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The design and management of multi-stakeholder research networks to maximize knowledge mobilization and innovation opportunities in the forest sector

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ABSTRACT

Our comparative analysis of forest research networks indicates the emergence and strengthening of a new model of knowledge co-production involving knowledge producers and users, with the goal of fostering innovation and addressing challenges facing the forest sector. However, effective movement towards this model requires attention to design and to management, particularly in relation to the expectations of partners (both university and non-university) who are used to traditional models of knowledge production and linear processes of knowledge extension. Based on our survey and literature review, we argue that in the short-term, the objective of producing applied research requires that forest research networks prioritize diverse and tailored knowledge mobilization strategies, rather than emphasizing knowledge production. With regards to the longer-term objective of facilitating new avenues for innovation in the forest sector this requires a knowledge mobilization strategy that entails a level of engagement with partners that is creative and transformative rather than mainly informative. Building an organizational culture of innovation requires a different approach to producing applied research, although many of the same skills are required. Our analysis suggest that if networks are to be effective in both these short and long term objectives, they should foster openness by establishing transparent and responsive organizational processes. Although such policies may exist and be available to partners, we found relatively little information available on the processes of transparency, accountability and conflict resolution within the websites of the networks we compared. Establishing clear roles and consistent channels of communications is imperative to facilitate the efficient and effective management of the network and manage partners' expectations, regardless of the partnership model.

1. Introduction

Formal research networks that represent multi-sector partnerships are becoming increasing common in national science policy frameworks (Hickey, 2013; OECD, 2010). Such networks coordinate research on complex problems and involve collaborative teams of researchers and partner organizations dispersed over a number of geographically separate sites. In Canada's forest sector, this approach appears particularly relevant as a means of bringing together universities and other research institutions, forest managers (both public and private), government policy makers, and industrial actors with particular interests in transformation and commercialization of forest products. The capabilities, effectiveness and impacts of such forestry networks has been the subject of several recent studies using various approaches (Ellefson et al., 2007; Raitzer, 2010; Scarascia-Mugnozza et al., 2012; Di Matteo et al., 2015).

Developing ways to strengthen knowledge dissemination and implementation appears to be influenced particularly by the conceptual approach adopted to understand the relationships between the parties and the epistemological orientation of the research collaboration (Fazey et al., 2014). Van Horne et al. (2006), propose an innovation value chain that situates research in response to a need identified by commercial or other interests and proceeding through a series of steps (including commercialization) to terminate with implementation through industrial production or adoption as a newly standardized process. Examining technology transfer, Ellefson et al. (2007) sought to identify a series of key elements that affected the effectiveness and efficiency of programs that sought to improve the application and commercialization of research and technological development. Interestingly, Ellefson and colleagues also distinguishe between four conceptual frameworks for scientific investigation: researcher-dependent diffusion of knowledge; an imprecise demand from users; a facilitated interaction between researchers and users; and a direct user-producer relationship. Where Van Horne et al. (2006) see a chain, Rametsteiner and Weiss (2006: 693) propose a more complex system view of innovation "as a complex non-linear process involving a range of actors and different interactions", emphasizing the social elements of the system. The challenge of identifying the different elements of such a system and of

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evaluating effectiveness and impacts are demonstrated in case studies such as that of Raitzer (2010) who established a dollar value of benefits resulting from policy changes in the Indonesian pulp and paper sector based on research by the international organization CIFOR. Raitzer described how a variety of actors (government, industry and non-government organizations) used research undertaken and diffused by CIFOR helped to modify policy – although the study also noted that the benefits "pale in comparison with the magnitude of the problems that remain" (Raitzer, 2010: 1516)

Public–private research partnerships raise a variety of issues, both for traditional research organizations such as universities and for the private sector (Hessels et al., 2014; Bozeman and Boardman, 2014). Institutional, disciplinary and motivational factors can facilitate or act as barriers to more democratic knowledge co-production (Jasanoff, 2004; Barry and Born, 2013). In the forest sector for example, forest scientists may expect research networks to provide funding and resources for specific academic projects, while the forest industry typically seeks information and technology for commercial application. A central question for public–private research partnerships is how to effectively mobilize knowledge to innovate while satisfying the reward and incentive structures of different organizations (Hessels et al., 2014). Levin (2008) suggests that assessing the effectiveness of knowledge mobilization in this context can be done using as a three-part question:

1. how to create research/evidence/knowledge that is rigorous and useful;
2. what processes can most effectively distribute or make available this research/evidence/knowledge; and
3. how to facilitate feedback and interaction among these elements given that the process does not flow simply in one direction.

In this article, we seek to generate a better understanding on how to design and manage public–private research networks to enable knowledge co-production for innovation in the forest sector. Our analysis responds in part to a recent call for "developing a better conceptual framework for explaining technology transfer and for guiding the subsequent design and implementation of technology transfer programs" in the forest sector (Ellefson et al., 2011). We also respond to Hickey's (2013) observation that studies showed the need for improvements in interactions between scientists and government and in communication with broader society. Accordingly, we choose to focus upon factors that appear to contribute to stronger relationships between public and private actors engaged in the production, diffusion and application of knowledge, with a focus on spurring innovation in the private sector. This appears to be equally applicable whether one adopts a value chain view of innovation (eg. Van Horne et al., 2006) or a systems view (eg. Rametsteiner and Weiss, 2006). Finally, we also seek to compare some of the conclusions from earlier work on the Canadian Sustainable Forest Management Network[1] (Klenk and Hickey, 2009, 2010, 2011, 2012; Klenk et al., 2010a, 2010b) with the experiences of other research networks operating elsewhere in Canada and internationally.

