A business case for climate change adaptation by forest industry in central Canada

Presented at the CIF/IFC 2020 National Conference and 112th Annual General Meeting held 15–17 Sept. 2020

by Sheri A. Andrews-Key^{1*}, Paul A. LeBlanc², and Harry W. Nelson³

ABSTRACT

Extreme weather events and increasing climatic uncertainty are already affecting the Canadian forest sector. Climate change projections indicate impacts will likely worsen with increasing risk to forest operations and resources. Despite the calls for adaptation, there is little evidence that adaptation is taking place, whether in terms of planning or practices. Much of the forest industry response to date has been *ad hoc* and reactive. In contrast, Louisiana-Pacific Canada Ltd. (LP) in Swan Valley, MB decided to proactively address climate impacts and risks. A Climate Vulnerability Assessment (CVA) was completed to review past weather-related disruptions, identify their vulnerabilities to both the current weather extremes and to future climates. Through the help of an independent facilitator, the Canadian Council of Forest Ministers' guidebook was tailored to meet LP's context and needs. The CVA team identified a wide range of possible adaptation options and created business cases for short-listed adaptation priorities that LP is beginning to pursue and implement. The outcomes from this effort show what is necessary to support an adaptation process that is mainstreamed into company decision-making procedures and can be applied more broadly across the Canadian forest sector. One key innovation was the incorporation of business cases into the assessment. Identifying and quantifying the expected benefits helped support adaptation implementation in several different ways. Furthermore, at a more systemic level, the experience identifies the importance local knowledge plays in advancing adaptation action and how these local efforts can contribute towards supporting more effective climate adaptation action across the entire forest management system. This work also contributes to laying the groundwork for future policy focus, integrating science, and management into forest management systems.

Keywords: climate vulnerability assessment, case study, vulnerability adaptation, business case, extreme weather, climate change

RÉSUMÉ

Les phénomènes météorologiques extrêmes et une incertitude grandissante au sujet du climat nt déjà l'industrie forestière canadienne. Les changements climatiques projetés laissent voir que leurs effets risquent d'empirer, augmentant du coup le risque qui plane sur les opérations et les ressources forestières. Les appels répétés à s'adapter au changement ne semblent pas avoir eu d'écho tant en matière de planification que d'exécution sur le terrain. Pour l'instant, la réponse de l'industrie forestière a consisté surtout en des actions ponctuelles et dans une approche réactive. De son côté, Louisiana-Pacific Canada Ltd. (LP) de Swan Valley au Manitoba a adopté une approche proactive pour sa gestion des effets et des risques liés aux changements climatiques. Elle a donc effectué une évaluation de sa vulnérabilité face au climat (*Climate Vulnerability Assessment - CVA*) afin d'analyser les perturbations passées liées à la météo et de faire ressortir les facteurs de vulnérabilité aux conditions de climat extrêmes présentes et à venir. Avec l'aide d'un facilitateur indépendant, LP a adapté le guide du Conseil canadien des ministres des forêts à sa situation et à ses besoins. L'équipe de CVA a pu ainsi trouver tout un assortiment de façons de s'adapter, et élaboré des analyses de cas pour une courte liste de priorités que LP a retenues et choisi de mettre en œuvre. Les résultats de cette initiative montrent qu'il est nécessaire de soutenir un effort d'adaptation qui s'applique à tout le processus décisionnel de la compagnie et qui pourrait s'étendre plus généralement à l'ensemble de l'industrie forestière canadienne. Une des innovations clés de cette démarche fut le recours aux études de cas pour appuyer les évaluations. Le fait de faire ressortir et de quantifier les avantages anticipés a permis de soutenir la mise en œuvre des actions retenues pour diminuer la vulnérabilité. Du point de vue systémique, l'expérience a permis de faire ressortir en outre l'importance de miser sur la connaissance locale pour mettre de l'avant des actions d'adaptation nécessaires, et de montrer comment ces démarches locales peuvent aider à soutenir des gestes d'adaptation plus efficaces à la grandeur du système d'aménagement forestier. On a ainsi jeté les bases de politiques misant sur la science et la gestion pour les futurs systèmes d'aménagement forestier.

Mots-clés: évaluation de la vulnérabilité face au climat, étude de cas, adaptation à la vulnérabilité, analyse de cas, conditions climatiques extrêmes, changement climatique

¹Innovative Climate Strategies, Saskatoon, SK, Canada S7H 0B2 *Corresponding author: sheri@climatestrategies.ca

²Louisiana-Pacific Canada Ltd., Forest Resources Division, Swan River, MB, Canada R0L 1Z0

³University of British Columbia, Faculty of Forestry, Vancouver, BC, Canada V6T 1Z4

Sheri A. Andrews-Key

Paul A. LeBlanc

Harry W. Nelson

Introduction

Forests are complex ecosystems being affected by climate change impacts to varying degrees on a global scale (Spittlehouse 2005). The health and sustainability of Canada's boreal forests are vulnerable to these changes (Ohlson *et al.* 2005). It is also increasingly evident that sustainable forest management objectives are expected to be more challenging to achieve with increasing climatic uncertainty (Swanston and Janowiak 2012). With the health and sustainability of forest ecosystems as a priority, scientists, forest managers, and policy makers have been investigating the effects that a changing climate will have on the current and future sustainability of the boreal forest (Gray 2012). The task confronting forest managers is to develop adaptation options for identified vulnerabilities in Sustainable Forest Management (SFM) systems that can be implemented into all aspects of existing management and operations (Halofsky *et al.* 2018) for continued forest and business sustainability.

