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How can formal research networks produce more socially robust forest science?

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ABSTRACT

Socially robust science refers to a mode of knowledge production that is validated through an expanded peer-review process, involving the knowledge users. It therefore integrates conventional criteria of validity with non-scientific criteria of usefulness. This paper seeks to better understand how university–government–industry–civil society (UGICS) research networks can produce more socially robust science. In Canada, there are numerous provincial, regional, and national forest research networks. One of the most notable of these organizations, in terms exemplifying a UGICS research network, was the Sustainable Forest Management Network (SFMN) (1995–2009), a Canadian Network of Centres of Excellence (NCE). The objective of this study was to elicit participants' experiences with, and perceptions of, the SFMN over its 14 years of operation. This paper reports the results of our survey research and draws upon the authors' previous evaluative research on the SFMN to offer suggestions for the design and management of UGICS research networks that seek to foster more socially robust science. These include considerations about network management and governance, funding allocation and partnership models, knowledge exchange and management and research capacity development. Specific attention is also given to how formal research networks might attract and retain partnership with civil society groups. We believe that these suggestions will be relevant to other publicly-funded research networks exhibiting a heterogeneous collaborative profile.

1. Introduction

Formal cross-sector research networks, funded, mandated and monitored by governments (i.e. university–government–industry research networks) have become commonplace in regional, national and international systems of innovation (Nelson, 1993). These networks are often characterized by a 'mode-2' approach to knowledge production – knowledge produced in a context of application, among other characteristics – with the research conducted in such networks generally meant to inform and sustain socioeconomic development (Gibbons et al., 1994). Although these university–government–industry cross-sector research networks are often referred to as 'triple-helix' networks (Etzkowitz and Leydesdorff, 2000), they may involve a number of different actors from civil society. Individuals or groups that fall under this category include non-governmental organizations, foundations, individual interested parties or interest groups, aboriginal groups and unions, to name a few.

Scholars commonly differentiate research networks whose primary aim is profit-generating innovation (Leydesdorff and Meyer, 2006; Etzkowitz and Zhou, 2006) from other research organizations that seek to foster sustainability, democratic science and participatory action research (Fischer et al., 2004; Guston, 2005; Bodorkós and Pataki, 2009). For example, researchers examining stakeholder rationales for engaging in cross-sector research collaboration, including the risks, the benefits, the barriers and the legacies of such collaborations have mainly reported their results on one or the other 'kind' of network (Hetzner et al., 1989; Lee, 2000; Rod and Paliwoda, 2003; Leydesdorff and Ward, 2005; Garrett-Jones et al., 2005; Atkinson-Grosjean, 2006; Corley et al., 2006; Belkhodja and Landry, 2007). However, such (often programmatic) distinctions between university–government–industry and university–government–civil society research networks do relatively little to further our understanding of why actors from different sectors get involved in research networks working towards both economic and social development goals (Minkoff, 2002; Lamb and Davidson, 2004; Ménard, 2004). Nor do these distinctions help us to better understand how university–government–industry–civil society research networks can produce more socially robust science. Socially robust science refers to a mode of knowledge production that is validated through an expanded peer-review process, involving the knowledge users. This mode of knowledge production brings together many different kinds of knowledge, experience and expertise, and the knowledge it produces is strengthened and modified by continued use and testing in the social world. It therefore integrates conventional criteria of validity with non-scientific criteria of usefulness (Nowotny, 2003).

Environment and natural resource-related research networks provide a rich source of case studies for advancing our knowledge about the benefits, the costs and the outcomes of university–government–

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industry–civil society (UGICS) research networks. In the field of forestry, for example, formal research networks seek to fulfill a broad range of objectives, including (but not necessarily) supporting social forestry goals (Hyde and Köhlin, 2000), industrial forestry goals, forest policy innovation, and ecological research needs. In Canada, where forests represent 10% of the world's forest cover and 30% of the world's boreal forest, there are numerous provincial, regional, and national forest research networks. One of the most notable of these organizations in terms exemplifying a 'multiple-helix' research network was the Sustainable Forest Management Network (SFMN) (1995–2009), a Canadian Network of Centres of Excellence (NCE).

The NCE program was created in 1988 by the Government of Canada to fund industry-relevant research and facilitate cross-regional, cross-disciplinary and cross-sectoral research excellence (Fisher et al., 2001). The NCE program's key expected outcomes were a greater social and economic relevance of research, the attraction and retention of world-class researchers, an increased (sectoral, disciplinary) diversity in collaborative research teams, and greater knowledge exchange among partners (NCE, 2002). The NCE program had a "sunset" clause whereby networks could receive NCE funding for up to two 7-year terms, with the possibility of a small budget for an additional two years to support knowledge exchange, after which no additional funding could be provided. Spurred by a "pipeline" model of knowledge production and uptake by knowledge users, in which funding "fundamental" knowledge leads in a linear fashion to applications and marketable products and processes, the NCE Directorate expected that, after 14 years, "all ideas would have moved through, and the network would be 'finished'" (Atkinson-Grosjean et al., 2001: 21).

Through the NCE program, the SFMN was established in 1995 and successfully obtained funding for two terms and an additional two years of funding for knowledge exchange. The Network was meant to foster a greater integration among forestry knowledge producers and users (academia, Aboriginal, industry, NGOs, government) in order to develop strategies and tools to sustain Canada's forest. Its objectives were to "stimulate fundamental and applied research; develop improved techniques and technologies and their use for managing and sustaining boreal forests; encourage technology and knowledge transfer among institutions carrying out such research and industry, governments and society; and train the next generation of Canadian scientists and researchers" (SFMN, 2007). Previous research on the legacies of the SFMN suggests that many of these objectives were achieved (Klenk and Hickey, 2009).

Basic descriptive statistics of the SFMN indicate that by the end of its second term, the Network's research teams had an average of 3.16 collaborators. These research teams represented, on average, 1.93 provinces, 3.10 institutions, and 1.55 sectors (Klenk and Hickey, 2009). More detailed analysis reveals that the SFMN's research collaborations involved a diversity of forest stakeholders from different provinces, institutions, and sectors of society, including aboriginal people and civil society (Fig. 1). In addition to creating a highly integrated network in which any researcher in the SFMN was connected to another through only one intermediate researcher (Klenk et al., 2010a), the SFMN's structure had positive impacts on scientific output (e.g. peer-reviewed journal articles) (Klenk et al., 2010a) and its funding strategy had a positive impact on the development of the fields of social forest sciences and aboriginal forestry research (Klenk et al., 2010b).

Our objective in this study was to elicit participants' experience with the SFMN with a view to drawing out some of their lessons learned to inform the design of future 'multiple helix' research networks. Given that the SFMN was notably heterogeneous in its collaborative profile and membership, we expected to find a greater degree of variation in the way stakeholders were motivated to join the Network and perceived the risks, rewards and legacies of their participation than in previous studies of participation in formal research networks reported elsewhere (Rod and Paliwoda, 2003). This paper reports the results of our survey research and identifies lessons for the design of UGICS research networks, including considerations about network management and governance, funding allocation and partnership models, knowledge exchange and management and

