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Climate change and Ontario forests: Prospects for building institutional adaptive capacity

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Abstract Institutions play an important role in the adaptive capacity of a system in responding to climate change. This review paper characterizes the status of the collective institutional response (government, industry, First Nation, community, civil society) to climate change in the forest sector of the Canadian province of Ontario, and highlights the presence and nature of inter-institutional networks as part of the response. Based on a synthesis of the commonalities in the public administration and policy literature on tackling wicked problems, and the resilience literature, inter-institutional networks, which foster exchange of different types of knowledge, are an important aspect of enhancing the adaptive capacity of social–ecological systems such as the forest sector. Based on a content analysis of publicly available documents and insights gained from representatives of government, community members and non-governmental organizations, mitigation and adaptations strategies are described. At the provincial level there have been some new innovations in inter-institutional networks, but expansion of the forest stakeholders involved in such networks would further enhance adaptive capacity. In particular, it is important to network with First Nations and other forest-dependent communities who have a heightened vulnerability to climate change. The presence of a collaborative capacity builder could foster the transfer, receipt and integration of knowledge across the networks, and ultimately build long-term collaborative problem-solving capacity in the Ontario forest sector.

Keywords Climate change · Forest sector · Canada · Ontario · Institutions · Adaptive capacity

In Canada, the Constitution Act of 1982 specifies that the Aboriginal Peoples in Canada consist of three groups—Indians, Inuit and Métis. However, the term First Nations is now more commonly used to replace Indian, which some people found offensive. Despite its widespread use, there is no legal definition of the term, First Nations, in Canada (Assembly of First Nations 2009).

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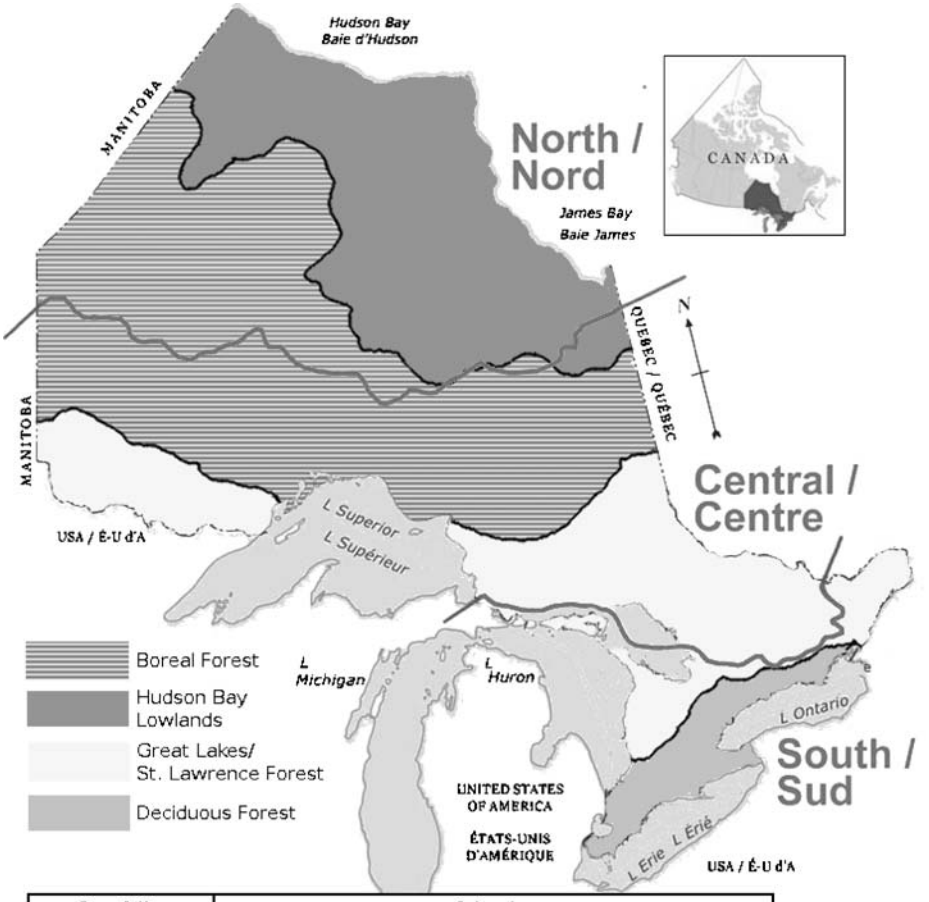
1 Introduction

The role of forest ecosystems in the global carbon cycle has gained more prominence with the world's concern about a changing climate. The now unequivocal evidence of increasing global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level are attributed to an observed increase in anthropogenic greenhouse gas concentrations; carbon dioxide, methane and nitrous oxide (Intergovernmental Panel on Climate Change (IPCC) 2007). Forest ecosystems influence the global climate as major contributors to the terrestrial carbon sink which absorbs about 30% of all CO_2 emissions every year and additionally stores large reservoirs of carbon (Canadell and Raupach 2008). While playing a role in mitigation, forests are also expected to face significant pressure from climate change over the next century. This will potentially disrupt the important ecological, economic, social, and aesthetic services that forests provide to natural systems and humankind (Bonan 2008; Eastaugh 2008).

Canada contains more than 400 million hectares of forested land, which accounts for almost half of its total landmass and approximately one-tenth of the world's total forest cover (Minister of Natural Resources 2007; Lemmen and Warren 2004). Forty percent of the world's boreal forests cover 58% of Canada's land area and form a vital component of the country's economy and culture (Lemmen and Warren 2004; Minister of Natural Resources 2007; Burton et al. 2003). With an area of 50 million hectares, the province of Ontario contains the largest portion of the boreal forest, representing two thirds of all its forest (Fig. 1) (Ontario Ministry of Natural Resources 2008b). The forest industry is an important part of the provincial economy, employing 66,800 people and generating $18.3 billion from manufactured wood products (Natural Resources Canada 2008b). Additionally, people in 260 communities owe their livelihood to Ontario's forests, through employment in forest-based tourism businesses, fishing and hunting, equipment manufacturing, transportation, trapping and retail and service industries (Ontario Ministry of Natural Resources 2008e). Some feel the boreal forest may face more dramatic climate change because of its northern continental interior location (Johnston and Williamson 2007; Ogden and Innes 2007; Intergovernmental Panel on Climate Change (IPCC) 2007). The vulnerability of such an important social–ecological system to climate change underscores the importance of searching for ways to enhance strategies for mitigation and adaptation and to build the adaptive capacity of the overall system.

In social–ecological systems, the existence of institutions and networks that learn and store knowledge and experience, create flexibility in problem solving and balance power among interest groups, play an important role in adaptive capacity (Tompkins and Adger 2004; Walker et al. 2006). Furthermore, institutions that fail to plan for changing environmental conditions and risks, constrain adaptive capacity and increase vulnerability (Adger and Vincent 2005). McKinnon and Webber (2005) feel that Canada's ability to effectively adapt to climate change in forests will depend on the institutional capacity and flexibility of management agencies, industry, academia, First Nations, individual communities and stakeholder groups. Using the Ontario forest sector as a case study, this review paper characterizes the status of the collective institutional response (government, industry, First Nation, community, civil society) to climate change.

