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Using climate vulnerability assessments to implement and mainstream adaptation by the forest industry into forest management in Canada

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Climate change is an increasing concern for forest managers and society as a whole. The impacts of climate change on forest ecosystems may limit the ability of forest managers to achieve sustainable forest management (SFM) objectives, and changes to management or practices may be required in response. While academic literature emphasizes the need for adaptation to climate change and proposes what kind of higher-level changes are required to facilitate that change, less attention has been paid to what forest managers need and their ability to implement adaptation. In this study, we describe a recent example of proactive climate change adaptation in Canada's forest industry, the first instance in which a Canadian forest company operating within a publicly owned land base has undertaken a formal climate change adaptation planning process. We show how Mistik Management Ltd., a partnership between nine indigenous nations and a pulp and paper company, used a climate change vulnerability assessment framework to identify vulnerabilities and develop management strategies to mitigate climate risks while also changing management practices. We show how Mistik is mainstreaming climate change considerations into their management system and implementing it through changes in their management practices. At the institutional level, we found no substantive barriers to Canadian forestry firms seeking to incorporate adaptation into ongoing planning and management activities and suggest how the lessons from Mistik's experiences can inform forest management adaptation policies and processes more generally, not only in Canada but elsewhere.

KEYWORDS

adaptation, climate change, climate science, forest industry, forest management, vulnerability assessment

1 Introduction

Canada's boreal forest, which accounts for 28% of the global boreal zone (Natural Resources Canada, 2018), contributes to the nation's environmental, economic, social, and cultural wellbeing. Climate change threatens the long-term health of Canada's boreal forest, which is expected to face significant climate impacts at both regional and national levels (Price et al., 2013). Since 1995, the Canadian Council of Forest Ministers (CCFM) has committed to a paradigm of Sustainable Forest Management (SFM) by developing criteria and indicators to measure and monitor the alignment of forest management practices with the express objectives of the SFM paradigm (Duinker, 2001; Canadian Council of Forest Ministers, 2006), with plans and policies built around these principles. This paradigm is challenged by climate change and the risks it poses to maintaining a stable and secure flow of goods and services from the forests,

leading policymakers, regulators, and managers to seek management strategies and practices to mitigate those risks and address those impacts (Halofsky et al., 2011). As nearly two-thirds of Canada's timber harvests (Natural Resources Canada, 2022) are drawn from the boreal forest, which predominantly falls under provincial jurisdiction, researchers, government decision-makers, and forest managers have come together in recent decades to address the impacts of climate change and ensure the long-term sustainability of forest management in Canada (Spittlehouse, 2005). There has been significant investment in climate change research from federal and provincial governments to help inform decision-makers and support adaptation planning (Johnston and Edwards, 2013). In 2015, the CCFM published a vulnerability assessment framework for use in the Canadian forestry sector as a tool for forest managers to use (Edwards et al., 2015).

These efforts and research have heightened awareness of the risks (e.g., Spittlehouse and Nelson, 2022) and have guided the development of strategic plans and frameworks by provincial and federal governments to address adaptation needs across various sectors. For the Canadian forest sector, those efforts have focused on providing climate science-related information and tools for forest managers. There has been far less attention paid to how and where adaptation is taking place and how to learn from those experiences to support adaptation, despite early evidence of some non-industrial tenure holders engaging in adaptation action (Furness and Nelson, 2016).

Concurrently, the risks associated with climate change are increasing, as seen in increased levels of natural disturbance events such as wildfire, the impacts of disease, and drought.[1] Policy and management responses have largely been reactive, with managers operating within existing regulatory frameworks (e.g., increased salvage harvesting), as efforts to fully integrate climate change considerations into decision-making processes and policies remain delayed (Fletcher, 2023). In part, this is because of the deep uncertainty climate change creates in relation to existing models and knowledge that are used to inform policy and practice (Fletcher, 2023). It is for this reason that Mistik stands out in their willingness and ability to proactively make changes in their management plan and practices to address climate risks. Mistik is a Woodlands Management Company, located in Northwestern Saskatchewan, Canada (Andrews-Key et al., 2022). In the remainder of this article, we show how the CCFM vulnerability assessment framework helped inform their actions, and what that process reveals more generally about how adaptation can be strengthened in the forest sector.

Climate change vulnerability assessments (CCVAs) have evolved over time, initially moving from a narrower focus on identifying potential physical impacts and risks posed by climate change, to identifying particularly vulnerable aspects of different systems and more recently prioritizing adaptation measures based on the adaptive capacity of the system in question (Füssel and Klein, 2006). CCVAs have now been applied to everything from species (Foden et al., 2019) to sectors (Parker et al., 2019) to climate-related risks more generally (Rehman et al., 2019). Some scholars have criticized vulnerability assessments for failing to capture the complex nature of socio-ecological systems and processes, a lack of dynamism, limited ability to effect change (Biesbroek et al., 2015; Ford et al., 2018), and treating adaptation as occurring within a "black box," wherein certain inputs are anticipated to produce certain outputs, ignoring the complex and dynamic sociopolitical decision-making processes through which change occurs (Wellstead et al., 2014). Other scholars have observed an implementation gap wherein adaptations are identified through vulnerability assessment processes, but changes are not made in response (Runhaar et al., 2018; Barr et al., 2021).