Climatic and weather extremes associated with climate change, have significantly affected forest management planning and operations to varying degrees (Edwards *et al.* 2015). It is anticipated that the forest sector will need to actively address climate change impacts and vulnerabilities in Sustainable Forest Management (SFM) systems in order to continue to achieve SFM objectives (Lempriere *et al.* 2008). The application of vulnerability assessment and adaptation frameworks in SFM systems is a valuable tool to help meet this need (Andrews-Key 2018; Halofsky *et al.* 2018). Climate change vulnerability assessment processes aid in increasing adaptive capacity and resilience, building flexible adaptation strategies into existing systems that support current forest management and practices (Andrews-Key 2018). SFM includes ecological, economic, social, and cultural elements that the boreal forest provides (CCFM 2008) and by its' nature asks managers and decision-makers to look ahead. To achieve sustainability, long-term management plans are developed to show how forests will be managed for future generations (Edwards *et al.* 2015). These multiple benefits involve several complex trade-offs. Climate change and the uncertainty it brings not only amplify complexity but may require additional considerations in the way forests are managed (Williamson *et al.* 2012). Many factors drive SFM planning and practices, including economics, environmental health, and social well-being (Marchi *et al.* 2018). Vulnerability assessment and incorporating climate change adaptation into planning and practices will be a key element to aid forest

managers in addressing climate change impacts (Ogden and Innes 2007).

Adapting practices, decisions, and policy for addressing climate change impacts is essential (Runhaar *et al.* 2018) to achieving SFM and will help increase the ability of managers to mainstream adaptations (Peterson *et al.* 2011). Mainstreaming climate adaptation into existing systems and policies is an important part of building capacity to address climate change vulnerabilities.

However, understanding and evidence of effective mainstreaming for adaptation is sparse (Runhaar *et al.* 2018). Through vulnerability assessment processes, adaptations are identified but often fail to be mainstreamed, which leads to an implementation gap (Runhaar *et al.* 2018). Examples where mainstreaming of climate adaptation have been effective are needed to build knowledge and understanding. This will help to bridge the implementation gap and aid in translating climate adaption into policy (Andrews-Key 2018). Through the case study presented in this paper, we demonstrate how a vulnerability assessment has led to effective climate adaption mainstreaming, providing evidence of how this has been accomplished, and insight into how this led to action (e.g., changes in actual decision-making) and a recognition that adaptation will be dynamic, not static.

Case Study

In west-central Manitoba (Fig. 1), extreme weather has been adding excessive uncertainty, reduced the ability to harvest, haul wood, and renew the forest in a timely fashion. The climate-related impacts and challenges have negatively affected forest management and operations in the region. This paper explores the approach to addressing these challenges by LP Forest Resources Division (FRD), located in Swan River, Manitoba, Canada. LP Forest Resources Division (FRD) is skillful at adapting to extreme weather on an *ad hoc* basis due to the high level of experience and the ability of the FRD management and operations staff. However, with future loss of experienced staff through retirement, combined with increasing climate uncertainty, this ability to adapt may decrease. Furthermore, responding to climatic extremes on a reactive basis does not provide an opportunity to assess whether these *ad hoc* strategies may be the most effective or efficient way to address these conditions, since these climatic extremes may become more pronounced in the future. LP decided to undertake a detailed assessment of LP Swan River's vulnerability to extreme weather impacts that: 1) included identifying current and future climate vulnerabilities; 2) addressed how to proactively prioritize and mitigate the risks associated with future climatic impacts on forest management activities such as road building, harvesting, hauling, and silviculture; and, 3) resulting in adaption strategies for planning, procedures, practices, creating the business case for adaptation leading to adaptation action. The Canadian Council of Forest Ministers (CCFM) framework for vul-

Fig. 1 West-central Manitoba case study area (bounded in light grey)

nerability assessment (Edwards *et al.* 2015) was used, focusing on climate change at the Forest Management Licence scale. The structured decision-making approach of the CCFM framework allowed the core team to follow the logical steps from a vulnerability assessment to identifying how adaptation in forest industry needed to be supported by the business case for adaptation (Andrews-Key and Nelson 2018). In this regard, the outcomes from this project takes a major step forward in helping to illustrate that a process that was originally seen by all parties as a formidable task, is in fact feasible and valuable for moving toward vulnerability adaptation action.