Our review first introduces a range of theories that offer insights on how research or created knowledge is mobilized into policy, industrial or commercial situations, resulting in applied knowledge. We then present an analytical framework, with seven key structures and processes based upon studies of the SFMN (Klenk and Hickey, 2012). Using this framework, we analyze the structure and processes of 22 research networks in the forest sector, both within and outside Canada. Finally, we make practical recommendations using our analytical framework to help practitioners with the design, management and assessment of knowledge mobilization and innovation in research networks in the forest sector.

[1] The Sustainable Forest Management Network (SFMN) operated from 1995 to 2009 and is still the most well-known example of a public–private forest research network in Canada.

2. Literature review

2.1. Research utilization and knowledge management in policy and practice

Over the last decade, there have been a large number of studies conducted to improve our understanding of the use of scientific information in forest policy (Konijnendijk, 2004; Mayer and Rametsteiner, 2004; Spilsbury and Nasi, 2006; Janse, 2006, 2008; Klenk and Hickey, 2012; Stevanov et al., 2013; Böcher and Krott, 2014). Many studies have developed an "ideal type" model of forest policy development as a framework to study research utilization. Typically, the policy process model is conceived as a series of activities that overlap, but may have different information requirements: setting the policy agenda, policy formulation, policy selection and legitimization, policy implementation, policy evaluation, and policy revision (Janse, 2006, 2008). Scientific evidence may be used throughout this policy process to focus attention on critical uncertainties, broaden the range of policy options, clarify the relationship between means and ends within particular policy options, simulate policy outcomes, engage in problem-solving activities and provide expert opinion on potential risks of implementing particular policy options. According to the 'Research, Integration, and Utilization' (RIU) model, knowledge integration plays a critical boundary-spanning role in enabling science utilization in forest policy (Stevanov et al., 2013; Böcher and Krott, 2014). Other studies have decomposed the science policy interface according to institutional, social, cultural and individual factors. Below we describe how these factors can affect how science is implemented in practice. While the literature we draw upon in this section mostly focuses on the science-policy interface, rather than on private-public research networks, it helps us understand the complex pathways through which science makes it way (or not) into applications.

Explanatory models of research utilization posit four major categories of explanations that have different implications for knowledge management with public–private research networks: engineering, organizational, cultural and interactionist (Landry et al., 2003; Amara et al., 2004; Ellefson et al., 2011). The engineering model suggests that research uptake depends on the characteristics of the research findings according to traditional scientific metrics of quality and type (e.g., applied versus fundamental research). From this perspective, strategic choices in terms of publication outputs must consider how best to communicate the complexity, validity, applicability and relevance of research results for the intended knowledge users. The likelihood of uptake is therefore directly influenced by the compatibility of research findings with an application context (Landry et al., 2003).

The organizational explanation on the other hand, focuses on the capacity of knowledge users to obtain relevant and applicable knowledge. Here the focus is on the positions of the knowledge users (e.g., managers, professionals, implementers) and the routines through which they acquire information. Strategic decisions in this perspective have to do with targeting research outputs that correspond to the information gathering practices of knowledge users (Ellefson et al., 2011). Greater research uptake is expected if knowledge users consider the research pertinent, if it corresponds to their needs and if they can rely on its credibility and legitimacy and if it is timely (Landry et al., 2003; Amara et al., 2004).

From a different perspective, the cultural explanation refers to differences in organizational cultures and information needs as potential obstacles to knowledge mobilization. Organizational structures that seek to bridge the gap between science and application include efforts to support knowledge extension and receptor capacity. Capacity-building workshops would seem germane to bridge the gap between organizations cultures in multi-stakeholder research networks (Landry et al., 2003; Amara et al., 2004). Van Horne et al. (2012) documented the ways in which research partnerships created different types of value for the various stakeholders.

Finally, the interactionist explanation emphasizes the social ties between the producers and the users of knowledge, especially trust and

learning. Research here has suggested that closer, longer-lasting interactions between knowledge producers and users increase the likelihood that this knowledge will be applied (Landry et al., 2003; Klenk and Hickey, 2012). It is hypothesized that more intense interactions provide knowledge producers with a greater understanding of user's needs, while users also have greater confidence in solutions proposed to them by researchers with whom they have a long-standing interaction. The four categories of explanations summarized here present quite different perspectives, but should also be seen as complementary: the engineering explanation focuses on the characteristics of the research; the organizational explanation considers the capacity of the users to apply the knowledge; the cultural explanation highlights differences or similarities among the parties; and the interactionist explanation considers the social dynamic between individuals.

To understand the complex pathways of knowledge utilization in the forest sector thus requires paying attention at the role of individual actors and their competencies and how these affect the relationships between actor groups. In addition, it requires that our models of research utilization move beyond the "input–output", "delivery–uptake" and "supply–demand" communication models which tend to assume a relatively linear model of policy-making, and which focus almost entirely on the relationship between university research and government policy makers (Janse, 2006, 2008; Stevanov et al., 2013). For example, models of research dissemination and implementation must take into consideration the characteristics of the knowledge producer (e.g. university, government, private, NGO, etc.), their particular objectives and constraints, and the networking skills and competencies they have, which will influence knowledge users' perception of the "relevance" of research products and their utilization in application. Such models should also include competency factors, such as the role and skill sets of knowledge brokers (Phipps and Morton, 2013), and the limitations of 'two communities' lens (Nutley et al., 2007) that may artificially separate academic researchers on the one hand and practitioners (including policy-makers) on the other in understanding the relationship between knowledge production and implementation, which we next present.