While progress has been made in better understanding the socio-economic linkages at both a higher level (Thomas et al., 2019), as well as at the community level, there has been less research examining the reasons for a lack of change beyond simply describing the factors that limit change (Eisenack et al., 2014). Oftentimes, these are linked to socio-economic factors that can contribute to vulnerability, such as differential access to resources and existing governance systems (Barr and Lemieux, 2021). Moser and Ekstrom (2010) identify barriers to adaptation action within a decision-making system. Some barriers stem from characteristics of climate change impacts, such as lack of knowledge, uncertainty, and distributional effects, while others—such as lack of leadership, politics, and risk-averse institutional culture—are associated with the challenges of organizational and institutional change (Ford and King, 2015; Barr and Lemieux, 2021). A common conclusion is that one of the difficulties inherent in adaptation is that it requires simultaneous change at both higher levels (e.g., policy and governance systems) and the local level (e.g., individual and organizational behavior and beliefs; Thomas et al., 2019).

Several explanations have been offered as to what is limiting adaptation in forestry in Canada, but no consensus has been reached around how potential limiting factors interact to produce inaction. Hotte et al. (2016) have suggested that divided responsibility between the firms that manage the forest and the government that owns the land creates challenges in deciding who should bear the cost of adaptation actions. Rayner (2012) suggested that decreasing government resources has reduced governance capacity in the Canadian forest sector, while forestry firms face competitive pressures along with an array of other issues contending for attention. Williamson and Nelson (2017) have argued that policy in Canada tends to be reactive, further contributing to a lack of adaptation action, which requires future-oriented planning over multiple time scales. Others have argued that a lack of local climate information, or an inability to translate it to local scales, has hindered the uptake of adaptation actions at the forest management level (Halofsky et al., 2011). Together, these factors offer multiple reasons as to why actors in the forest sector would be reluctant to introduce and champion changes that are new, complex, not well understood, or that have long-term horizons and uncertain outcomes. Given the reasons posed as to why change may not happen, it is instructive to then examine when change does happen (in this case a forest sector firm adapting) to investigate to what extent these factors (or others) are actually limiting adaptation. Flyvbjerg (2006) argues that case studies are essential for advancing theory around social sciences as they offer a unique opportunity to generate valuable, concrete, and context-dependent knowledge that cannot be obtained through other methods.

2 Approach

Mistik Management Ltd. (hereby referred to as "Mistik") undertook a climate vulnerability assessment that incorporated

1 https://changingclimate.ca/national-issues/chapter/7-0/

climate change impacts and adaptations into a 20-year forest management plan. Methodologically informed by community-based participatory research (Halseth et al., 2016), the processes involved in making the plan illustrate how vulnerability assessment and adaptation decision-making processes play out in a Canadian forestry context. Mistik not only has the responsibility of preparing a plan but is also the one responsible for implementing that plan (the importance of this is described in a subsequent section). Interviews and workshops were used to facilitate collaboration among participant groups as they worked through a structured decision-making process (Edwards et al., 2015) to guide the vulnerability assessment and develop an adaptation plan.

Mistik is the first forestry firm in Canada to undertake a full-scale vulnerability assessment that includes evaluations of both local climate risks and the company's internal capacity to respond and adapt to them. While Mistik was unsure what the vulnerability assessment would entail and the potential outcomes from such a process, they saw the importance of exploring their climate-related risks, what options they faced, and what they could do now and in the future to mitigate those risks and impacts. An important dimension of this effort is that Saskatchewan's provincial government sought to collaborate with an industry partner and use the outcomes of the vulnerability assessment to inform policy development around climate change and adaptation. This willingness provided an additional opportunity to explore what kind of policy support or development may be required to increase the ability of firms to adapt but also how to increase the adaptive capacity of the system as a whole.

Although the assessment was applied to a single organization, many of the findings are applicable to forest management organizations across Canada and forest managers more generally. First, there are broad similarities in SFM systems across Canada, as regulators and managers work toward common objectives of maintaining ecosystem services, while also identifying strategies to mitigate risks to the diverse forest values they aim to sustain. As is true in the Mistik context, the majority of Canadian forest managers work within a publicly owned land base with clearly delineated extent and are required to account for diverse stakeholder interests and values in decision-making when they are planning and carrying out their forestry activities. Second, the framework and guidebook used to facilitate the vulnerability assessment process (Edwards et al., 2015) are tailored to a Canadian, forestry-focused context but follow a standard process. This process includes examining locally relevant climate change impacts, assessing adaptive capacity, and identifying, prioritizing, and implementing adaptation measures (Glick et al., 2011; Janowiak et al., 2014; Halofsky et al., 2018). Third, selecting a case where adaptation did occur provides insight into the general theories proposed regarding the factors that limit adaptation in forestry and what is needed to support it.