Methods

The Climate Vulnerability Assessment (CVA) project assessed both current and anticipated climate change impacts by utilizing the Canadian Council of Forest Ministers guidebook (Edwards *et al.* 2015). The guidebook was designed to help forest managers work through a detailed vulnerability assessment, leading to adaptation development and implementation. In addition to the guidebook, the process was expanded to build the business case for adaptation through assessing associated costs for individual, prioritized adaptation options in a structured and strategic approach. The business case process involved the exploration of potential strategic and operational opportunities, feasibility, costs (economic, environmental, and social), and risks. In-person workshops were held for each phase (Fig. 1) facilitated by Dr.

Sheri Andrews-Key with LP Forest Resources Division operations and planning staff. In-person workshops, meetings, and conference calls were the main venues for facilitating the vulnerability assessment by the core team. Correspondence was carried out with other project collaborators and stakeholders as required. There were between two and 10 staff involved that included professional foresters, forestry technicians, and the Area Forest Manager for LP FRD. The core team for the climate vulnerability assessment and business case for adaptation was comprised of the District Forester and the Operations Manager Forester from LP FRD with Dr. Sheri Andrews-Key.

CCFM Framework

The Canadian Council of Forest Ministers (CCFM) framework allows for a range of values to be assessed that encompass both the biophysical and socioeconomic aspects of SFM. The framework provided a structured decision-making approach that enabled forest managers to assess vulnerability, the company's adaptive capacity, and to develop and apply adaptation options (Fig. 2). The four stages of the assessment include (Edwards *et al.* 2015):

- Phase One Explore organizational readiness;
- Phase Two Pre-vulnerability analysis;
- Phase Three Detailed vulnerability analysis; and,
- Phase Four Identify, implement, and monitor adaptation.

The vulnerability assessment portion of the overall project focuses on the results of the detailed vulnerability assessment (Phases One through Four). Information for each phase was gathered from existing scientific research, LP's internal forest management documents, and expert knowledge of forest managers and stakeholders.

The following timeframes for climate scenarios used were (IPCC 2014):

- Scenario 1 Timeframe: 2010–2039
- Scenario 2 Timeframe: 2040–2069
- Scenario 3 Timeframe: 2070–2099

The core team chose to use the worst-case climate change scenario, Representative Concentration Pathway (RCP) 8.5 (IPCC 2014). This is considered the worst case out of all the RCPs due to the greatest degree of temperature increase to the end of the century (2100). Using this scenario allowed for the development of a variety of potential adaptation options that could accommodate a range of climate change impacts.

McKenney *et al.* (2016) examined projections of wood supply and delivered wood costs across Canada under climate change using the same RCP 8.5 scenario. They report significant price increases (greater than 25%) for delivered wood costs in Manitoba but suggest wood supply availability will not be greatly affected (less than 2% losses). Brecka (2018) has suggested that under the RCP 8.5 scenario parts of the boreal could see a reduction in available harvest levels starting in 2050 by 75% or more for representative areas in the boreal parklands and boreal black spruce forest in southern Manitoba. Reductions of this magnitude would have a negative impact on the forest sector. However, the reduction

Fig. 2 Four phases and six components (blue boxes) of adaptation to climate change for Sustainable Forest Management (adapted from Edwards *et al.* 2015)

in volume does not necessarily translate directly into an equivalent economic loss. The ability of industry to adapt can partially mitigate changes in timber availability. Uncertainties around potentially offsetting changes in prices and demand for new products can either help mitigate or compound firms' competitive position. Another source of uncertainty is the systemic effect of reduced harvests. If harvest levels fall below a critical point, mills could close, and capacity may be lost. In addition, there could be negative impacts on infrastructure, including road and distribution systems, human capital invested in workers, and expertise required to conduct forest operations.

Outcomes

Phase One: Organizational Readiness

We explored the organizational readiness of LP Canada Ltd. Swan Valley to complete a climate vulnerability assessment. This phase needed to be completed before the assessment was started. LP Swan Valley has continually recognized the importance of climate variability and uncertainty in their management and planning through involvement in local climate vulnerability projects (O'Shaughnessy 2002; Johnston and Nicolichuk 2005) and other related work with climate change scientists over the years. Challenges relating to climatic variability and uncertainty were also being identified in operations and planning. LP was also in the process of completing their 20-year Forest Management Plan (FMP) and had allocated resources for this process. Other key factors that contributed to the company organizational readiness included strong support from senior management, and

observations regarding climate impacts from the forest managers based on experience and knowledge. Therefore, LP Canada Ltd. Swan Valley was deemed ready to start the process of exploring climate vulnerability assessment and could begin to proactively address increasing climatic uncertainty.

Phase Two: Pre-vulnerability analysis

LP Swan Valley formed a climate vulnerability core team which utilized both operational and planning staff. This was an important step to ensure we incorporated local knowledge into the climate vulnerability assessment.