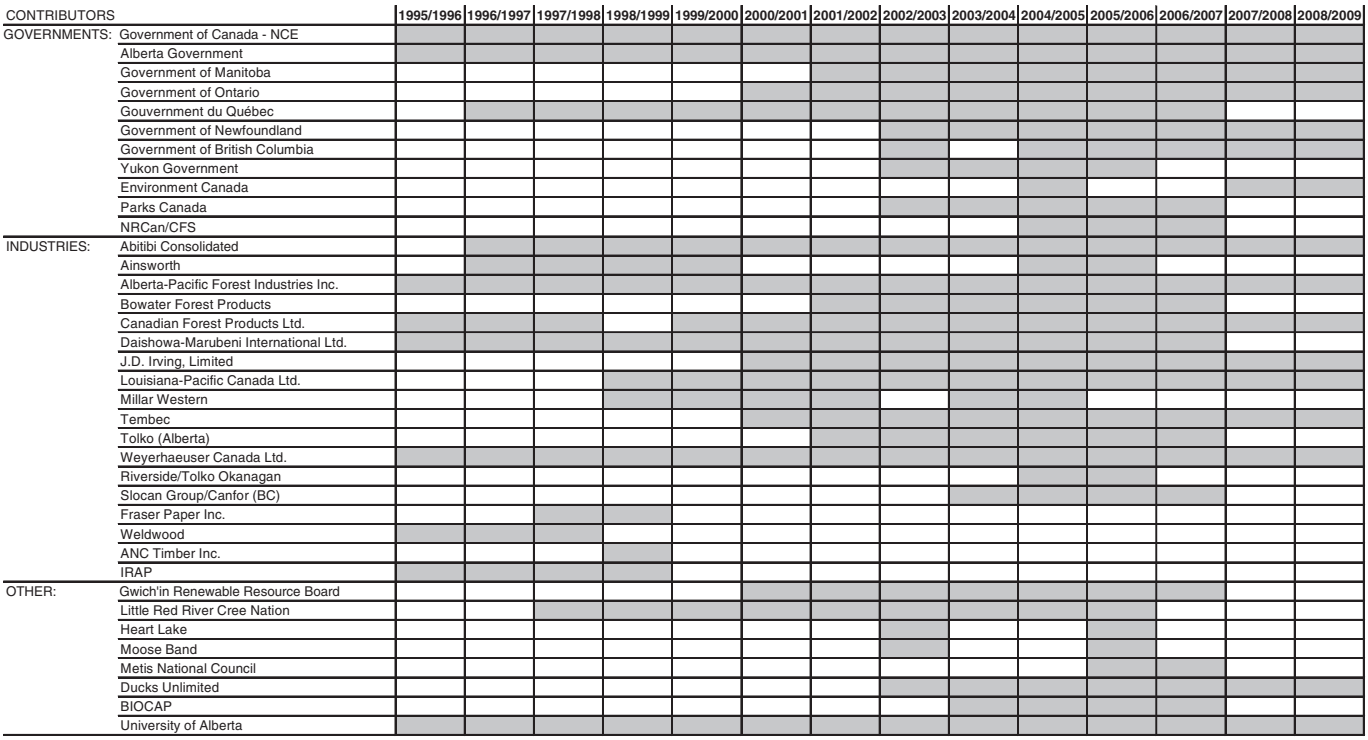

Fig. 1. A timeline of the evolution of SFMN partnerships (1995–2009).
Reproduced with permission from Klenk and Hickey (2009).

research capacity development. Specific consideration is also given to how formal research networks might attract and retain partnership with civil society groups.

2. Methods

2.1. Survey sampling

The data for this study were collected from a survey of the population we term the 'SFMN community'. By 'SFMN community' we mean individuals who occupied formal roles in the administrative body of the organization, partners (i.e. representatives of groups providing financial or in-kind support to the Network), Principal Investigators (i.e. lead researchers), and research collaborators (e.g. researchers, graduate students, aboriginal people, and individuals from different societal sectors such as industry, government and civil society) that took part in the Network between 1995 and 2009. All data were collected between April 9 and May 22, 2009.

2.2. Survey design

The internet-based questionnaire was launched in two languages to accommodate French-speaking members of the SFMN community. The questionnaire was designed to elicit respondents experience with the SFMN from a number of different angles relevant to the design features of formal research networks (i.e. reasons for participating, barriers and benefits of participation, network management and governance, funding allocation and partnership models, knowledge exchange and management and research capacity). The questionnaire combined Garrett-Jones et al.'s (2005) and Turpin and Garrett-Jones' (2009) surveys of the rewards, the risks, and the lessons learned of participants in Australian Cooperative Research Centres, which are formal research networks that serve a similar function to Canadian Networks of Centres of Excellence. We also constructed questions on the legacies and the organizational design of the Network. These legacies were obtained through interviews with key stakeholders while the organizational design items were elicited through an iterative Concept Mapping Policy Delphi exercise (see Klenk and Hickey, 2009, 2011, 2012).

Our questionnaire had 24 questions (including closed- and open-ended questions) in six sections and took approximately 15 min to complete. The first section elicited information about SFMN members' involvement in the Network. Section 2 asked respondents about their overall satisfaction with their experience with the Network. Section 3 sought information about the reasons for respondents' participation in the Network, the benefits and costs of participation, and any barriers to participation respondents may have experienced. Section 4 sought respondents' perspectives on the management and organizational structure of the Network and Section 5 sought respondents' evaluation of the Network's legacies. Lastly, Section 6 addressed respondents' assessment of design suggestions for any future research network. An electronic copy of the questionnaire is available by request to the corresponding author.

2.3. Response scales and analysis

In Section 1, the question had a seven-point scale (1 = extremely unsatisfied to 7 = extremely satisfied, including 'neutral'). In Sections 2 through to 6, the questions had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable). Finally, the question in Section 7 involved a four-point scale (1 = very undesirable to 4 = very desirable, with 5 = no opinion).

We used the Kruskal–Wallis test to determine the significance of the differences between grouping (independent) variables and the items being ranked (dependent variable) (Keller, 2005). The independent variables were the number of years respondents were involved in the SFMN (<1, 1–3, 4–7, 8–11, 12–14 years), the forest sector that respondents identified with (academic, government, and 'other' including industry, aboriginal, NGO), their location of residence (provinces and territories of Canada), their role in the SFMN (Principal Investigator, research collaborator, partner, administrative role at the SFMN), whether the respondents had applied for funding (yes or no), and the total amount of funding received ($0–50,000, $50,000–100,000, $100,000–500,000, >$500,000). Mann–Witney tests were then conducted to evaluate pair-wise differences among the grouping variable, controlling for Type I error across tests by using Holm's sequential Bonferroni approach (Keller, 2005). Only significant results were reported. Responses to open-ended questions were used to augment the quantitative data analysis.

In our discussion of the survey results and suggestions for the design of a future UGICS network in natural resource management, we draw upon the authors' previous research that includes an organizational history of the SFMN, a social network analysis, a communication audit of the administrative body of the Network, a expert-based future planning exercise and a bibliometric analysis, quantifying the social science research impact of the SFMN (see Klenk and Hickey, 2009, 2010, 2011, 2012; Klenk et al., 2010a,2010b).

3. Results

3.1. Survey response rate

A total of 478 individuals were invited by email to complete the online survey, however 41 emails were unavailable. Therefore our sample of the SFMN community had a total of 376 individuals. We obtained a response rate (number of completed surveys divided by number of individuals in the sample) of 26% ($\pm$2.3%, $\alpha = 0.05$). Although this response rate was lower than we would have liked, lower response rates are not unusual for surveys dealing with issues of a specific matter (Turpin and Garrett-Jones, 2009). Characteristics of the sample are described in Table 1.

3.2. Overall satisfaction

With regard to respondents' overall level of satisfaction with the SFMN, the survey results indicated that 73% were 'satisfied, strongly satisfied or extremely satisfied' while 27% were 'unsatisfied, strongly unsatisfied or extremely unsatisfied' (Table 2). Pair-wise comparisons indicated that respondents who had been involved with the Network for longer periods of time had significantly greater levels of satisfaction with the Network. In addition, respondents who had received a greater total amount of SFMN funding had significantly more satisfaction with the Network (Table 2).