2.2. Knowledge mobilization

Knowledge mobilization is concept that includes a number of different practices (Tabak et al., 2012) and due to its multifaceted nature, some researchers refer to it as K* (K-star) (Shaxson et al., 2012). For the purpose of our study, K* can be seen as a useful heuristic device to highlight the interconnections between the set of practices at the various interfaces between knowledge and application, including knowledge production, diffusion and implementation activities (Tabak et al., 2012). Rather than seeing these activities as strictly independent and focusing on each of them in terms of their distinctiveness, K* emphasizes the overlap that can happen between research, knowledge retrieval/storage/distribution, knowledge translation, knowledge brokering and knowledge exchange depending on the relationship between knowledge producers and users. Although these activities are distinct, there are not isolated from each other and certainly in situations where knowledge is co-produced with actors from the private sector, as in public–private research networks, there can be a significant overlap between research and implementation. Indeed, knowledge translation, brokering and exchange are intrinsic components of innovation, yet innovation also requires being able to discern needs and opportunities and enlist creative imagination to produce valuable goods, whether they be ideational or material (Powell et al., 1996;). Hence, numerous competencies and skills are required to broker knowledge and spur innovation, to which we turn to below (Straus et al., 2011; Phipps and Morton, 2013). Nevertheless, it should be noted that there are numerous theoretical models on bridging research and practice; for instance, Tabak et al. (2012) systematically review 61 models across different disciplines, including the better-known models of 'Knowledge to Action Cycle' (Graham et al., 2006) and 'Diffusion of Innovation' (Rogers, 2003). Given the numerous choices of knowledge mobilization models to choose from, we have decided to focus on the K* model because it is particularly helpful in relating the practices and competencies required for both dissemination and implementation in public–private research networks.

It is useful to think of the functions of K* as different levels of engagement, dedicated resources and select competencies for seeking, sharing or disseminating knowledge. For instance, Michaels (2009) proposes 6 knowledge brokering strategies for environmental policy problems which exhibit different intensities of engagement, skillsets and commitment of resources: informing, consulting, matchmaking, engaging, collaborating and capacity building. Those strategies that involve more effort to build relationships between knowledge producers and users subsume the strategies that involve less (Michaels, 2009: 997). Based on Michaels' work (2009), Shaxson et al. (2012: 15) have reinterpreted the six knowledge brokering strategies as K* functions (Table 1).

According to Shaxson et al. (2012), the range of K* functions highlights the similarities and differences between the range of practices exemplifying knowledge sharing. For example, many researchers and industry representatives are familiar with the model of "knowledge transfer", whereby results are passed from knowledge producers to knowledge users. This view corresponds to a linear model of knowledge utilization, concentrating on the informational functions of K*, and suggesting that information moves in only one direction. In contrast, the relational and systems functions of K* emphasize that information can and should move in different directions. In this view, both researchers and users are engaged in the co-production of knowledge and social learning. Relational K* functions are those related to knowledge translation and knowledge brokering, which involve helping people make sense of and apply information, as well as improving knowledge use in decision-making. Systems K* functions exhibit characteristics of structures and processes that enable change and sustain innovation in ways that are akin to adaptive management: continuous learning, flexibility, real-time feedback loops, distributed authority, readiness for adaptation and recursive evaluation (Baker et al., 2008; Gamble, 2012). Collaborating and synergising present particular challenges as they imply building relationships between individuals or groups that do not necessarily share the same organizational culture, incentive structures or objectives in knowledge production and use—it also requires particular facilitation qualities and skills: authenticity, realness, openness, respect and general credibility, accessibility, approachability, empathy, responsiveness, reliability, self-confidence, enthusiasm, creativity, active listening, courage, tact, and commitment (these competencies have been highlighted in the PARiHS model, Promoting Action on Research Implementation in Health Services, see Phipps and Morton, 2013; Stetler et al., 2011). Through collaborative teams the relational and system K* functions may purposefully develop and support approaches and processes that combine the sources of knowledge and the beneficiaries of that knowledge to interactively move towards a

Table 1
Knowledge brokering strategies for K*.

Strategy	Description
Informing	Dissemination of knowledge from producer to consumer, possibly also including producing and synthesizing knowledge.
Linking	Bringing together knowledge producers to knowledge users around a single issue, or within a single discipline.
Matchmaking	Connecting particular people who would not otherwise meet in order to bring in knowledge from other disciplines or across issues.
Engaging	Engaging potential users of knowledge by describing and framing issues inclusively.
Collaborating	Through formal engagement process, strengthening relationships and fostering deeper understanding on both sides.
Synergizing	Building receptive capacity within institutions so they can learn and address multiple issues simultaneously.

Adapted from Shaxson et al. (2012:15).

common direction such as meeting an identified community need (Bennet and Bennet, 2007).

K* functions are related of course to the purpose of the K* activity: producing and drawing knowledge into an organization, sharing knowledge between organizations or individuals (i.e., co-producing knowledge) and/or disseminating knowledge outwards from an organization. These purposes will, almost certainly, derive from the goals of each organization. Each purpose may enlist one or more of the K* functions and, depending on which ones are chosen, this will impact the role and responsibilities of the organizations involved in K*. The choice of K* will also be influenced by the political context of decision-making in the sector, the nature and interests of the partners and stakeholders involved in K* and which types of knowledge are valued in decision-making (e.g., tacit knowledge, expert knowledge, traditional knowledge, local knowledge, etc.) Choosing which K*functions to use, when they should be initiated and how they should be sequenced depends on the objective of particular projects or research networks and their innovation strategy, to which we turn next.

2.3. Open innovation networks

The "open innovation" model (Gassmann et al., 2010) appears particularly relevant to cross-sectoral research networks, involving industry and government partners. In open innovation, a network of knowledge users, producers and innovation champions develop pathways outside the strict confines of their particular organizations to facilitate the commercialization of their ideas (Fichter, 2009). For the private sector, open innovation requires that firms build close relationships with a range of other organizations in order to source ideas, processes and products. "Past research has consistently shown that companies, which have close relationships with customers, suppliers, research institutions and competitors are more likely to have product and process innovation success" (Ritter and Gemunden, 2003: 745). A firm's know-how, which is often in the form of tacit knowledge, is difficult to exchange, but sharing this knowledge can be done through persistent collaborative relationships and the creation of a shared language (e.g., heuristics, values, rules) (Kogut and Zander, 1992). Ritter and Gemunden (2003) propose four main cross-relationship tasks that firms (or networks in our case) should perform in a context of open innovation (Table 2). These tasks represent 'network competence': a skill set and a stance towards facilitating knowledge mobilization and innovation that involve the ability to plan financial, human and infrastructure resources; nurturing and maintaining dedicated channels of intraorganizational communication; adopting a "networking" orientation in human resource management, which requires developing a culture of openness and "thinking outside the box" in knowledge production and mobilization activities; and, ensuring transparent, accountable and responsive administrative processes (Ritter and Gemunden, 2003).

