Trends in research and collaboration in the Canadian Model Forest Network, 1993–2010

by Brian Bonnell[1]

ABSTRACT

A fundamental principle of the Model Forest concept focuses on the generation and sharing of knowledge through research, innovation and collaboration. Over 380 papers, published in journals, have been identified that are based on research and other activities supported by a Model Forest in Canada. Bibliometrics is a research method used to measure scientific output, level of influence of a researcher or organization, changes in research focus and levels of collaboration between researchers and organizations. This study presents an analysis of research trends and collaborative research activity within the Canadian Model Forest Network from 1993 to 2010 based on journal articles produced during that time period. The analysis shows publication of research varies among Model Forests and individual projects. The most significant result is a clear trend towards increased national-level collaboration in research activities with the Canadian Forest Service and various universities acting as key hubs in the publication of the results of Model Forest-supported research.

Key words: Model Forest, research, bibliometrics, collaboration

RÉSUMÉ

Un des principes fondamentaux du concept de Forêt Modèle est la génération et l'échange de connaissances par voie de recherche, d'innovation et de collaboration. Plus de 380 articles publiés dans des revues scientifiques sont fondés sur des recherches et d'autres activités appuyées par une Forêt Modèle canadienne. La bibliométrie est une méthode de recherche permettant de mesurer la production scientifique, le degré d'influence d'un chercheur ou d'un organisme de recherche, les changements d'orientation des programmes de recherche et le degré de collaboration existant entre les divers chercheurs et organismes. Cette étude analyse ici les tendances qui ont caractérisé les travaux de recherche et les activités de recherche coopérative au sein du Réseau canadien de Forêts Modèles, de 1993 à 2010, fondant sur les articles parus au cours de cette période. L'analyse montre que la production d'articles scientifiques varie selon les Forêts Modèles et selon les différents projets. Le résultat le plus significatif est une tendance claire vers une plus grande collaboration au niveau national dans les activités de recherche avec le Service canadien des forêts et de diverses universités agissant en tant que centres principaux dans la publication des résultats de la Forêt Modèle soutenu par la recherche.

Mots clés : Forêt Modèle, recherche, bibliométrie, collaboration

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Introduction

Canada's Model Forest Program was developed in response to changes taking place in the forest sector in the late 1980s and early 1990s. At that time there was a paradigm shift in forestry away from sustained yield management, focused on maintaining a continuous supply of timber, towards sustainable forest management (SFM) and a more social approach to resource management (Kimmins 1995). The Program brought together representatives of diverse organizations to develop innovative approaches to integrating policy and on-the-ground implementation of SFM (Hall and Bonnell 2004). A fundamental principle of Model Forests focuses on the generation and sharing of knowledge through research, innovation and collaboration (IMFN 2010).

Fourteen Model Forests currently exist in Canada (Fig. 1) and are linked together through the Canadian Model Forest Network (CMFN). The sites represent the diversity of Canada's forest regions, land tenure arrangements, and socio-economic and cultural conditions (CMFN 2011).

Since the inception of the Model Forest concept, significant funding has been expended on research activities in the Model Forests. Research activities accounted for 60% of the Model Forests' programming during 1992 to 1997 (NRCan 2006). Even though the focus on research activity has been reduced since then, it still remains an important activity of many Model Forests. Additionally, scientists from a range of academic and research institutions have been involved in all Model Forests on boards of directors, working groups, advisory committees and through supporting graduate students (Nantel 2001; NRCan 2002, 2006; Sinclair and Duinker 2008).

Over 380 articles have been identified that focus on Model Forests, identify a Model Forest as the study area, or are based on research supported by a Model Forest. Journal articles represent quantifiable outputs of research activities. Bibliometrics is a research method used to measure scientific output,

