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EDITED BY

Muhammad Shaaban,
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REVIEWED BY

Muneer Magry,
Nalanda University, India
Ozgur Dincyurek,
Eastern Mediterranean University, Türkiye

*CORRESPONDENCE

Effah Kwabena Antwi
✉ effah.antwi@canada.ca

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Developing practical climate adaptation and mitigation toolkits for Canadian forest-based communities: a systematic review

Effah Kwabena Antwi^{1*}, Akua Nyamekye Darko¹,
John Boakye-Danquah², Erin C. Fraser-Reid³,
Heather Macdonald⁴ and Priscilla Toloo Yohuno (Apronti)¹

¹Department of Natural Resources (Canada), Ottawa, ON, Canada, ²School of Environment and Sustainability, University of Saskatchewan, Saskatoon, SK, Canada, ³Northern Forestry Centre, Natural Resources Canada, Edmonton, AB, Canada, ⁴Great Lakes Forestry Centre, Natural Resources Canada, Sault Ste. Marie, ON, Canada

The effects of climate change events such as wildfires, storms, flooding, and pest outbreaks remain a constant threat to the health of Canadian forests. Consequently, adaptation and mitigation actions are necessary to reduce the effects and impacts of climate change and prevent further deterioration of forest health. Using a climate change toolkit is a common way for forest practitioners to understand their climate risks, develop locally relevant adaptation and mitigation options, and drive the implementation of strategies to improve forest resilience. In this review paper, we examine how climate change adaptation and mitigation toolkits have been developed in the Canadian forest sector, the challenges that were encountered, and if and how Indigenous and local knowledge were incorporated into the process. Our results show that toolkits developed holistically and comprehensively provide a good foundation for implementing long-term impactful climate action. Achieving this requires a broad understanding and mapping of climate issues, implementation options, as well as best practices for monitoring and evaluation of action plans. If developed appropriately, toolkits can provide flexible pathways that are tailored to local changing climatic patterns, events, and impacts within specific contexts or sectors, ultimately improving forest resilience in the face of climate change.

KEYWORDS

toolkit, climate change, adaptation, mitigation, forest sector, community engagement

1 Introduction

Climate plays a role in the structure, form, function, and health of forests; when the climate changes, the forest changes [United States Environmental Protection Agency \(USEPA\) \(2023\)](#). Significant evidence and scientific data point to the scale, scope, and long-term effects of climate change ([UN-HABITAT, 2014](#)). Increasing temperatures and changing rainfall patterns and amounts can alter the composition of the forest depending on the type of forest and location ([United States Environmental Protection Agency \(USEPA\), 2023](#)). As of 2020, forests covered over four billion hectares of the Earth's landmass, ~31 percent ([Alves, 2023](#)). However, between 2010–2020, there was a global forest loss of 4.74 percent ([Shahbandeh, 2023](#)), and in 2022 alone, the Earth lost over 6.7 million hectares of tree cover due to reasons including those related to climate ([Salas, 2023](#)).

Canada has 397 million hectares of forest and other woodlands, comprising about 25% of the world's boreal forest (Natural Resources Canada (NRCan, 2024)), and provides clean air, nature connection, economic gains, ecological and cultural benefits for all Canadians (Edwards et al., 2015). Nevertheless, these benefits are being endangered by the dire impacts of climate change on the forest. Climate change events such as wildfires, storms, flooding, and pest outbreaks have compromised forest health over the years (Almstedt and Reed, 2013). In 2023, more than a quarter million Canadians had their lives upended by wildfires and floods, and many more lost their livelihoods, homes, and possessions because of climate change (Phillips, 2023). These impacts are expected to worsen without immediate and intentional adaptation and mitigation action (Moshofsky et al., 2019). At the same time, forest management agencies are facing challenges related to limited funding, urban encroachment, and increased demand for forest resources due to population increase and the cost of forest management (Emmett et al., 2006; Steelman, 2008).

Adaptation and mitigation represent two interdependent strategies to address the effects of the changing climate in a complex socio-ecological system (United States Environmental Protection Agency (USEPA), 2023). Yet, across many parts of the world, this has not been done to the degree required to preserve forest goods and services for future generations (Nelson et al., 2016). The Government of Canada, through Natural Resources Canada, has over the years made efforts to mitigate the impacts of climate change. This includes an initiative to increase the area of protected and conserved forests from the current level of 17 percent to 25 percent by 2025 and 30 percent by 2030 (OntarioNature, 2020; Natural Resources Canada (NRCan), 2023). However, given the increased strains and demands resulting from shifting climate patterns, there is widespread recognition that those responsible for managing forests may encounter unprecedented difficulties in achieving the shared objective of forest protection (Edwards et al., 2015).

To support the on-going adaptive management and governance of forests in the context of climate change, the role of toolkits has become very important. Toolkits designed for identifying priority climate change risks, developing potential adaptation and mitigation actions, and implementing climate change adaptation and mitigation strategies to reduce the identified areas of risk, provide a flexible approach as they can be amended with changing climatic patterns, changing local priorities, or when new information becomes available, and can be used and adapted by diverse users to implement strategies that can reduce the impact of climate change (Edwards et al., 2015). Waldick et al. (2015) argued that toolkits can help stakeholders collaborate and share knowledge as they identify priority climate risks, develop feasible adaptation and/or mitigation actions and then implement strategies to mitigate and adapt to climate change.

Although the implementation of climate mitigation and adaptation strategies may vary from region to region, a toolkit can provide guidelines for identifying priority risk areas, developing feasible adaptation or mitigation actions, standardizing and contextualizing implementation strategies, and promoting adaptive management practices across various provinces in the country (Carlson, 2012). For example, Partners for Climate Protection

(Gross, 2021) and the Bowron and Davidson (2011) argued that small communities form 90 percent of communities in Canada and have unique challenges and opportunities that are often ignored in the development of national climate tools. They therefore developed toolkits to address these unique challenges and opportunities and serve as a guide for professional planning for small communities. Even as toolkits for climate change adaptation continue to be developed and adapted across multiple sectors and contexts, it can be unclear how toolkits are developed, by whom, and for whom, including what kinds of knowledge are considered (e.g., scientific, Indigenous and/or local knowledge).

This research employed a systematic literature review to explore factors considered in the development of climate adaptation and mitigation toolkits in Canada. Specifically, our review examined the structure and content of forest-related climate change mitigation and adaptation toolkits developed for the forest sector across Canada. This includes data on implementation steps/processes and challenges encountered in the development of toolkits. We also report on engagement approaches that inform the development or use of toolkits and how Indigenous knowledge, and voices are factored into the toolkit development. Finally, we provide recommendations for the use of climate change adaptation and mitigation toolkits in the forest sector in Canada. For this review, “forest sector” was deemed to include any natural forest ecosystem, regardless of whether it is managed by the forest industry, a provincial or federal forestry/parks/protected areas agency, or a forest-based community.