The Phase Two pre-vulnerability analysis workshop involved three important steps:

- i. Providing context for the assessment;
- ii. Describing and identifying current climate and forest conditions through trends, relationships between climate, forest conditions and management, uncertainties, and knowledge gaps; and,
- iii. Choosing future climate and forest scenarios (Edwards *et al.* 2015).

The forest managers for LP determined that climate change and increasing uncertainty are becoming a greater concern for SFM. Weather extremes have been affecting planning and forest management activities. In the last 25 years, there have been significant variability and extremes in precipitation, temperature, and wind. An example of this was unfrozen soil and warm winter weather reduced access to winter harvest areas.

The consensus amongst LP FRD staff was that climate change and climate variability was likely to increase in the future. Therefore, it is justifiable to be proactive in assessing climate vulnerabilities to address adaptive capacity and knowledge gaps. The team also determined that they needed to begin monitoring, evaluating, and developing potential adaptation options for the future.

Climate information for the licence area had been previously compiled in the Forest Management Plan (Louisiana-Pacific Canada Ltd. 2019) and included both temperature and precipitation data. In addition, climatic impacts of extreme weather observed by LP staff over the last 25 years were documented.

LP FRD staff recognize that their planning and management are vulnerable to climate change impacts to varying degrees. Currently, SFM objectives are being met successfully. However, with increasing climatic uncertainty, this may not be the case in the future. The core team used output from Representative Concentration Pathway (RCP) 8.5 scenario over three time periods for assessing and ranking SFM objective vulnerabilities according to a low-medium-high risk (Andrews-Key 2018). This allowed us to gain a stronger understanding of climate impacts, forest conditions and the dynamic inter-relationships. If the climate changes are less than RCP 8.5, LP would still be well-prepared to adapt, as a range of adaptation options were developed.

Phase Three: Detailed Vulnerability Analysis

Phase three involved a detailed assessment of LP's SFM objectives and adaptive capacity of their SFM system. LP management, planning goals, and objectives were deemed vulnerable to extreme weather. Through this assessment, the core team identified that under the current climate, they were able to successfully meet their SFM objectives. However, extreme weather vulnerabilities are expected to increase in

the future. Using the RCP 8.5 scenario, the core team evaluated the SFM objectives, described the know and potential vulnerabilities, and ranked the vulnerabilities according to a low-medium-high risk ranking.

The core team employed the assessment results to rank each of the SFM objectives according to management priorities, provincial regulations, and SFM certification requirements. The rankings were based on the number of objectives under each criterion, with one being the highest priority and four being the lowest priority. In some cases, both the vulnerability level and the priority were similar, (e.g., high vulnerability and high priority). However, there were also situations where the vulnerability was assessed at a higher value than its priority. Thus, the vulnerability assessment and the priority ranking for some SFM objectives do not correspond. In the situations where this occurs, it demonstrates that even though some SFM objectives are expected to have a high degree of vulnerability to climate change impacts moving into the future, forest managers' SFM goals and priorities may not align with the degree of vulnerability. Table 1 has become a tool in LP's SFM system and will be updated annually as vulnerabilities and priorities change through time.

Phase Four: Identify, Implement, and Monitor Adaptation

The phase four adaptation, identification, development, and evaluation workshop was completed with the core team. Using the CCFM inventory of potential adaptation options (Edwards *et al.* 2015) as a foundation, potential vulnerabilities were adapted for LP's context. The adaptation options were also evaluated, scored, and detailed (Table 2).

The core team then prioritized and short-listed 12 potential vulnerability adaptations based on the scoring. Note that five of these adaptations were related to Natural Range of Variation (NRV) so the five NRV adaptations were combined into one NRV vulnerability adaptation. This culminated with

Table 1. Sample of assessment and prioritization of SFM objectives and adaptive capacity under current and potential future climate change (Andrews-Key and Nelson 2020)

SFM Objectives	SFM Objective Impact	Adaptive Capacity	Prioritization ranking (1 to 4) of SFM objectives for management and planning purposes
CCFM Criterion 1: Biological Diversity Maintain ecosystem health and function	Low – certain pockets have had regeneration failure due to different weather events.	High	4 – Challenge down the road if we need to fill-in plant
Maintain the existing range of forest structure conditions over the long term	Low – Age class structure, snags, Seral Stage 1 NRV	High – but over the long term – unknown due to uncertainty	3
Provide additional, fine filter, protection of rare ecosystems and areas with high levels of biodiversity	Low – Buffered as well. Connected with SFI	High	3
Provide goods and services for present and future generations Maintain the representation of the current range of wildlife habitat associations	Low – Related to Seral Stage, LP “Biodiversity in a box” diagram	High	2