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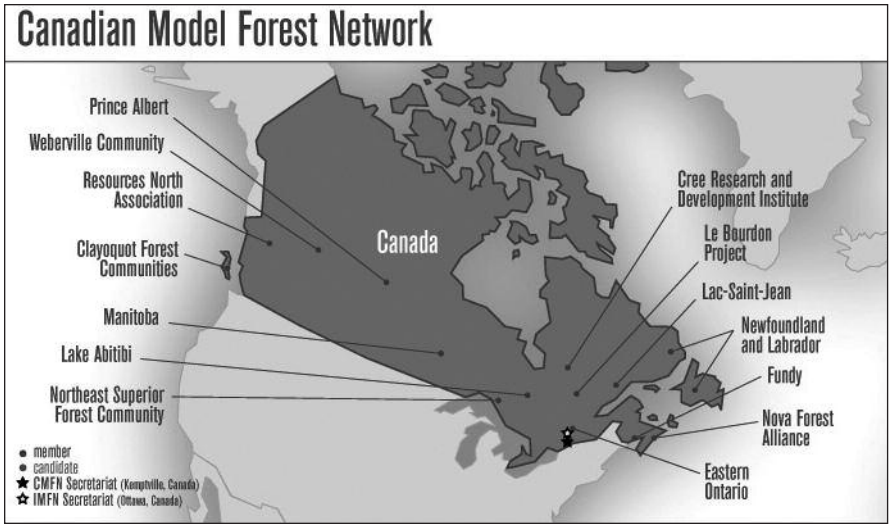

Fig. 1. Canadian Model Forest Network (2010[2]).

level of influence of a researcher or organization, changes in research focus and levels of collaboration between researchers and organizations (Archambault and Gagné 2004). This study presents an analysis of research trends and collaborative research activity within the CMFN from 1993 to 2010 based on papers published in journals during that period.

Methodology

The initial step in undertaking a bibliometric analysis of the research supported by Model Forests in Canada was the creation of a dataset. This study used journal articles and excluded book chapters, project reports, communications materials of research programs, and conference proceedings. Journal articles provided a more consistent dataset with respect to accessibility and author affiliations. Data on book chapters and conference proceedings were collected; however, it was felt that the dataset was incomplete and it was therefore excluded from further analysis.

The journal articles used for this study were identified and collected from a range of sources, including Model Forest Web sites, online databases such as SciVerse Scopus (Elsevier B.V. 2011), Google searches, direct contact with researchers and searches of individual journal Web sites. Articles had to meet at least one of three criteria for inclusion into the dataset:

1. A Model Forest provided support (financial or otherwise) to the research or other activities outlined in the article. In many instances, the Model Forest was acknowledged as a sponsor within the article, or the author acknowledged Model Forest support in personal communication; or
2. A Model Forest was specifically identified as the study area in the article; or
3. The article focused on Model Forests or the Model Forest concept.

Articles based on original research (peer-reviewed, n = 358) and professional articles (non-peer-reviewed, n = 26) were included in the dataset and used in the analyses. Copies of all identified articles were collected either electronically or in print to confirm that the Model Forest was listed in the acknowledgements, and/or identified as the study area. The copies of the articles were also used to confirm appropriate thematic categories.

Bibliometric data were arranged in an Excel spreadsheet with the following structure: Model Forest, publication year, bibliometric reference, number of citations, journal, authors and affiliations and level of collaboration. For most analyses, data were grouped by five-year period approximately corresponding to the five-year funding periods of the Canadian Model Forests: 1993–97, 1998–2002, 2003–07, and 2008–2010[3]. A three-year grouping was used in some instances to more clearly illustrate changes over time. Further data production and analysis was conducted for the following bibliometric indicators:

Number of articles

This included the number of papers by Model Forest, year, journal, theme and author affiliation. Articles acknowledging the CMFN or more than one Model Forest were labelled as "Canada" and not linked to the individual Model Forests.

Themes

Several approaches were used to assign themes to each article. An initial approach used keywords, both author defined and SciVerse Scopus database-defined. However, there were too many key words (approximately 880 and 1600, respectively) to allow for an effective or efficient analysis. A separate set of 45 themes (Table 1) was created for this study based on a review of the articles with each article assigned to at least one theme. As well, a three-year grouping of data was selected for

[2]The Long Beach Model Forest ceased operations in 2002 and the Bas-Saint-Laurent Model Forest in 2007. The Cree Research and Developemnt Institute (originally the Waswanipi Cree Model Forest) was establihsed in 1997, and the Nova Forest Alliance in 1998 (PEI was added to the Nova Forest Alliance in 2003). Clayoquot Forest Communities, Northeast Superior Forest Communities, Project Le Bourdon, and Forêt modèle du Lac-Saint-Jean were established in 2007. Weberville Community Model Forest joined the Canadian Model Forest Network in 2010. The Resources North Association was originally known as the McGregor Model Forest, Foothills Research Institute originally as the Foothills Model Forest, and the Model Forest of Newfoundland and Labrador originally as the Western Newfoundland Model Forest. The Foothills Research Institute left the CMFN in 2011.