2 Methods

The review process consisted of five different stages. The first stage involved the development of the review research objectives. This was followed by the process of finding potentially relevant toolkits that also contained sufficient background information to be assessed as part of our review. Thirdly, the identified documents were reviewed to identify the toolkits that met the inclusion criteria. Data was then extracted from the selected toolkits in alignment with the set objectives for the review during the fourth stage. Finally, the data was analyzed and reported as findings.

2.1 Development of a search strategy and Identification of relevant toolkits in scientific journal databases and gray literature sources

To identify toolkits relevant to this review, a search protocol was developed by the authors who have decades of experience in different fields of forestry research and climate change within Natural Resources Canada—Canadian Forestry Service (NRCan-CFS). The search protocol (Appendix A) for the toolkits was structured under three concept categories: climate change mitigation and adaptation terminologies, forestry terminologies, and toolkit terminologies.

TABLE 1 Databases and total records obtained after performing the search.

Database	Records
Scopus	3,282
Web of science	1,729
Google Scholar	170
GreenFile	111
ScienceDirect	1,874
Environment complete	108
Academic search complete	389
Gray literature	370
Total	8,033
Total after deduplication	6,091

Once the search protocols were finalized, we searched for publications in seven (7) academic journal databases (Web of Science, Scopus, Google Scholar, Academic Search Complete, Environment Complete, Science Direct, and GreenFILE). Searches were conducted from September to November 2023. Based on expert advice, we also conducted a thorough search of gray literature as most toolkits are not typically found in academic journals but rather on institutional websites. A group of forest climate change researchers at the Canadian Forest Service were asked to provide links to any known forest climate change toolkits. The engagement with forest climate change experts resulted in a list of 36 toolkits identified, of which a portion were eligible for this review. Our exploration involved specific websites listed in federal and provincial government databases and a Google search to include materials beyond academic sources. Some of the federal and provincial government websites used include: the Canadian Federal Open Science and Technology Repository, Canadian Climate Change Institute, Statistics Canada, Environment and Climate Change Canada, Natural Resources Canada GEOSCAN, Center for International Forestry Research (CIFOR) Library Database, and Environmental and Natural Resources. Due to limited search functionalities in many gray-literature databases, we utilized a condensed list of search terms employed in the journal literature search for the gray literature exploration. The details of the scientific and gray literature records and search combinations can be found in [Appendix B](#).

Searches within all databases were limited to toolkits written in English between the years 1997–2023, developed for use in Canada and within the subject area. [Table 1](#) shows the various databases searched and the respective records obtained. Searches of both the academic and gray literature initially returned 8,033 records. After removing the duplicates, 6,091 documents were identified for screening. To narrow down our search further, we then screened the records for relevance based on the following inclusion and exclusion criterion:

- i) Toolkits published between 1997–2023 (post-adoption of the Kyoto Protocol by Canada);
- ii) Toolkits published in English;

- iii) Toolkits developed for use in Canada;
- iv) Documents focused on the development of a framework/guideline or tool for climate change adaptation and/or mitigation, whether tested or not;
- v) Toolkits included considerations related to forest management or the forest sector.

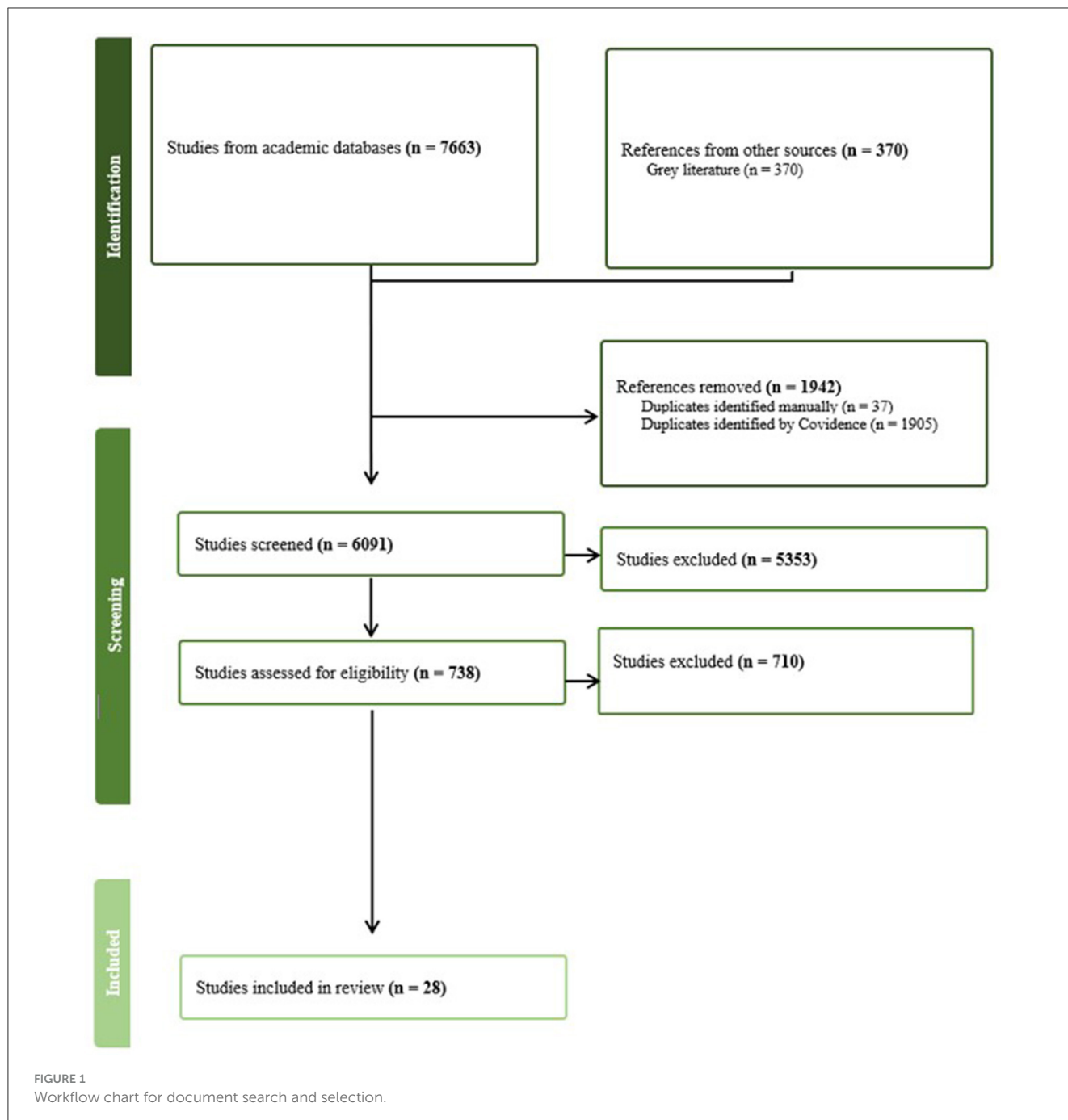
Toolkits that address climate change in general without any specific mention of the forestry sector were excluded as the review is specifically focused on toolkits that are designed to address forest sector climate change adaptation and mitigation, whether exclusively or in addition to other ecosystem types. In addition, we found several climate change toolkits designed in the US and often applied for use in Canada. However, such records were excluded to ensure that the toolkits were developed based on the unique climate change situation and forest conditions in Canada. As such, the study excluded the following:

- i) Publications that are not toolkits with outlined implementation guidelines for the forest sector exclusively or in addition to other ecosystem types. Specifically, we excluded documents that did not provide guidelines for climate change adaptation and mitigation actions. We also excluded primary studies and research that assessed climate change and mitigation in the forest sector and provided only recommendations for better adaptation and mitigation without structured guidelines or frameworks for implementation and community engagement.
- ii) Publications that presented modeling results and scenarios of future climate change with recommended adaptation and mitigation strategies for implementation but without a step-by-step guideline for implementation. This included publications that provided only information on adaptation and mitigation strategies without a clear implementation plan.
- iii) Finally, forest sector toolkits developed in countries other than Canada were also excluded. This meant that we also excluded toolkits developed without a focus on a specific country.

The search results from academic journals were combined using Covidence software, while the results from the gray literature were assembled using Microsoft Excel. Covidence is a web-based application that facilitates the data screening and extraction process.

2.2 Screening and reporting

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol ([Moher et al., 2009](#)); the screening process and results for both academic and gray literature are shown in [Figure 1](#). A total of 6,091 documents, including webpages, were screened for data extraction and analysis. A three-stage process was completed in Covidence and Microsoft Excel to select relevant toolkits for the study. First was the independent screening of the titles, abstracts, and methods by three experts. 5,353 records were excluded, while 738 records



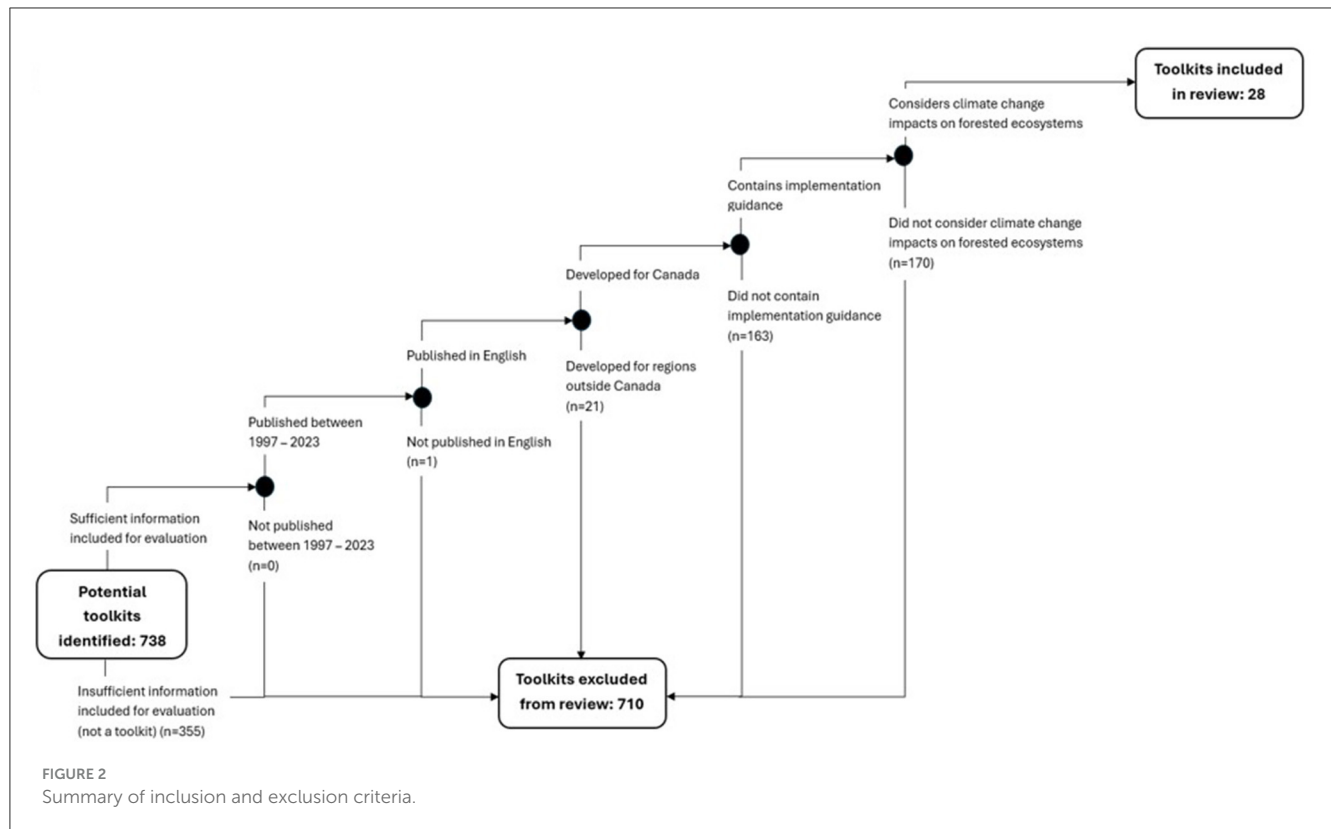
were retained for the next stage based on the study’s inclusion and exclusion criteria.

The next stage involved the screening of the full text, documents or webpages by three experts independently, mirroring the inclusion criteria. Where there were conflicts in agreement, a fourth author reviewed the full-text document or webpage, discussed their findings with the other reviewers, and made a final decision to include or exclude the document or webpage in line with the inclusion criteria. For the final review, two authors undertook a detailed review of the retained records to ensure consistency with the inclusion criteria and that all retained documents or webpages were ultimately relevant for this review. At the end of

the full-text screening, an additional 710 documents were excluded, and 28 documents and webpages were retained for data analysis and reporting as shown in [Figure 2](#). Of the records, 10 were from the academic literature, and 18 were from the gray literature; these included toolkits published in academic journals, on provincial and federal government institution websites and other gray sources.

2.3 Data extraction and analysis

Data were extracted from academic sources and gray literature, using a set of questions ([Appendix B](#)) designed in line with the



study's objectives. In December 2023, a team of climate change researchers at the Canadian Forest Service funded to develop a forestry sector climate change toolkit were asked to review the data extraction questions (search criteria) and to suggest recommended changes based on work undertaken. The finalized data were transferred to Microsoft Excel for in-depth analysis. Patterns or trends pertaining to the design of these toolkits were documented, and basic statistics were calculated using Microsoft Excel and NVivo 14, a qualitative data analysis software platform, was used to delineate themes that aligned with the study's objectives, such as the goal of the toolkit and the various considerations made in its development.