3.3. Participation in the SFMN

3.3.1. Reasons for participating in the SFMN

The reasons for participating in the SFMN that respondents most agreed with were 'the research focus at the Network matched my (our) own', 'I (we) had prior connections/relationships with individuals at the Network', 'I (we) wanted access to Network expertise', and 'I (we) wanted to engage in cross-sector collaboration'. Pair-wise comparisons indicate that respondents who had been involved in the Network for a longer period of time were more likely to have participated in the SFMN because of 'prior connections/relationships with individuals at the Network'. In addition, respondents that had a role in the administrative body of the organization were more likely to have participated in the Network because they had been 'invited to serve on a Network committee' (Table 3). Other reasons identified through the open-ended responses included the opportunity to gain funding; to work with researchers from across the country; to support graduate students; to attract researchers to investigate particular issues; to advance and disseminate methods for sustainable forest

Table 1
SFMN survey sample description.

Respondent information	n	%
Years of involvement in SFM Network		
Less than 1 year	1	1
1–3 years	19	20
4–7 years	21	22
8–11 years	25	26
12–14 years	23	24
Not at all	7	7
No response	1	
Forest sectors		
Academic	64	66
Government	22	23
Other (industry, aboriginal, NGO)	11	11
No response	0	
SFM Network role		
Principal Investigator	37	38
Research collaborator	37	38
Partner	5	5
Organizational group in the administrative body	18	19
No response	0	
Location of residence		
Alberta	21	22
British Columbia and Yukon	17	18
Manitoba and Saskatchewan	10	10
New Brunswick, Nova Scotia, Newfoundland and Labrador	13	14
Ontario	19	20
Quebec	16	16
No response	0	
Applied for SFM Network funding		
Yes	68	70
No	29	30
No response	0	
Received SFM Network funding		
Yes	60	88
No	8	12
No response	0	
Total amount of SFM Network research funding received		
<$10,000	4	7
$10,000–$50,000	11	19
$50,000–$100,000	11	19
$100,000–$500,000	26	45
>$500,000	6	10
No response	2	

management; to gain knowledge in social forestry; to share aboriginal policy development on aboriginal traditional knowledge with others; to shift the geographical focus of research in the Network; and to engage in interdisciplinary research related to the pulp and paper industry. Lastly, some respondents participated in the SFMN because of its commitment to aboriginal research.

3.3.2. Benefits of participation in the SFMN

Concerning the benefits of participating in the SFMN, there was greater agreement among respondents with the following: 'I (we) obtained access to new ideas, know-how, or technologies through Network the interaction', 'the multi-organization model of the Network enhanced my (our) collaborative activities', 'Network participation has increased my opportunities to author scholarly publications', 'engagement in the Network offered an avenue for bringing sustainable forest management concepts to fruition that would have been difficult to achieve otherwise', 'Network participation enhanced the career opportunities of my students', and 'my work at the SFMN has enhanced my career prospects generally'. The other proposed benefits elicited more equivocal responses (see Table 4). Pair-wise comparisons indicate that respondents who had been involved in the SFMN for a longer period of time agreed significantly more with many of the proposed benefits than those who had not been heavily involved in the Network. In addition, the academic respondents agreed significantly more than government representatives with the proposition that Network participation increased their potential for receiving Natural Sciences and Engineering Research Council (NSERC)/Social Sciences and Humanities Research Council (SSHRC) funding. Further, when compared to academic respondents, industry, aboriginal and NGO respondents were significantly more in agreement with the proposition that participation in the Network improved a process or product in their organization. In a different vein, Principal Investigators agreed significantly more with the proposition 'participation increased their opportunities to author publications' than respondents who had a role in the administrative body of the Network. However, respondents who had a role in the administrative body of the SFMN agreed significantly more with the proposition that 'I (we) learned about and helped shape the goals, methods and progress of the Network' than Partners. In addition, respondents who had not applied for funding agreed significantly more with the propositions that the Network provided access to new ideas and changed processes or products in respondents' organizations than respondents who had applied for funding. Finally, respondents who had received a greater total amount of SFMN funding agreed significantly more with the propositions that participating in the Network improved their career prospects, increased their opportunities to publish, and allowed them to influence the progress of the Network than respondents who had received less (Table 4).

Other perceived benefits identified through the open-ended responses included facilitating student networking; creating relationships with different sectors that could subsequently be maintained outside the Network; assisting policy development; and providing a means to gain departmental rewards or recognition.

3.3.3. Factors that contributed to benefits

A large percentage of respondents agreed that 'the efforts to communicate and stay in contact with participants' and 'the responsiveness of researchers to my (our) needs' were important factors that contributed to the benefits of participating in the SFMN. With regard to the other factors, responses were equivocal. Most respondents, however, disagreed with the proposition that 'my (our) ability to establish proprietary rights' was an important factor contributing to SFMN participation-derived benefits.

Pair-wise comparisons indicate that respondents who had been involved in the SFMN for a longer period of time agreed significantly more with respect to several proposed factors than respondents those who had not been directly involved in the Network. In addition,

Table 2
Survey item referring to participants' degree of satisfaction with Canada's SFM Network.

Item	n	No response	Average Ranking[a]	Neutral	Unsatisfied, strongly and extremely unsatisfied	Satisfied, strongly and extremely satisfied	Years involved *p* level	Amount of funding *p* level
Please indicate your overall degree of satisfaction with Canada's SFM Network.	96	1	4.6	5%	25%	70%	0.019[b,c]	0.000[b,d]

[a] The question had a seven-point scale (1 = extremely unsatisfied to 7 = extremely satisfied, including 'neutral').
[b] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[c] Significantly greater overall degree of satisfaction with the SFMN for respondents that had been involved for 4–7, 8–11 and 12–14 years compared to respondents that had never been involved in the Network ($\alpha = 0.005$).
[d] Significantly greater overall degree of satisfaction with the SFMN for respondents that received $100,000–150,000 and >$500,000 than respondents who received $0–50,000 in total funding from the SFMN ($\alpha = 0.0083$).

Table 3
Survey propositions referring to perceived reasons for participating in the SFM Network.

Proposition	n[a]	No response	Average Ranking[b]	Disagree, strongly and slightly disagree	Agree, strongly and slightly agree	Years involved *p* level	SFMN role *p* level
The research focus at the Network matched my (our) interests.	94	1	5.4	2%	98%	0.091	0.268
I (we) had prior connections/relationships with individuals at the Network.	89	1	4.7	18%	82%	0.029[c,d]	0.702
I (we) wanted access to Network expertise.	86	1	3.8	36%	64%	0.378	0.032[c]
I (we) wanted access to equipment and/or facilities at participating SFM Network organizations.	76	1	2.5	75%	25%	0.793	0.362
I (we) wanted access to Network students as prospective employees.	75	1	2.7	66%	34%	0.388	0.142
I (we) wanted to engage in cross-sector collaboration.	83	2	5.0	8%	82%	0.668	0.174
I (we) was (were) invited to serve on a Network Committee.	75	2	2.5	71%	29%	0.169	0.046[c,e]

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] Significantly more agreement with this reason for respondents who had been involved in the network for 8–11 and 12–14 years compared to respondents who had been involved for 4–7 years ($\alpha = 0.005$).
[e] Significantly more agreement with this reason for respondents who had a role on the administrative body of the network compared to principal investigators ($\alpha = 0.0083$).

respondents residing in Alberta agreed significantly more than British Columbia or Yukon-based respondents with the following factors: 'the existence of a strong champion in our organization' and 'management's support of the Network within our organization' were important factors contributing to participation-derived benefits. Respondents who had been Principal Investigators or partners in the Network agreed significantly more with the importance of having a strong champion within one's organization compared to research collaborators. Lastly, respondents who had not applied for funding agreed significantly more with the factors: 'having a strong champion of the Network in their organization' and 'the responsiveness of researchers to their needs' than respondents who had applied for funding (Table 5).

Other perceived factors identified through the open-ended responses included active involvement in setting SFMN research priorities: "the long-term collegial relationship with people in all sectors, which foster mutual respect and the expectation that individuals would learn from one another"; government, academic, and industry partners working together to set the research agenda and the call-for-proposals; the availability of adequate funding from the network and a critical mass of researchers working in the respondents' subject area.