[3]1993 was used as the starting time frame as there were no papers found for 1992 and five-year increments were used. As well, the time period 2008–2010 has been included to reference the number of articles only. Full information for 2011 and 2012 will not be available until 2013 or 2014 as databases such as Scopus are updated.

Table 1. Number of articles by key theme, 1993–2010

Key subject area (theme)	Number of articles						
	Total	1993–95	1996–98	1999–01	2002–04	2005–07	2008–10
Boreal forest	80	1	17	14	17	31	5
Wildlife	62	2	3	8	21	28	29
Avian/Birds	50	1	9	18	9	13	3
Habitat	41	0	5	9	12	15	18
Harvesting	34	0	4	5	9	16	4
Ecology and ecosystems	28	0	9	2	7	10	2
GIS/Remote sensing	26	0	3	2	9	12	19
Grizzly bear	25	0	0	1	13	11	21
Flora (including understory/bryophytes)	23	0	1	3	10	9	2
Entomology	20	0	1	6	3	10	1
Silviculture and regeneration	20	1	5	2	6	6	4
Small mammals	17	2	2	3	3	7	3
Decision Support Systems / Modeling	16	2	5	5	3	1	2
Forest and landscape management	16	0	5	2	8	1	7
Model Forest/IMFN	16	2	2	4	6	2	0
SFM	12	0	3	4	3	2	0
Community sustainability	11	0	0	1	6	4	0
Forest hydrology	11	0	6	3	2	0	0
Fragmentation	10	0	3	4	2	1	1
Forest carbon budgets	9	1	1	0	3	4	1
Socioeconomics	8	0	1	1	5	1	1
Forest fire	7	0	0	2	3	2	0
Conservation and stewardship	6	0	1	0	3	2	3
Criteria and indicators	6	0	0	1	3	2	1
Soil	6	0	2	2	1	1	0
Aboriginal	5	0	1	0	0	4	2
Climate change	5	0	0	1	1	3	0
DNA/Genetics	5	0	1	2	1	1	2
Forest values	5	0	2	2	1	0	1
Governance/Participation	5	0	2	1	2	0	1
Aquatic habitat and fish	4	0	0	2	2	0	2
Biodiversity	4	0	0	0	3	1	1
Policy	4	0	0	0	3	1	0
Recreation	4	0	1	1	0	2	0
Riparian	4	0	2	2	0	0	0
Water	4	0	1	1	0	2	0
Woodlots	4	0	0	1	3	0	0
Caribou	3	0	0	1	0	2	0
Natural disturbance	3	0	0	2	1	0	1
Community forestry	2	0	1	0	0	1	0
Forest Conditions/Monitoring/ Inventory	2	0	0	1	0	1	5
Forest certification	1	0	0	0	1	0	0
Mining/Oil & gas	1	0	0	0	0	1	1
Non-timber forest products	1	0	0	1	0	0	1
Roads	1	0	0	0	0	1	4

Note: each paper could be assigned one or more themes.

this analysis as it showed trends better than the five-year intervals.

Collaboration

To examine collaboration, each article was assigned one of five categories:

1. **Individual:** Only one author for the article.
2. **Group:** More than one author but all from the same section of an institution.
3. **Institutional:** More than one author but each from a different section within the same institution. For example, an article with two authors from the Canadian Forest Service but one affiliated with the Atlantic Forestry Centre and the other with the Northern Forestry Centre was designated as "institutional" collaboration.
4. **National:** More than one author from different institutions in the same country even if those institutions are located in the same city or province. This is also referred to as "inter-institutional" collaboration.
5. **International:** More than one author from different institutions in different countries.

Further analysis of national-level collaboration was undertaken to identify which institutions were collaborating the most. For this analysis, a paper counted as one collaboration

for each institution represented in the author affiliations and as one collaboration between the two institutions. If one institution was listed more than once for a particular article, the article only counted as one collaboration for that institution. For example, if two authors were from the Canadian Forest Service and one from the University of New Brunswick, then the article counted as one collaboration for the Canadian Forest Service and one for the University of New Brunswick. That same article also counted as one collaboration between the two institutions.