2.1 Background/context

In December 2014, the Saskatchewan Ministry of Environment convened forest industry, stakeholders, and government representatives to explore future climate impact scenarios and consider how these may affect SFM in the province. The results of this workshop highlighted knowledge gaps around the implications of climate change for SFM planning and policy. In response to the gaps highlighted in the workshop, it was agreed to undertake a pilot study to apply the CCFM vulnerability assessment framework (Edwards et al., 2015) in collaboration between the Ministry of Environment and Mistik Management Ltd. Mistik operates within a Forest Management Agreement (FMA) area located in west-central Saskatchewan (Figure 1). Mistik manages the jointly held forest tenure on behalf of nine Indigenous Nations and Paper Excellence, an international pulp and paper company (ownership of the FMA is divided equally between the nine nations and the company; Andrews-Key et al., 2022). The FMA consists of 1.8 million hectares of boreal mixed wood forest in the mid-boreal upland ecoregion (Mistik, 2007). The FMA's sub-Arctic climate includes long, cold winters and short, cool summers, with fewer than 4 months each year with a mean temperature above 10°C (Mistik, 2007). The region is characterized as dry sub-humid, receiving approximately 415 mm of precipitation each year, the majority of which falls between May and September (Mistik, 2007).

In Canada, the management of forests falls under provincial and territorial jurisdiction (Haley and Nelson, 2007). Each province has its own legislation, regulations, standards, and programs through which it allocates harvesting rights and management responsibilities. The forest industry undertakes management practices that do not adversely affect environmental conditions (e.g., soil, water quality, and biodiversity) and that can support those same management and planning activities in the future (Spittlehouse and Stewart, 2003). The majority of jurisdictions in Canada require firms holding forest tenure to submit long-term (e.g., 20-year) forest management plans that demonstrate how they will operate within the framework of SFM principles. The plans are reviewed and approved by the provincial or territorial government within which the forest land is located.

Mistik Management Ltd. was at the start of their required 20-year forest management plan (FMP) renewal when the partners for this project came together. In the time leading up to FMP renewal, a forest company strategically considers all aspects of their SFM planning and operations and typically allocates additional human and financial resources for this process. Accordingly, the FMP renewal provided an opportune period for the company to undertake a climate change vulnerability assessment and incorporate the results into their future SFM planning and operations.

2.2 Tailoring the vulnerability assessment framework to Canada

There are several different vulnerability assessment frameworks, but they all utilize similar elements and involve similar steps (Ohlson et al., 2005; Parry et al., 2007; Peterson et al., 2011; Halofsky et al., 2018). In the years leading up to 2015, the CCFM worked collaboratively with researchers and managers across Canada to develop a framework that delineates a structured decision-making process for assessing climate change impacts, vulnerabilities, and adaptation options related to SFM and tailored to a Canadian setting (Williamson et al., 2012; Edwards et al., 2015). This framework was used to guide the vulnerability assessment and offered the added benefit of incorporating the CCFM criteria and indicators for achieving SFM (Andrews-Key, 2018) which also guided the Saskatchewan approach to forest management planning (Province of Saskatchewan, 1996).