Adapted from Tables 4.2, 4.3, and 5.1 in Edwards [^] 2015

Table 2. Sample of potential vulnerabilities scored and detailed

*CCFM SFM Criterion	Climate Change Impact & Vulnerability	Planning Level	Adaptation Options	Score	**Feasibility Ranking 1 (low) – 4 (high)	Potential Challenges Barriers Recommendations	No.
Criterion 1: Biological diversity	Alteration of plant and animal distribution	Strategic	Minimize fragmentation of habitat and maintain connectivity	2	2 – strategic planning to increase block size in the FMP- connectivity – e.g. planning connectivity – e.g. planning for elk corridors. (refer to FMP increasing block size and two-year operating plan)	Science behind Natural Range of Variation suggests we need to increase block size to match historical disturbance sizes	1
Criterion 1: Biological diversity	Alteration of plant and animal distribution	Strategic	Maintain representative forest types across environmental gradients	1	1 – In Forest Management Plan – tracking cover types; part of FMP modelling – at landscape level – important! Highly rated by governments and Indigenous communities	Committed to tracking cover types (landscape-level) in the Forest Management Plan monitoring section.	2
...							
Criterion 6: Society's responsibility	Forest management policies and incentives do not encourage adaptation to climate change	Strategic	Remove barriers and develop incentives to adapt to climate change	3.5	3-4 In theory, barrier removal should be done by the regulator	Government needs to take the lead on this. We can provide suggestions	133

*Canadian Council of Forest Ministers – Sustainable Forest Management criterion adapted from Edwards *et al.*, 2015.

**1 – Desirable/Doable

2 - Possible but harder to accomplish

3 - Greater difficulty for feasibility and implementation

4 - Not Feasible

eight vulnerability adaptations in the final short-list. Business cases, complete with costs and risks, were developed for each of the eight vulnerability adaptations. These included:

1. Natural Range of Variation (NRV) fire emulation forest management;
2. Maintain representative forest types across environmental gradients (through adapting of monitoring);
3. Adjust harvest schedules to harvest stands most vulnerable to insect outbreaks;
4. Adopt a holistic management approach that balances timber and non-timber goods and services;
5. Decommission and rehabilitate roads to maximize forest carbon sinks;
6. Incorporate study of local forest-related knowledge into forestry and environmental education;
7. Protect higher-value areas from fire through Fire Smart techniques; and,
8. Enhance dialogue amongst stakeholder groups to establish priorities for action on climate adaptation in the forest sector.

The above adaptation options consider potential vulnerabilities to planning and operations identified in the assessment. It is important to note that many of the prioritized adaptation strategies were already key foundational practices of LP's existing SFM system. However, through the detailed

vulnerability assessment process and adaptation identification and development, these were the areas to focus on and adapt for increasing climatic variability and uncertainty.

Utilizing the short-list of climate vulnerability adaptations, we identified, implemented, and monitored these eight climate vulnerability adaptations to existing practices in LP's SFM system. LP's existing Sustainable Forest Management system was identified as highly useful to assist with this process. For example, the 20-Year Forest Management Plan (Louisiana-Pacific Canada Ltd. 2019) was well-suited to implement and monitor CVA #2 'Maintain representative forest types across environmental gradients.' Forest cover types by an environmental gradient (i.e., soil moisture regime and soil texture combinations) were in the forest inventory, the FMP strata, and the FMP modeling. This allowed representative forest types to be tracked over five-year increments and can be compared to the baseline at the beginning of the FMP, the year 2020.

Both direct and indirect costs were attached to the different strategies. Market impacts (e.g., fiscal impacts) and non-market impacts (e.g., social and cultural, and ecosystem goods and services) were considered as well. Trade-offs were also evaluated, such as reducing the risk of running the mill out of wood versus the extra cost of maintaining a higher wood yard inventory. A more complex trade-off example was implementing Natural Range of Variation. Increased distur-

bance sizes closer to natural fires trades off a potential social negative of larger disturbances with the ecological positives of increased coarse-filter biodiversity and a lower ecological footprint from less roads.

Trade-offs further enhanced the 'business case for adaptation' and how climate change and increasing uncertainty might influence investment decisions (e.g., access infrastructure, mill yard inventory, etc.) for future LP operations. The main benefit identified was the reduced opportunity cost from taking operational downtime (either the mill running out of wood or machines sitting idle in the cut block). However, the analysis showed that there were many ecological and social benefits such as improved forest stewardship and social licence that accompanied some of the adaption actions.

Business cases for adaptation

Business cases of each short-listed climate vulnerability were a key innovation that extended beyond the CCFM guidebook. The eight business cases for adaptation helped increase capacity within LP and were essential in identifying areas for proactive climate vulnerability adaptation. The business cases also helped assess the potential economic viability to reduce both operational and strategic risks. This allowed LP to make more informed decisions for short-term and long-term planning.

It is anticipated as the CVA work continues, we will explore points in time when there are shifts in external conditions (e.g., environmental change, market change, political change, etc.) that may affect forest planning and decision-making. The CVA is a 'living' document to be reviewed annually and mainstreamed into LP's Sustainable Forest Management system for planning and operations for climate vulnerability and adaptation. Another result of the work includes LP's upgraded Standard Operating Guidelines (SOGs) for planning, roads, crossings, harvesting, and silviculture that included climate vulnerability monitoring and adaptations where applicable.