Visualization of collaboration networks

A matrix was developed in Excel based on the number of articles co-authored by pairs of institutions during the period 1993–2008. Corel Draw was used to produce a representation of the relationships between the institutions involved in co-authoring articles designated as national-level collaboration[4]. Within the visualization, each circle represents an institution with a diameter proportional to its total number of articles in collaboration with other institutions. Lines between circles represent collaborations (co-authorships) between institutions. The thickness of the line is proportional to the number of collaborations, or co-authored articles, involving the two institutions. The length of the line is not representative of any factor.

Limitations of bibliometrics

Although bibliometrics is the most widely accepted method for measuring scientific activity output (Durieux and Gevenois 2010), it does have several limitations. These include:

- Not all of the authors of a paper may have actually worked together but may have only collaborated on the writing of the paper.
- Not all papers may be found within a single database. For example, 12 of the papers in the dataset were not available in the SciVerse Scopus database.
- Some papers may not have been included as the authors did not inform the sponsoring Model Forest of the paper or did not acknowledge the Model Forest as a supporter of the research activity.
- Not all Model Forest-supported research activities were published in journals. For many studies, only project reports were prepared (e.g., Langecin 1996). This grey literature has been excluded from the analyses as it does not appear in various databases.

As such, the results provide a reasonable approximation of the research trends in the CMFN.

Guiding questions for this paper

The following questions were used to guide the analysis for this paper: 1) which Model Forests are publishing the results of their research, 2) which journals are most actively being used, 3) what are the thematic trends in research being supported by Model Forests, and 4) what are the trends in collaboration between various researchers and organizations? Each of the identified questions will be examined in turn.

Findings and Discussion

Output by Model Forest and year

A total of 384 articles were identified that met the criteria for inclusion in the dataset. Overall, there was a relatively low level of publication of journal articles (n = 39) during the 1993–97 period. Prince Albert Model Forest accounted for 25% (Table 2). Despite the emphasis on research activity in Model Forests (NRCan 2006), it is reasonable that there would have been few publications during the initial five-year period considering lag-time between research initiation and publication. The number of articles then tripled during the 1998–02 period (n = 119) with research activities supported

[4]For this paper, only national-level collaboration was examined as part of the visualization analysis. As such, the matrix dataset consisted only of information derived from articles classified as "national" collaboration (n = 355).

Table 2. Number of articles by Model Forest, 1993–2010

	Number of articles				
Model Forest	**1993–97**	**1998–02**	**2003–07**	**2008–10**	**Total**
Foothills / Foothills Research Institute	2	22	44	39	107
Fundy	4	22	21	2	49
Lake Abitibi	1	7	35	4	47
Prince Albert	10	28	5	1	44
Western Newfoundland / Newfoundland and Labrador	8	13	16	2	39
Canada / Canadian Model Forest Network	7	9	13	2	31
Eastern Ontario	4	5	9	1	19
McGregor / Resources North Association	0	5	8	0	13
Bas-Saint-Laurent	1	5	6	0	12
Manitoba	1	1	5	1	8
Waswanipi Cree / Cree Research & Dev Institute	0	0	4	2	6
Long Beach	1	1	2	0	4
Nova Forest Alliance	0	1	0	2	3
PEI Model Forest Partnership	0	0	0	2	2
Total	**39**	**119**	**168**	**58**	**384**

Table 3. Number of articles by top 15 journals used, 1993–2010

Journal	Number of articles				
	1993–97	1998–02	2003–07	2008–10	Total
The Forestry Chronicle	7	24	29	1	61
Forest Ecology and Management	1	7	17	11	36
Canadian Journal of Forest Research	3	6	16	3	28
Canadian Journal of Remote Sensing	1	3	3	6	13
Journal of Wildlife Management	1	5	3	3	12
Canadian Journal of Zoology	0	8	1	1	10
Biological Conservation	0	1	3	4	8
Hydrological Processes	1	7	0	0	8
The Auk	1	5	2	0	8
Ecological Applications	1	3	3	0	7
Environmental Reviews	0	2	4	1	7
Journal of Mammalogy	0	2	3	2	7
Journal of Sustainable Forestry	5	2	0	0	7
Ursus	0	1	4	2	7
Canadian Field-Naturalist	0	2	4	0	6

by the Foothills, Fundy and Prince Albert Model Forests accounting for 60% of the articles produced. There was a further increase in the total (n = 168) for the 2003–07 period. Even though only three years are examined (2008–10), the final period clearly shows a substantial drop-off in publication rate as, with the exception of the Foothills Model Forest (now Foothills Research Institute, FRI), the number of articles per site ranged from zero to four.

