Land Use Policy 103 (2021) 105317

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Time for change: Learning from community forests to enhance the resilience of multi-value forestry in British Columbia, Canada

Tahia Devisscher[a,*], Jillian Spies[b], Verena C. Griess[a,c]

[a] Faculty of Forestry, University of British Columbia, Forest Sciences Centre, 2424 Main Mall, Vancouver, BC, V6T 1Z4, Canada
[b] Sto:lo Research and Resource Management Centre, 7201 Vedder Rd, Chilliwack, BC, V2R 4G5, Canada
[c] Institute of Terrestrial Ecosystems, Department of Environmental System Sciences, CHN K72.2, Universitätstrasse 16, 8092 Zurich, Switzerland

ARTICLE INFO

Keywords:
Climate change
Community forestry
Resilience
Wildfire
Social license
Land tenure

ABSTRACT

Forests around the world are experiencing the cumulative effects of rapid social and environmental change. Building resilience in the forestry sector has thus become of major importance in many countries, including Canada. While British Columbia (BC) generates the highest revenue from the forestry sector in Canada, the planning and management of forests in this province face several limitations that hinder the application of resilience thinking in a fully integrated way that accounts not only for ecosystem processes but also the close interconnection between forests and people. Community forestry in BC provides experience gained over 20 years that can form the basis for a more holistic, long-term approach to enhance the resilience of forested landscapes. Based on interviews with managers of 5 case study community forests (CFs), and a survey of all CFs in BC over three consecutive years, we present pilot practices to manage forests for resilience at the stand- and landscape-levels. Findings show that these practices mainly focus on (1) age and species diversification, (2) introduction of more drought-tolerant species, (3) systematic long-term monitoring of productivity and forest health, (4) wildfire risk management, and (5) introduction of enhanced silviculture such as thinning, rehabilitation and fertilization. Between 2016 and 2018, 38 CFs in BC invested more than CAD 4.5 million in enhanced silvicultural practices using their own funds. The area-based tenure of CFs motivated not only long-term planning and investment, but also shifted the mindset among residents towards a more multi-functional and dynamic view of the forest. Building adaptive capacity and social license, CFs foster a future where forest health and community well-being are compatible. These lessons can be scaled to BC and other forested landscapes in Canada and around the world. Scaling mechanisms include: (1) facilitating knowledge exchange; (2) increasing multi-stakeholder collaboration; (3) replication and mainstreaming of effective practices; (4) rethinking the forest tenure system; and (5) systematic research and monitoring to learn from pilot studies that could inform strategic interventions with landscape-scale impact. Multi-functional forests which are increasingly affected by climate change and novel disturbances could particularly benefit from the insights shared in this paper to build social-ecological resilience.

1. Introduction

Forests in Canada are increasingly experiencing the cumulative effects of forest operations and disturbances related to climate change. In recent years, extreme weather events prompted wildfires, insect outbreaks, landslides and flows of debris that caused significant impacts to national forests and budgets. For example, national wildland fire management cost has increased ten-fold in the past decades from about CAD 120 million per decade in the 1970s to over CAD 1 billion in more recent years (Sankey, 2018). The likelihood of insect outbreaks, such as mountain pine beetle (MPB), also increased significantly as milder winters have allowed for the persistence of insect epidemics. From 2000 to 2014, MPB was a hundred times more destructive than during the 1990s, defoliating over 77 million ha of forest (Canadian Council of Forest Ministers (CCFM, 2019). With climate change, and as human activity continues in forested land, it is likely that future disturbance will expand and intensify (Cooke and Carroll, 2017). Future fire occurrence across Canadian boreal forests is also predicted to increase significantly, albeit regional differences. Fire climate scenarios derived from the Canadian Climate Centre global circulation model suggest an increase in fire occurrence of 25 % by 2030 and 75 % by the end of this century (Wotton et al., 2010).

* Corresponding author at: Address: Forest Sciences Centre, 2424 Main Mall, Vancouver, BC, V6T 1Z4, Canada.
E-mail address: tahia.devisscher@ubc.ca (T. Devisscher).

https://doi.org/10.1016/j.landusepol.2021.105317
Received 6 April 2020; Received in revised form 19 September 2020; Accepted 23 January 2021
Available online 11 February 2021
0264-8377/© 2021 Elsevier Ltd. All rights reserved.

In general, climate change impacts on Canadian forests are projected to increase insect outbreaks, fire activity in western boreal forests, dieback of vulnerable species such as Aspen, changes in the forest carbon budget, and shifts in the range of many plant species (Natural Resources Canada (NRCAN, 2017). Boucher et al. (2018) applied climate projections based on a high-emissions scenario RCP 8.5 (i.e. assuming society does not make concerted efforts to cut greenhouse gas emissions) to model volume of harvestable timber at risk by a single or by cumulative disturbance(s). They found that when disturbances related to fire, MPB, and drought accumulated over time, changes in volume at risk are projected to occur as early as the first half of this century (2011–2041) in many regions of Canada. In zones of western Canada, 50–90 % of the total volume will be considered at risk over the second part of the century (2071–2100) because of projected increases in drought and MPB suitability (Boucher et al., 2018). Because of cumulative disturbances, most Canadian provinces could see response expenditures increase sharply by the end of the century (Sankey, 2018; Daniels, 2017).

British Columbia (BC) is Canada's most biologically and ecologically diverse province. Slightly over 60 % (57 million ha) of land in BC is covered by forest, of which timber harvest activities take place on roughly 22 million ha. Timber harvest in BC generates the highest revenue from the forestry sector nationwide, equivalent to about CAD 872 million in 2017 (Canadian Council of Forest Ministers (CCFM, 2019). The forestry sector also provided 140,000 jobs in 2017 (PricewaterhouseCoopers (PwC, 2019).

Like the rest of Canada, the forests and people of BC are experiencing impacts caused by the interaction of increased climatic variability and forest exploitation. While the patterns of changing temperature and precipitation are projected to differ across the world, BC is expected to have greater warming and precipitation changes than the global average with associated consequences on forests (Spittlehouse, 2008). For example, during 2000–2020 the forest in the south-central region of BC has been anticipated to convert from a net carbon sink to a carbon source during and immediately after the record-breaking climate-related MPB outbreak (Kurz et al., 2008).

Recent extreme weather events contributed to record-setting wildfires in BC. Because BC is one of the four provinces in Canada with the highest proportion of land in the wildland urban interface (WUI), fire risk in the WUI is also likely to be higher. In 2017, 80 % of the national fire management expenditure was spent in BC's WUI (Sankey, 2018). The WUI is a zone of transition between wildland (e.g. forested land) and human development (e.g. urban settlement). According to the Ministry of Forests, Lands, Natural Resource Operations & Rural Development (MFLNRORD, 2018), the 2017 wildfires displaced approximately 65, 000 people, burnt more than 1.2 million ha of forests, and cost more than CAD 568 million in direct fire suppression. The wildfires called for a 70-day state of emergency, which was surpassed in 2018 with an even larger fire outbreak that affected 1.35 million ha of forests. In the past two fire seasons, direct fire suppression costs in BC exceeded CAD 1 billion, without accounting for health impacts, stress and trauma, loss of habitat, ecosystem services and broad environmental damage (Daniels et al., 2018). The 2017 and 2018 wildfire events revealed an insufficient capacity to enhance community safety in BC (Abbott and Chapman, 2018). Across BC, about 685,000 ha of forests in the WUI show high to extreme fuel hazard, but only 10 % of this forested land was treated for fire prevention by 2018 (e.g. by introducing thinning, prescribed burning, or other fuel management practice) (Daniels et al., 2018).

In the context of the challenges described above, both forest management and legislation are witnessing the need to adopt a new paradigm that embraces dealing with uncertainty and increasing forest resilience to disturbance (Campbell et al., 2009). In BC, the theoretical framework for understanding and managing forests under climate change draws on ecological resilience, with the idea that it provides a sound framework for achieving sustainability goals in the context of an uncertain future (Campbell et al., 2009). The theoretical concept of ecological resilience underpinning this framework is based on the Walker et al. (2004, p. 2) definition: "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks". Folke (2016) synthesizes the evolution of resilience thinking and its application to the environment and social-ecological systems (i.e. intertwined systems of people and nature embedded in the biosphere). Resilience thinking is explained in relation to complex adaptive system dynamics (e.g. Levin et al., 2013) and learning how to live with change and uncertainty. An updated definition follows: "Resilience thinking is about how periods of gradual changes interact with abrupt changes, and the capacity of people, communities, societies, cultures to adapt or even transform into new development pathways in the face of dynamic change" (Folke, 2016, p. 2).

Currently, the management and planning of forests in BC face some underlying limitations that hinder the application of resilience thinking in a fully integrated, effective way that not only accounts for some of the ecosystem processes that may be affected by climate change (Metsaranta et al., 2011), but also considers the close interconnection between forests and people in the province. Without addressing underlying limitations, BC forestry will be ill prepared to anticipate and adapt to the climate change impacts expected this century.

The first limitation is the silo approach to timber harvest. To date, the emphasis in the sector has been placed on ways to maintain or minimize decline in long-run harvest levels through enhancing tree growth (Ministry of Forests Lands and Natural Resource Operations (MFLNRO, 2012). This volume-oriented approach has rather disincentivized more value-oriented, diversification strategies (Mitchell et al., 2017), and thus resulted in landscape homogenization and fuel accumulation that have unintentionally increased the vulnerability of forests to extreme events such large wildfires and beetle epidemics (Daniels, 2017; Dymond et al., 2015).

The second underlying limitation is the myopic, short-term tendency in the stewardship of forests. This is largely linked to the tenure system in which the sector operates. In many Canadian provinces, forests are publicly owned and operated based on provincial tenure systems that are increasingly perceived as inadequate to address the economic and social benefits they were designed to produce (Haley and Nelson, 2007). In BC, about 95 % of forests are publicly owned, and priorities for the timber extracted from these lands are inferred by the tenure system (Ambus and Hoberg, 2011). In 2018, volume-based licenses represented over 90 % of the total timber cut in BC. This form of tenure operates based on legal requirements that demand supervision of forest health conditions after a harvest operation until but not beyond 'free-to-grow state' is reached, equivalent to the time in which an "established seedling of an acceptable commercial species is free from growth-inhibiting brush, weed, and excessive tree competition" (British Columbia Forest Practices Board (BCFPB, 2019a). The focus on managing a forest stand until free-to-grow state is usually short-term (in average, ranging between 10–20 years in BC), while the rotation time required for harvest state can be 8–10 times longer. As a result, forest stands between free-to-grow and harvest states are effectively unmanaged and rarely monitored. This insufficient and short-term cycle of forest management creates not only detachment between the licensee and the land base, but dilutes social license and any sort of investment in long-term monitoring and opportunity to enhance forest resilience.

The lack of long-term incentive for monitoring by volume-based licenses also relates to the third limitation affecting BC forestry: the missing link between strategic and operational planning (Mitchell et al., 2017; British Columbia Forest Practices Board (BCFPB, 2019b). Linking operational, stand-level with strategic, landscape-level monitoring could help evaluate possible changes in 'beyond-free-growing' stand trajectories and identify adaptive management needed to anticipate and prevent possible disturbances. Adopting adaptive management at the landscape-level would help manage a mosaic of stands in diverse states of growth, increase diversity, and better orchestrate larger-scale strategies and tactical interventions that could more effectively reduce risks

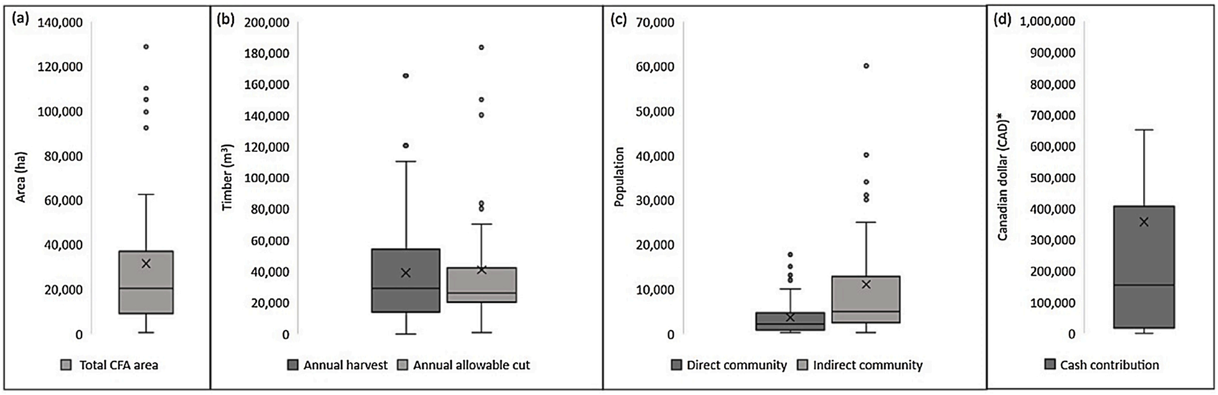

Fig. 1. Mean, median and range of (a) the area covered by a community forest agreement (CFA), (b) the annual harvest and annual allowable cut, (c) population directly and indirectly linked to a community forest, and (d) annual cash contribution to the community through grants, infrastructure improvements, special projects, among others (*highest outlier cash contribution at CAD 2.6 million not visualized). Distribution estimated based on 2016-2018 average data from 38 CFs.

posed by climate change and other drivers, hence effectively improving the resilience of forested landscapes (Woods et al., 2010; Dymond et al., 2015; Leslie, 2017). At the time of this study, only very constrained landscape-based efforts exist in BC to link stand-level planning prepared by forest professionals with the strategic land-use plans facilitated by the provincial government, more recently in closer partnership with First Nations (British Columbia Forest Practices Board (BCFPB, 2019b).