After summarizing the potential ecological and social impacts of climate change in Ontario forests, this paper reviews the literature on vulnerability and adaptation and discusses the important role of institutions in enhancing climate change response. Then, important principles related to adaptive capacity of social–ecological systems are outlined,



Cumulative stresses/region	Subregion		
	North	Central	South
Fire	Present to 20 years	Present to 20 years	No significant impact expected
Pests and Disease	20 to 50 years	20 to 50 years	No significant impact expected

Fig. 1 Map of Ontario forests showing areas of expected stress from climate change. Adapted from (Lemmen et al. 2008) and (Ontario Ministry of Natural Resources 2009)

based on a synthesis of the commonalities in the public administration and policy literature on tackling wicked problems, and the resilience literature. These principles emphasize the importance of inter-institutional networks, which foster exchange of different types of knowledge, in enhancing the capacity of a system to adapt to change. Next, based on a content analysis of publicly available documents, both print and web based, and insights gained from representatives of government, community members and non-governmental organizations, the mitigation and adaptation responses of the various institutions are described. The presence and nature of inter-institutional networks as part of the response is also highlighted. The paper concludes with a discussion of the results and suggests opportunities for building adaptive capacity to climate change within the Ontario forest sector.

2 Forests and climate change

Climate change has the potential to affect the future health of Canada's forest ecosystem in a variety of ways, with the main variables being temperature, precipitation and wind (Duinker 2008). Forests dynamics are typically characterized by natural disturbances from fire, insects, storms and wildlife as well as anthropogenic disturbances due to land use and natural resource management (Wulder et al. 2007; Soja et al. 2007). However, with a changing climate many of the natural disturbances are predicted to increase in magnitude. General agreement now exists that under current climate change scenarios, fire frequency and area burned in boreal regions are expected to increase, although there will be spatial and temporal variation (Soja et al. 2007; Flannigan et al. 2005a). Researchers have already established that forest fires increased significantly over the last 40 years in Canada despite concurrent increases in suppression capacity (Duinker 2008). Flannigan et al. (2005b) project that on average, area burned in Canada will increase by 74 to 118% by the end of this century in a $3\times CO_2$ scenario with consequent ecological, economic and social impacts. Specifically, boreal climate change is expected to result in increased ignitions from lightning, increased fire season length, and increased fire weather severity (Soja et al. 2007).

In Ontario, the total number of fires occurring is expected to increase 15% by 2040 and 50% by the end of the century. This is a result of changes in temperature and precipitation which will lead to an increase in the number of lightning and people-caused fires (Wotton et al. 2005). The increased fire load is expected to increase the cost of fire management in the province by at least 16% by the year 2040 and 54% by 2090. The forest products industry will also potentially be affected by increased fire disturbance resulting in a reduced quantity of wood. Fire incidence will also have an effect on forest-dependent communities in the short term through risk to life and property, and in the longer term through its effects on the supply of forest products, including both subsistence and commercial products (Browne and Hunt 2007; Soja et al. 2007; Davidson et al. 2003).

Insect disturbances can also have a large impact on forests and are becoming more prevalent and increasing in intensity with a changing climate, resulting in outbreaks by resident insect species and invasion by exotics. Wulder et al. (2007) document that in 2004, the total area of forest defoliated by insects or killed by beetles in Canada was estimated at 13.1 million ha. In the western province of British Columbia, outbreaks of Mountain Pine Beetle are estimated to kill 80% of the province's pine volume by 2013 (Wulder et al. 2007; Duinker 2008). Such outbreaks threaten the long-term viability of the forestry sector and sector dependent communities (Parkins and MacKendrick 2007). The Mountain Pine Beetle has expanded into areas that have no previous record of infestation and concerns have been raised that it will spread into jack pine forests in the boreal forest and spread eastward (Johnston et al. 2006; Wulder et al. 2007). In Ontario, an increase in the incidence of disease and insect infestation from such species as the spruce bud worm, is expected to result in an increased cost of producing forest products (Browne and Hunt 2007). Such insect outbreaks also may undermine the ability of northern forests to take up and store atmospheric carbon (Kurz et al. 2008).

Extreme weather events are likely to increase with climate change, including increased precipitation intensity, increased frequency, duration and intensity of drought, increased frequency and intensity of summer heat waves, abnormally warm winters, increased frequency and intensity of severe thunderstorms, windstorms, ice storms and hurricanes (Duinker 2008; Johnston et al. 2006). The impact of extreme weather was dramatically demonstrated by the 1998 ice storm that hit eastern Ontario and other parts of eastern Canada. Long term economic impacts have been evident in the maple sugar industry as well as other parts of the

sector (Lemmen and Warren 2004). Sohngen and Sedjo (2005) state that such an increase in natural disturbances will impact on the forest product markets globally.

Climate change is also expected to have an impact on ecosystem composition, structure and function. Some subalpine, alpine and boreal forest ecosystems are expected to disappear completely and be replaced by novel configurations (Gray 2005; Soja et al. 2007; Wulder et al. 2007). In the long term, climate change will alter the amount, quality and type of wood fiber available. On a provincial scale in Ontario, the supply of traditional forest products is expected to decline with a consequent impact on the forest industry and forest-dependent communities (Browne and Hunt 2007). Climate change also threatens existing protected areas which are designed to represent specific natural features, species and ecological communities (Scott and Lemieux 2005). Besides the effect on biodiversity conservation, such changes can affect nature-based tourism and recreation (Browne and Hunt 2007).

3 Vulnerability and adaptation

Within the climate change literature, the vulnerability of any system, such as the Ontario forest sector, is reflective of (or a function of) the exposure and sensitivity of that system to hazardous conditions and the ability or capacity or resilience of the system to cope, adapt or recover from the effect of those conditions (Smit and Wandel 2006; Smit and Pilifosova 2003; Adger 2006). This has been summarized as $V = f(\mathrm{E}, \mathrm{S}, \mathrm{A})$ where V is vulnerability of the system of interest, E is exposure, S is system sensitivity and A is adaptive capacity. The relationship between E, S and A varies depending on local circumstances, however, V is a positive function of the system's exposure and sensitivity and a negative function of the system's adaptive capacity (Ford and Smit 2004).

In their examination of the vulnerability of the Canadian forestry sector, Johnston and Williamson (2007) emphasize that climate variability and change will affect the full range of forest-based values so that assessment of levels of vulnerability will vary according to specific contexts (e.g. forest management agreement areas, forest-based communities or protected areas). Risk and uncertainty associated with forest management will increase significantly, an area that forest science and management has not historically addressed, but which carries significant socioeconomic consequences. Climate change impacts on forest management may be both negative and positive and so it is important to understand where opportunities might exist while reducing negative impacts (Ogden and Innes 2007).