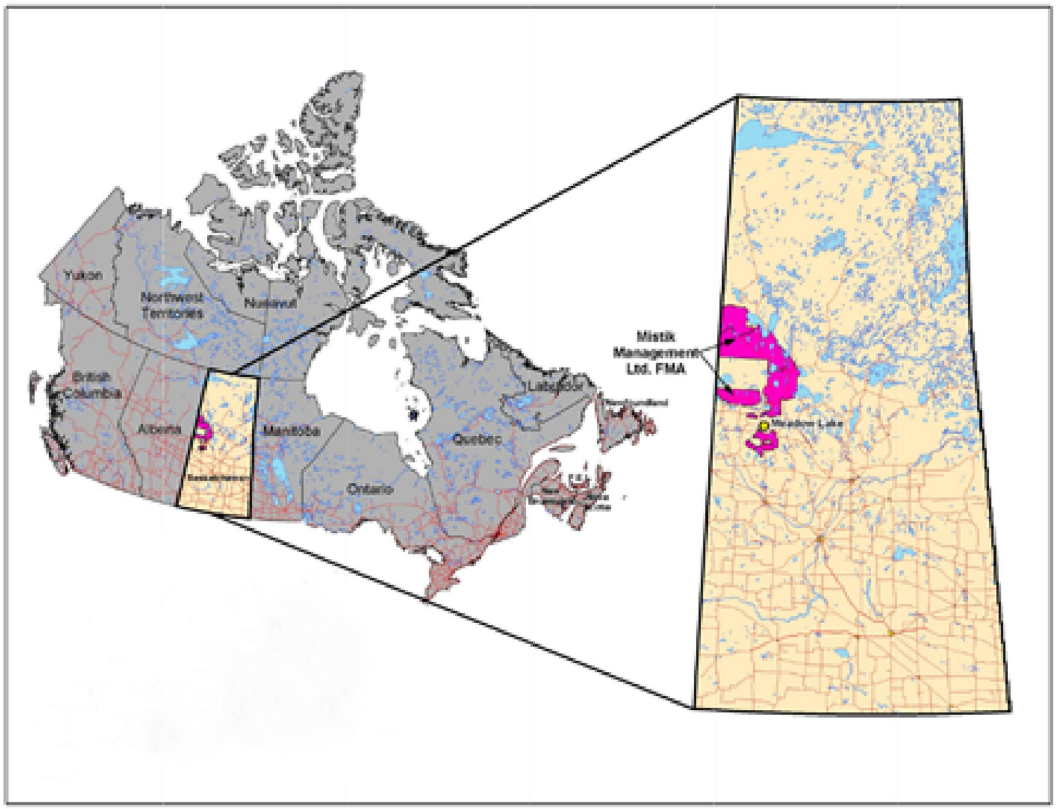

FIGURE 1
Location of the Mistik Management Ltd. Forest Management Agreement area (Mistik, 2007).

The Mistik project is the first to evaluate the applicability of the CCFM vulnerability assessment approach at the FMA level. The framework offers managers a great deal of latitude as it allows for a range of values to be assessed that encompass the biophysical and socio-economic aspects of SFM. These values are fed into a structured decision-making approach that enables forest managers to assess vulnerability and adaptive capacity and to develop and apply adaptation options (Edwards et al., 2015). The four stages of the assessment included the following: (1) exploring organizational readiness; (2) conducting a pre-vulnerability analysis; (3) conducting a detailed vulnerability analysis; (4) identifying, implementing, and monitoring adaptation measures (Figure 2).

In addition to testing and tailoring this approach with Mistik, the lead author facilitated this process and was involved throughout all aspects, including leading workshops, participating in meetings, synthesizing the results of those workshops and meetings, and feeding the results back into the ongoing process. A key element in that process was bringing in both local expertise and expert knowledge to develop an understanding of how and where vulnerabilities arose, and equally importantly, ways to address those vulnerabilities. Engagement of key members of the surrounding communities and forest managers was done through the well-established Public Advisory Group (PAG), which has a diverse membership, including Meadow Lake Tribal Council representatives. These workshops involved oral and written collection of knowledge shared by the participants. This was a collaborative process by all involved.

3 Results

3.1 Assessing organizational readiness

Gray (2012) developed a general framework for assessing organizational readiness in forest adaptation, with three main pillars: place and time perspectives (the context); community-empowered conditions; and knowledge-driven programs. Embedded in these pillars are themes such as a willingness to engage in partnerships to exchange knowledge and build relationships that support adaptation, an institutional culture that promotes informed leadership, learning, and adaptive management, and an ability to take action. Gray identifies no specific metrics; instead, he offers characteristics and attributes associated with these different themes. In this sense, an organization's readiness can, to some extent, be evidenced by its willingness to engage in the process. Reflecting this perspective, Mistik concluded that their organization was ready to undertake the assessment, despite not fully understanding what the process would entail. One of the main factors contributing to this readiness was that the company had just started the renewal of their 20-year forest management plan where they had already allocated resources for the plan renewal and these could also be used for the vulnerability assessment. Other factors that contributed to Mistik's organizational readiness included previous climate change work for their 2007 FMP, strong support from senior management, parent companies, the provincial government, and their Public Advisory Group (PAG), observations regarding climate impacts from Mistik managers based