3 Results and discussion: structure and composition of selected toolkits

3.1 Data Characterization (dates, types, and target groups)

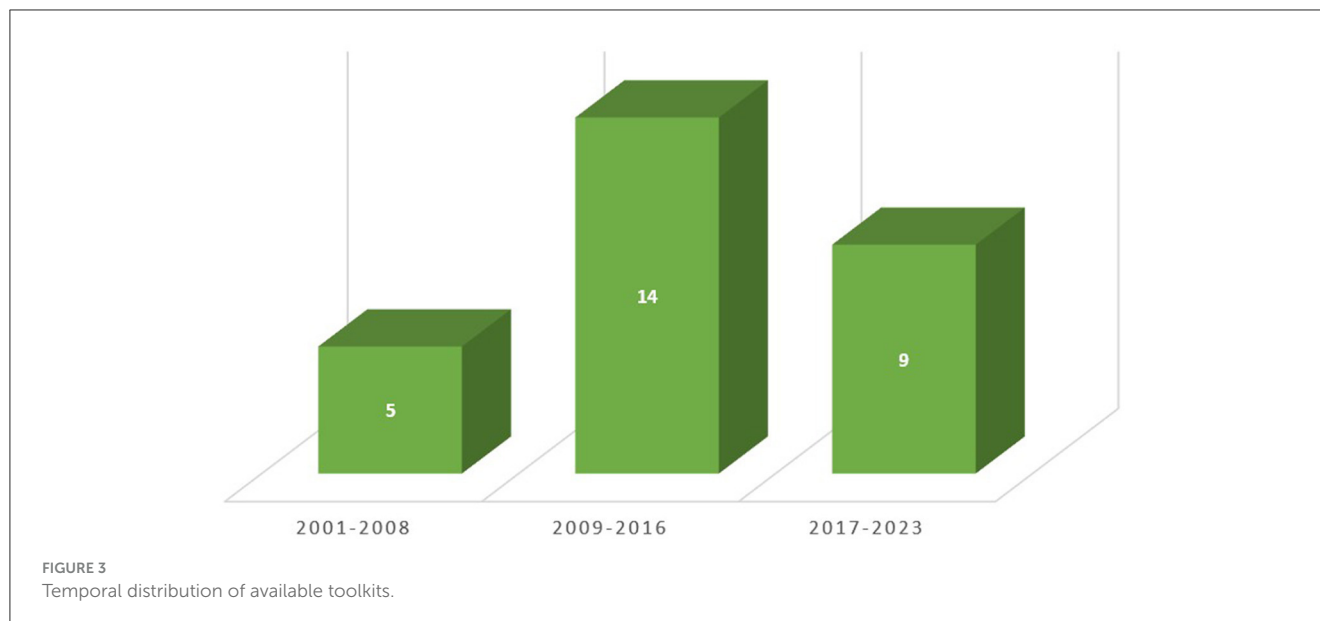
The majority of toolkits (50%, $n = 14$) were developed between 2009–2016 (Figure 3), indicating a rise in attention and initiatives toward reducing emissions and supporting vulnerable communities to plan and adapt to climate change after the 2009 Copenhagen UNFCCC conference (International Federation of Red Cross Red Crescent Societies, 2010). A reduction in publication is seen in the next few years, with nine (32%) toolkits published between 2017–2023. We found five (18%) toolkits published from 2001 to 2008. More than half (18) of the toolkits were found on institutional websites, where 10 represented academic

journal publications. This was to be expected as most toolkits (Table 2) are found in gray literature produced by governments or environmental non-governmental organizations (ENGO). Some of these institutions include the Canadian Institute of Forestry, the Canadian Council of Forest Ministers, and the Canadian Institute of Planners. Fourteen (50%) toolkits provided guidelines for adaptation strategies, while 11 (39%) addressed both adaptation and mitigation strategies, with only three (11%) documents concentrating solely on mitigation efforts.

The selected toolkits were designed to meet the needs of multiple groups (Figure 4). While the majority of toolkits mentioned that the guidelines can be used by a combination of different target groups including forest practitioners (20) and Indigenous communities (9), there is also recognition for non-Indigenous communities, land managers and planners, local government officials, and other stakeholders, indicating a comprehensive effort to design toolkits that can be used by a broad spectrum of actors to support climate action. Of the toolkits with a specific audience, six (6) of the toolkits in this scan were exclusively designed to address the needs of Indigenous groups and ten (10) for forest practitioners.

3.2 Climate events addressed by selected toolkits

The selected toolkits largely addressed multiple climate-related risks (Figure 5) that could directly or indirectly impact forests. Indeed, most toolkits took a wide view of potential climate change



impacts; only four (4) publications focused exclusively on forest ecosystems. In comparison, most toolkits addressed a combination of climate risks such as flooding and soil erosion (6), windstorms (5), animal, plant, and other non-human life (12), wildfires (21), invasive plant species (2), insect outbreaks (8), changes in forest cover, composition and size (19), winter roads (3), as well as other topics (8). The other topics included water supply, drought, water quality, rising sea levels, warming oceans, as well as transportation infrastructure issues in the forestry sector related to climate change. The combined focus on multiple issues such as wildfire and insect infestations echoed the interdisciplinary approach advocated in academic discussions such as [Carlson \(2012\)](#) and [Knight et al. \(2017\)](#) who emphasize the significance of addressing diverse concerns such as wildfires, forest impacts, and insect outbreaks in adaptation and mitigation planning.

3.3 Data sources used in the development of toolkits

We observed that most toolkit guidance was typically developed following a thorough review of documents to serve as base information and thus ensure a robust and comprehensive foundation for developing the toolkit. Most toolkits were developed using multiple data sources ([Figure 6](#)) including climate data (57%, $n = 16$) which included information on various climatic conditions, impacts and adaptation and mitigation strategies for the forest and other sectors, and data pulled from other reports (71%, $n = 20$) including the British Columbia Carbon Offset protocol (Ministry of Environment and Climate Change Strategy, 2022 in [Rojas et al., 2023](#)), Canada's National Assessment for British Columbia and South Okanagan Regional Growth Strategy (2011 in [Carlson, 2012](#)), and the National and provincial "state of the forest" reports (in [Williamson et al., 2012](#)). In addition, many toolkits that incorporated qualitative information and data to inform the development of the toolkits was gathered from experts

and key actors through interviews (64%, $n = 18$), surveys (43%, $n = 12$), meetings (43%, $n = 12$), and on-site visits (32%, $n = 9$), drawing from first-hand perspectives and experiences through stakeholder engagement and collaborative discussions to enrich the understanding of local nuances and challenges to climate change. Finally, the selected toolkits recommended the use of several relevant user-friendly resources in addition to the toolkits. These include study reports (100%, $n = 28$), glossaries (43%, $n = 12$) and videos (14%, $n = 4$) as support material for the toolkit.