Vulnerability in forests, however, comes from factors other than climate change and therefore, it is important to understand how they affect the vulnerability of the overall system (Johnston and Williamson 2007). Keskitalo (2008) emphasizes that in studying climate change it is important to view the overall impact of concurrent changes, such as broad socioeconomic changes or globalization, for they will impact communities and their overall vulnerability and possibly increase their vulnerability to climatic change. Market trends and globalization have had an impact on the Canadian forest sector leading to loss of employment in the industry. Additionally, factors such as land cover and land use changes, as a result of both human activities and natural processes, influence the vulnerability of the system (Williamson et al. 2007; Lemmen et al. 2008).

Adaptive capacity refers to the potential or capability of a system to adjust to and thereby limit risk (Adger 2003). It is similar to other commonly used concepts such as adaptability, coping ability, management capacity, stability, robustness, flexibility and resilience (Smit and Wandel 2006). It is a vector of resources and assets that represent the

asset base from which adaptation actions and investments can be made (Adger and Vincent 2005). Some determinants of adaptive capacity are mainly local while others reflect more general socio-economic and political systems. They include economic wealth, technology, information and skills, infrastructure, institutions, social capital and equity (Smit and Pilifosova 2001, 2003). These determinants are closely interconnected and important to consider when examining strategies to enhance the capacity of a system to adapt to climate change.

While considered to be a determinant of adaptive capacity in relation to climate change, institutions have long been identified as a key part of governing human interaction with a changing environment. Broadly defined, institutions are the prescriptions that humans use to organize all forms of repetitive and structured interactions (Ostrom 2005). Institutions apply both to structures of power and relationships as found in organizations with leaders, membership, resources and knowledge, and to socialized ways of looking at the world as shaped by communication, culturally ascribed values, and patterns of status and association (O'Riordan and Jordan 1999). According to Adger (2000), the institutions of the state, market, and civil organizations are major determinants of collective security, social vulnerability, and environment and resource allocation.

In social–ecological systems, the existence of institutions and networks that learn and store knowledge and experience, create flexibility in problem solving and balance power among interest groups, play an important role in adaptive capacity (Tompkins and Adger 2004; Walker et al. 2006). Furthermore, institutions that fail to plan for changing environmental conditions and risks, constrain adaptive capacity and increase vulnerability (Adger and Vincent 2005). Adaptive capacity is reflected in the adaptations or changes in a system to better deal with problematic exposures and sensitivities (Smit and Wandel 2006). Adaptation to climate change can be either anticipatory or reactive or given that the effects of climate change are already being observed in some areas, concurrent with those changes (Smit et al. 1999; Lemmen et al. 2008). Given the diversity of impacts of climate change, often the most appropriate adaptation responses will be multilevel responses (Adger 2003).

The role of institutions in adapting to climate change has also been identified in the forestry sector in Canada. In particular, Johnston and Williamson (2007), state that its ability to adapt is defined by factors such as the flexibility and efficiency of institutions and policy, as well as the distribution and availability of financial resources, technological capacity and human capital. Other important factors include knowledge and awareness of potential impacts, social networks, trust, isolation, infrastructure quality and perception of climate risk (Johnston and Williamson 2007). McKinnon and Webber (2005) feel that Canada's ability to effectively adapt to climate change in forests will depend on the institutional capacity and flexibility of management agencies, industry, academia, First Nations, individual communities and stakeholder groups.

4 Building adaptive capacity to change

Building adaptive capacity to change in social–ecological systems is a common theme across disciplines. This is particularly prominent in the literature on 'resilience' in complex systems. A complex system is characterized by being nonlinear with inherent uncertainty, containing many subsystems and being capable of self-organization. Resilience is considered to be an emergent property of such a system (Berkes et al. 2003). According to Walker et al. (2006), resilience is the capacity of a system to re-organize while undergoing change so as to still retain essentially the same function, structure, identity and

feedbacks. It does not refer just to being persistent or robust to disturbance. It is also about the opportunities that disturbance opens up in terms of recombination of evolved structure and processes, renewal of the system and emergence of new trajectories (Folke 2006). Four critical factors are seen as being necessary for building resilience and adaptive capacity in social–ecological systems in the context of change. These four factors, which interact across temporal and spatial scales are: learning to live with change and uncertainty, nurturing diversity for reorganization and renewal, combining different types of knowledge for learning and creating opportunity for self-organization toward social–ecological sustainability (Folke et al. 2003).

While using different terminology, the theory around strategies to building resilience and adaptive capacity in complex systems has overlaps with approaches in public administration and policy research circles to addressing 'wicked problems'. The term 'wicked problems' emerged from a recognition of the dynamic complexity of many public problems that defied the confines of established 'stovepiped' systems of problem definition, administration, and resolution (Rittel and Webber 1973; Weber and Khademian 2008). Wicked problems are considered to be unstructured so that causes and effects are extremely difficult to identify and model, thus adding complexity and uncertainty. Furthermore, the wicked problem space comprises multiple, overlapping, interconnected subsets of problems that cut across multiple policy domains and levels of government. This cross-cutting characteristic means that wicked problems are inescapably connected to other problems. Wicked problems are also relentless so that they cannot be solved once and for all (Weber and Khademian 2008).

A network approach is often argued to be the best approach to management of wicked problems where diverse actors from government bureaucracies, differing sectors and members of the public come together to share resources and knowledge (Kickert et al. 1997). Weber and Khademian (2008) argue that any effort to effectively manage a wicked problem will require effort to draw on a broad range of knowledge from the technical to the local, from within the network and without. New knowledge must also be developed to address the complexities of the wicked problem and to serve as a premise for cooperation, not command and control. Furthermore, they emphasize the importance of a collaborative capacity builder to aid the continuous transfer, receipt and integration of knowledge for long-term problem-solving capacity.

While the concept of forest management as a wicked problem has been discussed in the last two decades (Allen and Gould 1986; Wang 2002; Carroll et al. 2007), it is only recently that it has been applied in addressing the reality of climate change and forests (Chapin et al. 2008). Resilience, however, is often referred to in the climate change literature with discussion about its links with adaptive capacity to reduce system vulnerability (Folke 2006; Smit and Wandel 2006; Gallopin 2006). In the search for pathways to enhance adaptive capacity in a social–ecological system such as the forestry sector, the commonalities shared by these two approaches elucidate important principles. Key to both approaches is the recognition of uncertainty and change in a system that is multidimensional in nature. Therefore, new institutional arrangements that foster learning and continuous exchange of different types and sources of knowledge across scales are important.