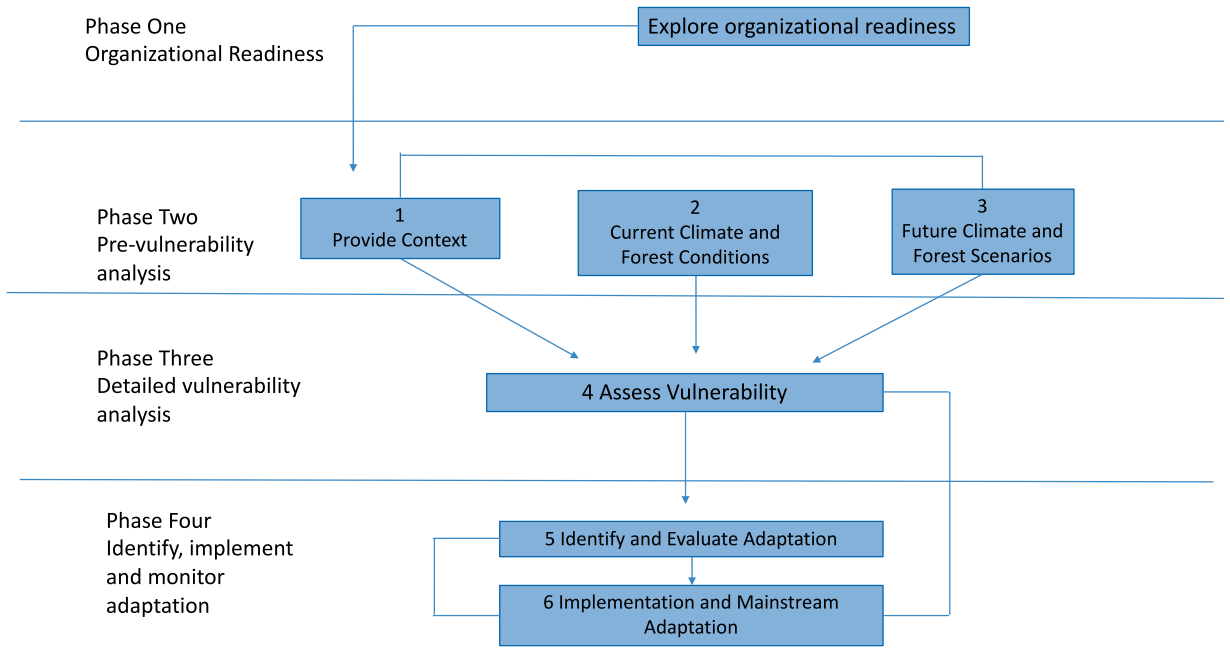

FIGURE 2
Four phases and six stages of adaptation to climate change in the context of sustainable forest management (adapted from Williamson et al., 2012; Edwards et al., 2015).

on experience, knowledge, and understanding, and observations and knowledge shared from community members as well (Mistik, 2018).

3.2 Initial and detailed vulnerability assessments

Several climate-related impacts were identified as likely to affect Mistik operations within the FMA in the future in phase 2 of the pre-vulnerability assessment (Mistik, 2018). Increased frequency and intensity of extreme weather events including wildfires and blowdowns were identified as an important climate change impact. Dwarf mistletoe (*Arceuthobium* spp.), already present within the FMA, is expected to increase in severity with increased climatic stress, and insect and disease outbreaks are expected to increase along with the introduction of non-indigenous organisms such as mountain pine beetle (*Dendroctonus ponderosae*). Overall, the abundance and ranges of invasive species were anticipated to increase. Mistik identified that changes in forest growth, mortality, and productivity, whether positive or negative, would affect the company's annual allowable cut. Mistik also noted that while the current regeneration of planted seedlings is excellent (98% as of 2017) (Mistik, 2007), climate projections suggest that this may decrease due to later spring frosts, seasonal weather variability, and drought, among others. Furthermore, changes in seasonality were recognized as likely to alter land and water conditions affecting silvicultural and harvesting activities. Warmer winters and earlier spring thaw will likely increase access issues associated with road rutting, road washouts due to flooding, and water bodies remaining fully frozen for shorter time periods.

Phase three of the framework, which involves conducting a detailed vulnerability assessment, included analyzing anticipated future impacts based on climate projection scenarios. A key result from this phase was the identification of knowledge gaps and uncertainties. Mistik identified uncertainty around the reliability and accuracy of climate model scenarios, and knowledge gaps around how to acquire equipment necessary for salvage harvesting in blowdown stands, as well as suitable alternative uses for salvaged wood.

As Mistik moved through the first three phases of the assessment process, it became clear that adaptation to climate change is inescapable. By identifying ongoing impacts, such as access issues, risks of damage to infrastructure, and risks of being unable to attain SFM objectives, the company was able to understand several ways in which climate change has already begun to affect their operations and management (Table 1).

A key outcome at this part of the process was the development of a shared understanding of relevant issues, and a willingness to move forward, despite a lack of certainty or agreement on the severity of climate impacts and associated risks.

3.3 Implementing and monitoring adaptation measures

One of the key outcomes of the third phase of the vulnerability assessment process leading into the fourth phase is the mapping of key vulnerabilities and adaptations to relevant timeframes. This is especially important when it comes to implementing actions as this allowed Mistik to establish when and where vulnerabilities are likely to emerge, when and which adaptation actions may be required, establish possible timing for those actions, and prioritize those actions. This mapping over different time frames also allowed Mistik to identify indicators and data sources that could be used to assess ongoing vulnerabilities and associated risks and what kind of monitoring should be implemented. There is also strong interest in

TABLE 1 Examples of climate-related impacts on the Mistik SFM system (Andrews-Key, 2018).

Climate impact	Description
Extreme weather events	Mistik has already experienced access and infrastructure issues in harvesting areas, including challenges with hauling, road rutting, and washout, and others due to more extreme precipitation and temperature events. Extreme cold or heat has also affected operations. For example, there have been challenges to equipment functionality due to extreme cold and safety concerns for contractors and field crews who work in both extreme cold and heat.
Wind events	Increase in frequency and severity of wind events leading to large-scale blowdowns, causing issues with how to manage and salvage wood from these areas.
Climate and seasonal variability	With changes in climate and seasonal variation, operations have been delayed due to late freeze-up and shorter winter seasons. Managers have also learned to be more proactive in identifying "back-up" harvest areas in the summer, in the case that some areas are too wet or too dry to harvest safely.
Disturbances	All types of disturbance events (e.g., wildfires, insects, diseases, and blowdowns) are expected to increase in intensity, duration, and frequency, impacting forest health and productivity.