3.3.4. Barriers to receiving benefits

There were three agreed upon barriers to receiving benefits from SFMN participation: 'difference in organizational values', 'insufficient influence on the Network's research agenda' and 'inequitable access/influence among Network members'. Most respondents disagreed with the following barriers: 'intellectual property issues', 'Network research was not sufficiently relevant to my (our) needs' and 'poor communication between the Network and me (us)'. In addition, pair-wise comparisons indicate that respondents who had not been directly involved in the SFMN, or that had received lesser amounts of total research funding from the SFMN, tended to agree significantly more with the following barriers: 'Network research was not sufficiently relevant to my (our) needs' and 'poor communication between the Network and me (us)' (Table 6).

Other perceived barriers to receiving benefits from participating in the SFMN, identified through the open-ended responses, included poor communication within collaborative research teams; the geographic location of the administrative body of the Network; a lack of coherence across research projects; a tension between research focusing on economic development and research focused on social and community forestry; the loss of partners over time; inequality of funding contributions from different provinces; an insistence on interdisciplinary research teams when these were not necessary to a research project; language issues; and the "short term focus of graduate student research and access to the data". Lastly, a perceived barrier that was commonly mentioned had to do with the view that the SFMN was exclusionary and exhibited favoritism.

3.3.5. Costs of participation

Most respondents disagreed with the propositions related to the costs of participation in the SFMN. Percentage disagreement ranged from 53% to 89%. The proposition 'my department/institution was subsidizing my (our) involvement in the Network' elicited a more equivocal response (53% in disagreement, 47% in agreement). Further, academic respondents disagreed significantly more than government or other respondents with regard to this cost. Respondents who had received between $50,000–100,000 agreed significantly more on the cost: 'my (our) participation created unreasonable delays in the publication of new findings' than those who had received over $500,000 in total SFMN funding (Table 7). Other perceived costs of participation identified in the open-ended responses were: onerous costs of membership for First Nations and non-governmental organizations; insufficient time to participate; reputational costs; opportunity costs; and that "reporting requirements were sometimes too onerous".

3.4. Management and structure of the SFMN

A large percentage of respondents agreed that 'the process by which proposals were evaluated was fair', 'the Network was too bureaucratic' and 'research funding was fairly distributed across social and natural science research proposals'. Two propositions elicited more disagreement than agreement: 'the Network operated more like a business' and 'the research objectives of the Network were too strongly driven by the commercial partners'. Responses were more equivocal with regard to the other propositions (Table 8).

Pair-wise comparisons indicated that respondents from British Columbia and the Yukon disagreed significantly more than respondents from other provinces on the issue of the fairness of the evaluation of proposals and with the proposition that the Network operated more like an academic department. Respondents who had been research collaborators disagreed significantly more with the issue of how the SFMN dealt with conflicts of interest than former partners or respondents who had a role in the administrative body of the Network. In a different vein, respondents who had not applied for SFMN funding agreed significantly more with the propositions that the evaluation of proposals was fair and that the Network dealt with conflicts of interests in a transparent manner than those who had applied for funding. In addition, respondents who had received less SFMN funding agreed significantly more with the proposition that the Network was too bureaucratic than those who had received over $500,000. Lastly, respondents who had received less SFMN funding

Table 4
Survey propositions referring to perceived benefits of participation in the SFM Network.

Proposition	n[a]	No response	Average Ranking[b]	Disagree, strongly and slightly disagree	Agree, strongly and slightly agree	Years involved *p* level	Sector *p* level	Location *p* level	SFMN role *p* level	Applied for funding *p* level	Amount of funding *p* level
The multi-organization model of the Network enhanced my (our) collaborative activities.	88	1	4.3	26%	74%	0.124	0.943	0.215	0.155	0.532	0.022[c]
The commercial partners in the Network gave an important focus to my (our) research objectives.	88	1	3.7	44%	56%	0.013[c,d]	0.359	0.312	0.067	0.216	0.156
Engagement in the Network offered an avenue for bringing sustainable forest management concepts to fruition that would have been difficult to achieve otherwise.	87	1	4.2	28%	72%	0.437	0.961	0.088	0.117	0.147	0.025[c]
Network participation enhanced the career opportunities of my students.	75	3	4.1	29%	71%	0.087	0.872	0.146	0.053	0.486	0.183
My work with the SFM Network has enhanced my career prospects generally.	78	3	3.7	38%	62%	0.044[c]	0.907	0.054	0.042[c]	0.439	0.000[c,e]
Network participation has increased my opportunities to author scholarly publications.	84	2	4.1	27%	73%	0.008[c,f]	0.054	0.867	0.034[c,g]	0.721	0.008[c,h]
Network participation has increased my potential for receiving NSERC/SSHRC research funding.	71	1	3.3	51%	49%	0.013[c,f]	0.036[c,i]	0.017[c,j]	0.067	0.482	0.026[c]
I (we) obtained access to new ideas, know-how, or technologies through the Network interaction.	89	2	4.3	22%	78%	0.006[c,k]	0.217	0.287	0.262	0.003[c,l]	0.035[c]
Network-funded research influenced the R and D direction of my (our) organization.	80	1	3.6	41%	59%	0.025[c,k]	0.880	0.040[c]	0.215	0.070	0.139
Network-funded research improved a product or process in my (our) organization.	73	2	3.5	48%	52%	0.311	0.017[c,m]	0.189	0.012[c]	0.001[c,n]	0.739
I (we) learned about and helped to shape the goals, methods and progress of the Network.	86	1	3.7	41%	59%	0.004[c,o]	0.846	0.128	0.001[c,p]	0.553	0.004[c,q]

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] Significantly more agreement with this benefit for respondents who had been involved in the network for 4–7, 8–11 and 12–14 years compared to respondents who had never been involved in the Network ($\alpha = 0.005$).
[e] Significantly more agreement with this benefit for respondents who received $100,000–500,000 and >$500,000 than respondents who had received $0–50,000 and for respondents who had received $100,000–500,000 than those who received $50,000–100,000 in total funding from the SFMN ($\alpha = 0.0083$).
[f] Significantly more agreement with these benefits for respondents who had been involved in the network for 1–3, 8–11 and 12–14 years compared to respondents who had never been involved in the Network ($\alpha = 0.005$).
[g] Significantly more agreement with this benefit for respondents who had been principal investigators than respondents who had a role in the administrative body of the network ($\alpha = 0.0083$).
[h] Significantly more agreement with this benefit for respondents who received $100,000–500,000 than respondents who had received $0–50,000 in total funding from the SFMN ($\alpha = 0.0083$).
[i] Significantly more agreement with this benefit for academic respondents than government respondents ($\alpha = 0.017$).
[j] Significantly more agreement with this benefit for Quebec respondents than BC and Yukon respondents ($\alpha = 0.0033$).
[k] Significantly more agreement with this benefit for respondents who had been involved in the network for 8–11 and 12–14 years compared to respondents who had never been involved in the Network ($\alpha = 0.005$).
[l] Significantly more agreement with this benefit for respondents who had not applied for funding than respondents who had ($\alpha = 0.05$).
[m] Significantly less agreement with this benefit for academic respondents than other (industry, aboriginal, NGO) respondents ($\alpha = 0.017$).
[n] Significantly more agreement with this benefit for respondents who had not applied for funding than respondents who had ($\alpha = 0.05$).
[o] Significantly more agreement with this benefit for respondents who had been involved in the network for 12–14 years compared to respondents who had never been involved in the Network ($\alpha = 0.005$).
[p] Significantly more agreement with this benefit for respondents who had a role in the administrative body of the network than respondents that had been partners ($\alpha = 0.0083$).
[q] Significantly more agreement with this benefit for respondents who received $100,000–500,000 than respondents who had received $0–50,000 in total funding from the SFMN ($\alpha = 0.0083$).

disagreed significantly more with the proposition that the Network dealt with conflicts of interest in a transparent manner than those who had received over $500,000 in SFMN funding (Table 8).