In the following sections of the paper the institutional configuration of the Ontario forest sector is characterized, keeping in mind the essential elements of the resilience and wicked perspectives. Initially, the responses of the component institutions to climate change are described. Responses to climate change can be categorized as either mitigation or adaptation (Lemmen et al. 2008). Mitigation responses are anthropogenic interventions

which seek to reduce the sources or enhance the sink of greenhouse gases (Lemmen et al. 2008; Intergovernmental Panel on Climate Change (IPCC) 2001). Adaptation to climate change refers to any modification in natural or human systems made in response to a changing climate. It involves making adjustments in decision-making, activities and thinking because of observed or expected changes in climate, with the goals of moderating harm or taking advantage of new opportunities (Lemmen et al. 2008; Intergovernmental Panel on Climate Change (IPCC) 2001). The presence and nature of inter-institutional networks, developed as part of the institutional response to climate change, are highlighted. Their composition, as well as the opportunities they present for cross-scale exchange of different types of knowledge, is described. By characterizing the system in aggregate, rather than ranking specific responses of its component parts, information is obtained concerning the institutional adaptive capacity of the forest sector as a whole. Opportunities for enhancing that adaptive capacity, in light of the important principles derived from the resilience and wicked literature, are discussed.

5 Institutional response: mitigation and adaptation

5.1 Government

It is generally held that established institutions in developed countries facilitate the management of climate related risks and provide the institutional capacity to help deal with future risks and adaptation to climate change (Smit and Pilifosova 2001; Intergovernmental Panel on Climate Change (IPCC) 2001). Adaptive capacity to climate change nationally, and in the province of Ontario, in particular, is considered to be high due to Canada's prosperity, high levels of education, access to technology and its strong and effective institutions (Lemmen et al. 2008). Forest management is the domain of the federal and provincial or territorial governments,[1] and these established institutions have a key role to play in facilitating a response to climate change in the forest sector. Over 90% of forests in Canada are publicly owned, Crown forests, with 77% being under provincial or territorial jurisdiction (Minister of Natural Resources 2007). However, the roles of the two levels of government differ. Provinces and territories have the authority to make laws governing the development, conservation, and management of forest resources and to develop their own set of legislation, regulations, standards, and programs. The federal government is responsible for external affairs, including trade, commerce, treaties and conventions. Responsibilities in Aboriginal and environmental affairs are shared by the provincial and federal governments (Canadian Council of Forest Ministers 2008b; Duinker 2002; Ontario Ministry of Natural Resources 2006b).

The Canadian Council of Forest Ministers provides a forum for the federal, provincial and territorial governments responsible for forests, to work cooperatively to address national and international issues and set direction for sustainable management of Canada's forests (Canadian Council of Forest Ministers 2008a). Their latest document on Canadian forest strategy "A Vision for Canada's Forests 2008 and Beyond", which is intended to have a 10-year term, identifies two priorities: transforming the forest sector, particularly through development of a new bioeconomy, and mitigating and adapting to climate change (Canadian Council of Forest Ministers 2008b). To achieve this vision, the need for active

[1] Canada is made up of ten provinces and three territories (Canadian Encyclopedia 2009).

participation and the building of networks among stakeholders is emphasized, which is an important aspect of building adaptive capacity in the sector.

5.1.1 Federal government

While under heavy criticism from environmentalists, the media and academics for lack of effective action on climate change (Simpson et al. 2007; David Suzuki Foundation 2008; Winfield 2008), the federal government has responded at the level of policy and with investment in research. In 2007, they developed a regulatory framework to reduce greenhouse gases and air pollution with compliance tools, including an emissions trading system with offsets and access to the Clean Development Mechanism and a technology fund (Drexhage et al. 2008). While many research projects on climate change have received federal funding, the most comprehensive document in this area, covering all regions and sectors, was published in 2008 (Lemmen et al. 2008).

Forests at the federal level are the purview of Natural Resources Canada and the Canadian Forest Service (CFS), in particular. A key part of climate change action at CFS has been the development of a Carbon Budget Model, in cooperation with their provincial and territorial counterparts (Natural Resources Canada 2006). This model serves to monitor past forest carbon stocks and changes in carbon stocks and predict those stocks in the future through incorporation of the forest inventory, growth and yield data, statistics on natural disturbance (fire and insects), land-use change (afforestation, reforestation, deforestation) and forest-management activities (Natural Resources Canada 2006). On the basis of this model, the government decided not to include forest management in Canada's Kyoto accounting since analysis suggested that there was a 90% chance of the forests being a net carbon source in 2008–2012 (Natural Resources Canada 2007a; Drexhage et al. 2008).

The federal report on the State of the Forest outlined a commitment to mitigating climate change through reducing carbon emissions or increasing sinks through actions such as managing forest fire, protecting against insects, reducing deforestation and managing forests and forest products to lower the human impact on carbon (Minister of Natural Resources 2007, 2008). Climate change in forests has had its most dramatic impact in western Canada with the Mountain Pine Beetle (MPB) infestation (Wulder et al. 2007; Kurz et al. 2008). Consequently the federal government has responded with investment in a MPB program to help assess the risk, control its spread and mitigate its impact (Minister of Natural Resources 2007, 2008; Natural Resources Canada 2007b). The reports also state a commitment to adapting to climate change, based on scientific research, through understanding and preparing for its impacts at the operational, planning and strategic levels. The importance of strong human networks within and between organizations, and high levels of trust between people is cited as an important aspect of adapting to climate change (Minister of Natural Resources 2007, 2008). Such an emphasis is consistent with the important principles for building adaptive capacity.

Another aspect of adaptation identified, is the new federal Forest Communities Program (FCP) which funds 11 sites across Canada, including two in Ontario, for 5 years and empowers forest-dependent communities to integrate a changing forest base into their local economies (Minister of Natural Resources 2007; Natural Resources Canada 2008a). This program is patterned on the success of the Model Forest Program which began in 1992 and ended in 2007.[2] Given that a rapidly changing climate has important implications for the

[2] Aspects of the Model Forests and FCP in Ontario in relation to climate change will be outlined further in the section on forest-dependent communities.

more than 300 communities whose livelihood is closely associated with forests, CFS researchers have also developed a framework for assessing the vulnerability of forest-based communities to climate change (Williamson et al. 2007). A federally funded program has also produced a general guide to introduce local level or municipal governments to adaptation to risks associated with climate change, such as an increase in forest fires (Mehdi 2006).