TABLE 2 Examples of adaptation actions undertaken by Mistik (Andrews-Key, 2018).

Action	Description
Increased monitoring and assessments	Identifying operational days lost and costs associated with impacts; informing annual assessments of road conditions and changes to maintenance schedules.
Changes in standard operating procedures to use information generated through a process	Using operational measures to make adjustments to tactical plans along with institutionalizing ongoing reassessment of impacts and effectiveness of actions.
Increasing flexibility through buffers	Enhancing the ability of managers to become more proactive in identifying "back-up" harvest areas in the summer, in the case that some areas are too wet or too dry to harvest safely, and seeking early approvals.
Identification of thresholds/timing	Identifying decision points and key assumptions in the management plan.
Adapt silvicultural rules and policies (where possible) to ensure the growth rates of trees are maintained or enhanced.	In response to decreased forest growth.
Minimize fragmentation of habitat and maintain connectivity	In response to the alteration of plant and animal distribution.
Continue to enhance and expand risk assessment methods	In response to recognizing any decreasing health and vitality of the forest ecosystem due to cumulative impacts of multiple stressors.
Continue to enhance a more holistic management approach that balances timber and non-timber values	In response to any decreasing health and vitality of the forest ecosystem.

doing so as the indigenous nations are as equally interested in the potential impacts on the forest and resources found there that provide foods, cultural and spiritual values, and non-timber products as they are in timber, typically the primary focus of forest management by firms.

This part of the process also provided a clearer understanding of what was within the control of the forest managers and what lay beyond it. For example, Mistik recognized that supply chain management and changing supply-and-demand trends in markets could affect their financial stability, whereas policy and third-party certification could impose costs or limit flexibility in adjusting forest management practices. They also identified wildfires and outbreaks of insects and diseases as potentially threatening timber supply, quality, and value, thus posing risks to the company's ability to manage costs and deal with the liability associated with those disturbances under the current policy framework. However, Mistik identified the above risks as beyond their control and therefore outside of their realm of influence. Characterizing vulnerability in this way allowed Mistik to prioritize adaptation actions but also indicated policy pressure points where change may be required to enhance Mistik's ability to adapt (i.e., in regards to recovering salvaged timber) or where policy change may be required to ensure the ability to cope with future impacts (increased incidence of wildfire).

Mistik identified a number of current adaptations (adapted from Andrews-Key, 2018) including both operational and strategic changes, several of which are shown in Table 2. These included the following:

(1) changes in operational practices such as incorporating an annual assessment of road construction and maintenance conditions to increase resilience to access disruption;
(2) establishing temporary stockpile sites and coordinating early approval of site location from the province;
(3) changes in monitoring such as reporting on climate-related indicators (e.g., operational days lost due to fire hazard and weather extremes, and number of days that ice is present on lake surfaces within the FMA); and.
(4) organizational learning leading to changes such as including observations in relevant internal standard operating procedures, conducting an annual reassessment of the organization's adaptation priorities and vulnerabilities related to their SFM objectives, and an annual reassessment of areas where improvement is required to address climate change impacts for Mistik and its stakeholders.

Another key outcome of this study was how climate change considerations were integrated into everyday operations, planning, and decision-making processes at all levels of the organization. While not an initial goal, Mistik also became aware of the ways in which the adaptive capacity of the organization, as well as that of the individual practitioners within it, increased as a result of this process, along with their stakeholder's understanding of climate change impacts. Managers and practitioners not only developed an increased

understanding of the impacts and vulnerabilities but also saw how their local knowledge and technical expertise could be used in conjunction with climate data. As a consequence, the organization has been able to develop an ongoing dialog internally and with stakeholders, including government regulators, allowing Mistik to better identify emerging vulnerabilities and changing risks and therefore move forward in identifying appropriate responses (Andrews-Key, 2018).

4 Discussion

In piloting the vulnerability assessment approach, Mistik provides an example that other firms may follow and demonstrates the applicability of the framework at the organizational level. Furthermore, the case study shows how vulnerability assessment processes can lead to mainstreaming climate change considerations into firms' planning and management systems (Johnston and Hesseln, 2012). Finally, this offers insight into the process of adaptation itself including the question as to what, if anything, limits implementation.

Several key lessons were learned by the forest managers involved in the vulnerability assessment process. First, by taking ownership of the vulnerability assessment process, organizations can reap the benefits of maximizing organizational buy-in. Local forest managers know their own SFM system best and have the knowledge necessary to undertake effective adaptation in their management area. Second, many of the tools required to complete vulnerability assessments are already part of forest planning and management. Climate change considerations can be incorporated into existing processes; changes to organizational structures and processes or new resources and positions are not necessary. The need for information is not a limiting factor. Third, developing a strong network of researchers, managers, and stakeholders who will be involved throughout all stages of the vulnerability assessment process can bridge different domains of knowledge and expertise and help ensure that the assessment has real-world applicability. Building partnerships is key. Fourth, a communications plan with defined roles and expectations can ensure that everyone is on the same page as the assessment evolves.