The combination of increasing threats to forests, and the current system in place in BC and beyond, calls for important changes in forest policy and management across BC, and Canada wide. While a provincial-level strategy to enhance the resilience of the sector is under development, we propose that community forestry in BC provides experience and evidence generated over 20 years of using a more integrated, long-term approach that has the potential to enhance social-ecological resilience of forested landscapes to the effects of climate change, while at the same time responding to multiple community values.

Community forests in BC have been studied in terms of their contribution to sustainable forest management, public education, social license, and governance (Bullock et al., 2017), but little attention has been given to their innovation and adaptation to increased disturbances related to climate change. Moreover, a recent bibliometric analysis of community forestry research in Canada found a prominence of social science, particularly geography. Minimal natural science research has been conducted regarding community forestry, which shows a clear disciplinary and knowledge gap and a missed opportunity to evaluate community forestry outcomes for ecosystems (Bullock & Lawler 2015). Our study is directly addressing both of these knowledge gaps. Despite accounting for only 1.8 % of the provincial land base (British Columbia Community Forest Association (BCCFA, 2018), community forests can play an important role by offering an alternative paradigm, space for experimentation, and provide evidence on the successful use of alternative considerations and practices to forest planning and management that are currently critically needed to strengthen the resilience of the forestry sector. We explore these considerations and give account of practices that could be strategically replicated and scaled up to address the 21st century challenges affecting BC forests. The specific questions guiding this study are:

(1) What can we learn from community forests in terms of managing forested landscapes for social-ecological resilience to climate-related risks while addressing multiple community values?
(2) How can we scale the approaches and practices piloted by community forests to overcome some of the current limitations faced by the forestry sector to address the challenges affecting BC forests this century?

2. Methods

Within Canada, BC is a leader in community forestry. The province introduced the Community Forest Pilot Program in 1998. The Forest Act was amended accordingly to include a new form of tenure, the community forest agreement (CFA). Community forestry was conceptualized as an area-based license with the objective to provide long-term opportunities for achieving a range of community objectives, values and priorities through the diversification of use and benefits derived from forests (British Columbia Community Forest Association (BCCFA, 2020). A CFA is issued for 25 years, thereafter replaceable every 10 years. The government of BC defines a CFA as a license managed by a local government, community group, First Nation, or combination thereof, for the benefit of the entire community (Government of BC, 2020). At its core, community forestry is about self-reliance, local control, and greater participation by communities and First Nations in the management of the land and the benefits offered by local forest resources. Local entities managing community forests (CFs) are expected to meet government requirements irrespective of their experience or available human and financial resources (Egunyu et al., 2016).

By 2001, 10 CF pilot sites had been identified and issued five-year probationary licenses. In 2002, the BC Community Forest Association (BCCFA) was formed as a province-wide network of community-based organizations engaged in community forest management (Gunter and Mulkey, 2017). The mission of the BCCFA is to promote and support the practice and expansion of sustainable community forest management in BC. In 2009, the probationary aspect of the tenure was removed from legislation, making agreement holders eligible to secure long-term renewable licensing. By 2019, there were a total of 58 CFAs in BC covering an area of about 1.5 million ha (British Columbia Community Forest Association (BCCFA, 2020), with another 5 formally in the application process. A more recent form of tenure is the First Nations Woodland Licenses (FNWL). In this study, we are not including FNWLs in the analysis. The existing CFAs range in size from 360 ha to around 130,000 ha, with an average of about 32,000 ha (Gunter and Mulkey, 2019). The CFs also differ greatly in terms of annual allowable cut and timber harvest area, and the yearly benefits they generate for the communities (Fig. 1).

Collectively, over 90 Indigenous and non-Indigenous rural communities are involved in community forestry in BC through partnership (British Columbia Community Forest Association (BCCFA, 2018). Currently, most of the communities that are members of the BCCFA have a population lower than 10,000, and about a third are First Nation-held CFs or partnerships involving First Nations (Gunter and Mulkey, 2019). There are three different groups of Indigenous peoples in Canada: First Nations, Métis, and Inuit people. First Nations make up 61 % of Canada's Indigenous population and most of the forest-dependent population.

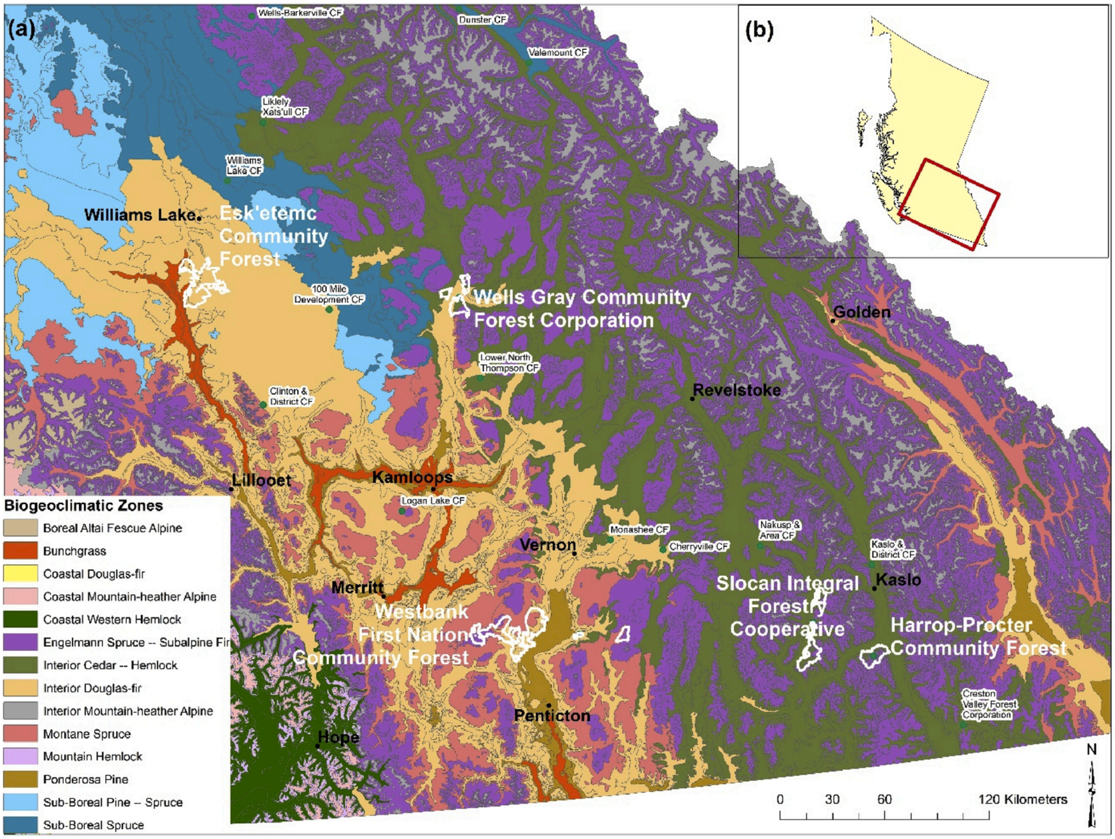

Fig. 2. Map shows (a) 5 community forests selected as case studies and their location in relation to the biogeoclimatic zones in (b) the southern interior of British Columbia, Canada. Source: MFLNRORD 2018.

Due to many unresolved land claims, many BC First Nations hold no legally recognized authority over their traditional lands, which limits their ability to influence forest management decisions (Karjala et al., 2003). Consequently, the direct involvement of First Nations in community forestry is an important development in BC and other provinces of Canada alike (Lawler and Bullock, 2017).

This study was conducted in partnership with the BCCFA. Since 2015, the BCCFA has implemented four annual surveys among its members to measure and track the benefits of community forests in BC. The survey comprises of 18 indicators that provide tangible, quantitative information on the economic, cultural and environmental benefits that community forests generate (see Table A1 for the full list of indicators). The survey was designed in consultation with the MFLNRO, independent advisors and community forest practitioners. In 2015/2016, very few CFs participated in the survey (we therefore decided not to use this dataset). In 2016/2017, 39 CFs completed the survey. In 2017/2018, 40 CFs participated in the survey, which is equivalent to about 93 % of the operating CFs in the BCCFA. In 2018/2019, 36 CFs completed the survey. A large part of the respondents (66 %) represent communities of under 3000 people, and 39 % are communities under 1000 people.

We used results of the last three surveys (2016–2018) in this study. We only focused on a selected sub-set of indicators that were most related to our research questions, namely: investments in intensive silviculture (Indicator 7); economic diversification (8); investments in recreation (12); proactive management of wildfire hazard (13), First Nations involvement (including if a CF is held by First Nations, or in partnership) (15); management of sensitive areas (16); investments in forest stewardship (17); and compliance with environmental standards (18).

Table 1
Community forests (CFs) selected as case studies, British Columbia, Canada.

	Total area (ha)	Direct Population 2018	Larger population 2018	Start year of license α	AAC (m^3, mean 2016–2018)	Annual harvest (m^3, mean 2016–2018)	Blocks	BEC
Esk'etemc Community Forest (E-CF)	31,000	450	10,832	2006	49,167	38,445	3	BG, IDF
Westbank First Nation Community Forest (W-CF)	46,626	850	34,000	2009	52,462	49,254	5	MS, PP, IDF, ESSF
Harrop-Procter Community Cooperative (HP-CF)	11,300	800	800	1999	10,000	9,392		ICH, ESSF
Wells Gray Community Forest Corporation (WG-CF)	13,146	2400	2,600	2006	24,833	29,474	4	ICH, IDF, ESSF
Slocan Integral Forestry Cooperative (S-CF)	16,000	2,000	6,500	2007	16,300	8,121	4	ICH, ESSF

Source: MacKillop (2018), MacKillop and Ehman (2016), BCCFA survey 2018, Ntityix Resources 2018 α = Year collected from interviews with CF managers; AAC = Allowable Annual Cut; BEC = Biogeoclimatic Ecosystem Classification; BG = Bunchgrass; IDF = Interior Douglas-fir; ICH = Interior Cedar Hemlock; ESSF = Engelmann Spruce-Subalpine fir; MS = Montane Spruce; PP = Ponderosa Pine.

In addition to the surveys, we conducted semi-structured, in-depth interviews with the managers of CFs we selected as case studies. The CFs we targeted in this study were selected based on purposeful sampling (Palinkas 2015) through a consultation process with the BCCFA using the following criteria: (1) demonstrated innovation in managing forests for resilience; (2) at least ten years of experience operating with a CFA to accumulate learning and evidence; and (3) governed primarily by non-Indigenous and/or First Nation communities (as opposed to e.g. a City Council). These criteria helped us identify case studies that had implemented practices and generated lessons to learn from in relation to increasing the resilience of forests, while at the same time responding to the social values of the community that was managing those forests. Five CFs were selected through this process (Fig. 2, Table 1): Slocan Integral Forestry Cooperative (SIFCo, S-CF), Wells Gray Community Forest Corporation (Wells Gray, WG-CF), Harrop-Procter Community Cooperative (Harrop-Procter, HP-CF), Westbank First Nation Community Forest (Westbank, W-CF), and Esk'etemc Community Forest (Esk'etemc, E-CF). We recognize that our selection criteria introduced some constraints for the findings. While the case studies represent a range of forest ecosystem types, it is important to recognize that all five CFs are located in the southern interior of BC.