Innovation champions can play a critical role within the firm/network for improving the performance of firms and innovation networks (Howell and Shea, 2001; Fichter, 2009). In the process of scanning the environment for new ideas, the most effective source of information is the champion's network of people inside and outside the organization (Howell and Shea, 2001). Their effectiveness is related to their ability to garner (positive) attention and connect the right needs with the right opportunities while having a sense of what would be a productive path to follow. The work of innovation champions obviously also require 'network competence' and social skills because firms and public–private research networks are social communities in which individual and social expertise is transformed into economically useful productions and services (Ritter and Gemunden, 2003).

In the last three sections we have described previous research on knowledge utilization focused on the science-policy interface, knowledge mobilization as an umbrella concept that require different sets of skills depending on the extent to which knowledge is co-produced by public and private actors, and insights gleaned from the literature on open innovation networks that seek to maximize knowledge application in economic development, all of which point to the importance of managing the relationship between the public and private actors is of crucial importance for effective innovation. While these bodies of literature also provide many ideas and suggestions for designing an effective public–private research network in the forest sector, we would argue that there is a need for an analytical framework that is grounded in empirical studies of past and current forest research networks. For example, a recent systematic assessment of the organizational structure and governance, partnership satisfaction, communication pathways, and impacts of The Sustainable Forest Management Network provides a useful analytical framework for comparing other public–private forest research networks.

2.4. The Sustainable Forest Management Network (SFMN)

The SFMN is probably Canada's most well-known example of a public–private forest research network. Beginning in 1995, it helped establish new research priorities for the forest sector (i.e., aboriginal forestry), supported policy-relevant research and organized knowledge mobilization for practitioners, managers and policy-makers. The SFMN had a broad membership base including government agencies (federal and provincial), universities, private companies and Aboriginal and environmental organizations, although the majority of the funding came from government. Core funding for the SFMN, under commitment from the federal government, ended in 2009, although some knowledge mobilization activities continued for several years afterwards (Klenk and Hickey, 2009).

The SFMN represents an important source of tacit knowledge on how public–private research networks might be designed to support innovation and sustainability in the forest sector. In a previous study, a

Table 2
Relationship-oriented tasks for building network competence in open innovation research networks.

Network competencies	Description
Access to financial, human and infrastructure resources	Key task: planning Internal analysis of resources: strengths and weaknesses of organizational processes and structures.
Establish dedicated channels of intra-organizational communication	Key task: organizing Develop specified ways to communicate across partnerships; build adaptive capacity to respond to partnership needs, being aware that response to one partner's needs may have an effect on your response to another partner's needs (i.e., have a network perspective).
Adopting a "networking" orientation in human resource management	Key task: staffing Allocate personnel to specific relationships; guide and coordinate personnel to build a culture of openness and networking.
Fostering openness in corporate culture by establishing transparent, accountable and responsive processes	Key task: controlling Enable feedback loops through the use of assessments: contribution of personnel, quantity and quality of communication activities as well as externally oriented contributions of partners or performance of the network as a whole.

Adapted from Ritter and Gemunden (2003).

Table 3
Structure and processes for forest research networks.

Structures and processes	Description
Knowledge exchange	The ability to facilitate the creation and use of knowledge for innovation
Knowledge management	The capacity to search for, store, retrieve and distribute accumulated information, including building institutional memory
Governance and organization	Organizational decision-making structures and processes; administrative allocation of tasks
Partnership terms of reference	The roles and responsibilities of partners
Funding model	Contract, grant, service orientation
Research capacity	Access to expertise and the formation of highly qualified personnel
Scope of research	Including fundamental and applied research, knowledge demands, knowledge gaps

Adapted from Klenk and Hickey (2012)

concept mapping policy Delphi was conducted to elicit the expert views of partners on how to design a public–private research network in the forest sector in Canada, thereby offering insights to some of the 'lessons learnt' of the SFMN (Klenk and Hickey, 2012). The results of this study suggest there are 7 key organizational structures and processes that deserve consideration in the design of public–private research networks (Table 3). Each of these organizational components are interconnected but refer to different aspects of knowledge mobilization and innovation and may take different forms depending on the mandate of the research network, its funding requirements, and the nature of its partnerships.

Our goal in this article is to understand how the design and management of public–private research networks in the forest sector affects their ability to promote knowledge mobilization and innovation. In particular, we seek to go beyond the elements of knowledge exchange processes (as summarized in Table 1) or the competencies needed to build relationships in a network (as presented in Table 2). Instead, we will consider these as different aspects of a K* approach where knowledge mobilization relies upon a set of functions and processes (Shaxson et al., 2012). To do so, we will use the 7 organization processes and structures that have been suggested as critical components in the design of public–private research networks (Table 3) and use these to compare the ways in which research, knowledge mobilization and innovation are treated in a range of other networks, both in Canada and internationally.

3. Methods

This study adopts a "desk-top" methodology to collecting and analyzing publicly available web-based information for a variety of Canadian and international networks that seek to foster research, innovation or knowledge mobilization in the forest sector. We analyze this information against a set of seven design issues identified in the literature, with a particular concern for the way that these issues impact upon knowledge mobilization between the various actors in each network.