To ensure that the team remains focused on the project objectives, outcomes and goals defined early in the assessment should be revisited regularly. Identification of external risks is important for two reasons: First, it can inform where policy change may be needed and the degree of potential change (whether it is an adjustment in regulations or settings (such as timing) or something more substantive) is required. Second, identifying what issues are within the power of the organization to address and which are beyond its control aids in prioritizing actions.

This project demonstrated the importance of building it as a bottom-up process, enabled by higher levels of government. Local collaboration was a critical starting point for building trusting relationships among the parties involved in the process. This collaborative approach was central to the project's ultimate success as those involved became fully engaged in creative problem-solving. Throughout the process, it also became evident that collaboration among the organization, stakeholders, and policymakers improves the effectiveness of mainstreaming adaptation through building a common understanding and familiarity of the participants of not only the impacts and risks but also uncertainties.

It also became clear that a knowledgeable facilitator is an important asset to a vulnerability assessment team and this collaborative process. The facilitator played an important role in guiding the organization through the vulnerability assessment process, ensuring that the group did not become overwhelmed or 'lost' in the process and that the task did not become someone else's responsibility sitting on top of their desk along with all their other responsibilities. The facilitator also identified the importance of developing a communications plan to strengthen knowledge flows among organization members, stakeholders, and policymakers. This helped foster discussion, promoted more effective mainstreaming, and aided in decreasing the implementation gap between identifying adaption measures and translating them into action by providing evidence and direction for policy change (Runhaar et al., 2018). This facilitated process also helped Mistik recognize that they had already been mainstreaming adaptation on a small scale in some areas (e.g., by modifying hauling schedules to coordinate with temperature variability and associated access issues; Mistik, 2018).

Mistik's experience also offers insight into the discussions around the challenges and barriers to mainstreaming and implementing adaptation actions. Many potential constraints have been proposed, ranging from more general ones such as a lack of scientific information and a lack of resources (both human and financial), toward more sector and organizational-specific ones such as policies and legislation, regulations, investments, protocols and guidelines, training, and operational procedures (Eisenack et al., 2014; Edwards et al., 2015; Williamson and Nelson, 2017). In particular, climate scientists and others have argued that a lack of information has been a limiting factor in the uptake of adaptation initiatives and that more and better climate science is essential to informing adaptation and moving ahead (Jantarasami et al., 2010; Fiedler et al., 2021). However, our results suggest that although climate science is important, it is only part of the picture and that local-level knowledge and expertise play a key role in implementing adaptation in several ways. Local knowledge and expertise are needed for interpreting scientific information, identifying where scientific information is lacking, and translating that information into adaptation action at the local level. Fletcher (2023) notes that providing information is not the same as decision-making. While it is possible to generate various scenarios and model runs based on different assumptions about future timber supply, the ultimate outcome depends on the decision-making process. It is this process—where divergent values are reconciled—that determines the appropriate harvest levels, rather than the climate science data alone.

Beyond the issue of scientific information, none of these other factors posed significant barriers to the assessment process undertaken in this project, nor did any of them prevent Mistik from moving forward with adaptation action. The need for extensive external resources (financial and other human resources) is commonly posed as a key challenge in the vulnerability assessment process (Moser and Ekstrom, 2010; Biesbroek et al., 2013; Barr and Lemieux, 2021), but this was not an issue here. Many of the resources and tools used in adaptation mainstreaming already existed within the SFM system. Another commonly cited barrier is policy yet that also was not an issue here. Provincial forest policies typically offer flexibility in how firms meet their SFM objectives; evidence from Mistik and other firms elsewhere in Canada engaged in adaptation shows that understanding the economic implications of the climate risks they bear—and the benefits from implementing changes in planning and practices—is

essential in making those changes (Andrews-Key et al., 2021). Several participants observed that they were able to link climate adaptation to their own area of practice and saw it as a necessary supplement to existing management practices, rather than an additional responsibility.

Finally, a common weak point of policy development is implementation: Policymakers oftentimes do not consider either implementation needs or how the different recipients interpret and translate that policy and whether it will result in the desired actions and outcomes (Kent Weaver, 2010). This lack of consideration can result in a lack of desired action or unintended consequences (Hudson et al., 2019). Here, Mistik's ability to plan and then implement management strategies, in combination with an organizational culture that was supportive of taking a proactive approach to adaptation, played a crucial role in their success. Through this CCVA process, managers and policymakers collaboratively identified where policy changes were required or could be anticipated to better facilitate adaptation while also offering the opportunity to carry out an implementation analysis that can improve policy development (Kent Weaver, 2010; Hudson et al., 2019). Furthermore, by identifying risks outside of Mistik's control, the participants were able to flag broader and emerging concerns for policymakers (e.g., increased wildfire severity and incidence) that may require a policy response. Contrary to the idea that vulnerability assessments lack the capacity to clearly describe adaptation processes and explain change (see Biesbroek et al., 2015; Wellstead et al., 2014), this research points not only to what is important in these processes but also to how these processes can contribute to change.