The interviews we conducted included guiding questions around 10 topics divided into 3 parts (see Table A2). The first part focused on the vision, the process of integrated planning and collaboration for multiple values that are important to the community. The second part sought to understand the investment in long-term environmental stewardship practices aimed at increasing the resilience of the forest and the community. Finally, the third part aimed at capturing reflections and lessons that could be scaled up/out, and used to inform potential strategic changes needed in the BC forestry sector. Interviews were conducted with the general managers of the case study CFs from April to May 2018, transcribed and coded. Interviewees provided prior informed consent to use the information they were sharing for this study, and gave permission to be quoted. Two interviewers conducted jointly the interviews over the phone. Each interview (phone) call was at least 1 h long, and we had several calls with each CF manager over multiple dates (see Table A3). In total, the in-depth interview covering all questions lasted about 4 h for each CF. The interview analysis was complemented with participatory observation at the BCCFA (2018) and BCCFA 2019 conferences conducted in Burns Lake and Mission, BC respectively. Attending these annual meetings helped validate findings with the general managers of the CFs and gain insight into contemporary topics that are of most importance for CFs in BC.

In Table 1 we provide a short description of the case studies, including: total forest area covered by the CF; population directly served by the CF; population of the surrounding area indirectly served by the CF; year of license agreement; allowable annual cut (i.e. annual amount of timber harvest from a specified area of land that can be harvested on a sustainable basis[1]); annual timber harvest; number of forest blocks; and forest ecosystem type in each case study using the BC's Biogeoclimatic Ecosystem Classification (BEC) system. The BEC system uses late-successional vegetation communities to represent the combined ecological effects of climate and soil (MacKenzie 2011). Vegetation in our case studies can be classified into the following 5 BEC zones (Table 1): Bunchgrass (BG), Interior Douglas-fir (IDF), Montane Spruce (MS), Ponderosa Pine (PP) and Engelman Spruce – Subalpine Fir (ESSF).

3. Results

3.1. Shift in mindset

3.1.1. Building bridges for a common vision

Qualitative findings reported in this section are based on the interviews conducted with the five case studies. Quantitative findings are based on the BCCFA survey, and indicators are noted accordingly. To build a common vision for CFs, managers from the case studies highlighted the importance of acknowledging diverse perspectives and values attached to forests. Instead of addressing sources of disagreement, the vision was developed focusing on values people agreed on. The Manager of S-CF coined the term 'elevator values', which he described as "*shared values that most people hold regardless of the differences in their perspectives*" (Martineau, 19 April 2018). The visions were built on these shared values to bring people with different perspectives together, and were updated over time to account for changing capacities and prevailing interests. For example, currently the vision of S-CF is "to be leader in climate change adaptation, community resiliency, ecosystem-based management and economic diversification". To achieve this, the CF adopted an integral forestry approach which includes: (1) forest practices that first determine the ecological limits to human uses of a specified land area and aim to maintain a fully functioning ecosystem over time, and given these limits, (2) management strategies that consider humans as part of the ecosystem and that aim to improve social conditions[2] . In the HP-CF, a common interest around forests was water. Nearly every household in the area obtained its drinking water directly from the streams in the CF land base. As a result, one of the main mandates in the common vision of the CF was to protect water (Leslie, 2017).

Over time, focusing on shared values and a common vision helped dissolve the sharp divide that existed within communities prior to the establishment of the CFs (Egunyu and Reed, 2017). The manager of HP—CF explained that in the past people who relied on the forest for their livelihood (e.g. from logging and or road building) would be at conflict with people who would value the forest for other reasons (e.g. conservation, recreation or spirituality). However, at present these two groups work with each other, are joint owners and collaborators in the CF. The manager of S—CF elaborated, "*The community forest created a bridge between two very divided sides of the community [logging and conservation fractions] and as the years go by I do not think that new residents moving in would be able to even see the divide*" (Martineau, 19 April 2018).

3.1.2. Growing trust and awareness

While the case studies were guided by a vision based on shared values, trust was built on the actions anchored in that vision. The manager of S-CF expressed this in a concise way, "*…the more you do the right thing, the more people trust what you do*" (Martineau, 19 April 2018). The 'right thing' refers to the alignment between the action and the vision for the CF, which means that operations need to reflect the shared values and multiple interests that prevail in the community. CF managers recognized the effort to build trust over long periods of time, and adverted the danger of losing trust in an instant. To avoid this, the manager of HP-CF highlighted the need to "*put the time [in] with the community, be a good listener, and be a good communicator*" (Leslie, 26 April 2018).

To maintain trust, the CF managers in the case studies organized a series of activities that enabled exchange with community members, including (1) field trips to show residents the most recent work and discuss implications, (2) an open-door culture where everybody is welcome to approach and ask questions at the CF office, and (3) annual reports that summarize all activities conducted over the year, including the financial performance. An open communication allowed CFs to be accountable towards the community, which in turn served to keep alignment with their vision. In the communication activities, the flow of information was two-way. While the CF was sharing information about their activities through field visits, consultations and reports, they were also seeking feedback from the community to adjust future plans and operations. Communication also provided space to voice any concerns

[1] https://www.bcfpb.ca/news-resources/glossary/

[2] https://www.sifco.ca/integral-forestry

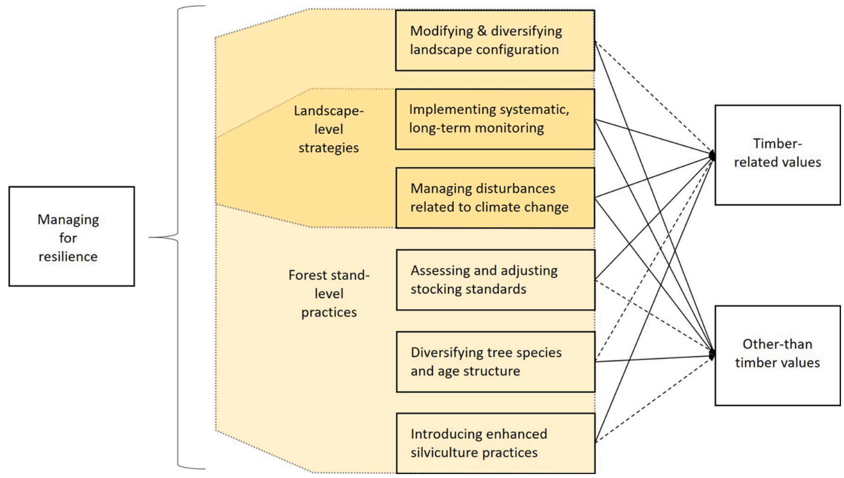

Fig. 3. Practices introduced by case study community forests to manage for resilience. Some practices are implemented at the forest stand-level, which are embedded within strategies designed for and introduced at the landscape-level. Forest management practices have direct (solid line) or indirect (dashed line) implications for timber and other values.

and get clarity on issues that may require further investigation. The manager of WG-CF provided an example: "*If citizens approach me with a concern, I take them to the field to inspect the site together and show them how things really are… This is a good way to dissipate negativity. This way we engage them and make a difference, we change attitudes*" (Brcko, 14 April 2018).

Overall, the interviews revealed that communication and capacity building were key factors to build trust among the community. This is particularly important because relationships of trust with the community allowed CFs to gain social license and operate and test alternative practices to manage the forest for resilience (cf. section 3.2). A distinct example was prescribed burning. The S-CF, for instance, educated people in the community for about six months before getting their approval to pilot the first prescribed burn. Once people observed and understood the effects, the social acceptance for a second burn was much higher. Education and trust helped CFs overcome the fear people have of new forest management practices, even if these practices are aligned to the integral vision of the CF. Exposure to recent disturbances such as large wildfires and insect outbreaks has helped CFs raise awareness about the consequences of not acting, and the urgency to manage novel risks in the context of climate change.

3.1.3. Sense of ownership

The CF case studies were all owned and governed by the community, which gave residents the opportunity to become witnesses and decision-makers regarding the operations on their land base. Egunyu and Reed (2017) recall that the Harrop-Procter community celebrated the signing of a CFA because it finally gave local people direct control over what happened in their forest. As such, an area-based license generated a sense of ownership, through which residents gained a "*say on how the forests around their community are being managed, and take part in recognizing the value of those forests*" (Gill, 19 April 2018). The HP-CF manager explained the effects: "*Having control of the forest and trust in your own [the community's] abilities changes the way in which you view the forest and what goes in it… The sense of ownership leads to more nuanced thinking… which is how the forest is, the world is, and decision-making is, particularly in the context of a complex disturbance-driven ecosystem managed for different kinds of values*" (Leslie, 26 April 2018).

In addition, the manager of W-CF emphasized that a renewed sense of ownership resulted in a secure, successful and locally-owned contracting force, which helped build know-how and technical skills over time. An area-based license also created the opportunity for some CFs – particularly if owned by First Nations such as Westbank and Esk'etemc – to tap into local memory and traditional ecological knowledge, with the intention to merge different worldviews in forest management practices. Another important effect of owning a CF license, which certainly contributed to building trust and social license, has been the distribution of funds generated by forest-based activities, with an annual average cash contribution of about CAD 390,000 per CF, and a total contribution of more than CAD 32 million between 2016 and 2018 based on survey results for 38 CFs. The annual reporting of CF performance to the community, which was confirmed by 95 % of 38 CFs, played a key role in building social license. CF managers placed importance on explaining the sources of revenue in a detailed and transparent manner, so that people would be able to connect the economic benefit to the community with the specific management, state and use of the forest.

3.2. Managing for resilience

An area-based license provides a unique opportunity to manage for the long term. A common view among the CF managers we interviewed was that adopting a longstanding vision is only possible when there is place attachment. The CF managers planned with future generations in mind, thus they did not necessarily foresee an end to the area-based license.

Managing a place for the long term allowed CF managers to take a more holistic approach, particularly when addressing climate change. A long-term approach also allowed them to take the risk to 'do the right thing'. Instead of focusing on only on timber harvest constraints, CF managers praised innovation and out-of-the-box thinking, as the manager of S-CF described: "*Think about what is the right thing to do, where you believe we need to go, and then start moving in that direction*" (Martineau, 19 April 2018). This attitude implied managing above and beyond what is required by regulation and underpinned many of the pilot activities and innovative practices that CF managers have introduced over the years to make their vision possible and integral to the shared values of the community.

The interviews showed that the vision for CFs had not changed considerably over the past 20 years. According to CF managers in our case studies, what changed is the way in which forests are managed. As the understanding of the land base, climate, ecology and socio-institutional context evolved, the approach to manage forests shifted from a more simplistic, dichotomous view of the forest to adopting systems thinking, which recognizes forests as ecosystems that are constantly changing. Logging, in this new way of thinking, is not only a tool to generate revenue, but also to manage risk, protect water, and build resilience (Fig. 3). More systemic thinking has not only resulted in the recognition of multiple values and uses of the forest, but also in the

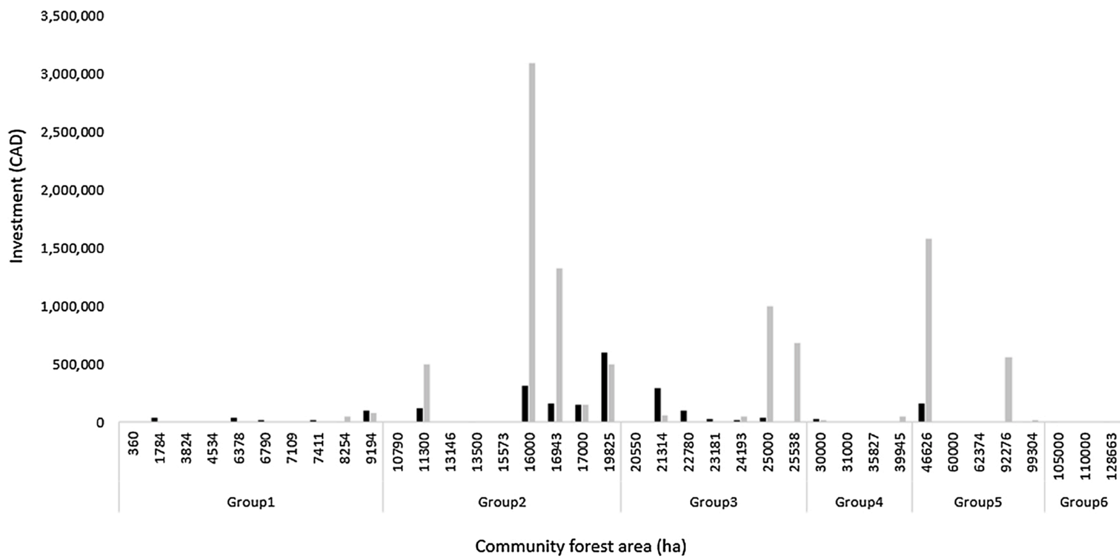

Fig. 4. Value of investments (total amount in CAD = Canadian dollar) by the end of 2018 funded by the community forest (black bars) and outside sources (grey bars) to reduce wildfire hazard in 38 community forests grouped by different size (land area in ha = hectares).

development and maintenance of operations that respect ecosystem functions, such as managing a road system to minimize impact on the watershed. It also implies accounting for increasing disturbances related to climate change affecting the forest in the long term. It is worth to highlight, however, that not all CFs had adopted this forward-thinking approach by the time of the study. We recognize that the selected case studies are cutting-edge, while other CFs are lagging behind in terms of innovation and adoption of ecosystem-based approaches.