3.4 Phases identified in forest sector climate change toolkits

Evaluating the selected toolkits has highlighted seven (7) different steps for the implementation of climate change mitigation and adaptation strategies in the Canadian forest sector. These include phases for: (1) planning, (2) identification of climate change impacts, (3) assessment of vulnerabilities, (4) articulation of goals and objectives, (5) identification of preferred approaches, (6) development of an action plan, and (7) monitoring and evaluation. All the selected toolkits included different elements of these steps.

3.4.1 The planning phase

Most toolkits ($n = 18$, 64%) recommended a planning process as part of the steps needed to implement adaptation and mitigation strategies. Some of the recommended actions to take at this stage include:

- Form a project team involving multiple actors such as community members, researchers, and government representatives for effective day-to-day implementation of strategies;

TABLE 2 Selected toolkits.

No.	Title	Year	Location	Type of journal	Type of toolkit
1	Climate change adaptation planning in remote, resource-dependent communities: an arctic example	2012	Paulatuk, Northwest Territories	Regional environmental change	Adaptation only
2	Adapting to climate change in the Southwest Yukon: locally identified research and monitoring needs to support decision making on sustainable forest management	2009	Southwest Yukon	Arctic institute of North America	Adaptation only
3	A structured decision-making approach to climate change adaptation in the forest sector	2005	Ontario	The forestry Chronicle	Adaptation only
4	A business case for climate change adaptation by forest industry in Central Canada	2021	Swan Valley	The forestry Chronicle	Adaptation only
5	Incorporating climate change adaptation into local plans	2014	Prince George, British Columbia	Journal of environmental planning and management	Adaptation only
6	Practitioners, priorities, plans, and policies: assessing climate change adaptation actions in a Canadian community	2014	Prince George, Northern British Columbia	Sustainability science	Adaptation and Mitigation
7	Using multi-criteria analysis and visualization for sustainable forest management planning with stakeholder groups	2005	British Columbia	Forest ecology and management	Adaptation Only
8	Integrating climate change adaptation into forest management	2005	British Columbia	The forestry Chronicle	Adaptation Only
9	Fire-smart forest management: a pragmatic approach to sustainable forest management in fire-dominated ecosystems	2001	Edmonton	The forestry Chronicle	Adaptation and Mitigation
10	Application of structured decision making to an assessment of climate change vulnerabilities and adaptation options for sustainable forest management	2009	Yukon	Ecology and society	Adaptation Only
11	Integrating climate change into forest management in south-central British Columbia: an assessment of landscape vulnerability and development of a climate-smart framework	2008	South-Central British Columbia	Forest ecology and management	Adaptation and Mitigation
12	Planning for climate change adaptation: lessons learned from a community-based workshop	2012	Prince George, British Columbia	Environmental science and policy	Adaptation Only
13	Future visioning of local climate change: a framework for community engagement and planning with scenarios and visualization	2011	British Columbia	Science direct	Adaptation and mitigation
14	Scaling up forest landscape restoration in Canada in an era of cumulative effects and climate change	2020	Edmonton	Science direct	Mitigation only
15	We are fire: a toolkit for applying indigenous-led fire practices and western fire management in the Saskatchewan river delta	2023	Saskatchewan	We are fire	Adaptation and mitigation
16	Climate change adaptation planning for indigenous people	2020	Alberta and Northern Ontario	Center for indigenous environmental resources	Adaptation and mitigation
17	Indigenous climate monitoring toolkit: guidance, good practices, and resources for indigenous communities.	2020	Ottawa	Indigenous climate monitoring	Adaptation and mitigation

(Continued)

TABLE 2 (Continued)

No.	Title	Year	Location	Type of journal	Type of toolkit
18	Climate change and sustainable forest management in Canada: a guidebook for assessing vulnerability and mainstreaming adaptation into decision making	2015	Alberta	Canadian council of forest ministers	Adaptation only
19	Climate change adaptation framework manual	2010	Alberta	Sustainable resource development	Adaptation only
20	Small and rural communities climate action	2021	Ottawa	Local governments for sustainability	Mitigation only
21	Reducing vulnerability to climate change: a toolkit for communities	2017	British Columbia	Canadian parks and wilderness society: British Columbia chapter	Adaptation only
22	Climate change adaptation planning: a handbook for small Canadian communities	2011	Montreal	Canadian institute of planners	Adaptation and mitigation
23	Preparing for climate change: an implementation guide for local governments in British Columbia	2012	British Columbia	Westcoast environmental law	Adaptation and mitigation
24	Mainstreaming climate change: integrated landscape assessment, decision-support process and tool kit guidebook to implementing the quantitative and qualitative aspects of the assessment	2015	Quebec, British Columbia, Atlantic Region, Ontario	International institute for sustainable development	Adaptation only
25	Urban forestry toolkit: exploring climate change in Marpole	2016	Marpole	Urban forest research hub	Adaptation and mitigation
26	Adapting sustainable forest management to climate change: a framework for assessing vulnerability and mainstreaming adaptation into decision making	2012	Ottawa	Canadian council of forest ministers	Adaptation only
27	First nations forest carbon toolkit	2023	British Columbia	Carbon toolkit	Mitigation only
28	Changing climate, changing communities: guide and workbook for municipal climate adaptation	2019	Delta, British Columbia	Local governments for sustainability	Adaptation and mitigation

- Identify champions and involve internal and external stakeholders with diverse expertise. For example, [Zahara et al. \(2023\)](#) reported the need to involve experts in fire management in Indigenous communities, such as the Indigenous Fire Knowledge Carriers, who have experience and knowledge with fire, if applicable;
- Identify the focus risk, conduct a background scoping, examine, revise, and approve project proposals;
- Consolidate existing data, assess project eligibility, and review documentation;
- Establish a governance structure, with governance defined as a process by which actors articulate their interests, prioritize issues, and enforce decisions ([FAO, 2022](#));
- Establish and maintain an effective protocol for communicating between partners (e.g., among the project team, local Indigenous communities, stakeholders, and partner agencies);
- Implement measures to build partnerships and foster community collaboration; and
- Gain community commitment and notify relevant departments and agencies.