There are several factors contributing to this decline. Most significant was the transition from Canada's Model Forest Program to the Forest Communities Program (FCP) in 2007, which led to a decrease in research capacity of the Model Forests (NRCan 2011). The FCP was launched in response to the economic decline and transition of the Canadian forest sector. This new program shifted away from SFM, with its priority focused on identification and development of economic development opportunities for local communities.

The decline was not experienced by the Foothills Model Forest/FRI, which was not a FCP funding recipient, has had a significantly higher budget than other Model Forests (NRCan 2006), and, since 2007, began to focus more heavily on research. The site accounted for almost 28% of the total papers published, more than double the second-ranked Model Forest.

Publication of the research results is dependent upon several factors, including: 1) the importance placed on publication by the Model Forest stakeholders (Bonnell 2012), 2) the specific individuals involved directly (e.g., researchers who have a high publication rate) or indirectly (e.g., Model Forest general managers or board members who have a research background and support publication), and 3) the ability of a Model Forest to attract or involve researchers and research institutes. For example, early on in its development, the Prince Albert Model Forest supported significant research activity and placed an emphasis on the publication and utilization of results. The initial high output of research papers was likely associated with having a general manager with a research background.

Similarly, the significant increase in journal paper output associated with Fundy's research activity probably relates to its close affiliation with the University of New Brunswick, the Greater Fundy Ecosystem Research Group and the Canadian Forest Service (CFS). The Eastern Ontario Model Forest, on the other hand, found it challenging to attract researchers to the area while, at the same time, the site had access to a large number of well-experienced professionals (Brian Barkley, former General Manager, Eastern Ontario Model Forest, 1993 to 2009, personal communication) who could provide scientific knowledge and advice through the Model Forest's Forest Science Committee (Hall 2006).

Other Model Forests, notably Manitoba, McGregor and Bas-Saint-Laurent, also supported significant research programs; however, few of the results were published in journals.

Journals used

Papers were published in more than 110 journals with nearly 16% (n = 61) appearing in *The Forestry Chronicle*, almost double the number in the next most used journal (Table 3). The diversity indicates that the research supported through Model Forests has the potential to reach a broad scientific and resource management audience.

Even though 15 (25%) of the Model Forest-related papers in *The Forestry Chronicle* can be classified as professional rather than technical or scientific, over 45 are based on research activities supported by Model Forests; significantly more than *Forest Ecology and Management* and *Canadian Journal of Forest Research* with 36 and 28 papers, respectively. Significantly, six of the top 15 journals focus on wildlife or natural history, including the *Canadian Journal of Zoology*, *Journal of Wildlife Management*, and the *Canadian Field-Naturalist*.

It is not surprising that *The Forestry Chronicle* is so prominent. First, while not excluding papers originating outside Canada, the journal has a strong focus on Canadian-based research. As the official journal of the Canadian Institute of Forestry, it is well known within the Canadian forest sector and thus has the potential to reach key audiences of the Model Forests. This supports the knowledge-sharing principle of Model Forests (IMFN 2010).

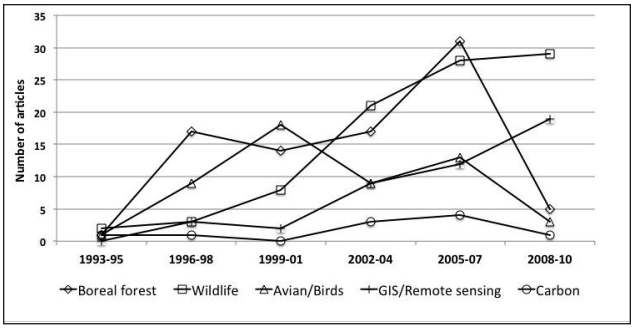

Fig. 2. Trends in journal article output based on themes (1993–2010).

There was a significant drop in the number of Model Forest-related papers appearing in *The Forestry Chronicle* between 2003–07 (n = 29) and 2008–10 (n = 1). This reduction corresponds with an increasing focus on wildlife and other themes in terms of publishing results, and since 2007, a shift in focus on community economic development with the advent of the FCP.

Research themes

Only five of the original 45 themes (Table 1) were examined in detail (Fig. 2). These are boreal forest, wildlife, avian/birds, GIS/remote sensing, and carbon (i.e., forest carbon budgets).