All CF managers we interviewed aimed at lowering future climate-related risks affecting the forests by increasing their resilience, while simultaneously enhancing multiple forest values deemed important to the community. CF managers recognized that managing for resilience required dealing with uncertainty and introducing alternative practices, some of which were compatible with timber harvesting, and some of which were not timber-oriented. Fig. 3 provides a depiction of these practices, and shows how they are closely inter-connected.

3.2.1. Mainstreaming and prioritizing climate change

Overall, the five case studies were already affected by impacts of increased climatic variability, such as warmer winters and prolonged drier summers. The CF managers we interviewed regarded climate change adaptation as priority for the continued sustainability of CFs. This prioritization changed over time. It moved from not perceiving climate change as a major consideration in the 1990s, to informally integrating some climate considerations into decision-making in the early 2000s, to formally mainstreaming climate adaptation into forest management plans in the past decade (Leslie, 2017).

In recent years, the CF managers decided to inform their strategic, landscape-level plans with climate change predictions. The S-CF manager, for example, started to select species that would survive and thrive under future projected drought conditions. The HP-CF manager embarked in a major multi-year climate adaptation project, which involved a risk assessment and the development of a new silvicultural strategy. In 2012, the HP-CF manager introduced some climate considerations in their planning by building on a resilience project implemented in the Kootenays in 2011, however climate adaptation has become their main priority only in recent years. With support from the Columbia Basin Trust, the HP-CF is aiming to become an example of a forest license managed for climate change adaptation. Among other things, the HP-CF manager is using future downscaled climate envelopes to inform their forest management practices and increase their resilience to drought stress and wildfires. Practices introduced in the HP-CF include: guiding land zoning; identifying location to plant drought-tolerant species; and targeting areas where to open fuel breaks and manage for multiple climate-related risks.

3.2.2. Managing climate-related risks such as wildfires

Among the most predominant climate-related risks mentioned by CF managers were droughts, wildfires, and insect outbreaks. The managers adopted different strategies to deal with these risks in the future, some of which entailed implementing enhanced silvicultural practices beyond what is required by existing regulation. Hereafter, we describe these strategies, most of which were piloted recently.

Managing wildfire risk was a top priority for most CF managers we interviewed. It was also a principal topic discussed at the 2018 and 2019 BCCFA conferences. Based on survey results, by early 2019 CFs had invested CAD 2.3 million in cash or in kind to reduce wildfire hazard, in addition to CAD 9.7 million provided by outside sources. In total, CFs had treated more than 6000 ha by the end of 2018. About 75 % of all CFs that answered the survey two times or more, also confirmed collaboration with the local government on a Strategic Wildfire Prevention Initiative project. There is no correlation between the size of the CF and the investment in wildfire prevention. In fact, the highest investments were made by mid-size CFs of 16,000–20,000 ha in size (Fig. 4).

Concern for wildfire risk management usually started after CFs faced a wake-up call. For example, in 2003 a large wildfire affected Harrop-Procter, followed by a second major wildfire in 2017. These events positioned fire as a high priority for forest management (Leslie, 2017). The vast majority of Harrop-Procter forests are approximately 100 years old, dominated by unbroken tracts of mature, coniferous forest, which originated from large fires started by mining and settlement activities in the early 20th century (Leslie, 2017). When the CF was created in the late 1990s, climate change was not a major concern, and natural disasters such as insect epidemics and fire were understood to occur at relatively low rates (Leslie, 2017). In that context, forest management at HP-CF aimed to safeguard undisturbed mature forest conditions and to promote further growth of old-growth forests. With the 2003 and 2017 wildfires, the community understood that large tracts of mature coniferous forest were vulnerable, and needed to be managed in a different way, particularly in the context of future droughts driven by climate change. There was also a growing recognition in the community of the risk that wildfire presents to the provision of clean drinking water (Leslie, 2017).

The story is similar for the S-CF. The management team at S-CF started to work on fire modelling and risk management strategies after the CF was affected by a large wildfire in 2007. Since then, the CF manager has been working with the local government in educating citizens about the need to manage wildfire in high-risk areas of the WUI. These high-risk areas, referred to as 'wildfire corridors', are very likely to carry fire in the landscape according to computational model outputs. In most cases, these areas are adjacent to the community. The S-CF manager used this information to plan the timber harvesting in a way it would reduce fuel load in high-risk areas. In other words, logging became a fuel management strategy to reduce wildfire risk. To date, all of S-CF's harvest activities are taking place in wildfire corridors identified by their model. The logging does not entail clear-cut, instead the CF team leaves about 40 % of the basal area with a 10-m spacing. Species considered more drought-tolerant are generally left behind. At the time of the study, debris from the logging was piled up and burnt, but the CF manager was considering alternatives to make profitable use of all non-commercial wood and residues. Logging was also used as a fuel management strategy by WG-CF, E-CF and W-CF, mainly in areas close to town.

In the case studies, CF managers started developing a system to manage risks by integrating stand- and landscape-level strategies. At the landscape-level, the managers of S-CF, HP-CF and WG-CF started to target forests at higher risk of drought and wildfire (e.g. forests on dry sites) for commercial logging, while simultaneously breaking up the uniformly dense and mature coniferous forest in these areas. Landscape-level fuel breaks were being created by not actively regenerating with conifers, but instead allowing the establishment of less flammable deciduous species (Leslie, 2017). At the same time, moist forests at lower risk of drought were managed for continuous forest cover, thus diversifying the forested landscape. The CF managers recognized that the same type of forest management cannot be applied everywhere because uniformity and the lack of landscape-level diversity were not likely going to build resilience to increasing, widespread climate-related disturbances (Woods et al., 2010; Perry et al., 2011).

Some case study CFs also introduced prescribed burning to manage wildfire risk. Prescribed burning has been recognized by the BC Wildfire Service (BCWS) as an effective tool to reduce fire hazards, particularly after the megafires observed in 2017 and 2018 (British Columbia Wildfire Service (BCWS, 2019a). According to the BCWS, a prescribed fire is an intentionally set fire that is planned and managed. Using fire-modelling outputs to back his decision, the manager of S-CF applied prescribed burning in areas sometimes only 50 m away from the community. Social acceptance was critical for the feasibility of this strategy. In 2018, the CF implemented controlled burning on 60 ha, and in 2020 two blocks (one block of 140 ha and another of over 600 ha) were planned to be burned, each time in coordination with the BCWS. The areas targeted for prescribed burning are wildfire corridors located close to the community. These areas were mainly Ponderosa pine stands with Douglas-fir ingrowth, and were south–facing areas across the landscape. The manager of E-CF also introduced prescribed burning with the support from the community – BWCS, First Nations and cattle ranchers – except that they incorporated traditional knowledge. Elders of the First Nation community voiced the need to 'bring fire back'. In this case, the objective of the prescribed burning was twofold: to manage fire risk and to restore grasslands from Douglas-fir encroachment. The first prescribed burning was conducted in April 2018 across 80 ha. In 2019, the timing of the burning was modified to account for new climatic conditions, as explained by the manager of E-CF: "*Based on traditional management, we would have done the burning a lot later. Later the grass is greener, which means you need hotter fires. But that also increases the risk of fire escapes*" (Chipman, 01 May 2018).

The managers of HP-CF and WG-CF—— also showed interest in prescribed burning, but the lack of appropriate firebreaks and resources were an impediment. Nevertheless, social acceptance for prescribed burning was not an issue in these CFs. In fact, the communities had been asking for it since the major fires in 2017. Managers in both CFs noticed a shift in the public conversation around wildfire over the past ten years, with an increased interest to embrace burning instead of suppressing it. A high level of concern regarding climate change was expressed in public meetings and there was considerable interest in discussing implications for forest management (Leslie, 2017). An approach for treating fuels on private properties, however, was still missing in the conversation. A common challenge mentioned by CF managers was that even when fuel was treated on CF land, forest in private property surrounding the town remained untreated, thus representing a future wildfire hazard. In the WG—CF, a local interface group was formed to assess the need to manage high-risk areas, including those on private property. At the time of the study, the manager of WG—CF was allocating some funding to support this initiative.

Whilst not yet implementing prescribed burning, the managers of HP-CF and WG-CF were using understory treatments, such as ladder fuel removal, falling and thinning to manage fire risk. Priority was given to areas close to the community. Although these CFs were not using a fire model to identify high-risk areas, they were using LiDAR to map understory fuel densities as part of their climate adaptation project and silvicultural strategy. Funding was another challenge noted by CF managers. Some CFs such as Wells Gray were not able to access District funding to implement fuel treatment, even if high-risk areas were adjacent to the community. Instead, the CF managers had to adhere and support the update of their District Fire Protection Plan.

3.2.3. Modifying species diversity and stocking standards

With more prolonged and drier summers induced by climate change, CF managers recognized the need to adapt the diversity and distribution of tree species they manage for. In the case studies, CF managers were encouraging a shift towards drought- and fire-tolerant species. Some CF managers had already observed a natural transition through wildfires, drought stress, and increased mortality in their forests over the last ten years. In specific areas, CF managers were allowing this trend to continue without much intervention. In other areas, management was actively assisting and accelerating this shift. For the latter, CF managers were generally prioritizing areas close to town.

CF managers assisted species transition using different planting strategies. For example, based on downscaled climate projections and slope aspect, the manager of S-CF was planning to plant within the next ten years species expected to survive drought and heat conditions simulated for the mid-century. The S-CF expected to be affected by more severe dry conditions within 30 years, with a transition away from the wet belt into a drier grass stand, specifically on south-facing slopes. The S-CF manager is planting a mix of species to build resilience, prioritizing fire-tolerant Ponderosa pine, and a higher proportion of deciduous species in the WUI.

Like in the case of S-CF, the manager of HP-CF used downscaled climate projections to inform planting decisions and selection of seeds from a warmer and drier climate. Recognizing there would be some natural regeneration, the manager of HP-CF described his planting strategy as "*augmenting natural regeneration with some more diversity*" (Leslie, 03 May 2018). From a perspective of resilience to drought and fire, the CF manager did not consider the planting of shade-tolerant species such as western redcedar, western hemlock or spruce appropriate. Instead, on warm, dry, southwest-facing slopes the manager was actively transitioning the existing forest stands away from these species and planting instead Douglas-fir, larch (Leslie, 2017), and more recently Ponderosa pine. He estimated that as much as 50 % of the CF land base would become suitable for pine. The HP-CF manager also aimed to increase the planting of deciduous species such as larch and Aspen, even if these tree species would not currently be considered of economic value. The manager of WG-CF was also planting deciduous species in the WUI, mainly to create a natural zone that could reduce fire risk around the town in the future.

Finally, CF managers were also adapting their stocking standards to anticipate future climate. At the time of the study, only S-CF had

Table 2
Benefits and investments estimated for (5) community forest case studies, and mean calculated for (38) community forests in British Columbia, Canada, 2016-2018.