To begin, we conducted a Google search for forest research networks in Canada using keywords: "forestry research", "forest innovation", "network" and "Canada". Results were then limited to organizations (networks) that: operated in the forest management and forest products sectors; involved partner organizations of at least two different types (research institution, private sector, and government); had their headquarters in Canada; and provided adequate information upon their websites concerning each of the seven design issues identified in our evaluation framework. A total of 16 forest research networks were identified in this way (see Table 4). Although we were focusing on the Canadian context, we also wished to include a more limited number of non-Canadian networks. Accordingly we repeated this search for international organizations, identifying a further 40 networks (see Appendix A of the supplementary data), although use of non-English keywords would almost certainly have provided a significantly higher number. Of these, we selected six representing a variety of sizes, locations and orientations, recognizing that such a selection inevitably excluded a number of worthwhile networks. Clearly, the contexts of these networks are very different – some are local (such as the Cooperative Forestry Research Unit in Maine, USA), others are national (such as FPInnovations in Canada), and three are international. Differences in context are likely to affect numerous characteristics of these networks, particularly the goals, the members and financial resources. However,

Table 4
List of research networks analyzed.

Research networks	Location	Website
Canada		
Alberta Innovates Bio Solutions	Alberta	www.bio.albertainnovates.ca
ArboraNano	National	www.arboranano.ca
Centre d'expérimentation et de développement en forêt boréale — CEDFOB	Quebec	www.cedfob.qc.ca
Le Centre d'enseignement et de recherche en foresterie de Sainte-Foy inc. — CERFO	Quebec	www.cerfo.qc.ca
Centre for Northern Forest Ecosystem Research — CNFER	Ontario	www.mnr.gov.on.ca/en/Business/CNFER/index.html
FOR@C De la forêt au client	Quebec	www.forac.ulaval.ca
FORREX	Quebec	www.forrex.org
ForValueNet	National	www.forvaluenet-foretvaleur.ca
FPInnovations	National	www.fpinnovations.ca
Forestry Research Partnership — FRP	Ontario	https://www.lakeheadu.ca/research-and-innovation/research-services/funding-prizes/funding-db/funding-agencies/node/14671
Innovative Green Wood Fibre Products Network	National	www.greenfibrenetwork.ca
Lignoworks	National	www.lignoworks.ca
NewBuilds	National	http://newbuildscanada.ca
NSERC Bioconversion Network	National	www.nsercbioconversion.net
Sentinel Bioactive Paper Network	National	www.sentinelbioactivepaper.ca
Value Chain Optimization — VCO	National	www.reseauvco.ca
U.S.A		
Cooperative Forestry Research Unit — CRFU	Maine	www.umaine.edu/cfru/
Hardwood Tree Improvement and Regeneration Center	Indiana	www.agriculture.purdue.edu/fnr/htirc/
New Zealand		
Scion		www.scionresearch.com
International		
Center for International Forestry Research — CIFOR		www.cifor.org
International Union of Forest Research Organizations — IUFRO		www.iufro.org
Innovawood		www.innovawood.com/

our objective is to gather a breadth of experience, rather than to analyze a single or several networks (eg Klenk and Hickey, 2009; van Horne et al., 2012) or to evaluate the relative success of different networks (eg., Di Matteo et al., 2015).

Our data collection consisted of searching for information on websites and in selected documents available on the web site (typically annual reports) that provided information relevant to design elements in the evaluation framework. Table 4 provides basic information on each network, along with a website for further information and the name or acronym used in this article. Further details of each network in relation to each of the seven design elements is provided in the Annexe attached as Supplementary Materials to the electronic version of this paper. In using web-based sources, we note that terms or explanations provided by an organization itself upon its website are not always clear or equivalent. For example, two organizations whose websites includes statements that they are engaged in close collaboration with a wide range of stakeholders may actually have different views of what "close collaboration" means and envisage quite different groups of stakeholders. However, consistent with our goal of gathering a breadth of experience, rather than analyzing a select number of networks, we use information as provided by each network without seeking to verify this independently.

4. Results and discussion

4.1. Knowledge mobilization strategy

A distinction can be seen between networks that focus on dissemination and translation (the technology transfer or value chain model) and those that adopt a broader knowledge brokering strategy. Of the 16 Canadian networks analyzed, three networks (CEDFOB, CERFO, FORAC) were primarily aimed at knowledge extension and transfer to support local forest landowners and industry. This is also the case for the Cooperative Forest Research Unit at the University of Maine, USA. The majority of Canadian research networks in the forest sector, however, seek to broker relationships between knowledge users and knowledge producers and facilitate innovation in forest product and technology development and planning and management tools. The New Zealand network (Scion) and the international networks (CIFOR, IUFRO and InnovaWood) seek to accelerate innovation in a much broader scope of research domains then the Canadian networks (e.g., poverty reduction, health, agroforestry, climate change mitigation, forest policy, and a vast number of forest-based products). In some cases, these networks act as a parent company for joint ventures or other companies (e.g., Scion).

Increasingly, firms and research networks in the forest sector seek to coordinate research priorities and the selection of research and development projects in close collaboration with partners, which is meant to help facilitate knowledge mobilization and innovation through the co-production of research or product development (Baba et al., 2009; Boyle et al., 2006; Gerwin and Barrowman, 2002). Studies of public–private partnerships have showed that the earlier knowledge users are involved in the research process, the more likely they will participate meaningfully in the implementation of research or product development (Boyle et al., 2006).

4.2. Knowledge management tools

All of the websites we searched provided information on the parties involved in the network, the activities undertaken, resources, news and events and contact information. Most websites had controlled access to offer added-value content to partners and members. The websites vary widely with regards to the diversity and amount of content provided (e.g., about the network's governance structure, staff, resources, etc.). A noteworthy example of an informative and easy to navigate website is by the European research network InnovaWood, which provides clear and in-depth information on their service package for members, education products, research products, project directory as well as information on its performance and impacts. The importance of developing a user-friendly web-based platform for exchanging information in business and innovation networks cannot be underestimated (Steward et al., 2012). Experience from the SFMN suggests that the multitude of choices for providing information can also raise problems, and suggests a periodic assessment or audit of communication in relation to the networks structure, personnel, needs and institutional cultures (Klenk and Hickey, 2010).