5.1.2 Provincial government

At the provincial level, the response of the government of Ontario to climate change is primarily characterized by a response at the level of policy, which has been coupled with investment in research. The key policy defining the response is outlined in the *Go Green* booklet, which contains a five-point action plan to reduce greenhouse gas emissions and seek ways to adapt to climate change (Ontario Office of the Premier 2007). Such measures include promotion of renewable energy and conservation, investments in improved transit systems, support of "green" technology for business, and the planting of 50 million trees in southern Ontario by 2020. A key part of the plan was the establishment of an advisory Expert Panel on Climate Change Adaptation whose members come from universities, environmental organizations, industry and Aboriginal groups (Ontario Ministry of the Environment 2008). Such a diverse inter-institutional panel provides opportunities for the continuous exchange of knowledge, which is an essential part of enhancing adaptive capacity from both the resilience and wicked problem perspectives, as outlined above. The Ontario government has also pledged to protect more than 225,000 square kms of the Northern Boreal Lands, one of the world's largest intact ecosystems, as a carbon sink and for protection of biodiversity (Ontario Office of the Premier 2008b). Additionally, the province joined with the province of Quebec to develop a regional cap-and-trade system for green house gas emissions and in July 2008, joined the Western Climate Initiative, a group of Canadian provinces and American states working together to find regional solutions to climate change (Ontario Office of the Premier 2008a).

While government response to climate change is being carried out through both the Ministry of Environment and the Ministry of Natural Resources (MNR), it is primarily MNR that is implicated in responses that affect forest ecosystems. Among their mandated activities that directly relate to forests are forest management, fish and wildlife management, lands and water management, Ontario Parks and protected areas, forest fire management as well as the technical and administration support needed for all these activities (Ontario Ministry of Natural Resources 2005). Under the auspices of Goal #1 (Healthy Natural Environment for Ontarians) in their strategic plan, *Our Sustainable Future*, MNR states that their response to climate change will be "strategic, adaptive, and based on sound science". Its three themes are to understand the impacts of climate change, mitigate the impacts where they can and help Ontarians to adapt to climate change (Ontario Ministry of Natural Resources 2006a, 2007).

A research emphasis characterizes MNR's progress in addressing the three themes of their climate change program.[3] In seeking to understand climate change, MNR scientists in collaboration with other partners, have conducted many studies on climate modeling and the response of various ecosystems to the effects of climate change. In forest ecosystems, an emphasis was placed on the development of a forest Carbon Budget Model to provide a

[3] Please see MNR web site for a complete list of research publications. http://www.mnr.gov.on.ca/en/Publication/index.html

quantitative assessment of the exchange of carbon between forests and the atmosphere, thus indicating if forests are a source of or a sink for greenhouse gases. Future modeling efforts will seek to incorporate life cycle analysis into its forest carbon accounting program by describing the storage of carbon in wood products, carbon emissions resulting from harvesting, manufacturing and transportation and avoided emissions when wood replaces fossil fuels or is used to replace more highly energy intensive building materials (Ontario Ministry of Natural Resources 2007). Research on this model is also being applied to identifying forest management options for optimizing carbon storage and opportunities for carbon trading in order to mitigate the impacts of climate change, MNR's second theme.

Under the theme of helping Ontarians to adapt, research is being conducted in collaboration with the Canadian Forest Service, to develop adaptation strategies for integration into the forest management planning process (Ontario Ministry of Natural Resources 2007; Colombo et al. 2005). While still the principal forest management planning tool in Ontario, the Strategic Forest Management Model, lacks the flexibility needed to take into account the change to forests that will gradually happen as the century progresses. While research continues on modifications to that model, the latest annual report on forest management submitted to the Ontario provincial parliament acknowledged the need to deal with the reality of forest management, in light of climate change (Ontario Ministry of Natural Resources 2008a). In particular, the increasing risk of natural disturbances was highlighted, such as blow down, fire and insect infestations. Research and monitoring continues in that area (Ontario Ministry of Natural Resources 2007; Langor et al. 2007).

The principal means of communicating research results is through the government web site where documents related to climate change, including forests, are publicly available. Reports are also provided to the Expert Advisory Panel. Beyond communicating the results of research to the public through the web site, MNR presently uses an informal approach to communicating this knowledge with stakeholders. Occasionally, meetings are held with municipalities, First Nations or other interested groups to stimulate thinking surrounding the potential effects of climate change (C-CIARN 2002). For example, a number of MNR staff did presentations at the Ontario Professional Foresters Annual General Meeting in April 2008 which had as its theme "Forestry: A Changing Climate". Government representatives expect that with the recent announcement of protection of the northern boreal region and the Far North Planning Process such meetings will increase. However, at the present time there appears to be no opportunity for continuous cross-scale interaction on the issues of climate change and the forest sector—something which would contribute significantly to increasing adaptive capacity from both the resilience and wicked problem perspectives.

5.2 First Nations

In Canada, many First Nations peoples live in the regions that are the most vulnerable to climate change impact; the north, the boreal forest, and along lakes and other waterways (Centre for Indigenous Environmental Resources 2008). They are the first to experience the devastating impact of climate change, including poor hunting, fishing and gathering, loss of land, threatened food security, increased risk of respiratory illness and, infectious disease and potential and real economic and cultural displacement (Assembly of First Nations 2008b). Recent risk assessments on the impact of climate change on Aboriginal communities identified impacts on traditional food supplies, increased risk of forest fires and impacts on infrastructure, including reduced winter road access and declining water

quality (Lemmen et al. 2008). In Ontario, the cultural, spiritual, social and economic well-being of many First Nations is dependent on a healthy forest ecosystem. Therefore, changes in forests as a result of climate change will have far reaching impacts.

At the national level, the Assembly of First Nations (AFN), the representative organization of the over 630 First Nations communities in Canada, has responded to the reality of climate change first of all by urging the federal government to take immediate action to meet the *Kyoto Protocol* targets and to support timely and adequate means to respond to the impact of climate change (Assembly of First Nations 2008b). AFN pledged its support to assist in this effort, citing the importance of First Nation traditional knowledge as a strategic component. Additionally, their response has focused on building capacity, supporting integration and addressing issues of jurisdiction (Assembly of First Nations 2008b).

The AFN Climate Change program has as objectives to support First Nations climate change, renewable energy and energy efficient projects, activities and research at the national, regional and community level; raise awareness of climate change and potential impact and adaptation in First Nations communities in southern and northern Canada; facilitate increased response of First Nations communities to climate change; strengthen First Nations regional and community environmental networks and facilitate integration and better coordination between federal departments on First Nations climate change issues (Assembly of First Nations 2008b). To this end, the AFN hosted a workshop on climate change impacts and adaptation in 2005 and climate change was an agenda item for the 2008 Annual General Assembly (Assembly of First Nations 2008a). The National Aboriginal Forestry Association (NAFA), while concerned about the effects of climate change in forests, has not had the resources to respond to the issue in a meaningful way.

At the local level, First Nations communities are very aware of the changes in the climate and how it is affecting the forest (Aboriginal and Northern Community Action Program 2007). Some Ontario First Nations have begun to raise awareness in their communities of how the climate change concept is being framed at the national and international policy level. The Aboriginal Strategy Group and the Mushkegowuk Environmental Research Council prepared a concept paper to assist the Mushkegowuk First Nations of northern Ontario in conceptualizing their land from a carbon perspective for climate change mitigation. It also discusses existing and developing frameworks relating to green house gas emissions and their valuation, including cap and trade systems. The paper states that

> "building awareness around climate change and specifically carbon management will place decision leaders and grass roots people in a position to develop proactive strategies around the threats and opportunities around climate change. Networking with decision makers and potential investors could also assist First Nations to develop viable carbon based businesses" (Aboriginal Strategy and Mushkegowuk Environmental Research 2008).