Topic	Indicator	Unit (period)	Wells Gray Community Forest Corporation	Slocan Integral Forestry Cooperative	Harrop-Procter Community Co-operative	Esk'etemc Community Forest	Westbank First Nation Community Forest	Community Forest mean (SE)
Population & area	Direct population	Indv (2018)	2,400	2,000	800	450	850	3,682 (±691)
	Indirect population	Indv (2018)	2,600	6,500	800	10,832	34,000	11,046 (±2,099)
	Total area in the Community Forest Agreement	ha (2018)	13,146	16,000	11,300	31,000	46,626	31,402 (±5,344)
Revenue & benefits	Annual volume harvested by the CF	m3 (mean 2016–2018)	29,474	8,121	9,392	38,445	49,254	39,037 (±5,808)
	Total cash contributed to the community	CAD (total 2016-2018)	1,352,119	80,930	35,900	536,411	1,254,974	936,801 (±201,430)
	Total in-kind contributions to the community	CAD (total 2016–2018)	7,345	30,000	20,000	52,800	79,629	65,776 (±25,725)
	Annual time spent by CF on delivering educational activities in the community	hours (mean 2016–2018)	27	372	57	67	42	48 (±12)
	Annual internal investment in education	CAD (mean 2016–2018)	0	14,819	1,833	3,333	3,333	4,241 (±1,165)
Investment in forest & risk management	Total value of internal investment in intensive silviculture	CAD (sum 2016–2018)	69,000	0	0	177,556	144,074	119,509 (±49,728)
	Total value from outside sources invested in intensive silviculture	CAD (total 2016–2018)	0	0	0	600,000	0	41,610 (±18,305)
	Total value of Land Based Investment/Forests for Tomorrow funding invested in intensive silviculture	CAD (total 2016–2018)	18,000	0	0	900,000	0	52,494 (±25,401)
	Total area treated with intensive silviculture	ha (total 2016–2018)	705	0	0	1,200	50	311 (±85)
	Total internal investment in recreation	CAD (accum 2018)	173,333	20,833	20,000	0	47,140	83,456 (±35,568)
	Total trail built and maintained by the CF, or other groups with CF funding	km (accum 2018)	0	7	20	0	8	47 (±18)
	Total internal investments, cash and in kind, to reduce wildfire hazard	CAD (accum 2018)	0	312,400	120,000	0	165,080	59,204 (±19,157)
	Total investment by outside sources to reduce wildfire hazard	CAD (accum 2018)	0	3,097,000	500,000	0	1,579,019	255,592 (±97,315)
	Total area treated for wildfire risk management	ha (accum 2018)	0	530	125	146	213	163 (±79)
	Annual internal investment in enhanced or modified management for ecological or social reasons within and outside the CF boundaries	CAD (mean 2016–2018)	0	117	55,157	33,667	46,487	31,175 (±14,757)
	Annual area treated within and outside the CF boundaries	ha (mean 2016–2018)	0	0	23	201	2,064	73 (±54)

CF = community forest; Indv = individuals; CAD = Canadian dollar; ha = hectare; km = kilometer; accum = accumulated to year. Mean refers to an annual figure estimated based on the period 2016-2018 (SE = standard error), while total refers to the total sum in that period.

received approval for new stocking standards. The manager of S-CF worked on two modifications. On the one hand, he introduced high-retention stocking standards that do not require any regeneration. On the other hand, he developed fire-adapted stocking standards for the WUI, which entailed lower densities of 300/400 trees per hectare and incorporated fire-tolerant deciduous species and evergreen species like Ponderosa pine. The managers of WG-CF and HP-CF were also customizing stocking standards to help reduce fire hazard on the WUI. According to the manager of S-CF, rewriting their stocking standards helped them manage their land for a healthy forest instead of aiming for even-aged, single-species stands. Overall, thinning, adaptation of stocking standards and selection of less flammable species was in line with best practices suggested in the 2019 BC FireSmart guidelines for yard and landscape zones 1.5–100 m from private homes (British Columbia Wildfire Service (BCWS, 2019b). Most importantly, these practices created flexibility for more creative ways to deal with fire risk in the future.

3.2.4. Adopting enhanced silvicultural strategies

To increase stand- and landscape-level resilience, CF managers adopted a series of enhanced silvicultural strategies. Based on survey figures, between 2016 and 2018, 38 CFs in BC invested more than CAD 4.5 million in enhanced silvicultural practices using their own funds, and an additional CAD 1.5 million using outside sources. On average, a CF would have invested internally almost CAD 120 thousand in a period of three years (Table 2). That would represent a bit more than 10 % of the total cash contributed in average by a CF to its community in that same period (Table 2).

As mentioned earlier, the HP-CF manager adopted a new silvicultural strategy as part of its climate adaptation project. The strategy proposed to address planting location, spacing, species selection, fuel breaks, and different kinds of treatments to be used across the land base. Overall, the strategy aimed at either decreasing density within stand or increasing diversity within the watershed, or landscape, as a way to increase resilience. The manager of HP-CF acknowledged that the forest they were managing was not only very dense, but also very homogenous in terms of age, structure, and species composition. Over time, this homogeneity had increased the vulnerability of the forest to disturbances. To overcome a similar problem, the manager of W-CF was introducing more species and multi-aged forests as a way to diversify the landscape and build resilience to drought and insect outbreaks in the future.

The manager of WG-CF also developed a silvicultural strategy as part of their climate adaptation planning. The strategy mapped distinct target areas for fertilization, clear-cutting, rehabilitation, and fuel management to reduce fire risk. The silvicultural strategy included areas that were understocked due to insect-induced mortality and were suitable for rehabilitation. Forest stands are considered understocked when the resources offered by a stand are not fully utilized by the trees growing in that space. In forestry, understocked usually refers to productive area which does not meet stocking standards (Thompson and Pitt, 2003). Following this conceptualization, if a productive area is understocked, the future potential of harvestable timber and associated profit is lost. The CF manager surveyed these understocked areas to identify affected locations, which could be targeted for rehabilitation planting. Rehabilitation planting within existing stands led to stands with at least 2 age cohorts, which slightly diversified the age structure.

As part of its enhanced silvicultural strategy, the manager of WG-CF was planting a mix of drought-tolerant species (including deciduous trees) at higher densities to compensate for potential loss under drier conditions. Depending on survival rates, the WG-CF manager contemplated thinning treatments to create appropriate spacing over time. The CF manager expected to see the development of chip and pellet mills, as well as other markets for timber waste or harvest residue, and saw this as a promising economic opportunity for the commercialization of small-diameter timber in the future. Where feasible, fertilization was also conducted at the time of planting to increase the likelihood of establishment and tree growth. The WG-CF manager was fertilizing stands in selected sites about 20 years before logging. In 2017, the CF manager could access funding from the Provincial government to fertilize 300 ha of 40-year-old second-growth forest, which had been previously thinned and pruned.

Overall, one of the silvicultural strategies adopted by several CF managers was high-retention. For example, the manager of S-CF mentioned leaving 40 % of the basal area post-harvest without regeneration obligations, while the manager of WG-CF would usually leave single trees and tree patches of 15–20 stems per hectare within cut blocks. The main rationale was to maintain a seed bank and assist new growth with more shade and cover under drier conditions. Visual concerns were also important, and some CF managers also worked with trappers to maintain appropriate connectivity among forest patches for habitat conservation. To this end, the WG-CF manager would usually leave about 15 patches of 0.2 to 0.4 ha in a 30-ha cut block.

3.2.5. Long-term forest monitoring

The interviews revealed that basic adaptive management principles were adopted by CF managers in all case studies, and this was motivated by a long-term perspective. Nevertheless, extensive monitoring programs to assess forest health over time were still incipient. The development of a long-term monitoring system that would go beyond the usual regeneration and free-to-grow surveys conducted as part of statutory requirements was in very early stages. As per usual, plantation surveys were conducted, and it was noticed that mortality rates had increased in recent years due to more frequent droughts. Losses were sometimes very high. In 2017, for instance, the manager of WG-CF reported 80 % loss of the trees planted in the same year due to very dry summer conditions.

In the HP-CF, early attempts to monitor forest growth and health under changing conditions started through strategic research partnerships. At the time of the study, the manager of HP-CF was collaborating with research institutions to assess natural and planted regeneration across different forest types and harvest treatments, looking at biomass production and the adaptability to climate change. The manager of W-CF was monitoring 20 to 30 year-old forest stands to assess whether they would be candidates for pruning or thinning in the short term. In their assessment, they would not only consider conditions for stand treatment, but also for wildlife habitat. In the W-CF, ongoing monitoring activity occurs across second-growth forest stands to evaluate ecosystem health and opportunities to increase resilience. Over the past several years, data from over 3,000 plots have been collected into a georeferenced database and modelled to evaluate temporal change.

The WG-CF had the most systematic monitoring system in place, using permanent sample plots in each BEC zone. The plots were established in 2016 and will be re-measured every 5 years. An initial set of 50 plots were installed across areas of second-growth forest greater than 25 years of age. The purpose of this system was to ensure that harvest would be sustainable and that the CF was not over-cutting when using Provincial timber supply data. With data collected from the sampling plots, the CF manager estimated their own growth curves, which were above the Provincial data. Despite this, the CF manager decided to maintain current harvest levels and consider the marginal difference as a reserve.

4. Discussion & conclusions

4.1. Transforming mindsets for adaptive capacity to environmental change

The case studies presented in this paper embraced a more systemic view of forests as ecosystems that are constantly changing and that are managed for multiple values. CF managers in the case studies used logging not only to generate profit, but to manage wildfire risk, protect water quality and wildlife habitat, promote non-timber forest products, and a range of recreational and visual benefits for communities. The CFs managers also promoted collaboration and co-ownership by dissipating conflicting interests over time. This approach to forest management demonstrated a shift in mindset among residents towards a more nuanced, multi-functional and dynamic view of the forest (Teitelbaum, 2016).

The qualities and capacities fostered by CFs captured in this study are directly related to key themes identified in the recent BC flood and fire review (Abbott and Chapman, 2018) as lessons to build resilience, namely: importance of common ground to agree on despite multiple interests; communication and awareness for social acceptance; innovation and constant evolution of knowledge and tools integrating local knowledge; and long-term investment. In the case studies, CF managers often referred to the work as essential to nurture relationships of trust, two-way communication, accountability, sense of ownership, awareness and adaptive management. By building social license, the CF operations strengthened components of adaptive capacity, which were identified as key to build social resilience in other studies, such as: flexibility in problem solving and readiness to change strategies; ability to balance power among interest groups; ability to self-organize and act collectively; learn to live with change and uncertainty; and combine different types of knowledge (Cinner et al., 2018; Folke et al., 2002). In addition, the case studies demonstrated the essential role of social capital to build adaptive capacity (Brooks and Adger, 2005), particularly by fostering transparent decision-making systems, and investing in the improvement of local labor and education.

The process of public education, communication and learning that occurred through discussions, field visits and decision making facilitated by CF managers also resulted in higher levels of social acceptance to disaster risk management over time. CF managers appreciated how residents recognized the need to apply alternative ways to manage more recent disturbances, for instance by using prescribed burning to reduce future wildfire risk (Copes-Gerbitz et al., 2020). This acceptance reflected the evolution of community priorities and risks, including concerns with novel disturbances related to climate change (Leslie, 2017).

Activities such as thinning and prescribed burning in E-CF, S-CF and HP-CF contributed to communication networks and raising awareness, both of which are deemed key social and psychological factors to influence motivation and action to reduce wildfire risk in the WUI (Paveglio et al., 2012; Blades et al., 2014). Although exposure to wildfire alone is an insufficient predictor of wildfire mitigation action (Paveglio et al., 2016), its value was reinforced when paired with the local context created by CF operations, which not only stimulated a sense of community and ownership of the forest at risk, but also raised awareness around innovative risk management practices in the WUI. This is a critical basis to move towards allowing more wildfire on the landscape and creating a culture of co-existence with wildfire, which is a proposed future path for wildfire risk management in Canada (Tymstra et al., 2020). In the case of E-CF, this included collaborating with First Nations to build on traditional ecological knowledge. Incorporating local knowledge in managing wildfire has been identified as an important challenge by frontline responders (Abbott and Chapman, 2018), and therefore the work done by CFs in integrating different forms of knowledge earlier on in the process of planning and prevention is crucial (Copes-Gerbitz et al., 2020). Studies argue that this integration will only be successful if it occurs naturally (Abbott and Chapman, 2018), which emphasizes the importance of social license cultivated by CFs.