Other comments about the management and structure of the SFMN included different expectations about the knowledge exchange products and target audiences and different perspectives on project management

Table 5
Survey propositions referring to the perceived factors that contributed to SFM Network-derived benefits to participants.

Proposition	n[a]	No response	Average Ranking[b]	Disagree, strongly and slightly disagree	Agree, strongly and slightly agree	Years involved *p* level	Location *p* level	SFMN role *p* level	Applied for funding *p* level	Amount of funding *p* level
The responsiveness of researchers to my (our) needs.	66	1	3.5	41%	59%	0.023[c,d]	0.144	0.459	0.042[c,e]	0.171
The efforts to communicate and stay in contact with participants.	90	1	4.2	21%	79%	0.057	0.159	0.576	0.809	0.026[c]
The existence of a strong champion in our organization.	75	1	3.3	51%	49%	0.069	0.024[c,f]	0.001[c,g]	0.004[c,e]	0.169
Management's support of the Network within our organization.	75	1	3.3	47%	53%	0.035[c,h]	0.029*[c,f]	0.036[c]	0.218	0.032[c,i]
My (our) ability to influence the research agenda.	85	2	3.4	46%	54%	0.023[c,j]	0.136	0.044[c]	0.163	0.044[c]
My (our) ability to establish proprietary rights.	54	4	2.3	78%	22%	0.046[c]	0.486	0.842	0.184	0.397

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] Significantly more agreement with this factor for respondents who had been involved in the network for 1–3, 8–11 and 12–14 years compared to respondents who had never been involved in the Network ($\alpha = 0.005$).
[e] Significantly more agreement with these factors for respondents who had not applied for funding than respondents who had ($\alpha = 0.05$).
[f] Significantly more agreement with these factors for respondents from Alberta than BC and Yukon respondents ($\alpha = 0.0033$).
[g] Significantly more agreement with this factor for respondents who had been principal investigators or partners than respondents who had been research collaborators ($\alpha = 0.0083$).
[h] Significantly more agreement with these factors for respondents who had been involved in the network for 8–11 and 12–14 years compared to respondents who had never been involved in the Network ($\alpha = 0.005$).
[i] Significantly more agreement with this factor for respondents who received >$500,000 than respondents who had received $50,000–100,000 in total funding from the SFMN ($\alpha = 0.0083$).
[j] Significantly more agreement with this factor for respondents who had been involved in the network for 1–3, 8–11 and 12–14 years compared to respondents who had never been involved in the Network ($\alpha = 0.005$).

and timelines across sectors. On a different note, responses to the open-ended questions were equivocal about the process of evaluating proposals as indicated in the following quotes: "evaluation of proposals seemed to be fair according to the criteria laid out. Our proposal probably didn't fit the criteria even though it was important to us" and "our field was perceived as marginal. I don't think we got a fair hearing". In addition, several responses related to the issues of partisanship, transparency and due process.

3.5. Perceived legacies of the SFMN

A large majority of respondents agreed with the seven proposed legacies, with percentages ranging from 76% to 89%. Respondents who had been Principal Investigators agreed significantly more that 'the Network conducted leading-edge research in sustainable forest management' than respondents that had been research collaborators. Overall, respondents who had received a lesser total amount of SFMN

Table 6
Survey propositions referring to the perceived barriers to receiving benefits from SFM Network participation.

Proposition	n[a]	No response	Average Ranking[b]	Disagree, strongly and slightly disagree	Agree, strongly and slightly agree	Years involved *p* level	Amount of funding *p* level
Differences in organizational values, mission or priorities (e.g. academic versus corporate values).	82	1	3.9	39%	61%	0.106	0.108
Intellectual property issues.	68	1	2.4	81%	19%	0.147	0.127
Insufficient influence on the Network's research agenda.	86	1	4.1	36%	64%	0.074	0.016[c]
Network research was not sufficiently relevant to my (our) needs.	78	2	3.2	56%	44%	0.003[c,d]	0.010[c,e]
Inequitable access/influence among the various Network members (some members have more access/influence than others).	78	2	4.2	33%	67%	0.066	0.020[c]
Poor communication between the Network and me (us).	83	2	3.4	57%	43%	0.009[c,f]	0.007[c,g]

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] Significantly more agreement with this barrier for respondents who had never been involved in the network than for respondents who had been involved in the network ($\alpha = 0.005$).
[e] Significantly more agreement with this barrier for respondents who received $0–50,000 and $50,000–100,000 than respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[f] Significantly more agreement with this barrier for respondents who had never been involved in the network than for respondents who had been involved for 4–7 and 8–11 years in the network ($\alpha = 0.005$).
[g] Significantly more agreement with this barrier for respondents who received $0–50,000 than respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).

Table 7
Survey propositions referring to the perceived costs encountered through participation in the SFM Network.

Proposition	n[a]	No response	Average ranking[b]	Disagree, strongly and slightly disagree	Agree, strongly and slightly agree	Years involved *p* level	Sector *p* level	Amount of funding *p* level
My (our) participation created unreasonable delays in the publication of new findings.	72	2	2.0	89%	11%	0.856	0.226	0.028[c,d]
My department/institution was subsidizing my (our) involvement in the Network.	81	1	3.2	53%	47%	0.136	0.000[c,e]	0.967
My (our) conditions of employment (e.g. workload model, performance criteria and rewards) didn't adequately reflect the time I (we) needed to devote to the Network.	78	1	3.1	60%	40%	0.426	0.170	0.117
My (our) participation created pressure on me (us) to spend too much time on commercial activities.	73	1	2.1	88%	12%	0.017[c,f]	0.078	0.155
My (our) participation in the Network undermined intellectual exchange and cooperative activities within my (our) organization.	80	2	2.0	89%	11%	0.234	0.641	0.146
The SFM Network didn't provide my (our) organization with an adequate return on investment.	71	2	2.7	72%	28%	0.125	0.085	0.328

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] Significantly more agreement with this cost for respondents who received $50,000–100,000 than respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[e] Significantly less agreement with this cost for academic respondents than for government and other (industry, aboriginal, NGO) respondents ($\alpha = 0.017$).
[f] Significantly more agreement with this cost for respondents who had never been involved in the network than for respondents who had been involved for 4–7 years in the network ($\alpha = 0.005$).

funding disagreed significantly more with the perceived legacies than respondents who had received a greater amount of SFMN funding (Table 9).

Other perceived legacies identified through the open-ended responses included "getting researchers from across the country to tackle problems together and with multiple perspectives which may have pushed thinking faster and further than would otherwise have occurred"; being a model for interdisciplinary research; "starting to cross the divide between social science and natural science research on forestry"; providing support for emerging talent such as graduate students and young researchers; providing an opportunity for students to write for a diverse audience and facilitating interactions between students and a diversity of academic researchers and industrial actors; and "creating a network of national relationships between government, industry and academic partners that would not have otherwise been created".

Table 8
Survey propositions referring to the management and structure of the SFM Network.

