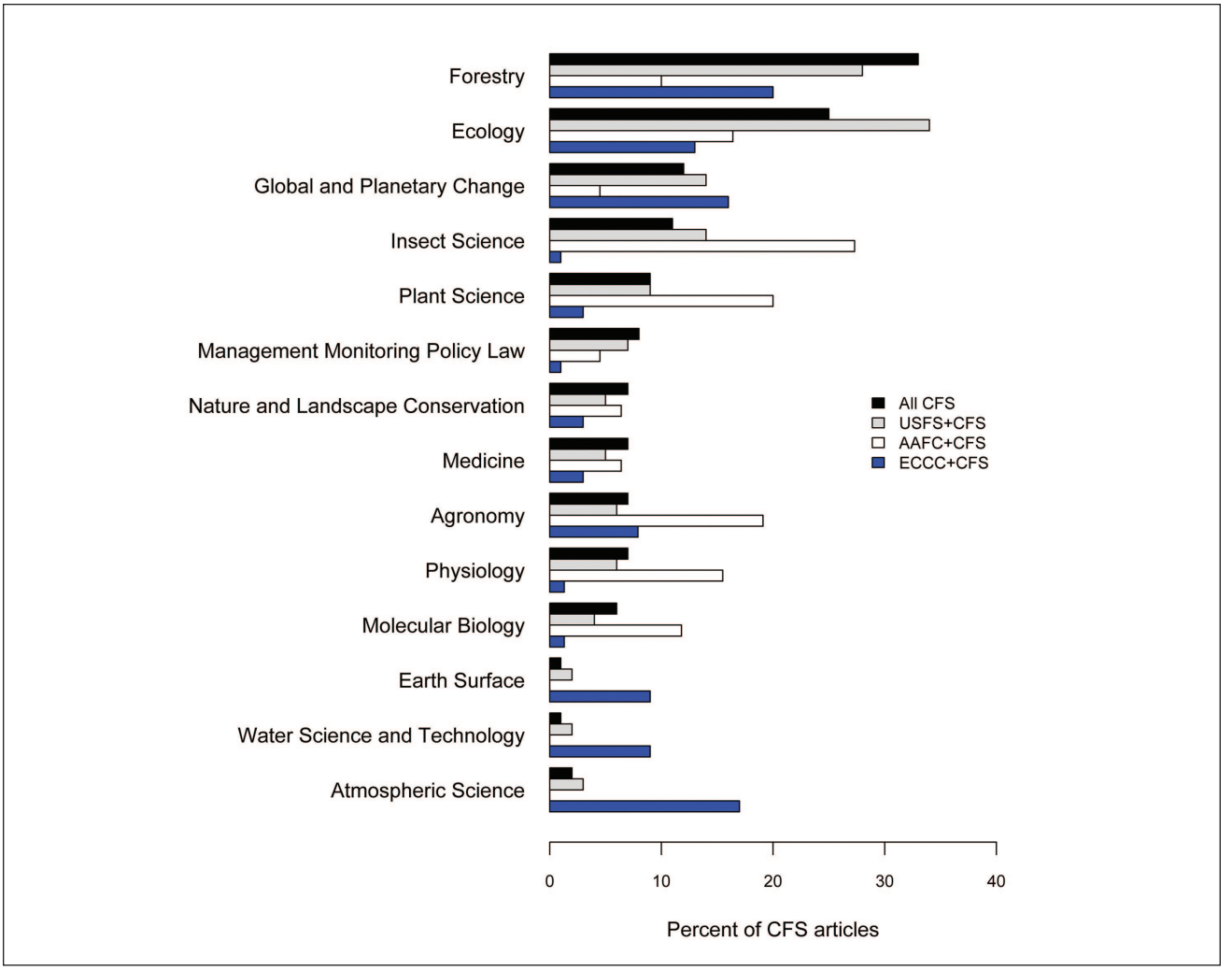

Fig. 3 Percentage of articles by SJR journal subject category by co-author type.

Collaboration and research impact

Across all journals, CFS authored or co-authored papers were cited at 133% of the expected citation rate by journal category, or 33% above average for the journal category. By publication, CFS articles were cited at 114% of the respective journal average, or 14% above what would be expected for publication journals (see Table 2). Comparatively, articles with a university co-author were cited at 153% of the category normalized impact and 122% of journal normalized impact. Articles with a provincial government co-author were cited at 144% of the category normalized average and 118% of the subject normalized number of citations. CFS papers co-authored with a U.S. agency were cited at 324% of the subject average and 186% of the relevant journal average. Articles co-authored with another Canadian federal department or agency were cited at 192% of the category average and 160% of the journal normalized impact.