3.4.2 Identifying climate change impacts

Identifying climate change impacts was a recurring theme in forest sector climate change toolkits. Specifically, 20 (71%) toolkits involved steps to understand the impacts of climate change on forests and forest users through scientific climate data and community engagement. Examples of toolkit recommendations to assess climate change impacts include actions such as:

- Assess people's understanding of climate change impacts;
- Conduct forest sector and stakeholder focus groups to share observations and discuss persistent climate impacts;
- Conduct forest sector and stakeholder engagement workshops to learn about past changes using specific examples or important resources as discussion points;
- Develop an influence diagram and scenarios for climate change impacts on the forest sector and community; and

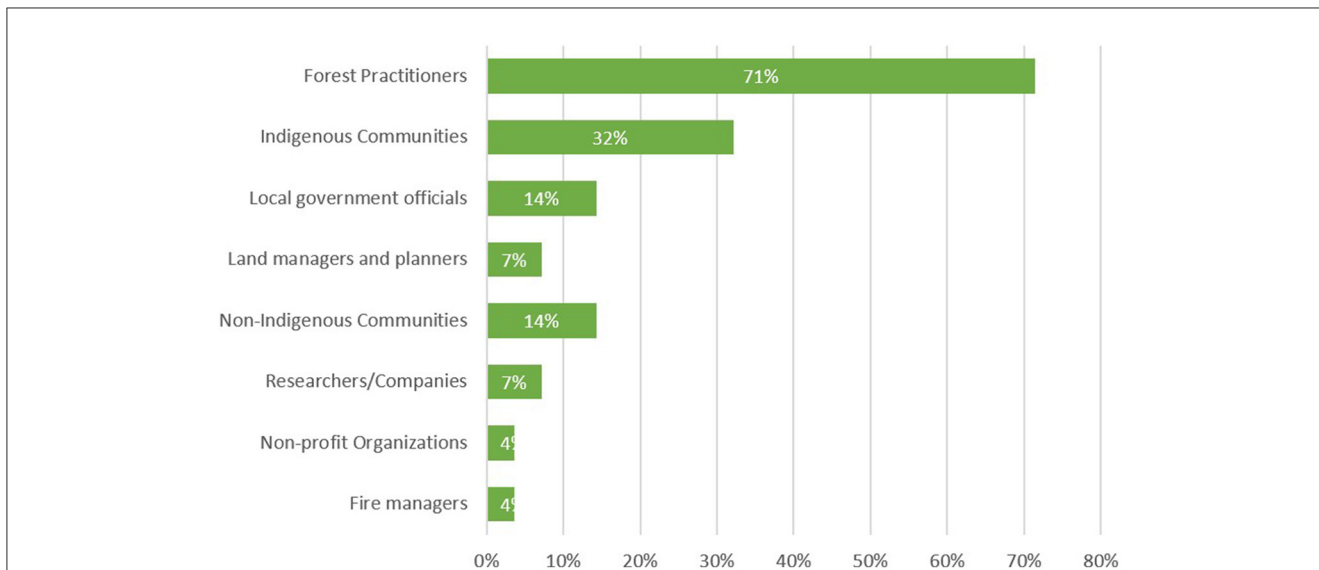


FIGURE 4
Target group addressed in toolkits.

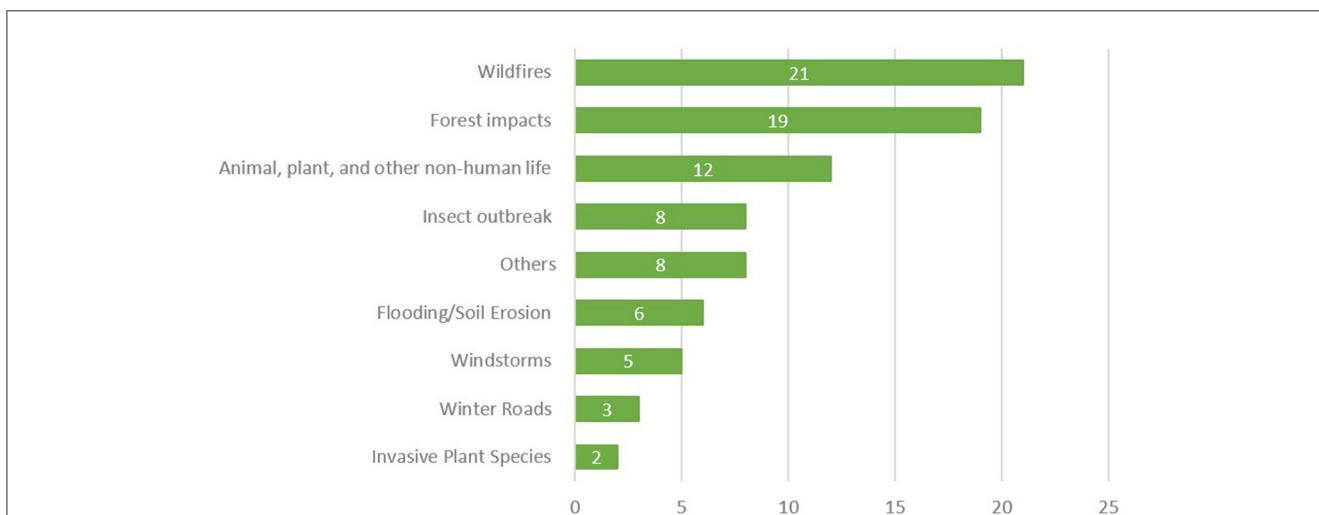


FIGURE 5
Climate change risk addressed in the toolkits.

- Increase awareness of climate science and current and projected climate change impacts by engaging and educating the public.

3.4.3 Assessment of community and ecosystem sustainability and vulnerabilities

Understanding the strengths and weaknesses of a community or ecosystem is foundational for implementing effective adaptation and mitigation strategies. This process aids in recognizing assets that can be leveraged and identifying weak points that require attention in the face of climate change. Half of the toolkits ($n = 14$, 50%) identified this step as vital in the development of

toolkits. Some general considerations from the toolkits to understand the strengths and weaknesses of a community or ecosystem include:

- Conduct vulnerability and feasibility assessments to identify sources of vulnerability and to develop a contextual understanding;
- Conduct adaptation and mitigation planning workshops for community members to identify community/forest ecosystem strengths and weaknesses;
- Identify vulnerable components of the forest sector, which could include businesses, culture, health, subsistence harvesting and/or transportation. Specific vulnerabilities may vary based on the particular location, local priorities or

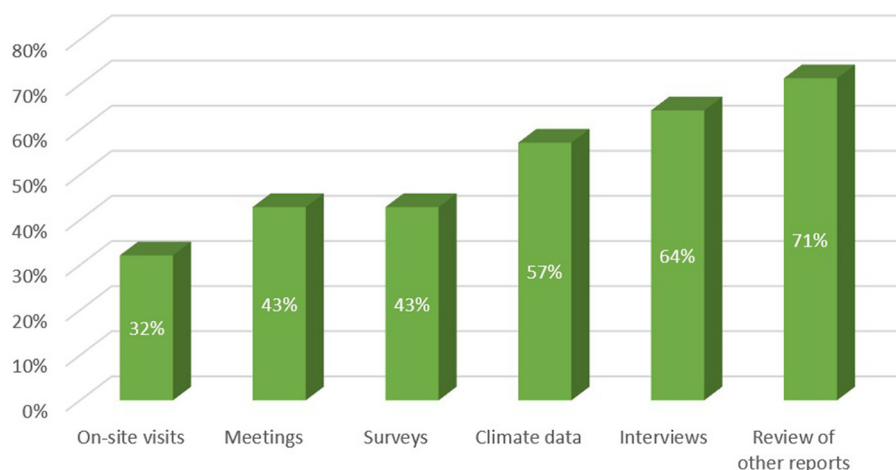


FIGURE 6
Sources of data collection.

issues, and the specific climate changes that are projected for the region.