4.2. *Creating incentives for long-term planning and resilience*

The case studies provide insights into how a new adaptive forest management paradigm can be embraced in BC. We recognize that not all CFs are as proactive in this regard, but we propose learning from existing positive experiences that can be considered cutting-edge in the province. The recent BC flood and fire review (Abbott and Chapman, 2018) highlighted that investment is vital to realizing any substantial improvement in better preparing the province for possible disasters going forward. This included proactive investments in technology, infrastructure and capacity. In the BC forestry sector, investment of this kind would inevitably require a longer-term, place-based approach to forest management, which is more aligned with area-based tenures like CFs than with the volume-based tenures on crown land.

The enhanced silvicultural practices that CFs have introduced were motivated by the interest among communities to improve forest health and productivity conditions in the long-term. The non-transferable nature of the CFA tenure created incentives for long-term planning and investments in the forest (Leslie, 2017). The main reason justifying these investments was the community's ability to benefit from the results of these efforts in the future. At the same time, in contrast with other forms of forest tenure in BC, CFA holders must really face the long-term consequences of their decisions, and conversely are driven to learn and constantly improve their practice (Gunter and Mulkey, 2017). In other words, those who bear the risk also stand for the benefit. Without this kind of incentive, where place attachment, learning, and sense of ownership make a difference for community safety, investment in technology to build resilience to climate change and future disturbances will remain unattractive. In turn, inaction to build resilience may lead to an undesirable closure of mills and collapse of the sector by the end of the century.

As illustrated by the case studies in this paper, CFs have invested proactively in ecological stewardship and enhanced silviculture to build resilience. A changing understanding of disturbance ecology and wildfire risk challenged the initial forest management assumptions in CFs, which tended to manage forests for relative stable, undisturbed forest conditions (Leslie, 2017). Understanding that extreme weather events may become more frequent in the future, with an increase in the rate of forest disturbances such as insect and wildfire (Woods et al., 2010), climate change adaptation became the top priority in some case studies, and silvicultural strategies were developed to explicitly address environmental change. This study provided insights into some of these new practices, which included: identification of priority areas for forest conversion and creation of more open and fire-adapted forest types; integration of prescribed burning; introduction of more drought-tolerant species in combination with natural regeneration; modification of cut block size and shape to provide more shade and improve micro-climate conditions for growth; and increased diversification of planted species, among others.

Moreover, CF managers in this study emphasized the importance to work beyond forest stands, adopting a landscape-level approach. For instance, the S-CF manager considered the forests beyond the boundaries of their tenured lands and participated in the creation of a truly resilient bioregion and community. Case studies such as HP-CF were moving away from uniform landscapes to increase resilience through landscape-level diversity (Perry et al., 2011; Leslie, 2017). On the one hand, this included diversifying forest management practices and forest stands throughout the landscape by transitioning for example south-facing forest stands to more drought- and wildfire-tolerant species, while conserving sensitive forests (e.g. riparian zones) and reserves of moist old-growth forest at lower risk. On the other hand, it entailed increasing landscape diversity by enhancing biological diversity. CF managers in the case studies were removing some species at risk, and investing in both planted and natural reforestation of mixed species. They were also increasing structural diversity by managing uneven-aged forest stands.

Other studies in BC have shown that landscape diversification is particularly critical in the context of climate change. Under a changing climate, Temperli et al. (2012) projected that timber production will fall dramatically in the latter part of the 21 st century due to drought. Temperli et al. (2012) simulated a greater reduction in harvest rates for monocultures relative to forest management strategies that increased diversity and fostered drought-tolerant species. Simply harvesting drought-intolerant species and planting with the same species did not lead to an appreciable change in landscape composition over 20 or 70 years (Schneider et al., 2010). Instead, landscapes having higher structural and species diversity through target harvesting of drought-intolerant species and assisted regeneration with a mix of species demonstrated to have greater resilience, and to provide better stability in growing stocks, higher harvest rates in the long term, and more consistent net revenue over time (Dymond et al., 2014). According to Dymond et al. (2015), uneven-aged forest management that targets a drought-adapted, diverse, and resilient species mixture can be combined with timber production in the long term. Experimental treatments in BC also showed that mixed stands of species and silvicultural techniques that foster complexity lower the impacts of disturbances and reduce productivity losses (Griess and Knoke, 2011). Furthermore, higher retention combined with limiting clear-cut area in the landscape can help increase connectivity for many different forest dwelling species (Spies et al., 2019).

Logically, managing the forest for resilience also calls for investment in long-term monitoring, which was only starting to become institutionalized among our case studies. Long-term information about forest health is critical to inform adaptive management approaches in a context of increased uncertainty and rapid environmental change. It is a critical tool to support learning and decision making for the development of novel, community-based solutions to increase social-ecological resilience. Even if still not formal, the level of forest health monitoring conducted in some case study CFs was more systematic than the prevalent randomized monitoring efforts of post free-growing, secondary forest reverted to the Crown and conducted by the provincial government (*pers. comm.* FREP, 13 April 2018). Lack of systematic monitoring means that there is uncertainty about the quantity and quality of provincial forest stands in relation to timber supply planning and forest health, particularly in the context of climate change. Current monitoring practices in the case studies allowed informing the modification of stocking standards and adopting more realistic and adaptive decisions to address future disturbances and climatic conditions. This is particularly relevant if considering the cumulative effects of disturbances predicted to impact forests in BC (Boucher et al., 2018). We also recognize the need to monitor forest health not only in young and mature forest stands, but also in protected old-growth forests, which are considered more resilient due to their higher complexity and could be used as reference when assessing the effects of multiple disturbances.

4.3. Time for change: scaling up, updating policies, and advancing research to address emerging challenges in forestry

The forestry sector in BC is undergoing significant changes with the growing complexity of climate change and related disturbances, but policy making, research and technological improvements are not keeping pace. Main reasons include a lack of tools to aid decision making, higher economic costs, and policy barriers (Hagerman et al., 2010). The 2018 blueprint for wildland fire science in Canada (2019–2029) identified a series of knowledge gaps and research priorities that illustrate the need to generate more evidence on strategies that can help build resilience to the challenges ahead (Sankey, 2018). These knowledge gaps were clustered into 6 themes. The strategies adopted by the CF managers in the case studies provide insights to inform 4 out of these 6 themes, namely: delivering innovative fire management; managing ecosystems; building resilient communities and infrastructure; and recognizing Indigenous knowledge.

The insights presented in this study could be used to inform knowledge gaps identified not only in the national blueprint for wildland fire, but also in the four-year Forest & Range Practices Act (FRPA) improvement process started in 2018. The public discussion paper proposed for the FRPA review process includes questions such as "How should the province identify opportunities and priorities for adapting forest management to a changing climate, such as mitigating the effects of beetle infestations, drought and fire?" (MFLNRORD 2019, p.7). The approaches and practices adopted in the CFs described in this study, which were implemented in deliberation and agreement with close-by communities, provide a promising entry-point to answering these questions, and the opportunity to learn from evidence that could be scaled up or mainstreamed in other forms of tenure in BC.

The BCCFA has been formally involved in discussions with the Ministry's Forest Practices Advisory Council on best ways to share accumulated knowledge, while at the same time making sure that proposed amendments to legislation do not hinder the objectives and innovative work conducted by CFs. The BCCFA has been an effective learning network (Gunter and Mulkey, 2017), which has stimulated collaboration among CFs, and created a space for exchange to catalyze action and scale practice. In recognition of the CFs' role in contributing to resilient forest ecosystems and human communities, the BCCFA recently amended the purpose underpinning its constitution. As of the BCCFA 2019 conference, the purpose of the Association includes to "promote community forestry as a strategy for forest ecosystem resilience and community economic development" (Gunter and Mulkey, 2019). The BCCFA defined a resilient forest landscape as "one that can continue to provide resources and ecological functions over time as climates change, although the species composition and structure of that ecosystem may change"[3] (British Columbia Community Forest Association (BCCFA, 2020). The amendment confirms the potential of community forestry as a source of practical knowledge to build resilience in the sector.

Scaling up community forests, or at least mainstreaming some of their practices to manage forests for social-ecological resilience, could bring a major change to forestry in BC. This change would catalyze a shift from a resource extraction-based economy to a more holistic economy that values diversification. This shift could be informed by the long-term thinking, landscape management approach, and monitoring practices piloted by CFs. Although CF managers acknowledged that part of their success is due to their small size and direct connection with the community, they also noted that the uptake of forest management practices first experimented within CFs could be replicable across BC and somewhat scalable in areas two to three times the size currently managed. Based on what we learned from the case studies, there is no doubt CFs offer unique opportunities for the development of novel solutions to increase resilience and address the challenges faced by the BC forestry sector this century. This recognition also goes in line with recommendations included in the recent BC flood and fire review. Abbott and Chapman (2018) suggested that, based on proactive risk management practices, the CF program should be expanded to other communities where interest and capacity exist. Such a strategy would be particularly relevant in communities at high fire risk currently located or rapidly expanding into the WUI. In line with this motion, a new resolution of the Union of BC Municipalities called on the provincial government to increase the number and size of community forests to help achieve wildfire protection in the WUI (Daniels et al., 2018).

In the process of replicating and upscaling some of the innovative climate adaptation and risk management strategies piloted by CFs, some critical elements need further consideration and research. First, the introduction of wildfire risk management activities such as thinning and prescribed burning may be easier to introduce in smaller areas and within the WUI, but at the landscape level it will require the collaboration of different tenures and private landholders to achieve effectiveness in controlling wildfire corridors and break the uniformity of the landscape (Copes-Gerbitz et al., 2020; Abbott and Chapman, 2018; Leslie, 2017). Increased collaboration to manage novel disturbances at the landscape level also calls for additional public education and a better understanding of social acceptance around innovative forest management practices and landscape-level transformations. As previously stated, uniformly dense forests that lack diversity are less likely to be

[3] https://bccfa.ca/society-constitution-and-by-laws/

Table A1
Indicators used in the annual survey by the British Columbia Community Forest Association.

Indicator	Rationale	Number of questions
1. Number of jobs	Local employment in rural communities is one of the primary benefits of community forests. This indicator measures the total direct employment & contract labor generated by community forests in relationship to the harvest volume allocated to community forests.	9
2. Total economic activity	As long-term area-based tenures, community forests support community economic development and contribute to diversification of rural communities. The total annual cost of sales and expenditures is an indicator of the total economic activity generated by the community forest.	3
3. Community contributions	The cash and in-kind contributions made by the community forest are an important indicator of the local economic benefits generated by the community forest. In many cases, these contributions serve social objectives, in addition to economic ones.	3
4. Funds leveraged by the community forest	In many cases, the profits generated and contributions made by community forests are used as seed money to grow larger projects and generate even more local benefits. This indicator shows how CFA funds are used to leverage additional funds for community priorities. As with Indicator #3, often these projects serve social objectives, in addition to economic ones.	2
5. Cut control	Community forests play an active role in the forest sector through harvesting. This indicator measures success at meeting cut control requirements, keeping the supply of logs flowing.	3
6. Distribution of log sales	Community forests supply wood on the open market to major industry, and also to small and medium sized mills and value-added manufacturers. In doing so, they strive to support the full spectrum of milling and manufacturing facilities. This indicator provides updated information on the distribution of log sales that can be tracked over time.	3
7. Investment in intensive silviculture	As long-term, area-based tenures, community forest agreements create strong incentives for investment in the future. This indicator will measure investments in the future economic return of the forest. By measuring the investments in intensive silviculture, incremental to legal Indicator #7, it will demonstrate efforts to increase the growing capacity in community forest, with the intent of increasing the AAC.	7
8. Economic diversification	One of the provincial objectives for the community forest program is to diversify the use of and benefits derived from the community forest agreement area. The CFA tenure is one of only two forest tenures in BC that has the right to develop and manage Non Timber Forest Resources . The indicator shows the degree to which community forests are generating revenue from sources other than timber.	2
		4
9. Community accountability	One of the elements of community forests that set them apart from other forest tenures is their accountability to their local communities. This accountability is the cornerstone of local decision-making. In community forestry, management decisions are made by those who have to with live the outcomes. When local people have a hand in management of the forests adjacent to their rural communities, they are more likely to be innovative in the integration of multiple values in their decision-making. This indicator measures whether the community forest reports out annually to its community on its progress towards objectives as identified in the Community Forest Agreement Management Plan.	
10. Public engagement	While Indicator #9 focuses on reporting out to the community, this indicator measures the efforts of the community forest to engage with the diversity of community members and perspectives. Outreach to the full array of forest users and community members leads to an improved awareness of forest management among members of the public, and increases potential to resolve conflicts over timber harvesting in watersheds and other sensitive areas.	3
11. Investments in community education	Community forests provide an opportunity to link community members to the forest, and to increase their understanding of forest ecosystems and management. As long-term, area-based tenures, community forests provide enhanced opportunities for education and research. Community forests can be laboratories for testing innovative forest practices. This indicator measures the investments the community forest is making in education and capacity building.	4
12. Investments in recreation	One of the most significant benefits of community forests are the investments the organization makes in creating, improving and maintaining recreational infrastructure and opportunities. This indicator measures the value of the cash and in-kind investments in recreation that the community forest has made.	6
13. Proactive management of wildfire hazard	The combined effects of climate change, the mountain pine beetle, past management increasing forest fuels and the province's limited fire suppression capacity are leading to an increase in wildfire incidence and severity. Community forests are situated in the interface between communities and wild forest lands, and are uniquely positioned to serve as a leader in the coordination and management of these areas to reduce the risk of catastrophic wildfire. Efforts to manage the wildfire hazard to communities are primarily driven by social objectives, however depending on the ecosystem type, history and outcome of the treatments; they may	8