Proposition	n[a]	No response	Average Ranking[b]	Disagree, strongly and slightly disagree	Agree, strongly and slightly agree	Location *p* level	SFMN role *p* level	Applied for funding *p* level	Amount of funding *p* level
The Network was too bureaucratic.	81	2	3.8	43%	57%	0.683	0.445	0.112	0.016[c,d]
The process by which proposals were evaluated in the Network was fair.	83	3	3.8	37%	63%	0.004[c,e]	0.058	0.037[c,f]	0.026[c]
Research funding was fairly distributed across social and natural science research proposals.	70	2	3.7	43%	57%	0.269	0.031[c]	0.098	0.496
The Network dealt with conflicts of interest in a transparent manner.	54	2	3.6	48%	52%	0.464	0.003[c,g]	0.001[c,f]	0.007[c,h]
The Network operated more like a business.	67	2	3.1	66%	34%	0.150	0.740	0.235	0.643
The Network operated more like an academic department.	67	3	3.5	48%	52%	0.009[c,i]	0.663	0.822	0.451
Tensions between partners arose because they held different views on the importance of meeting project deadlines.	47	3	3.5	45%	55%	0.625	0.996	0.156	0.228
The research objectives of the Network were too strongly driven by the commercial partners.	77	4	3.3	57%	43%	0.905	0.323	0.091	0.227

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] Significantly more agreement with this perspective on the management and structure the network for respondents who received $0–50,000 and $50,000–100,000 than respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[e] Significantly less agreement with this perspective on the management and structure the network for respondents from British Columbia and the Yukon than respondents from New Brunswick, Nova Scotia, Newfoundland, Ontario, and Quebec ($\alpha = 0.0033$).
[f] Significantly more agreement with these perspectives on the management and structure the network for respondents who had not applied for funding than respondents who had ($\alpha = 0.05$).
[g] Significantly less agreement with this perspective on the management and structure the network for respondents who had been research collaborators than respondents who had been partners or had a role in the administrative body of the network ($\alpha = 0.0083$).
[h] Significantly less agreement with this perspective on the management and structure the network for respondents who received $0–50,000 and $100,000–500,000 than respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[i] Significantly less agreement with this perspective on the management and structure the network for respondents from British Columbia and the Yukon than respondents from Ontario and Alberta ($\alpha = 0.0033$).

Table 9
Survey propositions referring to perceived legacies of the SFM Network.

Proposition	n[a]	No response	Average ranking[b]	Disagree, strongly and slightly disagree	Agree, strongly and slightly agree	SFMN role *p* level	Amount of funding *p* level
The Network had a positive impact on social science research in forestry.	77	2	4.6	18%	82%	0.223	0.008[c,d]
The Network had a positive impact on Aboriginal-related forest research.	70	2	4.5	16%	84%	0.105	0.023[c,d]
The Network contributed to a 'change of culture' in forest-related research in Canada.	83	2	4.3	24%	76%	0.204	0.008[c,e]
The Network produced useful knowledge exchange and technology extension products.	79	2	4.7	11%	89%	0.026[c]	0.014[c,d]
The Network's facilitated cross-sector networking.	89	3	4.8	19%	81%	0.043[c]	0.010[c,f]
The Network trained highly qualified personnel (post graduate students) with 'real-world' experience dealing with different forest sectors.	84	2	4.9	14%	86%	0.076	0.021[c,d]
The Network conducted leading-edge research in sustainable forest management.	88	2	4.8	17%	83%	0.044[c,g]	0.016[c,d]

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] Significantly less agreement with these perceived legacies for respondents who received $0–50,000 than respondents who had received $100,000–500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[e] Significantly less agreement with this perceived legacy for respondents who received $50,000–100,000 than respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[f] Significantly less agreement with this perceived legacy for respondents who received $0–50,000 than respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[g] Significantly more agreement with this perceived legacy for respondents who had been research principal investigators than respondents who had been research collaborators ($\alpha = 0.0083$).

Respondents who disagreed with the proposed legacies mentioned as reasons for their position issues related to the broad scope of the research funded by the network and the level of participation of partners in the design and training of highly qualified personnel. While the research program of the SFMN actively sought the participation of partners in graduate student committees, such opportunities were not necessarily taken advantage of:

> I was disappointed as a provincial scientist that despite our significant financial and time contributions and the number of projects that we partnered in, that we did not sit on a single graduate student committee and therefore were not able to provide these students with the "real world" perspective of a regulatory agency. In fact, several times we heard students we had supported make very disparaging (and often misleading or inaccurate) remarks in their presentations about our agency's policies. While the students need to be free to express their science-based perspectives, a stronger understanding of the broader regulatory context would have improved their understanding of the application of their results.

3.6. Design suggestions for a future Network

The most agreed-upon design suggestions for a future, hypothetical forest-related cross-sector research network were: 'clearly and explicitly identifying the role (and limits) of partner involvement' (97%) and 'ensuring research funding flexibility to allow regional resource management issues to be addressed as they arise' (95%). While respondents agreed with most of the proposed design elements, three items elicited equivocal responses: 'getting provinces to lead the Network instead of the federal government', 'keeping the same management structure' and 'funding more leading edge, individual researchers rather than funding more collaborative projects' (Table 10).

Pair-wise comparisons indicated that academic respondents disagreed significantly more with the suggestion to 'fund research on policy issues, so that knowledge can be directly translated into new practices' than industry, aboriginal or NGO respondents. Respondents who had a role in the administrative body of the Network agreed significantly more with the suggestion to clearly identify the role of partners than respondents who had been research collaborators. In addition, respondents who had not applied for SFMN funding agreed significantly more with the suggestion to ensure funding flexibility, but on the other hand, disagreed significantly more with the suggestion to fund individual researchers than respondents who had applied for funding. Lastly, respondents who had received between $50,000–100,000 agreed significantly more with the suggestion to keep the same management structure than respondents who had received over $500,000 in SFMN funding (Table 10).

Open-ended responses provided numerous additional suggestions and advise for a future research network. Responses addressed seven main themes. The first theme referred to the management and structure of a future network. Respondents' suggestions and advice included a perceived need for regional research nodes; a perceived need for professional management with a well-defined management structure that includes expert science panels and expert industry panels; enhanced transparency and due process. With regard to the second theme, research funding allocations, one respondent suggested that "an Innovation Fund of 10% of the total funding for proposals should be set aside and perhaps not given each year to fund worthy proposals that may not be able to meet established criteria but would be useful to the Network and important to the forest community". Another respondent suggested that a future network should make funds available to any researcher, not just academic Principal Investigators.

The third theme addressed partnership considerations. One respondent bemoaned a perceived lack of 'meaningful' commitment from provinces other than Alberta, which was a significant funder of the SFMN. Other respondents made suggestions such as "a special Aboriginal Committee or Aboriginal Forest Network or Aboriginal Working Group or Aboriginal Research Group needs to be formed and promoted — full funding is necessary to encourage First Nation Communities to see the Network as a partner and not a burden". Another respondent noted that it is "very important to maintain/create/improve incentives for academics to work with government/industrial partners throughout the life of the study. This is the value of a Network to the non-academic partners". Lastly, one respondent suggested that a future network should have programs designed to enhance the participation of researchers located in small universities and rural regions and who generally have less access to provincial funding.

The fourth and fifth themes referred to knowledge exchange and knowledge management, which are here considered as separate, but related, considerations. More specifically, knowledge management

refers to processes and structures that facilitate cross-sector, interdisciplinary dialogue and social learning as well as information communication within organizational groups in the administration of the Network. With reference to knowledge exchange, respondents' suggestions included providing resources to publicize Network research results to the general public and improving 'receptor capacity' (i.e. knowledge uptake) in partner organizations. With reference to knowledge management, one respondent suggested that a future research network should mitigate the risk that members become isolated by providing resources for intra-institution and intra-SFMN forums and interaction.

The sixth and seventh themes referred to research capacity and the scope of research of the Network. Respondents' suggestions for improving research capacity included paying more attention to existing research strengths in various institutions and fostering synergies to avoid duplication. Another comment addressed the issue of facilitating meaningful collaborations: "funding of groups always seems like a good idea, but too often it is simply a group in name and not in practice. Large groups rarely have meaningful collaborations". Lastly, respondents' suggestions about the scope of research of a future network included ensuring that social sciences and humanity projects have access to funding because many policy-relevant and historical questions may be addressed through this kind of research and including more long-term research programs in addition to short-term, mission oriented, research.