- Identify forest sector management options that will be resilient to future climate conditions;
- Assess the forest sector's sustainability through government consultation and planning efforts;
- Consider quantitative and qualitative values including ecosystem services, carbon sequestration, and recreational benefits;
- Educate community members on the vulnerability of local forested ecosystems and the forest sector to climate change; and
- Periodically reassess identified vulnerabilities and strengths as new knowledge and insights become known.

3.4.4 Articulation of implementation goals and objectives

Most toolkits stressed establishing clear goals and objectives for implementing climate change adaptation or mitigation strategies and this step was recommended by several tool kits ($n = 11$, 39%). This articulation phase provides a roadmap for adaptation and mitigation efforts, outlining the desired outcomes and the specific steps to achieve them. To clearly define the goal of the strategy the following recommendations were made:

- Conduct interviews with open-ended questions with local residents to understand their perspectives and interpretations of climate change adaptation and mitigation;
- Establish adaptation and mitigation visions and objectives, identify options, drivers, and constraints;
- Apply systematic techniques in defining problems and setting objectives;
- Establish linkages with local/regional economic activities and social values;

- Provide a detailed description of the context and the management approach to be used; and
- Consider non-climatic factors affecting forested ecosystems and/or the forest sector.

3.4.5 Identification of preferred adaptation/mitigation approaches and solutions

Identifying preferred adaptation and mitigation priorities and potential solutions ensure alignment with forest sector preferences and enhances the likelihood of successful implementation. Involving local residents, stakeholders, and forest users in identifying preferred adaptation and mitigation approaches is paramount to drafting tailor-made solutions as this ensures a bottom-up approach that aligns with local needs and preferences. More than half of the toolkits ($n = 15$, 54%) recommended this step and to do this effectively, the following recommendations were made:

- Determine if adaptation and mitigation are required, identify feasible options and create a comprehensive list of priority solutions based on community preferences;
- Facilitate workshops involving scientists, practitioners, and community stakeholders to build consensus on the need for climate action;
- Learn more about any past successes and local decision-making processes to understand how these experiences might inform the current climate change adaptation and mitigation planning process;
- Compile data through interviews, surveys, and workshops and consider social and cultural structures;
- Identify informal adaptation and mitigation actions and existing policies; and
- Screen adaptation and mitigation strategies for compatibility or inconsistency with existing policies and initiatives.

3.4.6 Action plan and implementation recommendations

This phase, which includes translating goals into actionable strategies, was an element of 16 (57%) toolkits reviewed. Identified planning steps for climate change in forest-based communities included:

- Preparation of the plan beginning with establishing principles, specifying policies, prioritizing actions, and analysing program gaps;
- Development of a matrix for plans commonly used in the sector or the community;
- Creating a detailed action plan and sharing it with stakeholders;
- Seeking council or community approval for the adaptation/mitigation framework and priority actions;
- Mobilization of resources through national and subnational programs, climate finance instruments, and private sector engagement;
- Implementation of strategies and mainstreaming adaptation and mitigation into local plans, policies, and budgets;
- Development of an implementation schedule detailing milestones and timelines, including a timeline for reviewing the plan;
- Outlining key indicators for tracking project success and challenges; and
- Emphasizing the ever-evolving nature of an adaptation and mitigation plan, and ensuring it is flexible enough to respond to variable needs and circumstances.

3.4.7 Continuous monitoring and evaluation

Monitoring and evaluating the effectiveness of implemented actions was recommended as an important step in 64% ($n = 18$) of selected toolkits. Toolkits can also be used to incorporate the monitoring and evaluation of strategies, track progress, assess effectiveness, and identify areas for improvement in climate change adaptation and mitigation initiatives (Andrews-Key et al., 2020). Examples of continuous monitoring and evaluation steps included:

- Outlining steps for monitoring, evaluating, and reporting the effectiveness of implemented actions;
- Addressing monitoring needs through community involvement;
- Analysing how the local climate will change by gathering scientific information and community knowledge;
- Tracking implementation progress, reporting to measure success, identifying gaps and follow-up actions;
- Third-party evaluation to identify responsibilities and areas where the plan or implementation has fallen short;
- Revision of the adaptation and mitigation plan based on new data;
- Communication of accomplishments both internally and externally to stakeholders and the forest sector at large.

3.5 Indigenous leadership in the development of local and regional climate change toolkits

Custom-made toolkits provide an opportunity for different communities to develop guidelines for forest climate change adaptation that meet their specific needs and represent their voices. For instance, Childs et al. (2020) developed the Indigenous Climate Monitoring toolkit and described how available climate change tools did not adequately address the unique needs, cultures, and values of their communities. Indigenous communities have the right to protect their forests from climate change and other threats as per the Office of the High Commissioner for Human Rights (2007), adopted by Canada in 2021.

Nine (9) of the selected toolkits mentioned that the recommendations for implementation could be used by various target groups including Indigenous communities. Six (6) toolkits were developed by Indigenous organizations for Indigenous communities. Nearly all (27) of the toolkits were developed through stakeholder engagements involving local government experts, national institutions such as Natural Resources Canada, non-governmental organizations, researchers, and technical specialists. Some of the toolkits were led by Inuit, Metis, and First Nations [specifically Champagne and Aishihik, Cree and Anishinaabe, First Nations Traditional Territory in southwest Yukon and the British Columbia Assembly of First Nations (BCAFN)] people. Engagement tools documented in this review included the development of glossaries and tools contextualizing climate change within the history and culture of the local community.

Indigenous-led climate change toolkits recommended language camps and school programs incorporating climate change as an educational theme. Some toolkits reviewed, developed a climate change-related vocabulary in Indigenous languages such as Ininimowin/Cree (We are Fire, Climate Change Adaptation Planning for Indigenous people by Zahara et al., 2023), Inuvialuktun (Climate Change Adaptation planning for Indigenous people by Anderson et al., 2020), Heiltsuk and Sk̓w̓x̓w̓7mesh sníchim (First Nations Forest Carbon Toolkit by Rojas et al., 2023) to incorporate native language in adaptation planning documents and other similar documents such as forest management plans. Some of these engagement measures aim at long term goals of increasing youth understanding and ability to recognize climate vulnerabilities and impacts. Using these steps, Indigenous communities are leading local efforts to contextualize and identify vulnerabilities and strengths using local customs and terminologies.

All 28 reviewed toolkits (Indigenous or non-Indigenous) suggested the involvement of community members and consistently underscored the significance of community engagement, reflecting a commitment to involving local communities in Canada. Community engagement was done by encouraging local governments and forestry agencies to involve citizens including elders, youth, women, cultural leaders, and marginalized groups in creating targeted adaptation and mitigation strategies. In addition, tools such as workshops, surveys and interviews were used at various stages of planning and

decision-making to increase awareness on climate impact, solicit opinions, and conduct monitoring activities.