The outcomes from the business case for adaptation analysis aided in a more structured economic approach to addressing climate impacts and vulnerabilities within LP's SFM system to be more proactive and less reactive in terms of risk assessment. In turn, this helps guide future investment and strategic planning. This work also demonstrates the viability of adaptation options to reduce future costs of continuing to do 'business as usual' without adaptation. The results will help drive economic activity and value from the forest, seen as critical if forest industry firms are to remain competitive (Lempriere *et al.* 2008).

Discussion

The consequences of 'doing nothing' with regards to Climate Vulnerability Assessment are significant. A reactive approach to extreme weather events can cost more to harvest the same amount of wood (e.g., paying to move logging contractors to a drier area) or to run the risk of running out of wood for the mill, the resulting opportunity cost of forgone production. The 'do nothing' approach also cannot benefit from potential adaptation opportunities.

The LP Swan Valley's Climate Vulnerability Assessment (CVA) resulted in eight prioritized business cases. Natural Range of Variation (NRV) fire emulation was already a pro-

ject in progress but being identified as a prioritized CVA business case will give NRV an even greater internal effort. The outcomes from this climate vulnerability analysis and adaptation implementation will aid in a more structured economic approach to address climate impacts and vulnerabilities. LP's Sustainable Forest Management system will be more proactive and less reactive for future investment and strategic planning. This work demonstrates the viability of adaptation options to reduce current and future costs of continuing to do 'business as usual' without climate change adaptation.

The business case for adaptation has been an important element in motivating adaptation action (Andrews-Key and Nelson 2020) for LP. This has helped to address climate change impacts and provide proactive options for some operational and strategic planning practices. This is an important tool in mainstreaming of adaptation into all aspects of LP's SFM system.

Planned climate vulnerability adaptation is superior to reactive adaptation. There are both operational and strategic benefits to proactively implementing the climate adaptations into the LP Sustainable Forest Management system. Expected benefits from proactively implementing these climate vulnerability adaptations include: a greater stability of wood flow; improved forest stewardship; greater social licence; cost-savings; and reduced opportunity cost from lower operational downtime.

The results of this climate vulnerability assessment and adaptation planning will help drive economic activity and value from the forest. Through the process of developing the business case in the vulnerability assessment, we also assessed the potential adaptation options that could reduce future costs and help minimize negative financial impacts from climate change. One example of this is maintaining enough wood in the mill yard to avoid the 'empty mill yard syndrome'. Past practices have not favored having additional 'insurance' wood in the mill yard due to the increased short-term costs of increased inventory. Wood flow from the forest to the mill yard can be interrupted or even cease due to extreme weather events, potentially causing a mill shut down. An unplanned mill shut down is potentially costlier than having an insurance pile of wood in the mill yard.

Another benefit of CVA is forest certification. LP is certified to the 2015-2019 Sustainable Forestry Initiative (SFI) standard. The upcoming 2022 SFI standard will require evidence of climate smart forestry, including identifying climate change risks and opportunities. This CVA project will provide leading-edge evidence for the new Sustainable Forestry Initiative (SFI) Objective 9 'Climate Smart Forestry'. LP plans to upgrade its' SFI handbook evidence to the new SFI standard for the upcoming fall 2021 SFI external audit.

As climate change impacts and uncertainty increase pressures on the ability of the forest industry to manage and operate within achievable Sustainable Forest Management practices, it is recognized that identifying the risks and vulnerabilities to SFM needs to be part of practice. It is also important to demonstrate to consumers and the public that SFI certified members are addressing climate change and are adapting management and planning to continue best practices on the land base to ensure the continued health and sustainability of forest ecosystems.

Table 3. Barriers to successfully reducing climate vulnerability impact contrasted with elements of success for LP Swan Valley

Barriers to participate in the climate vulnerability adaptation process	Elements of Success for Climate Vulnerability Assessment (CVA) at LP Swan Valley
Engagement and participation of local forest management professionals	CVA process utilized LP operational and planning staff
Lack of knowledge and training	Collaboration: CVA in conjunction with experienced researchers; also helped provide bridge between science providers and practitioners/managers.
Availability of resources for adaptation	Funding from Natural Resources Canada combined with significant in-kind LP staff time over the entire climate vulnerability process justified by Business Case development.
Lack of mechanisms for sharing and integrating pertinent knowledge	Many of the foundational pieces exist: Climate Vulnerability Assessment can be used to show how they fit into the process of mainstreaming change along with incorporating local knowledge; the Business Cases for Adaptation are an especially effective mechanism for sharing information and facilitating implementation to adaptation action.
Lack of a mandate to adapt	Recognition of the recurring extreme weather event problem; leads to internal motivation within the organization and Business Case supports action
A reliance on planning and monitoring approaches that do not account for climate change.	Beginning to implement CVA business cases (one at a time) which will change the planning and monitoring approaches.
Lack of existing grounded evidence of implementation of adaptation resulting in successful adaption action.	The creation and results of the Business cases have provided the evidence and support required to move to implementation action of prioritized adaptation options into LP SFM system.