4. Discussion

4.1. Participation in the SFMN

4.1.1. Reasons for participating in the SFMN

There are a number of generic motives for engaging in cross-sector research collaboration in 'triple-helix' organizations, including access to expertise, improved access to funds, knowledge advancement, intellectual companionship, curiosity, mentoring, and career development, among others (Katz and Martin, 1997; Beaver, 2001; Bozeman and Corley, 2004). Our survey revealed that the most agreed upon rationales for members of the SFMN community to engage in collaborative research were similar to those reported in Turpin and Garrett-Jones' (2009) study of Australian Cooperative Research Centres and Lee's (2000) survey of faculty members in US universities who were engaged in research and development projects with industry. In these studies, securing funding and gaining insights in research areas that were relevant to individuals' interests were ranked highly. However, while one of the most commonly cited reasons for cross-sector collaboration is securing access to equipment and/or facilities (Belkhodja and Landry, 2007; Heinze and Kuhlmann, 2008), our results indicate that this reason was not as important in the context of the SFMN. In addition, open-ended comments suggest that strategic positioning and networking were important reasons for engaging in cross-sector research collaboration, which supports the findings reported in Belkhodja and Landry's (2007) study of 'triple-helix' collaboration of Canadian natural sciences and engineering researchers. The importance of networking for the participants of the SFMN was further supported by the results of a social network analysis of the evolution of collaborative research teams during the Network's 14 years of operation (see Klenk et al., 2010a). The results indicated that the development of the Network exhibited a common pattern witnessed in network evolution, where the rate of 'attachment' of new actors in networks has shown a tendency for the most connected actors to attract newcomers, leading to the phenomenon of the 'rich getting richer' (Barabási et al., 2002; Dorogovtsev and Mendes, 2002; Wagner and Leydesdorff, 2005). Therefore, the importance of networking and strategic positioning was exemplified in the SFMN, where newcomers attached themselves to (highly connected) 'stars'. In a research network setting, this pattern is common because these 'stars' are likely to have more prestige and power to influence the development of the network or the direction of the research.

4.1.2. Benefits of participating in the SFMN

Similarly to Turpin and Garrett-Jones (2009), the most important perceived benefits of participating in the SFMN were intangible, referring to social capital development and enhancing career prospects. It is known from other studies that prior relationships structure the internal dynamics of new formal research networks. For example, in a bibliometric analysis Ryan (2008) has shown that the relationship networks that existed at the start of the funding persisted throughout the funded period. Likewise, Arnold (2005, p 13–14) described the persistence of particular participants in evolving research networks in the European Framework Programme (FP):

> Many organizations' participation in FPs is short lived, but there is a core of frequent participants, who sit at the heart of evolving networks. Evaluation and study evidence support the idea that there are virtuous circles that lead a limited sub-set of participants to become major actors within the FPs. In the 2004 FP5 impact survey 55% of the FP5 participants also participated in FP6 while more than 70% applied. Around 60% of the research institutes, universities and large firms that participated in FP5 continued their participation in FP6, but this percentage dropped to around 35% for SMEs (small and medium sized enterprises).

In the SFMN, individuals and organizations interfaced with the Network at different times during its evolution (Klenk and Hickey, 2009) and it should be noted that their perception of benefits associated with their participation in the SFMN may have changed over time.

Our results suggest that respondents perceived increased productivity in scientific outputs (e.g. publications) as a very important benefit. Results from two previous studies provide measures of this benefit of participating in the Network. A social network analysis and bibliometric analysis of the SFMN revealed that it was effective in enhancing the productivity of its social science researchers with regard to peer-reviewed publication outputs (Klenk et al., 2010a, 2010b). The impact on the productivity of natural scientists who participated in the Network has not been assessed.

4.1.3. Barriers to, and costs of, participating in the SFMN

Our survey results also suggest that differences in organizational cultures and the (unequal) influence of participants on setting the Network's research agenda were perceived barriers to receiving benefits from participating in the SFMN. These results are similar to those reported in Rod and Paliwoda's case study of the 'triple-helix' Institute of Pharmaco-Economics in Alberta, Canada (2003). In following with Rod and Paliwoda's (2003) and Heinze and Kuhlmann (2008) findings, our results also highlight the importance of cohesion, collegiality and shared vision.

In terms of the costs of participation, it was notable that academic respondents' disagreed significantly more with the proposition that 'my department/institution was subsidizing my (our) involvement in the network' than government and other respondents (industry, aboriginal, NGO). While research networks such as the SFMN have been characterized as 'parasitic' on university departments, in that their existence depends on a supportive university institution whose material and 'in kind' resources they entrain (Atkinson-Grosjean, 2006), this perspective was not considered to be a significant issue to individual academics participating in the Network. This might be explained in part because universities received funds for indirect costs related to how much SFMN grant money researchers at the institution received, with the exception of the host institution which received funds to offset the costs of administering the SFMN. Unlike academic partners, other partners were expected to pay member fees, negotiated according to the individual circumstances of the partner. This meant that Aboriginal partners and industry partners facing financial difficulty were often excluded from paying fees in contrast to government partners. Such

Table 10
Survey propositions referring to design features for a future, hypothetical forest-related research network.

Proposition	n[a]	No response	Average Ranking[b]	Undesirable and very undesirable	Desirable and very desirable	Sector *p* level	SFMN role *p* level	Applied for funding *p* level	Amount of funding *p* level
Clearly and explicitly identify the role (and limits) of partner involvement.	90	2	3.6	3%	97%	0.318	0.029[c,d]	0.728	0.301
Broaden membership to include mining, oil and gas, power generation companies.	89	1	2.9	29%	71%	0.328	0.824	0.851	0.846
Focus on the bridge between ecological, social and economic issues (this is not to say that each project has to have all elements).	95	1	3.4	12%	88%	0.183	0.876	0.913	0.437
Create a system of membership fees that contains incentives for different contribution amounts.	74	2	2.7	36%	64%	0.129	0.176	0.601	0.082
Get the Provinces to lead the Network instead of the Federal government (since they own the most forested land and are responsible for managing it).	85	1	2.5	47%	53%	0.405	0.809	0.307	0.699
Keep the same management structure.	74	2	2.3	51%	49%	0.618	0.208	0.065	0.006[c,e]
Increase support for Aboriginal traditional knowledge research and its potential applications.	84	2	2.9	31%	69%	0.103	0.598	0.462	0.627
Give equal importance to projects synthesizing the 'state of knowledge' as to projects proposing new research.	89	2	2.9	33%	67%	0.110	0.179	0.643	0.694
Give greater consideration to knowledge/technology transfer in research funding allocations (i.e. research proposals should include more detailed knowledge transfer plans).	91	2	3.0	29%	71%	0.005[c]	0.017[c]	0.025[c,f]	0.601
Ensure research funding flexibility to allow regional resource management issues to be addressed as they arise.	88	3	3.4	5%	95%	0.133	0.456	0.569	0.571
Focus research on policy issues, so that knowledge can be directly translated into new practices.	91	3	3.0	22%	78%	0.030[c,g]	0.499	0.612	0.038[c]
Fund more leading edge, individual researchers rather than funding more collaborative projects.	90	2	2.7	44%	56%	0.546	0.212	0.048[c,h]	0.282

[a] Excluding responses of 'no opinion' and 'not applicable'.
[b] The question had a six-point scale (1 = strongly disagree to 6 = strongly agree, with 7 = no opinion; and 8 = not applicable).
[c] Significant difference between groups within the independent variable at $\alpha = 0.05$.
[d] This design element of a future network was significantly less desirable for respondents who had been research collaborators than for respondents who had had a role in the administrative body of the organization ($\alpha = 0.0083$).
[e] This design element of a future network was significantly less desirable for respondents who had received $50,000–100,000 than for respondents who had received >$500,000 in total funding from the SFMN ($\alpha = 0.0083$).
[f] This design element of a future network was significantly less desirable for respondents who had applied for funding than for those who had not ($\alpha = 0.05$).
[g] This design element of a future network was significantly less desirable for academic respondents than for other (industry, aboriginal NGO) respondents ($\alpha = 0.017$).
[h] This design element of a future network was significantly more desirable for respondents who had applied for funding than for those who had not ($\alpha = 0.05$).

disparity between partners likely impacted the perceived costs of participating in the SFMN.