CFS articles with a greater number of authors had higher normalized citation rates and a smaller percentile within subject area (both indicative of higher research impact, see descriptive bivariate analyses in Table 2). Factoring in other model variables, co-authorship with a U.S. government agency was a statistically significant predictor of higher journal normalized citation impact (χ^2 =9.80, p=0.0017, see Table 3a) and category normalized citation impact (χ^2 =54.10, p<0.0001; Table 3b). Co-authorship with another federal government department or agency was also statistically predictive of greater journal normalized citation impact (χ^2 =3.74, p=0.05; Table 3a) and category normalized citation impact (χ^2 =4.96, p<0.05; Table 3b). Presence of a provincial government coauthor was not statistically predictive of journal or category normalized impact. While university authorship was not a significant independent variable for journal normalized impact, having a university author was statistically predictive of higher category normalized citation impact (χ^2 =20.12, p<0.0001). In other words, having a university co-author increased journal prestige.

U.S. government collaboration was also statistically predictive of publication of CFS work in more select journals, based on journal percentile in the respective subject area (t=-5.23, p<0.0001; Table 3). Collaboration with a federal Canadian department or agency was statistically predictive of a more select percentile of papers (t=-3.44, p<0.0001). University authorship was also statistically predictive of journal percentile (t=-8.24, p<0.001).

In all regression models conducted, number of authors was significantly related to article impact, which may help motivate the trend towards increased number of authors observed in CFS publications over the past five decades (Bonnell et al. 2012; MacDonald et al. 2020). The number of authors on a paper can influence subsequent citations in multiple ways, including through self-citation. As a result, controlling for this variable in the regression models is important in order to take the number of authors on the citation score, allowing the analysis to isolate the impact of type of co-author separately from simply the number of authors.

While citation counts were not our primary focus, for illustrative purposes we summed the number of citations of CFS research (2002-2017) as counted by Incites in 2020 (Clarivate Analytics 2020). Considering all articles over the 2002 to 2017 time period, 103 775 citations were identified for CFS-affiliated research by Incites in 2020. Of these, 19 338 citations were identified as a collaboration between the CFS and a U.S. government agency, and 8921 citations were identified for the 179 articles co-authored with another Canadian federal agency. Of the top twenty articles during the 2002 to 2017 time period in terms of impact (Table 4), ten were co-authored with a U.S. government agency, almost all had a university author/co-author (18), and two are co-authored by another Canadian federal agency.

In cases where there was a university and another governmental partner, the addition of the university author incrementally increased impact (as shown in Table 2). Regression models confirmed that university plus another government collaborator statistically increased the research impact of government-to-government collaborations by themselves. In particular, having a university author statistically increased the journal normalized research impact of publications authored by a U.S. (χ^2 =108.09, p<0.0001, see Table 6) or federal Canadian (χ^2 =10.84, p=0.001) agency. The main effect for provincial government co-authorship was not a statistically significant

Table 2. Average Research Impact Measures for CFS authored/coauthored papers, by number of authors, and type of co-authorship (with a U.S. or federal Canadian department agency). Main effects in bold.

	Category Normalized Citation Impact	Journal Normalized Citation Impact	Percentile in Subject Area	Count
All CFS authored/coauthored	**1.33**	**1.14**	**44.06**	**3404**
Coauthor type				
University	**1.53**	**1.22**	**40.43**	**2249**
U.S. federal government	**3.24**	**1.86**	**31.57**	**303**
U.S. federal government + university	3.98	2.16	27.70	226
Canadian federal government	**1.93**	**1.60**	**33.86**	**167**
Canadian federal government + university	2.14	1.68	29.78	115
Canadian federal department + U.S.	3.04	2.07	22.06	24
Canadian province/territory	**1.44**	**1.18**	**42.93**	**1402**
Province/territory + University	1.61	1.24	40.33	969
Province/territory + U.S.	3.85	1.96	27.21	124
Number of Authors				
1–4	0.88	0.91	50.99	1296
5–8	1.26	1.12	42.11	1725
9–12	1.85	1.32	36.36	259
13–20	4.30	2.50	16.97	88
>20	10.42	6.16	9.31	36

Table 3. Regression model on a) Journal Normalized Citation Impact (n=3261) and b) Category Normalized Citation Impact (n=3276), using number of authors and flags indicating U.S. or external Canadian government co-authors as predictors. Table columns include degrees of freedom (DF), coefficient estimate