However, "it appears that there is a fair amount of uncertainty with respect to the best road forward on climate change-inspired land use projects relating to the Mushkegowuk territory". This issue of economic opportunities from boreal forest carbon sequestration is also being studied in other First Nation communities in other parts of Canada (Krcmar and van Kooten 2005). Since such ventures are at an exploratory stage the institutional networks required for their implementation have not yet been developed. Additionally, although there is a First Nations representative on the Ontario Expert Advisory Panel on climate change, there appears to be no involvement specifically in the Ontario forest sector on this issue.

5.3 Forest-dependent communities

Apart from the unique relationship of First Nations communities to the forest, there are other communities whose livelihoods are also dependent on the forest. Such communities are often those that have been reliant on the forest sector for employment and the forest for sustenance and social activities. In recent years, however, the forest economy has undergone a transition due to a variety of factors, resulting in the closing of mills and the loss of jobs (Parkins and White 2007; Davidson et al. 2003; Lemmen et al. 2008). In Ontario, the forest supply near established major mills is dwindling, forcing the industry to move farther north into areas that are more costly to harvest. Energy costs, which have risen by as much as 30%, have also affected logging, road building and transportation which have been cited as the main reasons for recent mill closures (Lemmen et al. 2008). In addition to these non-climatic stresses, climate change is expected to result in an increase in global timber supply which will have implications for global markets. This in turn may have a negative effect on job availability in the Canadian forest industry (Williams et al. 2005; Davidson et al. 2003; Parkins and MacKendrick 2007). This stress is in addition to more direct effects of climate change on forest-dependent communities as outlined previously, such as from an increase in forest fires.

Responses of forest dependent communities in Ontario to climate change are intertwined with their response to other uncertainties in the forest industry. These can be summarized by a focus on discovering new economic activities that are derived from local resources and a desire for more direct control over their economic future. In this way, they may exploit the value of the forests in mitigating climate change as an adaptation strategy for their communities. Such adaptations are primarily being facilitated by programs from the federal government which provide opportunity for building adaptive capacity through establishment of cross-scale institutions. For example, with funding from CFS's new Forest Communities Program, The Northeast Superior Forest Community, formed from a group of municipalities dominated by traditional forestry towns, is proposing a linkage with the private sector on a project for the development of carbon offsets for trading as one economic diversification strategy (Northeast Superior Forest Community 2008).

The Eastern Ontario Model Forest, which was originally funded through the earlier CFS Model Forest Program,[4] has been active in establishing networks of diverse stakeholders for research on climate change since the devastating ice storm that hit Ontario in the late 1990's (Eastern Ontario Model 2008). They also continue their research and extension on invasive species, such as the Emerald ash borer, whose spread is exacerbated by a changing climate. Workshops have been held to sensitize private wood lot owners to forest management issues related to climate change and they maintain a web site where a wide variety of information is available. At the time of writing, the Lake Abitibi Model Forest was in the process of organizing a conference as a way to enhance awareness of climate change in the municipalities of their northern region. The Model Forest Program is also finalizing a guide that will help communities begin to think about adaptation to climate change.

Apart from government-funded programs, other grass roots initiatives have started to re-evaluate the structure of the forest sector in Ontario and focus on solutions that will achieve long-term sustainability for communities in northern Ontario. The Northern Ontario Sustainable Communities Partnership (NOSCP), made up of individuals and organizations,

[4] The Model Forest Program's goal was to be a 'living laboratory' where people with a direct interest in forests, could participate in decisions about sustainable management, while being supported by the latest science and technology (Duinker and Trevisan 2003).

including municipalities, NGO's, academics and Aboriginal groups, is an example of an inter-institutional network which seeks to promote community-based decision making and shared stewardship of northern forests in light of growing environmental, economic and social challenges. Such a change in governance would localize control of forest management and remove the dominance of the existing Crown forest tenure management system, which some see as having failed (Northern Ontario Sustainable Communities Partnership 2007a, b, c; Robinson n.d.; Haley and Nelson 2007). It would also allow the community to focus on non-timber uses of the forest like environmental services, such as carbon sequestration. Such networks are an important part of the adaptive capacity of the system.

5.4 Forest industry

The forest products industry in Ontario is made up of many different companies, both Canadian and multinational (Ontario Ministry of Natural Resources 2008e). As in other parts of Canada, the provincial Crown forests are the industry's principal source of wood and access to an area of forest or management unit is granted under Canada's Crown forest tenure system (Haley and Nelson 2007; Ontario Ministry of Natural Resources 2006b). Under this system, an individual forest company obtains a Sustainable Forest License from the province, which requires it to carry out the activities of forest management planning, access road construction, harvest, renewal and maintenance, monitoring and reporting subject to MNR regulations and approvals. A Forest Management Plan is prepared for a 10 year period for each management unit and is approved when the MNR Regional Director is satisfied that the plan balances the objectives related to forest diversity, socio-economics, forest cover and silviculture. It is prepared with the assistance of an interdisciplinary planning team and a Local Citizens Committee and input from Aboriginal communities and interested members of the public (Ontario Ministry of Natural Resources 2006b).

The response of the forest companies in Ontario to climate change has primarily related to mitigation of climate change through a reduction in green house gas emissions. Under their Impact Zero program, Tembec pledged to reduce greenhouse gas production by six percent versus 1990 levels, in absolute terms by 2008 (Tembec 2008). Weyerhaeuser states that they meet 70% of their operations' energy needs through the use of renewable and greenhouse-gas-neutral biomass fuels such as wood residuals and other organic byproducts. The company has committed to reducing their green house gas emissions so that by 2020 they will be 40% less than they were in 2000 (Weyerhaeuser 2008). AbitibiBowater has a biomass power generation project at Fort Frances, Ontario which is one of eight such cogeneration facilities (Abitibi Bowater 2008). In challenging economic times such changes have served to minimize company expenses as well as benefit the environment. The Ontario government has also provided $350 million in loan guarantees to companies to stimulate new investment in value-added manufacturing, energy conservation and energy co-generation (Ontario Ministry of Natural Resources 2008d).