Conclusions

Climate change and the need for adaptation within the Canadian forest sector has long been recognized (Lempriere *et al.* 2008). While there have been efforts to promote actions, including the provision of information and tools, there has been little adaptation implementation on the ground to-date (Halofsky *et al.* 2018). Hagerman and Pelai (2018) reviewed recommendations for responding to climate change in forest management. Their systematic review of the scientific literature found that most climate recommendations were too general, non-specific, and difficult to action. They also note consistently poor implementation and lack of forest management benefits over the last two decades. However, through recent (2015 to present) work done in the Canadian Prairies by Andrews-Key (2018) with five large-scale forest industry partners, successful examples of climate vulnerability assessment, adaptation, and implementation are underway. The results of the assessments and implementation action have demonstrated realized value for forest industry practitioners (Andrews-Key 2018).

The results from working with LP operational and planning staff, directly through the CVA process, was one of several elements of success at LP Swan Valley. LP staff ensured climate vulnerabilities and their possible solutions were relevant and specific to their management area and situations. Their localized knowledge applied to climate vulnerability adaptations, greatly enhanced the potential for the business cases to demonstrate both short- and long-term benefits. This

supports the argument made by Nelson *et al.* (2015) and Andrews-Key (2018) that the engagement and participation of local forest management professionals is a necessary requirement to successfully reduce the impacts of climate change on forest management, leading to adaptation action within SFM systems. This work has also aided in bridging the gap from assessment of vulnerabilities to implementation action, identified by Runhaar *et al.* 2018.

Other factors that are considered to play a role in adaptation are considered in Table 3 with an emphasis on how the use of business cases for adaption helps overcome some of the issues that have been raised as potential barriers, such as a lack of a mandate (Moser and Ekstrom 2010; Williamson *et al.* 2012; Edwards *et al.* 2015; Nelson *et al.* 2015; Andrews-Key 2018). As is the case elsewhere (Andrews-Key 2018), policy did not present a barrier, although this work did point to where policy change may be needed in the future. It also had the benefit of starting to provide the evidence to help inform and motivate those future changes.

Vulnerabilities, risks, and disruptions to forest management activities such as road building, harvesting, hauling, and silviculture can be reduced or even overcome by the Climate Vulnerability Assessment (CVA) process. This is especially true when CVA results are then used to develop the business cases for adaptation, which are a valuable tool in leading to adaptation action. In the case of LP Swan Valley, the business case adaptations are beginning to be proactively implemented. There can be trade-offs to implementing CVA

Fig. 3 SFI certified land bases in Canada; <https://certificationcanada.org/index.php/maps-en/national/sfi> [accessed November 23rd, 2020]

business cases, such as the extra cost of maintaining a higher wood yard inventory, but there are also potential cost savings and benefits from less risk and more stable wood flows.

This CVA approach can play a key role in supporting adaptation needs on a much larger scale (Andrews-Key 2018). ‘Climate Smart Forestry’ will soon be used across the Sustainable Forestry Initiative certified land base in both Canada (Fig. 3) and the United States. Climate Vulnerability Assessments can benefit all other SFI certified land bases in North America.

Mainstreaming adaptation to address climate change impacts and increasing climatic uncertainty can be a daunting task for the forest sector. However, through use of applied examples and collaboration through science-management-policy partnerships, adaptation mainstreaming can be supported and become part of existing systems. The work with LP Swan Valley and other vulnerability assessments completed by Andrews-Key (2018), and Andrews-Key and Nelson (2020), lay the groundwork for further efforts. For example, building collaboration and relationships, working with government to identify needed policy changes, and working with stakeholders will be necessary to support further climate adaptations.

Acknowledgements

This Climate Vulnerability Assessment was part of a larger research project, the Northern Prairie Forests Regional Integrated Assessment funded by Natural Resources Canada. Thanks go to Keith Proctor, Operations Supervisor at LP Swan Valley for infusing significant operational knowledge and experience into the Climate Vulnerability Assessment process and business cases.

References

- Andrews-Key, S.A. 2018. Vulnerability and Adaptation to Climate Change in Sustainable Forest Management and the Forest Industry in Saskatchewan. Doctoral Dissertation, University of Saskatchewan.
- Andrews-Key, S.A. and H. Nelson. 2020. Northern Prairie Forests Regional Integrated Climate Change Assessment – Vulnerability Assessment Summary Report. Final report to NSERC. 35 p.
- Brecka, A. 2018. Past and Future Impacts of Climate Change on Boreal Forest Timber Supply. Master’s Thesis. Lakehead University, Ontario.
- CCFM. (2008). [[Canadian Council of Forest Ministers]. A vision of Canada’s forests: 2008 and beyond. Ottawa, Ontario
- Edwards, J., C. Pearce, A. Ogden and T. Williamson. 2015. Climate change and sustainable forest management in Canada: A guidebook for assessing vulnerability and mainstreaming adaptation into decision making. Climate Change Taskforce, Canadian Council of Forest Ministers. Ottawa, ON. 172 p.