Based on changes in the total number of articles produced (Table 2), it was expected that there would be a general drop-off for most, if not all, themes. While this was seen for most themes (Table 1), there has been a steady increase in the number of articles published for a few themes during the 2008–10 period (Fig. 2). In particular, wildlife research articles and those focusing on GIS/remote sensing increased from 1993 through to 2010. However, there is some overlap in these two categories as some of the remote sensing research focused on wildlife and wildlife habitat.

As well, 67% of the papers published in 2008–10 are based on research supported by the Foothills Model Forest/FRI. In particular, FRI's Grizzly Bear Research Program has placed a strong emphasis on scientific credibility through peer-reviewed research (Bonnell 2012) and involves a large number of researchers as FRI staff and with universities (Stenhouse and Graham 2011).

Wildlife research has been an important component of most Model Forests in Canada as wildlife–forestry interactions were a key source of conflict within the sector when the Model Forests were first established (e.g., American marten in Newfoundland). Most Model Forests in Canada, particularly those in the boreal zone, have supported wildlife research activities on both large and small mammals, habitat, birds and other species. However, much of that work was published only as project reports and not in journals.

With the increasing emphasis and importance on the decline of the woodland caribou populations and the issues related to conservation of caribou habitat in Canada (OWCRT 2008, Faille *et al.* 2010), it was expected that there would be an increasing number of research articles focused on caribou. However, between 1993 and 2010, only three journal articles were produced: Foothills in 2000, Manitoba in 2006 and McGregor in 2007. Much of the work on caribou, however, was never published in peer-reviewed journals (e.g., MbMF 2010, MFNL 2012).

Similarly, whereas adaptation and mitigation strategies related to climate change are key forest sector research topics (Lazar 2005, Lemprière *et al.* 2008), there has been little work on the theme published by the Model Forests (Table 1). There have been some papers published related to carbon budgets in the forest sector based on research that has been supported by Model Forests (Fig. 2); however, this does not highlight the role played by Model Forests in acting as pilot sites in the development of an operational scale carbon budget model (Price *et al.* 1994; Kurz *et al.* 2002, 2009).

Up until 2008–10, the number of articles being published that related to boreal forests was increasing (Fig. 2, Table 1). Both the increase from 1993–95 (n = 1) to 2005–07 (n = 31) and a subsequent significant decline in 2008–10 (n = 5) assigned one or more themes. not surprising. First, most Model Forests in Canada are located within the boreal so it would be expected that much of the research supported by those Model Forests would focus on boreal issues. Finally, the decline follows the general decrease in journal publication by most Model Forests as a result of a move away from research towards economic development with the advent of the FCP.

Collaboration

Scientific collaboration has been increasing in both frequency and importance over the last two decades (Sonnenwald 2007, National Science Board 2012). In their study on 20 university disciplinary areas, Franceschet and Costantini (2010) have shown that collaborative papers have a greater impact and are more valued by peer experts. Further, they found that both the impact and quality of papers are further enhanced when the author affiliations are heterogeneous.

Collaboration is examined in several ways. First, each article was assigned one of five categories—individual, group, institution, national, or international—to define the level of collaboration between authors. Trends in the level of collaboration, both in terms of number and percent of papers, were reviewed for three-year increments between 1993 and 2010.

Table 4. Average number of authors per article, 1993–95 to 2008–10

	Number of articles					
Level of collaboration	**1993–95**	**1996–98**	**1999–01**	**2002–04**	**2005–07**	**2008–10**
Individual	–	1.0	1.0	1.0	1.0	–
Group	2.3	2.5	2.8	2.8	2.5	2.3
Institution	2.0	3.8	5.0	3.3	3.6	4.6
National	3.5	3.6	3.3	3.7	3.9	4.6
International	3.0	3.4	2.8	4.2	4.7	6.9
All	2.7	2.7	3.1	3.2	3.5	4.6

Next, a brief review was completed of the number of authors per paper. Finally, a more detailed examination of national-level collaboration was undertaken to identify which institutions were collaborating.

The highest number of authors on a single article was 13, while the overall average was 3.4 including single-author papers. There was a steady increase in the average number of authors per article between 1993–95 and 2008–10 with a pronounced increase in the last period (Table 4). The 2008–10 increase is due to the majority of the articles in that period originating from the Foothills Model Forest/FRI and, in particular, the Grizzly Bear Research Program, which has generally supported a large number of authors per publication.