The Forest Product Association of Canada (FPAC) has also announced that they will commit to industry wide carbon-neutrality by 2015 without the purchase of offset credits (Forest Products Association of Canada 2007). To attain this goal they have joined in a partnership with WWF-Canada and an advisory panel of government, university, private sector and environmental organization experts. The development of this cross-scale network, an essential element in building adaptive capacity, is a key part of its mitigation response. According to a study commissioned by FPAC, the forest products industry has

more complex connections to the climate change issue than any other industry, due to its carbon and green house gas profile (Upton et al. 2007). Therefore, to achieve their goal they commit to reducing direct and indirect emissions, increasing the sequestration potential of forests and products and increasing avoided emissions (Forest Products Association of Canada 2007; Upton et al. 2007). As a first step toward this goal, member companies have already cut their use of fossil fuels by 45% through the use of self-generated renewable sources which provide 60% of their pulp and paper facilities' energy needs. Since 1990 this has resulted in a 54% improvement in greenhouse gas emissions intensity, a 40% reduction in landfill waste and a 44% reduction in greenhouse gas emissions (Forest Products Association of Canada 2007). It should be noted that this claim, among others, has been disputed by some environmental organizations (Forest Ethics n.d.-a).

Unfortunately, however, based on available information, the forest industry in Ontario has not yet begun to incorporate climate change into their forest management plans, and is not yet required to do so by the Ontario government. As noted earlier, MNR is continuing to research changes to their forest planning model. While many companies have been certified in sustainable forest management by the Forest Stewardship Council, or other third party systems, these schemes do not yet incorporate climate change into their system of requirements (Johnston and Williamson 2007; Forest Stewardship Council of Canada 2008). It should be noted, however, that some private land owners in Ontario have already begun to manage their forests in light of climate change by favoring species which are expected to do better under climate change conditions.

5.5 Non-governmental organizations

As evident from the partnership of WWF-Canada with FPAC in the initiative to achieve carbon neutrality of the forest industry, one response of non-governmental organizations to climate change has been to work with industry to mitigate its effects. As stated previously, such networks foster the exchange of different types of knowledge which build the capacity of the forest sector to respond to climate change. Other non-governmental organizations, such as the Pembina Institute, also form part of the FPAC advisory panel (Forest Products Association of Canada 2007). This willingness of non-governmental organizations to partner with industry is also seen in the Boreal Leadership Council, which has members representing the forest industry as well as First Nations and other private companies (Canadian Boreal Initiative n.d.).

A primary focus of climate change action by NGO's has been a campaign to protect the boreal forest to safeguard the carbon stores, for carbon sequestration and for protection of biodiversity. The Canadian Boreal Initiative (CBI) brings together a wide range of conservation organizations, First Nations, industry leaders and others to create new solutions for Boreal conservation and sustainable development (Canadian Boreal Initiative 2005). Among the lead initiatives of the Boreal Conservation Framework is to ensure ecological resiliency so boreal species can adapt to natural disturbances and climate change. As well, they commit to maintaining and enhancing the significant carbon sequestration and storage value of Canadian boreal land and waterscapes (Canadian Boreal Initiative n.d.).

Through public campaigns, NGO's have raised awareness nationally and internationally, and lobbied industry and government to reduce destructive practices and to protect forests in order to mitigate climate change (Canadian Boreal Initiative 2005; Sierra Club of Canada 2003; Forest Ethics n.d.-b; Ferguson et al. 2008). These groups applauded the Ontario government's announcement to protect half of the northern boreal forest in 2008 (Forest 2008a; Greenpeace 2008; Wildlands League 2007). It is important to note that while

environmental NGOs have proposed forest preservation as one of the most important measures to address global warming, this view is not universally shared. Ter-Mikaelian et al. (2008), scientists at MNR, state that the concerns raised by environmental NGO's about detrimental effects of forest management in general, and logging in particular, on carbon stock in boreal forests are based either on incorrect accounting or a misinterpretation of results contained in the scientific literature. They conclude that forest management in Ontario, as governed by the Crown Forest Sustainability Act increases total forest carbon stock over the long term.

6 Discussion

6.1 Mitigation and adaptation responses

The response to climate change is clearly in the early stages in Ontario, particularly in the forestry sector. Responses by most institutions involved in the sector are focused primarily on mitigation. This is evident from both federal and provincial policies as well as in the actions of the forest industry to reduce greenhouse gas emissions. Other mitigation strategies focus on the role of forests in sequestering carbon, as evidenced from the building of the forest carbon model by the federal and provincial forest management agencies. The provincial government's plan to protect a large area of the northern boreal forest is also a climate change mitigation strategy that is a result, in part, of the lobbying efforts of national and international environmental NGOs.

At the federal and provincial level there is also concern to develop adaptation strategies. This is evident in the Canadian Council of Forest Ministers' (CCFM) vision for Canadian forestry in the next 10 years which emphasizes the need for the sector to adapt to climate change. The adaptation responses at this time, however, are limited in their scope. The established institutions of the federal and provincial government are primarily placing emphasis on investing in the generation of scientific knowledge as an adaptation response. In the United States, the Forest Service, while still in the process of researching field-proven methods, has started to advise resource managers on how to re-frame forest and resource management strategies for a changing climate (Millar et al. 2008).

Institutions that learn and store knowledge and experience are considered to be an important aspect of increasing the overall adaptive capacity of a system to climate change (Tompkins and Adger 2004; Walker et al. 2006). Therefore, the research that is being funded and carried out by different levels of government is a vital part of reducing the vulnerability of the forest sector to climate change. However, while such vision statements and research are important and promising, Johnston et al. (2006) caution that many federal and provincial committees that have emerged to examine climate change issues and problems and propose strategic directions, are still focusing on synthesizing the information pertaining to climate change related problems. Overall little effort has been made to develop narrower, more focused sector-specific policy solutions.

The emphasis in the research by the federal and provincial governments has been on the generation of scientific knowledge concerning climate change. This narrow focus, however, constrains the adaptive capacity of the system. According to the principles for building adaptive capacity presented earlier, combining different types of knowledge from both inside and outside government is a key factor in enhancing adaptive capacity in social–ecological systems (Folke et al. 2003; Weber and Khademian 2008). Indigenous knowledge has already been shown to be important in understanding and adapting to climate change in

Canada (Ford et al. 2006). Furthermore, such knowledge has been important in management of other social–ecological systems in Canada (Sherry and Myers 2002; Berkes 2002). Collaborative planning models for sustainable forestry that incorporate indigenous knowledge are already being explored in Ontario (Ontario Ministry of Natural Resources 2008c; O'Flaherty et al. 2008). Therefore, such models may provide insight into ways to develop inter-institutional networks to enhance adaptive capacity to climate change as emphasized in the CCFM's vision statement.

It is often emphasized that ultimately understanding vulnerability to climate change becomes most important at the community level, as that is the scale at which policy action takes place (Williamson et al. 2007; Davidson et al. 2003; Parkins and MacKendrick 2007). Therefore, it is significant that the federal government has gone beyond studying the vulnerability of forest-dependent communities to climate change to developing a program to help communities adapt. The Forest Communities Program, while limited in scope, represents a response at the federal level to help communities diversify their economy, and thus reduce their vulnerability to the uncertainty in the forest sector from a variety of stresses. This program, as well as funding through the original Model Forest Program, fosters educational and capacity-building opportunities across diverse stakeholders to enhance the adaptive capacity of forest communities faced with climate change. Although the third theme of the Ontario Ministry of Natural Resources climate change strategy is to help Ontarians to adapt, at the time of writing there appeared to have been little quantifiable progress in this area in the forestry sector.