(*continued on next page*)

Table A1 (*continued*)

Indicator	Rationale	Number of questions
	also bring economic and environmental benefits.	
14. Forest worker safety	One of the provincial government's objectives for the community forest program is to advocate forest worker safety. Community forests are invested in workers going home safely each day.	5
15. First Nations involvement	The BC Community Forest Association promotes forest management which respects First Nation rights and cultural values, and which fosters understanding and cooperation between rural communities and First Nations. Many community forest agreements are held by First Nations, and even more are partnerships between Aboriginal and non-Aboriginal communities. This indicator measures the breadth and depth of First Nations involvement in the community forest.	2
16. Management of sensitive areas	Community forests, by their design, must integrate the values of the communities that manage them. This unique model of forest management sees CFA managers gaining the social license to operate in highly constrained areas that have not been previously accessible due to local values. And, while taking all that into consideration, they also comply with the tenure regulations and Acts of British Columbia.	6
17. Investments in forest stewardship	This indicator measures the investments the community forest is making in enhanced forest stewardship, incremental to legal requirements.	4
18. Compliance with environmental standards	This indicator shows whether the management of the community forest is in compliance with statutory requirements for resource management.	5

Source: British Columbia Community Forest Association. 2017. Community Forest Indicators 2016. Measuring the Benefits of Community Forestry. BCCFA, Victoria. 40 pp.

resilient to widespread droughts, wildfires, and insect infestations associated with climate change (Woods et al., 2010; Perry et al., 2011). Thus, more research, expert (incl. traditional) knowledge integration, and technological advancements are needed to understand the effective landscape configuration to lower the risk of cumulative, novel disturbances in the context of BC. Understanding past large-scale dynamics could bring insight into landscape-level strategies needed to face novel disturbance dynamics induced by climate change. In addition, only 0.3 % of the forest area is actively managed in BC on an annual basis, which means that the interventions will be spatially-constrained and need to be strategic to have an effect at the landscape level, e.g. time will be required to observe a major shift in landscape diversity (Dymond et al., 2014). In this regard, most of the forest in BC will have to adapt naturally (Bunnell and Kremsater, 2012), which calls for closer, systematic monitoring to inform future strategic interventions with landscape-scale impact.

Second, more effort and studies are needed to develop incentives that demonstrate how the scaling of intensive silvicultural practices can be economically feasible and attractive to volume-based licensees. The diversification of the sector, which includes reforestation of mixed species and the use of non-commercial timber for alternative products, is only recently considered a necessary strategy to enhance forest health and has received support from the provincial government through multi-year programs such as Forests for Tomorrow, Community Resiliency Investment, and the Land Based Investment Strategy. However, sustainable investment in forest stewardship will require allocations that are not always relying on government funding in the long term. In some locations, area-based tenures may be the only way forward to sustainably and responsibly manage forested land for social-ecological resilience. This recognition informs the increasing need to rethink the forest tenure system in BC and other provinces across Canada (Hayley & Nelson 2007).

Finally, CFs provide promising pilot studies that have been around since 1999 to advance forest management practices. We presented a few case studies, but the network of CFs is large and could be used to conduct systematic, applied research that could strategically inform BC forestry decisions. There is a need for forestry research and biophysical studies to complement existing social science research in community forestry (Bullock & Lawler 2015). This could inform interdisciplinary findings and more integrated approaches to manage forest ecosystems. Many CFs, with their broad mandate to manage for the long term and respond to emerging public priorities, are leading the way in forward-thinking forest management. CFs are encouraging new generations to enter the forestry community and envisage a future where forest health and community well-being are compatible and thriving. This is certainly a unique opportunity for government, academia and practitioners to leverage testing and learning about novel forest management solutions that could be replicated, and to the extent possible scaled up, to build resilience to climate change and related disturbances while at the same time addressing multiple social values. This opportunity for learning is relevant to BC and other forest landscapes in Canada and around the world.

CRediT authorship contribution statement

Tahia Devisscher: Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing. **Jillian Spies:** Investigation, Data curation, Writing - original draft. **Verena C. Griess:** Supervision, Writing - review & editing.

Table A2
Guiding questions applied in the in-depth interview with (5) community forest case studies, British Columbia, Canada.

PART I. Planning for multiple values and scales

1. *Vision & values:* What steps did you take to determine your long-term vision and how do you recognize multiple values (of the community members) in this collective vision? How do you currently capture those values? What is the time frame of your vision?
2. *Collaboration for multiple benefits:* How do you interact with other tenure holders in and around the community forest to foster the multiple benefits provided by forests (e.g. recreation, hunting, non-timber forest products, etc.)
3. *Integrated planning:* How do you integrate landscape- and stand-level planning? Is the landscape boundary broader than the community-forest boundary? Who is involved in the planning process?

PART II. Stewardship and resilience

4. *Stewardship:* We noticed that you have invested in environmental stewardship practices (e.g. in intensive silvicultural practices), how can you make this work socially and economically feasible on a yearly basis for the long term?
5. *Managing for resilience:* What strategies do you use to manage your forests for long-term resilience, including considerations such as increasing climate-related risks (e.g. wildfires and insect outbreaks)? How do you manage for ecological resilience while addressing the well-being of the community?
6. *Monitoring:* What long term monitoring system (landscape- and stand-level) do you have in place to make sure you are meeting community values and you are aligned with your vision? How does this monitoring relate to your resilience strategies? How does this monitoring differ from, or complement, compliance with environmental standards set by regulation (incl. inspections and effectiveness evaluation)?

PART III. Lessons, scalability and future outlook

7. *Reflection:* Describe the difference in your community before and after the establishment of the community forest agreement.
8. *Lessons:* Based on the experience you gained, what would you have done differently since you started your license? What lessons did you learn and you would like to share?
9. *Outlook:* What long-term initiatives do you envision to accomplish by the end of your license agreement, and beyond?
10. *Scalability:* How would you envision the replication and up-scaling of good practices led by Community Forests across British Columbia?

Note: These are guiding questions only. More questions were asked during the interview in relation to the 10 core topics listed in the table.

Table A3
Interview schedule with the managers of (5) community forest (CF) case studies, British Columbia, Canada.

Community forest (CF)	Interviewee (CF manager)	Interview date
Esk'etemc Community Forest	Gord Chipman	18/04/2018 01/05/2018
Westbank First Nation Community Forest	Dave Gill	19/04/2018 30/04/2018
Harrop-Procter Community Cooperative	Erik Leslie	19/04/2018 26/04/2018 03/05/2018
Wells Gray Community Forest Corporation	George Brcko	14/04/2018 01/05/2018
Slocan Integral Forestry Cooperative	Stephan Martineau	19/04/2018 24/04/2018 09/05/2018

Note: Each interview (phone) call was at least 1 h long, and we had several calls with each CF manager over multiple dates.

Acknowledgment

The authors would like to thank the managers of the five community forests interviewed in this study for the critical insights they shared: George Brcko, Dave Gill, Gord Chipman, Erik Leslie, and Stephan Martineau. We are also very grateful to the British Columbia Community Forest Association (BCCFA) for their support and providing the survey data we used in the analysis. Special thanks to Susan Mulkey and Jennifer Gunter from the BCCFA for their valuable insights and continous commitment. The lead author would also like to express gratitude to the UBC Wildfire Discussion Group, especially to Ira J Sutherland and Kelsey Copes-Gerbitz for the stimulating discussions that have certainly enriched this study. The authors are also very thankful for the constructive comments and thoughtful suggestions provided by two anonymous reviews, which have greatly improved the manuscript. Thank you to the Social Sciences and Humanities Research Council (SSHRC 435-2014-1714 and 201709BPF-393653-294704) for generously funding this research. The authors have no conflict of interest to declare.

Appendix

References

Abbott, G., Chapman, M., 2018. Addressing the new normal: 21st century disaster management in British Columbia. Report and Findings of the BC Flood and Wildfire Review, p. 148. https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/embc/bc-flood-and-wildfire-review-addressing-the-new-normal-21st-century-disaster-management-in-bc-web.pdf.
Ambus, L., Hoberg, G., 2011. The evolution of devolution: a critical analysis of the community forest agreement in British Columbia. Soc. Nat. Resour. 24 (9), 933–950. https://doi.org/10.1080/08941920.2010.520078.
Blades, J.J., Shook, S.S., Hall, T.E., 2014. Smoke management of wildland and prescribed fire: understanding public preferences and trade-offs. Can. J. For. Res. 44, 1344–1355. https://doi.org/10.1139/cjfr-2014-0110.
Boucher, D., Boulanger, Y., Aubin, I., Bernier, P.Y., Beaudoin, A., Guindon, L., Gauthier, S., 2018. Current and projected cumulative impacts of fire, drought, and insects on timber volumes across Canada. Ecol. Appl. 28 (5), 1245–1259. https://doi.org/10.1002/eap.1724.
British Columbia Community Forest Association (BCCFA), 2018. Prioritizing Community-based tenures for wildfire mitigation & rural development. A Proposal for Community Forest Program Expansion (online). URL: https://bccfa.ca/wp-content/uploads/2018/07/Community-Forest-Program-WUI-Expansion-Report.pdf.
British Columbia Community Forest Association (BCCFA), 2020. What is Community Forestry? (online). URL: https://bccfa.ca/what-is-community-forestry/.
British Columbia Forest Practices Board (BCFPB), 2019a. Glossary (online). URL: https://www.bcfpb.ca/news-resources/glossary/#F.
British Columbia Forest Practices Board (BCFPB), 2019b. Tactical Forest Planning: the Missing Link Between Strategic Planning and Operational Planning in BC. Special report. Victoria, p. 17. https://www.bcfpb.ca/wp-content/uploads/2019/07/SR58-Tactical-Forest-Planning.pdf.
British Columbia Wildfire Service (BCWS), 2019a. Factsheet Prescribed Fire (online). URL: https://firesmartbc.ca/wp-content/uploads/2019/05/Factsheet_Prescribed-Fire-3.pdf.
British Columbia Wildfire Service (BCWS), 2019b. BC FireSmart Begins at Home Manual (online). URL: https://firesmartbc.ca/wp-content/uploads/2019/09/FireSmart_Booklet_web-Updated.pdf.
Brooks, N., Adger, W.N., 2005. Assessing and enhancing adaptive capacity. In: Lim, B., Spanger-Siegfried, E. (Eds.), Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Cambridge University Press, Cambridge, pp. 165–181.
Bullock, R., Broad, G., Palmer, L., Smith, M.P. (Eds.), 2017. Growing Community Forests: Practice, Research, and Advocacy in Canada. Univ. of Manitoba Press, Manitoba.
Bunnell, F.L., Kremsater, L.L., 2012. Migrating like a herd of cats: climate change and emerging forests in British Columbia. B.C. J. Ecosys. Manage. 13 (2), 27–50.
Campbell, E.M., Saunders, S.C., Coates, D., Meidinger, D., MacKinnon, A., O'Neill, G., Mackillop, D., Delong, C., Morgan, D., 2009. Ecological resilience and complexity: a theoretical framework for understanding and managing British Columbia's forest ecosystems in a changing climate. Technical Report-Ministry of Forests and Range,