Research networks typically provide access to publications of various types: research articles, technical notes, knowledge syntheses, press releases, thesis, newsletters, conference abstracts and proceedings, management or information guides, periodical series, and opinions and editorials. While all networks provide access to some of these types of publications, only a few (such as IUFRO) include the full range of possible materials. With so many possible types of publication, networks need to make strategic choices about the types of publication that best correspond to their knowledge mobilization objectives.

The electronic media and Web 2.0 are being increasingly used to provide information, deliver training and promote the network and its members. These include a variety of options that were unavailable a decade ago: YouTube videos of scientists or partners at work, radio podcasts, photo galleries, computer applications, webinars, and social media such as Facebook, Twitter, Flickr, Slideshare and blogging. The international network CIFOR has invested significantly in such tools as part of their knowledge mobilization and innovation strategy. Organizations used to communicating research findings through traditional academic publication processes (with peer review) may be reluctant to engage in social media. However, as Brown (2009: 18) argues, "Ultimately, the choice for organizations is a simple one: they either take part in these conversations or they don't. What they have to realize though is that if they don't participate in these conversations they won't simply go away. The dialogue will go on without them." Potential uses of social media for research networks include engaging knowledge users in data collection and monitoring research activities; crowdsourcing ideas within an open innovation strategy; eliciting and documenting research applications through blogs and podcasts; and reviewing and rating research results (Steward et al., 2012). The latter could be used as an ex-ante means of evaluating the effectiveness of knowledge co-production and mobilization strategies.

Networks that have existed for some time often provide searchable databases for previous and ongoing projects. Some networks also provide Google maps on which the location of their partners is indicated as well as the location of ongoing projects. Researchers have argued that knowledge management, especially with regards to making knowledge available to users and members, is critical to organizational learning and may suffer from a lack of foresight and dedicated resources in academia and large research networks (Sousa and Hendriks, 2008). Moreover, knowledge management entails enabling people to 'see' beyond their institutional boundaries, in turn requiring the coordination and translation of partners' organizational incentives, interests and expectations.

Most research networks conducting research on forest management and planning use workshops, field tours and on-site training and seminars as knowledge mobilization tools. FORAC and other networks offer software (freeware) and decision-analysis tools (and games) for their members. The Centre d'expérimentation et de développement en forêt boréale (CEDFOB) also has a research and demonstration site and conducts ongoing round-table discussions with different stakeholders to broker relationships and help build better communication, knowledge exchange and trust among their members. Increasingly, networks are employing knowledge management professionals, variously referred to as business development managers, engagement specialists, network liaison managers, extension coordinators and donor relation managers. Their roles include facilitating relationships between researchers and

partners, promoting knowledge mobilization inside and outside the network, and creating opportunities for applying knowledge and innovation produced in the network.

4.3. Governance and organization

The research networks analyzed typically adopt governance arrangements that seek to combine a hierarchical structure for operational management with a more collegial (peer-oriented) approach for research and innovation efforts. Most networks are structured as a corporation with a Board of Directors, representing major stakeholders, who are responsible for strategic decision-making in the network. A network director (or executive officer, or manager) is generally in charge of operational decision-making in the network, including overseeing the administration of staff. This structure offers a clear line of accountability but is less appropriate for governing knowledge production, particularly due to peer-review quality control in science. Accordingly, most networks in our sample have established a form of science committee that is responsible for recommending research priorities, developing calls for proposals, and determining proposals to be funded. The science committee also typically includes program directors in charge of the coordination, monitoring and reporting on the knowledge being produced in their particular program of research. Generally the network director overseas the science committee, but sometimes this committee interacts directly with the Board.

Most networks also present characteristics of a hybrid, but mostly horizontal structure, integrating four of the five organizational types proposed by Mintzberg (1998): professional, diversified, innovative and entrepreneurial structures. The "professional" structure includes the Board of Directors, a network Director, staff and a science committee, with relatively clear roles and responsibilities. This is usually the most visible part of the organization and should be clearly articulated to increase transparency, accountability and responsiveness (Klenk and Hickey, 2012). "Diversified" networks are those that are larger, often covering a broad geographical space and/or a range of disciplines and domains, and are usually divided into divisions. The "innovative" structure typically includes teams of highly trained personnel and experts, among which power is unevenly distributed. The creative and adhoc nature of innovation can result in tension with the professional parts of the network. Finally, research networks often exhibit 'entrepreneurial' structures, such as a Principal Investigator leading a highly productive team of undergraduate, graduate and postgraduate researchers. The hybrid and 'diversified' structure of networks can sometimes lead to strong informal patterns of communication, affecting the efficiency and flow of information, especially with regards to perceptions of transparency in administrative decision-making and the allocation of resources to partners (Klenk and Hickey, 2010). We also found that while all networks provide research information, relatively few provide detailed information on their own organizational structure and processes. The more common types of organizational information include annual reports and meeting notes, program brochures, program and project reports, knowledge mobilization activities and success stories. Less commonly information is available on organizational structure, terms of reference, partnership funding models and processes for selecting research projects. A perceived lack of transparency and accountability with regards to how decisions are made within research networks (e.g., allocation of tasks and resources, setting research priorities, monitoring of research activities, management of partnerships and mechanisms for dealing with conflicts of interests and complaints) can limit the recruitment and retention of partners and thus impede research uptake and implementation in the long term (Klenk and Hickey, 2012).

Finally, in order to thoroughly understand the governance and organization of public–private research networks, one must take account of the partnership and funding models utilized (Ellefson et al., 2011).