The analysis of author affiliation shows there was a substantial increase in the number of articles produced with inter-institutional authorship in Canada (i.e., national-level collaboration) (Fig. 3). As well, while the total number of articles being produced has declined, the percentage based on national-level collaboration has remained high (Fig. 4).

A further analysis was conducted on the articles with national-level collaboration (n = 355), resulting in a collaboration network map (Fig. 5). In the publication of Model Forest-supported research findings, the CFS clearly has the highest number of papers (n = 53) authored based on inter-institutional collaboration. This is followed by the University of Saskatchewan (n = 38), Foothills Model Forest/FRI (n = 28), the Universities of Alberta (n = 27) and Calgary (n = 24), and the Canadian Wildlife Service (n = 22).

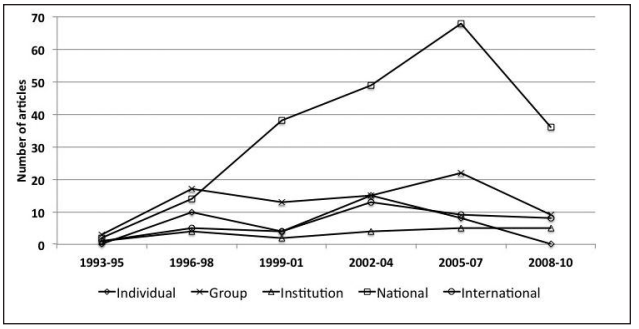

Fig. 3. Number of articles by level of collaboration.

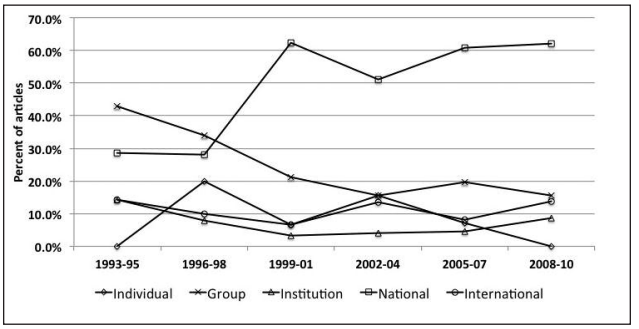

Fig. 4. Percent of articles by level of collaboration.