4.2. Management and structure of the SFMN

With regard to the management and structure of the SFMN, our results indicated that respondents were equivocal about the administrative procedures of the Network. This finding is similar to the findings of Turpin and Garrett-Jones (2009). However, this result differs from the results of a communication audit conducted within the SFMN, which surveyed 77 individuals from the governing body of the Network, including staff, management, and the various committees (see Klenk and Hickey, 2010). This communication audit revealed that the flow of communication within the administration of the Network relied on a formal structure layered with a substantial informal communication pattern which may have affected the effectiveness of official structures and processes, resulting in management challenges and communication dissatisfaction. Open-ended comments from the survey indicated that some respondents had strong feelings about what they perceived to be a lack of inclusiveness, transparency and due process in the governance of the Network and in the procedures for evaluating proposals. These issues are related to some respondents' dissatisfaction with perceived inequalities in access/influence among various members. Thus, although the majority of respondents were satisfied with the SFMN overall, a future research network would likely benefit from a detailed consideration of communication in the design and management of the network.

4.3. Legacies of the SFMN

Despite some misgivings about network structure and governance, respondents were overwhelmingly in agreement with the proposed legacies of the SFMN. Perhaps not surprisingly, the respondents who had received a greater total amount of SFMN funding generally tended to be in stronger agreement with the proposed legacies. However, the interpretation of these results should take into consideration several caveats: 1) self-reported achievements may be unduly flattering or critical; 2) often, there is a time-lag between research activities and expected outcomes; and 3) there are inherent difficulties in attributing direct causal links between network research and outcomes and impacts. Despite these qualifications, our survey responses support the results reported in a previous study of the organizational history of the SFMN based on detailed interviews with key informants (see Klenk and Hickey, 2009).

4.4. Design suggestions for a future Network

Respondents' rankings indicated agreement with many of the proposed design elements of a second-generation network which included expanding network membership; ensuring flexibility to address emerging research, management, and policy issues; clarifying the roles and responsibilities of partners; seeking greater interdisciplinary dialogue; and continued support for knowledge and technology transfer among partners. Several of these recommendations are similar to those reported in Heinze and Kuhlmann's (2008) study of inter-institutional research collaborations in the German public

sector. In addition, the fact that respondents from industry partners, aboriginal and civil society groups agreed significantly more with the proposition that a future network should "fund research on policy issues so that knowledge can be directly translated into new practices" than the academic researchers, confirms the importance of considering the nature of knowledge production and its evaluative criteria in the design of research networks. Furthermore, many of the open-ended responses suggested a need for more innovative organizational structures to better integrate aboriginal people within the knowledge production process and possibly allow non-academics to be Principal Investigators, which the mandate of Canada's NCEs does not presently (2012) permit.

These results suggest that although the SFMN brought together collaborators from diverse societal sectors to engage in a process of science co-production with an expanded peer-review community, the Network's funding allocation processes and criteria, and its incentive structures for collaboration (e.g. the nature of the knowledge being produced, among others) were perceived by some as limiting the extent to which the Network contributed to the production of more socially robust science.

5. Suggestions for formal research networks

In what follows we make suggestions that have emerged from our research on the SMFN that will benefit the design and management of university–government–industry–civil society (UGICS) networks seeking to foster more socially robust science. We believe that these suggestions will be directly relevant to other Canadian Networks of Centres of Excellence in environmental and natural resource sciences which exhibit a heterogeneous collaborative profile and, more broadly, to participants in other publicly-funded research networks operating internationally.

To begin, our research on the management and governance of UGICS networks suggest that a reflexive approach to setting the research agenda of the network is required to ensure adequate deliberation on the nature of knowledge production and the roles of partners and collaborators (Klenk et al., 2011). Reflexivity involves a continuous reconsideration of the practices, structures and outcome of governance, which has three main implications for actors and institutions (Hendriks and Grin, 2007):

- It demands that they reflect on how their frames of reference, structures and patterns of action contribute to persistent problems;
- It requires that they accept that seeking to eliminate uncertainty, ambivalence, and interference from uncontrolled influences in decision-making is impossible due to the relentless emergence of unintended consequences, 'side-effects', 'externalities';
- It requires balancing the use of instrumental specialization with a wide range of criteria of relevance, trading-off values and engaging in interaction with experts and stakeholders in decision-making processes.

To a certain extent, the SFMN exhibited reflexivity in the development of their research program and funding allocation mechanisms over the course of their mandate by engaging in collaborative decision-making and participatory agenda setting with their partners. To what extent the SFMN questioned it's frames of reference as to the criteria of scientific "excellence" and "relevance" guiding its mode of knowledge production is an open question.

Other suggestions include ensuring an equitable distribution of access/influence of partners. The need for a more equitable distribution of power/influence of partners is in keeping with Garrett-Jones et al.'s (2005) assessment of Australian Cooperative Research Centres (CRC), which suggested that the factors leading to a lack of trust between partners were inadequate commitment of resources, either actual or perceived, and the domination or undue influence on the direction of the collaboration or the potential rewards. The disparity between partners' financial contributions to the SFMN is likely a key to explain the perceived uneven distribution of power/influence over decision-making.

Another suggestion concerns establishing a diversified organizational structure to orchestrate the experience and expectations of partners whose 'home organization' is of a 'professional', 'bureaucratic', or 'entrepreneurial' structure (Mintzberg, 1998). The need to create a more diversified network structure is in line with Adler et al.'s (2009) suggestion for a need to formalize a more balanced matrix organizational structure in cross-section research networks. Our evaluative research suggests that such a structure would increase management responsiveness to different partner's research needs, facilitate the management of partner expectations, and more successfully attract and retain a broad array of partners from different sectors of society, thus improving the social relevance of the network.

With regard to funding allocation and partnership models, our research suggests that consideration should be given to seeking a balance between funding research focused on economic or social development goals and providing civil society actors, government and industry partners with opportunities to obtain funding as Principal Investigators of projects. While the NCE mandate does not allow funding non-academic Principal Investigators, greater access to research funding for non-academic researchers may help foster varied forms of participation from different societal sectors in the knowledge production and research agenda setting process, by experimenting with different modes of research coordination (Lepori, 2011).

With reference to knowledge exchange and management (KEM), the SFMN's knowledge exchange model is exemplary and suggests that formal research networks devolve responsibilities for KEM to regional nodes rather than keeping control of such activities in the administrative node of the network. These nodes might be focused on regional networks oriented towards more topical research agendas (e.g. aboriginal forestry, sustainable forest communities, and so forth), to support greater 'bottom-up' and more tailored KEM strategies in response to partnership and local needs. In parallel, more consideration should be given to understand the information needs and processes of knowledge uptake in partner organizations to better design KEM strategies. This action is also meant to support the co-production of scientific knowledge and involves discussing the criteria by which the quality of the knowledge produced will be assessed.

Lastly, with regard to research capacity and the scope of research, our multi-faceted study of the SFMN suggests giving a louder 'voice' to participants whose influence on the direction of research has historically been weak (e.g. aboriginal groups and forest communities) and establishing processes and structures so partners making limited (in-kind or monetary) contributions can review the allocation of funds and assess the extent to which funded-research projects address their needs and interests. These recommendations speak to the legitimacy and accountability measures instituted within research networks to hold administrators accountable and be responsive to the interests of all network participants. Our research suggests that such measures would facilitate the production of more socially robust science.

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