4.4. Partnership/clients

All networks in our sample use a vocabulary that stresses partnerships and client relations, including terms such as "collaboration" and "alliances". For FPInnovations, "Accelerating innovation and enabling partnerships among industry, governments and academia" is one of four key elements of their Mission statement.[2] Sentinel network states "We invite companies to collaborate with us to move the products, platforms and processes from the laboratory to where they can benefit industry and consumers".[3] We assume that this reflects a deliberate strategy to break away from a more traditional view of research as a process that is driven by professional researchers working within certain institutions, responding to academic incentives. The importance of partners and clients is now recognized in most models of the innovation process, whether as an originator of needs (the innovation value chain of Van Horne et al., 2006), as the recipient of technology transfer (Ellefson et al., 2007), as an actor within a complex non-linear system (Rametsteiner and Weiss, 2006) or as differing sources of value (van Horne et al., 2012). The types of partner (or client) organizations associated with the networks we examined were highly variable, including individual companies, industry associations, research institutions (typically universities), government agencies and specific user groups – such as local forest owners and forest management professionals in the case of CFRU in Maine. We could not discern any patterns on partnership models with regard to the local, regional or national scales of the networks, or in relation to other factors such as scope of research.

For most networks, it appears implicit that partners will influence the governance of the network, or contribute to decisions about priorities associated with knowledge mobilization. This can occur in many ways. Networks with a limited number of members may assign a seat upon the board or executive committee to each partner, or to representatives of groups of partners. Other networks establish committees or evaluation processes that evaluate proposed projects or activities against the identified needs and priorities of members. In some cases, partners may be able to vote upon a range of options, choosing where and how network resources should be allocated.

Consistent with the idea of meeting client needs, most networks provide a range of services, or packages for accessing research and support including grants, cooperative agreements, fee for service, endowment funds and donations, paid for research, and even venture funds (e.g. FORREX). Some networks offer arrangements whereby certain knowledge produced is proprietary to those who financed it, effectively creating a distinction between "clients and partners". (e.g., access to results from pay-for-service research is not generally made available to all partners). For instance, the New Zealand research network Scion is notable for creating companies to develop and market innovations. Their 'diversified' network structure is in line with Adler et al.'s (2009) suggestion for a need to formalize a more balanced matrix organizational structure, including innovative and entrepreneurial structures, in public-private research networks. Thus, when considering partnership models within the context of knowledge mobilization in public–private research networks in the forest sector, the following strategic questions should be considered:

- What incentives would attract and retain knowledge users in the co-production of knowledge to accelerate research implementation?
- What timescales are necessary to address research priorities and how does this timescale mesh with partnership expectations?
- How do research impacts serve both knowledge producers and knowledge users?

[2] FPInnovations Mission, https://fpinnovations.ca/about-us/Pages/mission-vision-values.aspx, date accessed 19 June 2015.

[3] Sentinel Bioactive Paper Network, http://www.bioactivepaper.com/about-us/, date accessed 19 June 2015.

4.5. Funding model

We found great diversity in the funding models used by research networks and, in fact, no two networks were funded in exactly the same way. The funding model adopted by a network is not neutral, particularly in relation to the contributions of partners and clients and the role that they will have in network governance. As Hickey (2013) concluded after an international review, publically-funded research is increasingly adopting collaborative models, providing a greater role for stakeholders in research planning and evaluation indicators that consider productivity and policy impact. Most networks analyzed receive funding from government, industry and other partners, while only a few (e.g. CRFU) are funded entirely by voluntary dues or donations. It is difficult to ascertain the proportion of funding obtained from various sources as most networks do not provide complete details on sources in amounts in their publically available reports, possibly as budget information may be considered as confidential. We consider that the diversity of funding models used by research networks is best represented as a spectrum of possibilities within which each network situates itself in relation to the capacities and expectations of partners.

A basic characteristic of funding arrangements for research networks is the relative balance between funds from social partners and those from commercial partners. Governments have long been a primary source of finance for "fundamental" research, while private industry has traditionally focused upon development or upon application. However, almost all networks analyzed here call upon both governments and private companies (with some industry associations). It should also be noted that implementation activities are often carried out within private enterprise and so costs associated with these are less visible than the research or transfer activities that may be undertaken by the network. The distinction between social and commercial partners must also be broken down into several possibilities. Although governments are major funders of universities, traditions of academic independence and domains of competence and expertise make researchers an actor in their own right. Non-government organizations, and other civil society actors, are also increasingly to be found in networks – seeking to promote knowledge in areas of concern to them. Environmental NGOs and indigenous peoples organizations both partnered in the SFMN, making financial and in-kind contributions and being a user/implementer of knowledge products. Among commercial partners, some networks use a membership system whereby the benefits of the network are available to all members, while others (such as FPInnovations) complement this with a fee-for-service approach whereby members also have the option of financing specific research over which they will have particular rights.

4.6. Research capacity

The presence or absence of "in-house" research capacity is highly dependent on the origins and nature of the research network. Research networks that depend principally on government funding typically, have little in-house capacity, focusing instead on collaboration with academic and industry researchers to produce knowledge. In this respect, they exhibit an open innovation approach. Some government-funded networks may exist primarily to connect and fund government researchers, such as CNFER, Alberta Innovates Bio Solutions, Scion. In knowledge extension networks such as CERFO and CEDFOB, in-house capacity is often concentrated on transfer and application activities, rather than on research. International research networks such as CIFOR and InnovaWood may have large in-house science capacity but also collaborate with other knowledge producers.

Typically, forest research networks involving universities and industry have two mandates: 1) addressing the research priorities of funding agencies; 2) responding to the most pressing needs of their partners, which means that they are expected to produce and mobilize research for application within a relatively short timeframe. However, although forest research networks are focused on achieving these short-term goals, these goals may be embedded into a longer-term, broader vision of innovation in the forest sector. Hence, forest research networks typically assess their strategic plans periodically with the objective of eliciting and responding to the needs of their partners and concomitantly searching for and facilitating potential new avenues for innovation. Many forest research networks explicitly seek to build a culture of applied research and innovation and thus require a design that will enable them to produce knowledge for a context of application while at the same time build upon past and ongoing research and practice to signal when and how innovation might be spurred.