Frequent and meaningful engagement between government and industry (as the forest managers) is integral to a process of learning and policy development. It creates the necessary opportunity for communication and information sharing to close the implementation gap. This, in turn, provides a mechanism for increased knowledge transfer within the SFM system, supporting adaptation mainstreaming by providing various interest groups access to insights on how forest management practitioners use information to support adaptation decision-making while also identifying areas where information is lacking (Nelson et al., 2016; Halofsky et al., 2018; Williamson et al., 2019).

For this to be successful, a feedback loop must exist between knowledge generation at local levels and policy development at higher levels, which then informs further improvement at the local level. Identifying and developing these feedback loops is essential, as well as incorporating local knowledge in a systematic way to improve policy and recognition that more effort and attention should be paid to improving the relationships and partnerships through which this knowledge can be shared. We believe this is equally true in other jurisdictions.

More generally, this experience illustrates the importance of learning which can be a driver of policy change (Bennet and Howlett, 1992). Vulnerability assessments can be designed and facilitated to offer learning opportunities that support organizational and policy development in several different ways. One of these is the iterative nature of the process, which fosters self-reflection as participants engage with the experts and professionals involved throughout, helping to ensure the outcomes are relevant and usable. Understanding better this learning process can contribute to informing and improving future efforts (Dujin, 2020). In addition, as other firms begin to engage in similar processes, a larger pool of practical examples will further increase the knowledge around effective mainstreaming of adaptation in the forest sector, increasing forest managers' ability to manage forest ecosystems sustainably in an uncertain future (Edwards and Hirsch, 2012; Spittlehouse, 2005; Williamson et al., 2019).

5 Conclusion

Vulnerability assessments have been challenged as being static and limited in their capacity to account for social and other factors that might affect adaptation (Ford et al., 2018). The results of this assessment counter that critique: By using a climate vulnerability assessment process, Mistik showed how adaptation planning can be embedded into existing systems that also incorporate a commitment to ongoing and collaborative learning with external actors (e.g., the provincial government). Mistik demonstrated the potential for vulnerability assessments to produce ongoing, dynamic, and flexible adaptation planning processes rather than static plans.

The evidence from the Mistik experience suggests that there are no substantive barriers (e.g., policies, lack of financial resources, and lack of information) to Canadian forestry firms seeking to engage in adaptation planning and mainstream climate considerations into their ongoing planning and management activities. It offers insights into what governments can do to further support adaptation efforts. Rather than focusing solely on providing more and more climate science, we suggest that firms need assistance in making existing climate science relevant to their local context and creating opportunities to incorporate their own knowledge into processes for identifying and implementing adaptation actions. Adaptation decision-making must be informed by accessible scientific information so that practitioners are able to relate it to their local contexts and realities. This finding is consistent with recent observations of a need for better utilization of local land managers' tacit knowledge in adaptation decision-making, given the scope, complexity, and speed with which climate change is expected to affect forests (Nelson et al., 2016).

Scientific and governance institutions need to go beyond merely providing information. They should offer dedicated support for fostering knowledge sharing and collaboration among scientists, forest managers, government, and other stakeholders or rights holders. This will help facilitate learning and, ultimately, enhance the sustainability of Canadian forest ecosystems (Gitay et al., 2001; Halofsky et al., 2018; Williamson et al., 2019). The type of collaboration that took place between researchers and the firm and regulators has also been identified as key to building effective science–management–policy partnerships as knowledge translation is facilitated through such processes and the gap between the provision of information by scientists and uptake of that information by practitioners is narrowed (Littell et al., 2012). This is not just limited to managers and scientists; Fletcher (2023) noted the importance of constructive relationships among different disciplinary experts in navigating the uncertainty around climate change.

We see learning as a key issue in advancing adaptation. The adaptation literature is replete with recommendations that more transformative change is required, but there is little practical evidence about how this may be attained. This study offers one potential pathway for supporting transformative policy learning: forest managers committing to climate change vulnerability monitoring and

assessment and collaborating with researchers and policymakers to share findings and knowledge to understand where and how either our policies or our goals may need to change in response to a changing environment (Pahl-Wostl, 2009).

If we can build these relationships and partnerships, this will increase the adaptive capacity of the forest management system in Canada that takes into account the ecological and social diversity across the country. Rising to the challenge of balancing policy development with the continuous integration of local context and knowledge is necessary to ensure that adaptation policy is effective on the ground while bridging potential divides between regulators and managers (Hotte et al., 2016). This combination of local knowledge paired with higher-level policy change will underpin our ability to successfully conduct adaptive forest management and successfully navigate an uncertain future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

SA-K: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. HN: Writing - review & editing, Methodology, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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