Forest Science Program, British Columbia, Victoria, p. 44. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr055.htm.
Canadian Council of Forest Ministers (CCFM), 2019. Forest Insects (online). URL: http://nfdp.ccfm.org/en/data/insects.php.
Cinner, J.E., Adger, W.N., Allison, E.H., Barnes, M.L., Brown, K., Cohen, P.J., Gelcich, S., Hicks, C.C., Hughes, T.P., Lau, J., Marshall, N.A., 2018. Building adaptive capacity to climate change in tropical coastal communities. Nat. Clim. Chang. 8 (2), 117–123.
Cooke, B.J., Carroll, A.L., 2017. Predicting the risk of mountain pine beetle spread to eastern pine forests: considering uncertainty in uncertain times. For. Ecol. Manage. 396, 11–25. https://doi.org/10.1016/j.foreco.2017.04.008.
Copes-Gerbitz, K., Dickson-Hoyle, S., Hagerman, S.M., Daniels, L.D., 2020. BC Community Forest Perspectives and Engagement in Wildfire Management. Report to the Union of BC Municipalities, First Nations' Emergency Services Society, BC Community Forest Association and BC Wildfire Service. University of British Columbia, Vancouver, p. 49. https://treering.sites.olt.ubc.ca/files/2020/09/BC-Community-Engagement-in-Wildfire-Management-Community-Forest-Perspectives-2020568.pdf.
Daniels, L.D., 2017. Wildfire 2017. UBC Fac. For. Branchlines 28 (3), 12–13. https://forestry.ubc.ca/news/branchlines/past-issues/.
Daniels, L.D., Hagerman, S.M., Ravensbergen, S., 2018. Wildfire prevention and fuels management in the wildland-urban interface: BC community perceptions. Report to the Union of BC Municipalities, First Nations' Emergency Services Society. BC Community Forest Association and BC Wildfire Service, Vancouver, p. 30. https://www.fness.bc.ca/downloads/wildfires-report.pdf.
Dymond, C.C., Tedder, S., Spittlehouse, D.L., Raymer, B., Hopkins, K., McCallion, K., Sandland, J., 2014. Diversifying managed forests to increase resilience. Can. J. For. Res. 44 (10), 1196–1205. https://doi.org/10.1139/cjfr-2014-0146.
Dymond, C.C., Spittlehouse, D.L., Tedder, S., Hopkins, K., McCallion, K., Sandland, J., 2015. Applying resilience concepts in forest management: a retrospective simulation approach. Forests 6 (12), 4421–4438. https://doi.org/10.3390/f6124377.
Egunyu, F., Reed, M.G., 2017. Harrop-procter community forest: learning how to manage forest resources at the community level. In: Bullock, R., Broad, G., Palmer, L., Smith, M.P. (Eds.), Growing Community Forests: Practice, Research, and Advocacy in Canada. Univ. of Manitoba Press.
Egunyu, F., Reed, M.G., Sinclair, J.A., 2016. Learning through new approaches to forest governance: evidence from harrop-procter community forest, Canada. Environ. Manage. 57 (4), 784–797. https://doi.org/10.1007/s00267-015-0652-4.
Folke, C., 2016. Resilience (Republished). Ecol. Soc. 21 (4), 44. https://doi.org/10.5751/ES-09088-210444.
Folke, C., Colding, J., Berkes, F., 2002. Building resilience for adaptive capacity in social-ecological systems. In: Berkes, F., Colding, J., Folke, C. (Eds.), Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press, Cambridge, UK.
Government of B.C, 2020. Community Forest Agreements (online). URL: https://www2.gov.bc.ca/gov/content/industry/forestry/forest-tenures/timber-harvesting-rights/community-forest-agreements.
Griess, V.C., Knoke, T., 2011. Growth performance, windthrow, and insects: meta-analyses of parameters influencing performance of mixed-species stands in boreal and northern temperate biomes. Can. J. For. Res. 41 (6), 1141–1159. https://doi.org/10.1139/x11-042.
Gunter, J., Mulkey, S., 2017. The British Columbia community forest association: realizing strength in regional networking. In: Bullock, R., Broad, G., Palmer, L., Smith, M.P. (Eds.), Growing Community Forests: Practice, Research, and Advocacy in Canada. Univ. of Manitoba Press, pp. 149–159.
Gunter, J., Mulkey, S., 2019. Community Forest indicators 2019. Measuring the Benefits of Community Forestry. British Columbia Community Forest Association. https://bccfa.ca/bccfa-2019-community-forest-indicators-report/.
Hagerman, S.M., Dowlatabadi, H., Satterfield, T., 2010. Observations on drivers and dynamics of environmental policy change: insights from 150 years of forest management in British Columbia. Ecol. Soc. 15 (1).
Haley, D., Nelson, H., 2007. Has the time come to rethink Canada's Crown forest tenure systems? For. Chron. 83 (5), 630–641. https://doi.org/10.5558/tfc83630-5.
Karjala, M., Sherry, E., Dewhurst, S., 2003. The aboriginal forest planning process: a guidebook for identifying community-level criteria and indicators. Ecosystem Science and Management Program. University of Northern British Columbia, Prince George, BC, p. 90. https://www.for.gov.bc.ca/hfd/library/documents/bib95274.pdf.
Kurz, W.A., Dymond, C.C., Stinson, G., Rampley, G.J., Neilson, E.T., Carroll, A.L., Ebata, T., Safranyik, L., 2008. Mountain pine beetle and forest carbon feedback to climate change. Nature 452 (7190), 987–990.
Lawler, J.H., Bullock, R.C., 2017. A case for indigenous community forestry. J. For. 115 (2), 117–125. https://doi.org/10.5849/jof.16-038.
Leslie, E., 2017. Fire and Water: climate change adaptation in the harrop-procter community forest. In: Bullock, R., Broad, G., Palmer, L., Smith, M.P. (Eds.), Growing Community Forests: Practice, Research, and Advocacy in Canada. Univ. of Manitoba Press, pp. 180–185.
Levin, S., Xepapadeas, T., Crépin, A.S., Norberg, J., De Zeeuw, A., Folke, C., Hughes, T., Arrow, K., Barrett, S., Daily, G., Ehrlich, P., 2013. Social-ecological systems as complex adaptive systems: modeling and policy implications. Environ. Dev. Econ. 18 (2), 111–132. https://doi.org/10.1017/S1355770X12000460.
MacKillop, D.J., 2018. A Temporary Supplement to Land Management Handbook 71: a Field Guide to Ecosystem Classification and Identification for Southeast British Columbia: two Biogeoclimatic subzones/variants in the Golden-invermere TSAs, Victoria, p. 38. https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/TS-LMH-71.pdf.
MacKillop, D.J., Ehman, A.J., 2016. A field guide to site classification and identification for southeast British Columbia: the south-central Columbia Mountains. Land Management Handbook 70. Victoria.
Metsaranta, J.M., Dymond, C.C., Kurz, W.A., Spittlehouse, D.L., 2011. Uncertainty of 21st century growing stocks and GHG balance of forests in British Columbia, canada resulting from potential climate change impacts on ecosystem processes. For. Ecol. Manage. 262 (5), 827–837. https://doi.org/10.1016/j.foreco.2011.05.016.
Ministry of Forests Lands and Natural Resource Operations (MFLNRO), 2012. Beyond the Beetle A Mid-Term Timber Supply Action Plan (online). URL: http://www2.gov.bc.ca/assets/gov/farming-naturalresources-and-industry/forestry/forest-health/mountain-pinebeetle/midterm_timber_supply_action_plan.pdf.
Ministry of Forests, Lands, Natural Resource Operations & Rural Development (MFLNRORD), 2018. Annual Service Plan Report 2017/18, Vitoria. https://www.bcbudget.gov.bc.ca/Annual_Reports/2017_2018/pdf/ministry/flnro.pdf.
Mitchell, S., Larson, B., Griess, V., Simard, S., Delong, D., Nelson, H., Melton, J., Sheppard, J., 2017. UBC Rethink Silviculture Discussion Paper. University of British Columbia, Vancouver, p. 16. https://doi.org/10.14288/1.0394382. http://hdl.handle.net/2429/76032.
Natural Resources Canada (NRCAN), 2017. Climate Change Impacts on Forests (online). URL: https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/impacts/13095.
Paveglio, T.B., Carroll, M.S., Jakes, P.J., Prato, T., 2012. Exploring the social characteristics of adaptive capacity to wildfire: insights from Flathead County, Montana. Human Ecol. Rev. 19 (2), 110–124. https://doi.org/10.1016/j.jenvman.2013.08.036.
Paveglio, T.B., Abrams, J., Ellison, A., 2016. Developing fire adapted communities: the importance of interactions among elements of local context. Soc. Nat. Resour. 29 (10), 1246–1261. https://doi.org/10.1080/08941920.2015.1132351.
Perry, D.A., Hessburg, P.F., Skinner, C.N., Spies, T.A., Stephens, S.L., Taylor, A.H., Franklin, J.F., McComb, B., Riegel, G., 2011. The ecology of mixed severity fire regimes in Washington, Oregon, and Northern California. For. Ecol. Manage. 262 (5), 703–717. https://doi.org/10.1016/j.foreco.2011.05.004.
PricewaterhouseCoopers (PwC), 2019. British Columbia's Forest Industry and the Regional Economies (online). URL: https://www.cofi.org/wp-content/uploads/FINAL-COFI-Regional-Economic-Impact-Study_Final_March2019-2.pdf.
Sankey, S., 2018. Blueprint for Wildland Fire Science in Canada. Canadian Forest Service Northern Forestry Centre, Natural Resources Canada, Edmonton, p. 60. ISBN 978-0-660-27623-27626.
Schneider, R.R., Latham, M.C., Stelfox, B., Farr, D., Boutin, S., 2010. Effects of a severe mountain pine beetle epidemic in western Alberta, Canada under two forest management strategies. Int. J. For. Res. https://doi.org/10.1155/2010/417595.
Spies, J., Devisscher, T., Bulkan, J., Tansey, J., Griess, V.C., 2019. Value-oriented criteria, indicators and targets for conservation and production: a multi-party approach to forest management planning. Biol. Conserv. 230, 151–168. https://doi.org/10.1016/j.biocon.2018.11.022.
Spittlehouse, D.L., 2008. Climate change, impacts, and adaptation scenarios: climate change and forest and range management in British Columbia. BC Min. For. Range, Res. Br., Victoria. BC Tech. Rep. 045. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr045.htm.
Teitelbaum, S. (Ed.), 2016. Community Forestry in Canada: Lessons from Policy and Practice. UBC Press, Vancouver, p. 374.
Temperli, C., Bugmann, H., Elkin, C., 2012. Adaptive management for competing forest goods and services under climate change. Ecol. Appl. 22 (8), 2065–2077. https://doi.org/10.1890/12-0210.1.
Thompson, D.G., Pitt, D.G., 2003. A review of Canadian forest vegetation management research and practice. Ann. For. Sci. 60 (7), 559–572. https://doi.org/10.1051/forest:2003060.
Tymstra, C., Stocks, B.J., Cai, X., Flannigan, M.D., 2020. Wildfire management in Canada: review, challenges and opportunities. Prog. Dis. Sci., 100045 https://doi.org/10.1016/j.pdisas.2019.100045.
Walker, B., Holling, C.S., Carpenter, S.R., Kinzig, A., 2004. Resilience, adaptability and transformability in social–ecological systems. Ecol. Soc. 9 (2), 5. http://www.ecologyandsociety.org/vol9/iss2/art5/.
Woods, A.J., Heppner, D., Kope, H.H., Burleigh, J., Maclauchlan, L., 2010. Forest health and climate change: a British Columbia perspective. For. Chron. 86 (4), 412–422. https://doi.org/10.5558/tfc86412-4.
Wotton, B.M., Nock, C.A., Flannigan, M.D., 2010. Forest fire occurrence and climate change in Canada. Int. J. Wildland Fire 19 (3), 253–271. https://doi.org/10.1071/WF09002.