Innovation thus occurs in a broader setting than just the research institute. Recognizing this means that research priorities and design can take account of socio-economic and political factors or issues (Di Matteo et al., 2015). A network that builds links with this broader context is also better equipped to identify new and changing needs or demands that could potentially be translated into commercial opportunities. Detecting these signals is an activity associated with developing network 'search' capability for innovation (Laursen and Salter, 2004), 'network competence' (Ritter and Gemunden, 2003) and essential qualities of effective knowledge brokering (Phipps and Morton, 2013). But before such competencies and skills can be honed, one must know what innovation channels the research network can and should focus on (Linder et al., 2003).

4.7. Scope of research

Similarly to forest research institutes in Europe (Di Matteo et al., 2015), most of the research networks we analyzed have a fairly broad scope of research, representing the interests of partners and covering forest management, forest planning, forest operations, forest products development and decision-analysis tools. Traditional forestry disciplines are well represented, with silviculture, forest ecology, harvesting, forest operations, forest regeneration, tree improvement, forest inventory, wood processing, wildlife habitat and biodiversity conservation being common. A variety of non-traditional topics are also appearing, representing both innovative developments in traditional fields and the human dimensions of forestry. The first category includes bioenergy, value-chain analysis, nano products, new forest products and climate change adaptation and mitigation. The second category covers issues such as Indigenous forestry, non-timber products, social aspects of forest management and forest policy and governance. Interestingly, the international networks appear to cover both traditional forestry disciplines and the human dimensions of forest resource management, while most of the Canadian research networks focus on traditional forestry concerns and innovation in forest products. IUFRO uses a diversified model of working divisions and groups, providing a forum for individual researchers to collaborate on emerging themes that may not attract interest or support within the researchers own organization. The potential for research networks to target emerging or politically salient research is enormous, as demonstrated by the SFMN's role in facilitating greater engagement of Aboriginal peoples in forest-related research through targeting funding and K* activities (Klenk et al., 2011a). Lastly, while most Canadian networks limit their activities to the forest sector, FORREX and Alberta Innovations Bio Solutions also work in other sectors. There is a clear link here between partnership models and scope of research, which gives rise to important strategic questions for effective knowledge mobilization:

- Who should be involved in setting research agendas?
- To what extent and how often are research priorities revisited?

5. Conclusion

Our comparative analysis of forest research networks indicates the emergence and strengthening of a new model of knowledge co-

production involving knowledge producers and users, with the goal of fostering innovation and addressing challenges facing the forest sector. This model differs significantly from traditional university-based research. Whereas university-based research is governed by the incentive structures of academia and funding councils (e.g., peer-review articles, presentation at conferences, highly trained personnel), forest research networks are generally governed by the needs of their partners and thus embody a reflexive and responsive problem solving orientation. However, effective movement towards this model requires attention to design and to management, particularly in relation to the expectations of partners (both university and non-university) who are used to traditional models.

In the short-term, the objective of producing applied research requires that forest research networks engage in knowledge mobilization functions, rather than concentrating upon research functions. As summarized in Table 1, K* functions reflect the need to create opportunities for researchers and knowledge users to be in contact on a regular basis, to keep abreast of research development and the assessment of research results and applications. Useful K* tools include developing an informative website, engaging in information sharing activities conducted in person or through multi-media, using demonstration sites, providing tailored research outputs (e.g., briefs, reports, academic papers) and giving training sessions. Human resources should be allocated the tasks of assessing the current state of knowledge (e.g., scoping and information gathering), building rapport with potential knowledge users (e.g., brokering) and translating research results for a context of application. Whether and how to involve knowledge users in knowledge production upstream of the research process to facilitate knowledge mobilization should be considered in light of partners' expectations, needs and capacities. The level of engagement with partners reflected in these K* functions is tightly knit to make sure knowledge production responds to the needs of partners, and that knowledge produced is communicated to and used by partners.

The longer-term objective of facilitating new avenues for innovation in the forest sector requires a different knowledge mobilization strategy that entails a level of engagement with partners that is creative and transformative rather than mainly informative. Building an organizational culture of innovation requires a different approach to producing applied research, although many of the same network competence skills are required (Table 2). First, an effective knowledge mobilization strategy must consider building knowledge users' capacity to use research and this can be done by engaging in the co-production of knowledge: "Creating a culture of research use within organizations (both research and policy/practice organizations) can help support the collective and embedded nature of the links between research and decision-making" (Phipps et al., 2012:172). Second, to build capacity in innovation, forest research networks should establish dedicated channels of intra-organization communication to facilitate the exchange of ideas, learning and institutional memory based on partners' shared experienced—here effective knowledge brokering skills will be critical (Phipps and Morton, 2013). That is, open innovation requires facilitating connections between current knowledge and experience in a *creative way* for new solutions or opportunities to happen. Hence, it is critical to bring together people from different organizational settings, expertise and experiential backgrounds. Third, forest research networks must develop core competencies in "networking" to building relationships with partners and potential knowledge users (Strauss et al., 2011).

If networks are to be effective in both these short and long term objectives, they should foster openness by establishing transparent and responsive organizational processes. Although such policies may exist and be available to partners, we found relatively little information available on the processes of transparency, accountability and conflict resolution within the websites of the networks we compared. Establishing clear roles and consistent channels of communications is imperative to facilitate the efficient and effective management of the network and manage partners' expectations, regardless of the partnership model. Although results of this comparative analysis builds upon a recent systematic assessment of a public-private research network in Canada, the Sustainable Forest Management Network (1995–2009), validating our comparative analysis would require further in-depth case studies of other public-private research networks in different social, cultural and economic contexts.

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Appendix A. Supplementary data

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