Variable	DF	Coefficient Estimate	Standard Error	Wald's 95% Confidence Limits		χ^2	p
a) Journal Normalized Citation Impact							
Intercept	1	-0.238	0.035	-0.306	-0.170	47.30	<.0001
Number of authors	1	0.058	0.005	0.049	0.067	158.61	<.0001
U.S. government partner	1	0.176	0.056	0.066	0.286	9.80	<.005
Canadian federal department	1	0.134	0.069	-0.002	0.270	3.74	0.0530
Provincial government	1	-0.007	0.031	-0.067	0.053	0.05	0.82
University	1	0.003	0.033	-0.063	0.068	0.01	0.94
b) Category Normalized Citation Impact							
Intercept	1	-0.433	0.040	-0.511	-0.356	120.27	<.0001
Number of authors	1	0.080	0.006	0.069	0.090	211.57	<.0001
U.S. government partner	1	0.464	0.063	0.340	0.587	54.10	<.0001
Canadian federal department	1	0.171	0.077	0.021	0.321	4.96	0.03
Provincial government	1	-0.018	0.034	-0.048	0.085	0.29	0.59
University	1	0.165	0.037	0.093	0.237	20.12	<0.0001

standard error, 95% confidence limits, χ^2 and probability (p).

Table 4. OLS regression model on Percentile in Subject Area using number of authors and a flag for a co-author from a) U.S. government agency; b) Canadian federal government agency; or c) both U.S. and Canadian federal government agencies (n=3374). Table columns include degrees of freedom (DF), parameter estimate, standard error, t-value, and probability using a two-sided test (Pr > |t|). Smaller percentile values reflect better relative scores.

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	55.450	0.966	57.42	<.0001
Number of authors	1	-0.775	0.095	-8.16	<.0001
U.S. federal government	1	-8.465	1.733	-4.88	<.0001
Canadian federal department	1	-6.406	2.229	-2.87	0.004
Provincial government	1	-0.609	0.964	-0.63	0.53
University	1	-8.483	1.020	-8.32	<.0001

main effect. In contrast, the main effect of a university author was statistically significant on journal normalized citation impact (χ^2 =4.11, p<0.05; Table 6).

Discussion

Based on this study, collaboration with external departments and agencies resulted in higher impact CFS research as measured by normalized citation impacts. One of the strongest effects of collaboration was for U.S. government agencies. Specifically, controlling for a range of other collaboration types and number of authors, articles co-produced between the CFS and another U.S. government agencies (mainly the USFS) produced an impact of over three times the journal category average. This finding suggests that a fruitful way to increase research impact, for journals historically or currently publishing CFS work, would be to expand work that has previously been developed on the Canadian sides of the border to include a continental analysis. Such research should address required planning, for instance, to overcome border effects, for instance, when developing fire, carbon, climate, biomass, and many other products produced by the CFS. Recruitment of invited pieces with U.S.-Canadian authorship may be a useful first step.

A second primary conclusion from the study is that university collaboration pays off in terms of research impact. The testing of main effects indicated that university authorship promotes high quality research, primarily through publication in better journals. University authorship also increased the impact of U.S. and federal Canadian collaborations with CFS (interaction effect). Importantly, in cases where external governmental co-authors were present, having a university author had a significant incremental effect on research impact. University collaboration was in fact the most common types of CFS partnership of those considered, accounting for more than half of CFS publications over fifteen years.

One caveat associated with this research is that publications do not fully communicate the knowledge exchange ambitions of policy making agencies. For instance, the UK Research and Innovation (2022) clarifies the greater definition of impact as 'an effect on, change or benefit to the economy, society, culture public policy or services, health, the environment or quality of life, beyond academia'. Future research could focus on the policy impacts of CFS-provincial/territorial collaborations to explore the full range of impacts of CFS more fully and forestry research in general. Qualitative analyses, including case studies and policy document reviews are important in addition to this quantitative assessment, for a broad range of partners, including First Nations.

Collaboration is occurring at the CFS on multiple levels. Nearly 20% of articles published by CFS authors were co-authored by an external governmental partner at the federal, provincial/territorial or U.S. federal level. Based on our analysis, the USFS is the most frequent single research partner over a 15-year period from 2002 to 2017 with 252 articles. Other frequent partners include Agriculture and Agri-Food Canada (110 articles over 15 years), the Ontario Ministry of Natural Resources (112 articles), Environment and Climate Change Canada (77 articles), BC Ministry of Forests and Range (79), and Quebec Ministère Des Ressources naturelles et de la Faune (56).

Conclusion

This paper addressed two objectives: 1) To investigate how collaboration impacts the reach of CFS research; and 2) To assess whether collaboration with national and sub-national government bodies is unique to collaboration with other partners. In respect to these research questions, 1) We determined that collaboration significantly impacts the reach of CFS research, based on citations comparing collaborative CFS research and non-collaborative CFS research. 2) Specifically, U.S. government co-authorship was the greatest single predictor of selected standardized bibliometric measures of CFS research impact. University collaboration also had a significant impact on research impact, partly through the quality of journal. While this study did not include policy and social impacts, future research will consider citations concurrently with other indicators.