First Nations and local forest communities have also been proactive in thinking about networking with other institutions in adapting to climate change. This has primarily been related to a need for economic diversification in order to provide a sustainable livelihood in more isolated regions of the province. Therefore, the response of valuing the carbon sequestration potential of forests, as part of an adaptation strategy, provides an opportunity to increase the overall adaptive capacity of a forest-dependent community. However, such initiatives are still in their early stages and the long term benefit of such projects is uncertain.

Beyond advances in mitigation, an identified need in adaptation in the forestry sector is to understand how climate change can be better incorporated into long-term forest planning (Johnston et al. 2006; Ogden and Innes 2007). A range of alternative adaptation options are possible at both the strategic planning level and operational level that both government and industry should consider (Ogden and Innes 2007). The lack of action of the Ontario forest industry in this regard is, unfortunately, consistent with much of the industry worldwide. Broadmeadow and Carnus (2007) state that the limited response globally is not acceptable in an industry that has planning horizons of upward of 50 years and needs to be one of the first to respond. However, there is evidence of an increasing awareness of the issues in Europe and the United States (Millar et al. 2007; Ogden and Innes 2007). In other parts of Canada, while much forest management and planning is more aimed at preserving the status quo than allowing for change, there is also progress being made (Ogden and Innes 2007).

In western Canada, the provincial government of Alberta, the University of Alberta and the forest industry have joined together to cooperatively advance the science and management of forest ecosystems faced with climate change, among other issues (Grover and Fast 2007). This inter-institutional linkage is an example of a network which builds adaptive capacity through continuous exchange of different types of knowledge. Some companies have also begun to integrate climate change considerations into their forest plans in western Canada (Johnston and Williamson 2007; Minister of Natural Resources 2008). Of necessity, forest managers are already adapting to the impact of climate change in

British Columbia. Additionally, the Future Forest Ecosystem Initiative of the Ministry of Forests and Range was also created to tailor its management framework to a changing climate (Minister of Natural Resources 2008Government of British Columbia 2008). Also, the province of New Brunswick has stated that it will undertake the necessary actions to address climate change considerations through its forest management plan for 2007–2012 (New Brunswick Department of Environment 2007). Such provincial government actions may address the current lack of requirement for adaptation strategies in forest management plans, which is a major policy barrier constraining response to climate change (Spittlehouse 2005). The Ontario Ministry of Natural Resources is also studying this issue but has not yet made changes.

6.2 Institutional arrangements and adaptive capacity

As outlined previously, new institutional arrangements that foster learning and continuous exchange of different types and sources of knowledge across scales are an important indicator of adaptive capacity in responding to change in social–ecological systems (Weber and Khademian 2008; Folke et al. 2003). Well-connected networks enhance communication, favor collaboration, build social capital and foster innovation which is essential in dealing with an issue such as climate change (Carlsson and Sandstrom 2008). Therefore, the existence of an Ontario Expert Advisory panel which includes academics, non-governmental organizations, industry, and First Nations representatives is an important response to climate change at the provincial level. It has the potential to facilitate the continuous exchange of knowledge between different stakeholders and the provincial government. Such a network could increase the overall capacity of Ontario to respond to the reality of a changing climate in all sectors, including forests. Ontario and British Columbia, which created its Climate Action Team in 2007, are in the forefront of building adaptive capacity to climate change by creating such inter-institutional linkages (Government of British Columbia 2007). The linkages of NGOs, government and academics with the forest industry, also create opportunities for learning around the issues of mitigation and adaptation.

As indicated previously, institutional networks that specifically link provincial government with the local level on climate change and forests appear, unfortunately, to be limited. This constrains the development of institutional adaptive capacity that could be enhanced by proactive engagement at the local level with communities, who are particularly vulnerable to the effects of climate change, but often marginalized from decision-making. The development of such networks in Ontario, to involve First Nations and other forest-dependent communities, NGOs, and the forest industry, would foster the exchange of different perspectives and types of knowledge. Such institutional flexibility in problem solving would enhance the adaptive capacity of the Ontario forestry sector to climate change (Adger and Vincent 2005; Lebel et al. 2006; Ostrom 2005; Berkes 2002).

The fostering of such cross scale interactions has recently been shown to be an important strategy to address the increasing risk of forest fire due to climate change in the United States (Chapin et al. 2008). These interactions provide policy flexibility that allows Alaskan fire managers and communities to design locally appropriate solutions to reduce a community's vulnerability to climate change. In British Columbia, the formation of regional-scale Beetle Action Coalitions in response to the Mountain Pine Beetle infestation is an institutional innovation that enhances local capacities, as well as helps local communities to have a stronger voice for negotiation with provincial and federal governments. Through their simultaneous management of networks and hierarchies, they

also provide provincial government with an emerging opportunity to extend their competencies with regard to policy development and investment at the community level (Parkins 2008).

In addressing the complexity of climate change in Ontario forests, it is important to recognize the reality that networks often become insular and polarized. Wellstead and Stedman (2007), from their research on natural resource sectors in western Canada, suggest that a network broker is needed to overcome these inter-institutional gaps. Such a person would facilitate an environment of policy learning around climate change by establishing links across institutions in natural resource policy communities. In the Ontario forest sector, the presence of such a collaborative capacity builder, from either inside or outside government, could foster the transfer, receipt and integration of knowledge across the networks and ultimately build long-term collaborative problem-solving capacity (Weber and Khademian 2008).

7 Conclusion

The adaptive capacity or capability of a system to adjust to and thereby limit risk in the face of climate change is, in part, determined by the institutions that are part of the system. In particular, institutional networks that foster exchange of different types of knowledge, create flexibility in problem solving and balance power among interest groups, play an important role in adaptive capacity. In the Ontario forest sector the current institutional response to climate change, primarily emphasizes the generation of scientific knowledge about the effects of climate change and possible mitigation and adaptation strategies. However, there is recognition of the need to build cross-scales linkages among different institutions in order to facilitate a climate change response. At the provincial level there have been some new innovations in institutional networks, but expansion of the forest stakeholders involved in such networks would further enhance adaptive capacity. In particular, it is important to network with First Nations and other forest-dependent communities at the local level who have heightened vulnerability to climate change. The expansion of such institutional networks would foster learning and continuous exchange of different types and sources of knowledge across scales. The presence of a collaborative capacity builder, from either inside or outside government, could foster the transfer, receipt and integration of knowledge across the networks and ultimately build long-term collaborative problem-solving capacity in the Ontario forest sector.

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