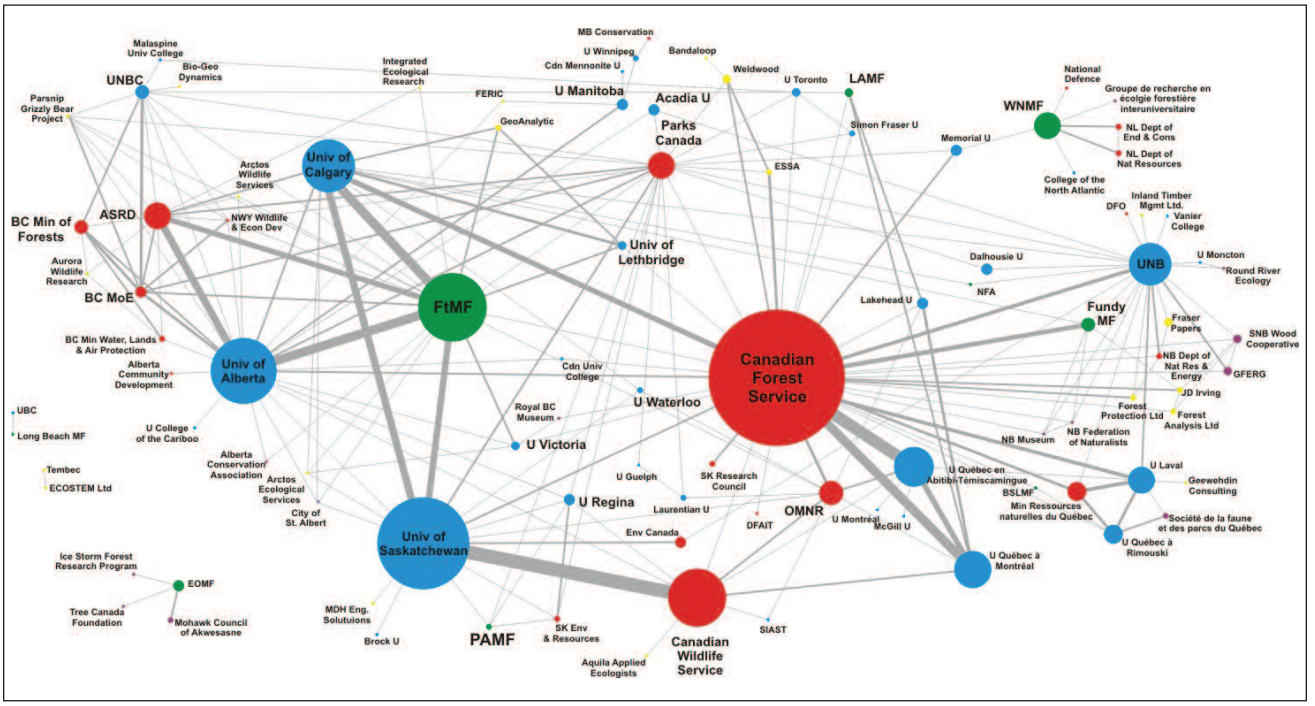

Fig. 5. National-level collaboration network map of papers published based on Model Forest-supported research in Canada, 1993–2008[5].

[5]The size of circles and thickness of lines represent the number of articles either for that institution (circle) or between institutions (lines). The length of a line does not signify anything. Red represents government agencies (federal, provincial, municipal), blue are universities and colleges, green are Model Forests, yellow represents consulting firms, and purple for other organizations (e.g., NGOs, cooperatives).

Additionally, with links to 39 institutions, the CFS is the centre of a Canadian collaboration network for research activities supported by Model Forests. Although the Model Forest Program was a CFS-funded initiative, the program did not fund CFS researchers directly. Program funds went to the Model Forests who were then free to choose which institutions and individuals to partner with for research and other activities. Other key research focal points include the University of Alberta (n = 26), Parks Canada (n = 24), Foothills Model Forest/FRI (n = 22) and the University of New Brunswick (n = 21).

A combination of cross-posting of individuals (e.g., a government researcher also having an affiliation with a university), a high publication rate by an individual researcher, and a graduate student who went on to pursue further research opportunities, probably led to the University of Saskatchewan and the Canadian Wildlife Service having the greatest number of collaborations on papers (n = 15). Other substantial collaborations occurred between CFS–Université du Québec en Abitibi-Témiscamingue (n = 13), Foothills Model Forest/FRI–University of Alberta (n = 11), Foothills Model Forest/FRI–University of Calgary (n = 11), University of Calgary–University of Saskatchewan (n = 11), and CFS–Université du Québec á Montréal (n = 10).

Finally, both the Foothills Model Forest/FRI and the Model Forest of Newfoundland and Labrador/WNMF act as collaboration hubs as both had researchers on staff in addition to supporting university- and/or government-based researchers.

The growth in national-level collaboration can be viewed as an indication of: (i) a more efficient research process because researchers can access support across greater distances and outside their own institutions (Adams *et al.* 2005); (ii) a greater impact resulting from the papers if collaboration is present (Katz and Hicks 1997); (iii) the role of the Model Forest supporting the research in the facilitation of links between researchers, and/or; (iv) increased engagement in collaborative research due to a reduction in funding. All four factors probably contribute to the trend.

While collaborative research is more highly cited (Presser 1980) and higher citation rates (not examined here) suggest collaboration raises the quality of research, there is a difficulty in separating talent from an ability to attract co-authors (Adams *et al.* 2005). Collaboration is also important because of its role in facilitating knowledge flows between researchers (Adams *et al.* 2005) and others, which is an important principle of Model Forests. A recent study on research utilization in three Canadian Model Forests highlighted the role of the Model Forests in facilitating cooperation (Bonnell 2012), although the extent to which this led to co-authorship on published papers is unknown.

Conclusion

Bibliometrics, which was used for the analysis in this study, is a tool that can be used effectively for exploratory work in examining trends. However, it does not explore the "why" of trends, which requires further research and discussion with those involved. Furthermore, this analysis does not provide an assessment of the total research activity and output of Model Forests. Its assessment of journal articles is an approximation of research trends with acknowledged bias towards sites that used this means of publishing results.

However, some conclusions can be drawn. First, the analysis thus far shows that the publication and use of Model Forest-supported research varies among Model Forests and individual projects. As well, there has been an increasing focus on boreal-related, wildlife and forest management research in the Model Forests since their inception in 1992–93. The most significant result is that there has been a clear trend towards increased national-level collaboration in research activities with the Canadian Forest Service and various universities acting as key hubs in the publication of Model Forest research results.

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