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Table 5. List of 20 articles authored/co-authored by the CFS from 2002–2017 with highest category normalized citation impact, with indicators for the presence of a U.S. or Canadian federal government agency co-author. Table columns include the article title, number of authors, journal name, year of publication, normalized journal citation score, category normalized citation score, percentile in subject area, and presence of a university or U.S./ Canadian department co-author.

A) 20 CFS co-authored articles with highest category normalized citation impact	# of Authors	Journal Name	Year	Times Cited	Journal Norm. Cite Impact	Category Norm. Cite Impact	Percentile in Subject Area	U.S.	Can dep	Univers-ity	Prov
A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests	21	For. Ecol. Manag.	2010	2945	75.26	168.26	0.02	1	0	1	0
A Large and Persistent Carbon Sink in the World's Forests	19	Science	2011	2440	9.20	84.46	0.01	1	0	1	1
Landsat-8: Science and product vision for terrestrial global change research	35	Remote Sens. Environ.	2014	724	17.09	38.62	0.02	1	0	1	1
Mountain pine beetle and forest carbon feedback to climate change	9	Nature	2008	1040	2.73	30.43	0.04	0	0	0	1
Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions	8	Bioscience	2008	898	9.25	28.33	0.06	1	0	1	1
Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites	30	Environ. Sci. Pollut. Res.	2015	403	30.46	25.53	0.06	0	0	1	0
Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects	10	Bioscience	2010	603	8.37	23.86	0.12	1	0	1	0
Environmental fate and exposure; neonicotinoids and fipronil	14	Environ. Sci. Pollut. Res.	2015	340	25.7	21.54	0.10	0	0	1	0
Opening the archive: How free data has enabled the science and monitoring promise of Landsat	6	Remote Sens. Environ.	2012	472	7.05	18.70	0.12	1	0	1	1
Effects of neonicotinoids and fipronil on non-target invertebrates	19	Environ. Sci. Pollut. Res.	2015	279	21.09	17.67	0.13	0	0	1	0
Global wildland fire season severity in the 21st century	7	For. Ecol. Manag.	2013	221	9.46	17.32	0.06	0	0	1	0
Edge influence on forest structure and composition in fragmented landscapes	11	Conserv. Biol.	2005	660	8.95	15.95	0.13	0	0	1	1
A synthesis of radial growth patterns preceding tree mortality	67	Glob. Change Biol.	2017	114	5.75	14.97	0.10	1	0	1	1
The global Landsat archive: Status, consolidation, and direction	11	Remote Sens. Environ.	2016	179	6.45	14.95	0.16	1	0	1	1
Toward more realistic projections of soil carbon dynamics by Earth system models	42	Global Biogeochem Cycles	2016	156	7.48	13.78	0.09	1	0	1	1
LiDAR remote sensing of forest structure	6	Prog. Phys. Geogr.	2003	525	7.66	13.70	0.16	0	0	1	1
Climate change presents increased potential for very large fires in the contiguous United States	6	Int. J. Wildland Fire	2015	110	9.23	13.60	0.05	1	0	1	0
Detecting the effect of climate change on Canadian forest fires	5	Geophys. Res. Lett.	2004	433	9.51	13.21	0.32	0	1	1	1
Carbon accumulation in agricultural soils after afforestation: a meta-analysis	4	Glob. Change Biol.	2010	362	4.51	12.48	0.16	0	1	1	0

Table 6. Focused regression model on a) Journal Normalized Citation Impact (n=3,289) and b) Category Normalized Citation Impact (n=3,304), using the interaction between a university author and three government authorship types (U.S., Canadian federal, and provincial). Table columns include degrees of freedom (DF), coefficient estimate, standard error, 95% confidence limits, χ^2 and probability (p)

Variable	DF	Coefficient Estimate	Standard Error	Wald's 95% Confidence Limits		χ^2	p
a) Journal Normalized Citation Impact							
Intercept	1	0.043	0.027	-0.009	0.095	2.58	0.11
University	1	0.076	0.037	0.003	0.149	4.11	0.04
U.S. government + university	1	0.653	0.062	0.530	0.776	108.09	<0.0001
Canadian federal department + university	1	0.279	0.085	0.113	0.445	10.84	0.001
Prov government + university	1	0.003	0.038	-0.071	0.078	0.01	0.94
b) Category Normalized Citation Impact							
Intercept	1	-0.0040	0.0297	-0.062	0.054	0.02	0.89
University	1	0.2266	0.0413	0.146	0.308	30.10	<0.0001
U.S. government + university	1	1.1428	0.0696	1.006	1.279	269.40	<0.0001
Canadian federal department + university	1	0.3136	0.0944	0.129	0.499	11.04	0.0009
Prov government + university	1	0.0234	0.0424	-0.060	0.106	0.30	0.58

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