- Hagerman, S. and R. Pelai. 2018.** Responding to climate change in forest management: Two decades of recommendations. *Front. Ecol. Environ.* 16: 579–587.
- Halofsky, J., S. Andrews-Key, J. Edwards, M. Johnston, H. Nelson, D. Peterson, K. Schmitt, C. Swanston and T. Williamson. 2018.** Adapting forest management to climate change: The state of science and applications in Canada and the United States. *Forest Ecol. Manage.* 421: 84–97.
- IPCC. 2014.** Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate change [Core Writing Team, R.K. Pachauri and L.A. Meyer (Eds.)]. IPCC, Geneva, Switzerland, 151 p.
- Gray, P. 2012.** Adapting sustainable forest management to climate change: A systematic approach for exploring organizational readiness. Canadian Council of Forest Ministers, Ottawa, ON.
- Johnston, M. and N. Nicolichuk. 2005.** Assessing future landscape fire behavior potential in the Duck Mountains of Manitoba. Summary document 06-01. Saskatchewan Research Council and Prairie Adaptation Research Collaborative (PARC). 8 p.
- Lemprière, T.C., T.C. Bernier, A.L. Carroll, M.D. Flannigan, R.P. Gilson, D.W. McKenney, E.H. Hogg, J.H. Pedlar and D. Blain. 2008.** The Importance of Forest Sector Adaptation to Climate Change. Natural Resources Canada, Canadian Forest Service. Northern Forestry Centre, Edmonton, Alberta. Information Report NOR-X-416E. 78 p.
- Louisiana-Pacific Canada Ltd. 2019.** Forest Management Licence # 3 2020-2039 Forest Management Plan. LP Canada Ltd., Swan Valley Forest Resources Division. 558 3rd Ave. S., Swan River, MB. 7 Chapters plus Appendices and maps.
- Marchi, E., W. Chung, R. Visser, D. Abbas, T. Nordfjell, P. Mederski, A. McEwan, M. Brink and A. Laschi. 2018.** Sustainable Forest Operations (SFO): A new paradigm in a changing world and climate. *Sci. Total Environ.* 634: 1385–1397.
- McKenney, D., D. Yemshanov, J. Pedlar, D. Allen, K. Lawrence, E. Hope, B. Lu, and B. Eddy. 2016.** Canada's Timber Supply: Current Status and Future Prospects under a Changing Climate. Natural Resources Canada, Canadian Forest Service.
- Moser, S. and J. Ekstrom. 2010.** A framework to diagnose barriers to climate change adaptation. *P. Natl. Acad. Sci. USA* 107: 22026–22031.
- Nelson, H., T. Williamson, C. Macaulay and C. Mahony. 2015.** Assessing the potential for forest management practitioner participation in climate change adaptation. *Forest Ecol. Manage.* 360: 388–399.
- Ogden, A. and J. Innes. 2007.** Incorporating climate change adaptation considerations into forest management and planning in the boreal forest. *Int. For. Rev.* 9: 713–733.
- Ohlson, D., G. McKinnon and K. Hirsch. 2005.** A structured decision-making approach to climate change adaptation in the forest sector. *Forest Chron.* 81: 97–103.
- O'Shaughnessy, S.A. 2002.** Forest sector adapting to climate change: A framework for determining the ability of the forest sector to adapt to climate change: Master's Thesis, University of Saskatchewan, Saskatoon, SK.
- Peterson, D., C. Millar, L. Joyce, M. Furniss, J. Halofsky, R. Neilson and T. Morelli. 2011.** Responding to climate change in national forests: A guidebook for developing adaptation options. U.S. Department of Agriculture, Forest Services, Pacific Northwest, Portland, PNW-GTR 855, 109 p.
- Runhaar, H., B. Wilk and Å. Persson. 2018.** Mainstreaming climate adaptation: taking stock about “what works” from empirical research worldwide. *Reg. Environ. Change* 18: 1201–1210.
- Spittlehouse, D. 2005.** Integrating climate change adaptation into forest management. *Forest. Chron.* 81: 691–695.
- Swanston, C., and M. Janowiak. (Eds.) 2012.** Forest adaptation resources: Climate change tools and approaches for land managers. U.S. Department of Agriculture, Forest Services, Newton Square, PA. NRS, 87 p.
- Williamson, T., M. Campagna and A. Ogden. 2012.** Adapting sustainable forest management to climate change: A framework for assessing vulnerability and mainstreaming adaptation into decision making. Canadian Council of Forest Ministers, Ottawa, ON.