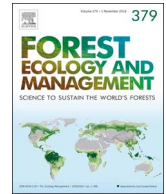




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Adapting forest management to climate change: The state of science and applications in Canada and the United States

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ABSTRACT

Over the last decade, considerable progress has been made in developing vulnerability assessment tools and in applying these methodologies to identify and implement climate change adaptation approaches for forest ecosystems and forest management organizations in Canada and the United States. However, given that adaptation processes are in early stages, evaluation of approaches across agency, organizational, and geographic boundaries is critical. Thus, we conducted a qualitative comparison of three conceptual frameworks for climate change vulnerability assessment and adaptation efforts in the Canadian and United States forestry agency contexts. We focus our comparison on components of the conceptual frameworks, development process, intended users, similarities and differences in institutional contexts (geographic and organizational), and implementation. Finally, we present case studies to illustrate how the frameworks have been implemented on the ground and in different contexts. Despite different trajectories of development, the Canadian and US forest agencies have developed similar conceptual frameworks for vulnerability assessment and adaptation. We found that key components of the conceptual frameworks included: establishing a science-management partnership; evaluating current forest conditions and management objectives; conducting detailed science-based vulnerability assessments; developing adaptation approaches and on-the-ground tactics; implementing adaptation tactics; and monitoring outcomes and adjusting as needed. However, the contexts in which these frameworks are implemented vary considerably within and between countries, mostly because of differences in land ownership, management norms, and organizational cultures. On-the-ground applications, although slow to develop, are beginning to proliferate, providing examples that can be emulated by others. A strategy for accelerating implementation of adaptation in Canada and the United States is suggested, building on successes by federal agencies and extending to public, private, and crown lands.

1. Introduction

Climate change vulnerability assessment for natural resources has been in practice in North America for approximately 10 years (Füssel and Klein, 2006; Campbell et al., 2009; Peterson et al., 2011; Johnston and Edwards, 2013; Brandt et al., 2017). Climate change adaptation for natural resources has been in practice in North America for about the same length of time (Blate et al., 2009; Halofsky et al., 2011b; Janowiak

et al., 2011; Bierbaum et al., 2013; Littell et al., 2012; Janowiak et al., 2014; Gauthier et al., 2014; Swanston et al., 2016). This is a relatively short period of time, compared to the 30 years of scientific data available on the effects of climate change. On-the-ground implementation of climate-informed resource planning and management is in its early stages in most locations (Halofsky et al., 2015, 2017a; Ontl et al., 2017), and mainstreaming of climate change, or the continuous and ongoing consideration of climate change issues in forest management decision

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making (Williamson et al., 2012), is in its infancy (Halofsky et al., 2015).

There are several reasons why mainstreaming of climate change and adaptation implementation have not progressed more rapidly. First, resource managers and decision makers often perceive climate change as complex with uncertain effects on resource conditions (Lawler et al., 2010; Littell et al., 2012; Nelson et al., 2014), and combined with a real or perceived lack of authority to implement adaptation practices, they are hesitant to address it. Second, most resource agencies and timber management entities are already committed to existing tasks and feel that they do not have sufficient time or resources to incorporate another item into their work program (Timberlake and Schultz, 2017). Third, until recently (CCFM, 2008; Obama, 2009, 2013; USDA FS 2012), there have been no mandates or guidelines for prioritization by government agencies or other bodies (e.g., organizations that verify sustainability) to consider climate change as part of the overall mission of sustainable forest management. Finally, a lack of information at locally relevant scales required for adaptation planning and decision making might also have contributed to slow progress in adaptation (Lawler et al., 2010; Littell et al., 2012; Nagel et al., 2017). These barriers are not necessarily unique to forest management contexts; a number of adaptation scholars have identified similar issues and challenges in broader adaptation contexts (e.g., Pahl-Wostl, 2009; Moser and Ekstrom, 2010; Eisenack et al., 2014).

Despite these limitations, considerable progress has been made in assessing climate change vulnerabilities of forest ecosystems and developing adaptation options for forest management in North America (Johnston and Edwards, 2013; Janowiak et al., 2014; Le Goff and Bergeron, 2014; Halofsky et al., 2015, 2017a; Halofsky and Peterson, 2016; Swanston et al., 2017). With implementation of climate-informed planning and management starting to accelerate across Canada and the United States (US), it is an opportune time to review what has been accomplished to date, and to identify useful practices, tools, and methods of science delivery. We conducted a qualitative review of major climate change adaptation frameworks for federal and Crown forestry agencies in the US and Canada. Our objective was to compare the frameworks and implementation approaches to identify similarities and differences in key components of the frameworks and their application, identify strengths and limitations, and determine next steps for the facilitation of climate change adaptation in forest management across the northern tier of North America. The authors of this paper have observed that the conceptual basis and guidelines for climate change adaptation in Canada and the US are remarkably similar, but the manner in which implementation occurs across geographic and political landscapes differs between the countries. Thus, we provide examples of implementation of the frameworks to highlight similarities and differences among frameworks and the contexts in which they are applied.

2. Review methods

We reviewed three major climate change adaptation frameworks used by forestry agencies in Canada and the US, including the Canadian Council of Forest Ministers (CCFM) framework (described in Williamson et al. (2012) and Edwards et al. (2015)), the Climate Change Response Framework (CCRF; <https://forestadaptation.org/>, described in Swanston et al. (2016)), and the Adaptation Partners framework (<http://adaptationpartners.org>, described in Peterson et al. (2011) and Halofsky et al. (2017a,b)). We chose these frameworks because they are either government-endorsed approaches (in the case of the CCFM approach) or are the most widely used (in the case of the CCRF and Adaptation Partners frameworks in national forest units of the U.S. Forest Service). We qualitatively compared: conceptual theory; development process; key components; intended users; scope; geographic, social, and political contexts; and implementation approaches.

Section 3 provides descriptions of the adaptation frameworks.

Section 4 provides case studies which were chosen by the authors to illustrate application of the frameworks in different contexts. Section 5 provides an evaluation of the frameworks, and identifies key elements, strengths and limitations, and important differences in application. We conclude with a discussion of lessons learned through implementation of the frameworks and potential next steps to further climate change adaptation in forestry.

3. Adaptation framework descriptions

3.1. The need for new approaches and conceptual frameworks

The requirement for new tools and approaches is based on recognition among forest managers in Canada and the US that climate change introduces a number of new challenges. Climate change is unprecedented; consequently, novel effects on forests can be anticipated, and innovative and untested response strategies may be required (Millar et al., 2007). Climate change is dynamic and ongoing, necessitating a forward-looking approach to forest management. The effects of climate change on forest systems and processes are complex, and there is an increased level of uncertainty about what future forests will look like, requiring adaptive management approaches (Peterson et al., 2011).

Climate change can cause multiple co-occurring changes in growing seasons, growing conditions (temperature and soil moisture), site conditions (wet, dry, melting permafrost), winter minimum temperatures and frost-free days, phenology, biotic disturbance (insects and disease), and abiotic disturbance (wildfire, extreme weather events, drought) (Fischlin et al., 2007; Edwards and Hirsch, 2012; Price et al., 2013; Peterson et al., 2014). Potential forest management-related effects include changes in forest health, regeneration success, growth and productivity, distribution and composition of species, forest structure, and age-class distribution. These effects, in turn, have implications for forest management goals, including biodiversity, ecosystem health, carbon, timber supply, non-timber goods and services, habitat, outdoor recreation, conservation, public safety, and social and cultural values (Edwards and Hirsch, 2012; Gauthier et al., 2014; Peterson et al., 2014). Thus, there is a need for a comprehensive and multi-faceted approach to climate change vulnerability assessment and adaptation.

The challenges noted above mean that new approaches to decision making and new kinds of information are required in support of forest management (Williamson et al., 2012). Assessments of current and potential future effects of climate change facilitate identification of robust and effective adaptation options and can also motivate engagement by raising awareness of possible risks. However, these assessments need to be forward looking, account for uncertain future climate, and be sufficiently comprehensive to consider multiple aspects of sustainable forest management. Given the complexity and uncertainty of effects, adaptation decision making will be most effective if it is part of a continuous process of implementation, monitoring, and modification (or adaptive management) (Millar et al., 2007; Peterson et al., 2011; Littell et al., 2012).

3.2. The Canadian approach to vulnerability assessment and adaptation

3.2.1. Institutional context

Most (94%) of the forest land in Canada is retained under public ownership (NRCan, 2016). Provincial and territorial governments manage most of this public forestland. The goals of forest management across Canada are generally consistent with principles of sustainable forest management. Sustainable forest management is defined as “management that maintains and enhances the long-term health of forest ecosystems for the benefit of all living things while providing environmental, economic, social, and cultural opportunities for present and future generations” (CCFM, 2008). Provincial and territorial forest management agencies have the primary responsibility for identification

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