3.6 Conditions for using climate change toolkits

Toolkits are helpful to standardize and contextualize strategies, but at the same time, the use of toolkits must be guided by any caveats identified by their creators. Authors of the various toolkits reviewed outlined a number of these conditions, such as the lack of transferability of the toolkit to different contexts, and the need to combine toolkit recommendations with other information to support decision-making. For example, Zahara et al. (2023) stated that their toolkit on Indigenous-led fire prescription is unique to Indigenous groups with specific considerations for the community's land, water, set of holistic values, and objectives. It is therefore recommended that this toolkit be used for implementation among these communities. Anderson et al. (2020) in their toolkit developed for Indigenous communities also advised users of their toolkit to make intentional and tailor-made considerations when working with Indigenous groups who have different languages, cultures, and traditional ways of life.

Some of the toolkits developed did not contain an explicit temporal component. For instance, Nitschke and Innes (2008) indicated that vulnerability assessments are constantly required to determine new and future susceptibilities and impacts. Toolkit guidelines need to be examined in combination with local, comprehensive vulnerability assessments to provide decision support on forest management (Nitschke and Innes, 2008).

Another caveat stated by Bowron and Davidson (2011) was the fact that their toolkit is not a substitute for professional advice and should be used in combination with the advice of a climate change specialist. In addition, some toolkits were designed for small Canadian communities and may not be appropriate for larger municipalities or communities outside of Canada (Gross, 2021). Anderson et al. (2020) recommend that their toolkit be used in conjunction with other resources and expertise as the toolkit handbook is not a complete guide to climate change adaptation planning.

Further, Waldick et al. (2015) stated that when using their guidebook for mainstreaming adaptation, a review of the whole document should be conducted by a smaller expert group to identify various steps relevant for adaptation. Although the knowledge held by forest practitioners provides insights into practices that are important to achieving management objectives considering climate change, Ogden and Innes (2009) stated that the recommendations are only a starting point and that since case studies outlined were not designed to suggest the production of generalizations, caution should be used in applying the recommendations elsewhere (Ogden and Innes, 2009). Caveats were an important part of the toolkits reviewed and were used as a means to help users avoid the misapplication of recommendations and guide them toward the path for effective implementation.

3.7 Reported challenges encountered in the development of toolkits

The development of toolkits is a process that is not void of challenges. Some challenges identified by our review include lack of funding to develop toolkits, lack of capacity and expertise to develop and implement recommendations from the toolkit, community engagement challenges including language barriers, cultural differences, a lack of continuous engagement among stakeholders and changes to communities' priorities.

Financial constraints often posed a significant barrier to developing and implementing adaptation and mitigation actions in the forest sector, noted by approximately one-third of toolkits. Undertaking in-depth research and meaningfully engaging stakeholders requires funding that is over and above regular expenditures. Among the toolkits that mentioned lack of funds as a hindrance, five were developed by universities, including the University of British Columbia (Ogden and Innes, 2009; Picketts, 2014; Picketts et al., 2012; Mansuya et al., 2020) and the University of Guelph (Pearce et al., 2012). In addition, agencies such as the British Columbia Ministry of Forests (Spittlehouse, 2005), Canadian Institute of Planners (Gross, 2021) and Crown-Indigenous Relations and Northern Affairs Canada (Anderson et al., 2020) also cited financial constraints as a challenge. This shows that the challenge associated with the lack of funds for the development and implementation of climate change toolkits cuts across all sectors (government, academic bodies, and local community organizations).

Additionally, the toolkits developed by Bowron and Davidson (2011) and Carlson (2012) for the Canadian Institute for Planners both stated that implementation of their toolkits will be difficult, especially in small communities that may lack the expertise and capacity needed to both develop and implement these plans. Sheppard et al. (2011), Waldick et al. (2015), and Meaney and Jackson (2019) stated that adaptation planning based on scientific predictions can be difficult because of insufficient local data and the constant evolution of scientific data. For some toolkits, limited audience engagement at the different stages of development was identified as hindering the toolkit's inclusivity and effectiveness in addressing diverse perspectives (Anderson et al., 2020; Ogden and Innes, 2009).

Some additional challenges identified were language barriers, changes to community priorities, and cultural differences, mostly between the designers of the toolkits and the communities where the toolkits are intended to be used (Childs et al., 2020; Zahara et al., 2023). A unique challenge highlighted in a 2001 toolkit developed by Natural Resources Canada (Hirsch et al., 2001) was the institutional separation between fire management and forest management agencies in many provincial/territorial governments, which has contributed to these specialities operating in separate silos and limiting the implementation of holistic adaptation and mitigation actions targeting areas of climate change risk to forest ecosystems. As a response to the complexity of wildfire information management, the Canadian Interagency Forest Fire Center coordinates information and resource sharing between the federal, provincial and territorial governments of Canada, as well

as coordinating with international firefighting partners (CIFFC, 2024).

Finally, continuous engagement in adaptation and mitigation planning, as well as stakeholder consultation, is often lacking in the forest sector, which hinders the creation of new guidelines for the toolkits considering the evolving nature of forest sector objectives and goals (Ogden and Innes, 2009; Anderson et al., 2020). Additional challenges may arise from a lack of continuous engagement in implementing meaningful input from diverse stakeholders due to conflicting interests, necessitating a careful balance in addressing various perspectives. It is important to be cognisant of the challenges faced by authors while developing toolkits so toolkit users can establish measures to avoid or manage similar challenges should they arise when trying to take climate change adaptation and mitigation actions in the forest sector.

3.7 Limitations of this review

This scan of climate change toolkits included only English documents and toolkits with forest impacts as a focus of implementation. Therefore, trends in climate change toolkits more broadly may not be represented by this analysis. However, the focus of the review was on forest-related toolkits; thus, efforts were made to capture all such documents. The study also excluded toolkits produced in the U.S., even though there are similarities in respective national/local forest structure and therefore in related challenges. The focus of the review was on Canadian toolkits in order to assess our national capacity for forest-related climate change adaptation and mitigation using toolkits as a measure.

The largest number of toolkits were identified from the gray literature, which often relied upon online materials. Because of the prevalence of forest climate change toolkits published online, this scan does not reflect toolkits published online but then taken down from a website, or toolkits from agencies that have changed or no longer exist. In sum, the dataset of toolkits should be considered to reflect those active as of the scan completed in 2023.

4 Discussions and conclusions

This review has synthesized information on how toolkits for climate change adaptation and mitigation in the forest sector are developed, and provided information on the steps commonly adopted to develop climate change adaptation toolkits. This review also considered if and how local and Indigenous Knowledge (IK) are incorporated, and the challenges that were encountered in toolkit development.

A key outcome of this review showed that the successful development of climate change adaptation and mitigation strategies is dependent on the set of guidelines driving their implementation. Toolkits developed holistically and comprehensively provide a good foundation for implementing long-term, impactful climate action. A summary of the recommended steps for climate change adaptation and mitigation strategy implementation, and the likely outcome, is shown in [Figure 7](#) to suggest an

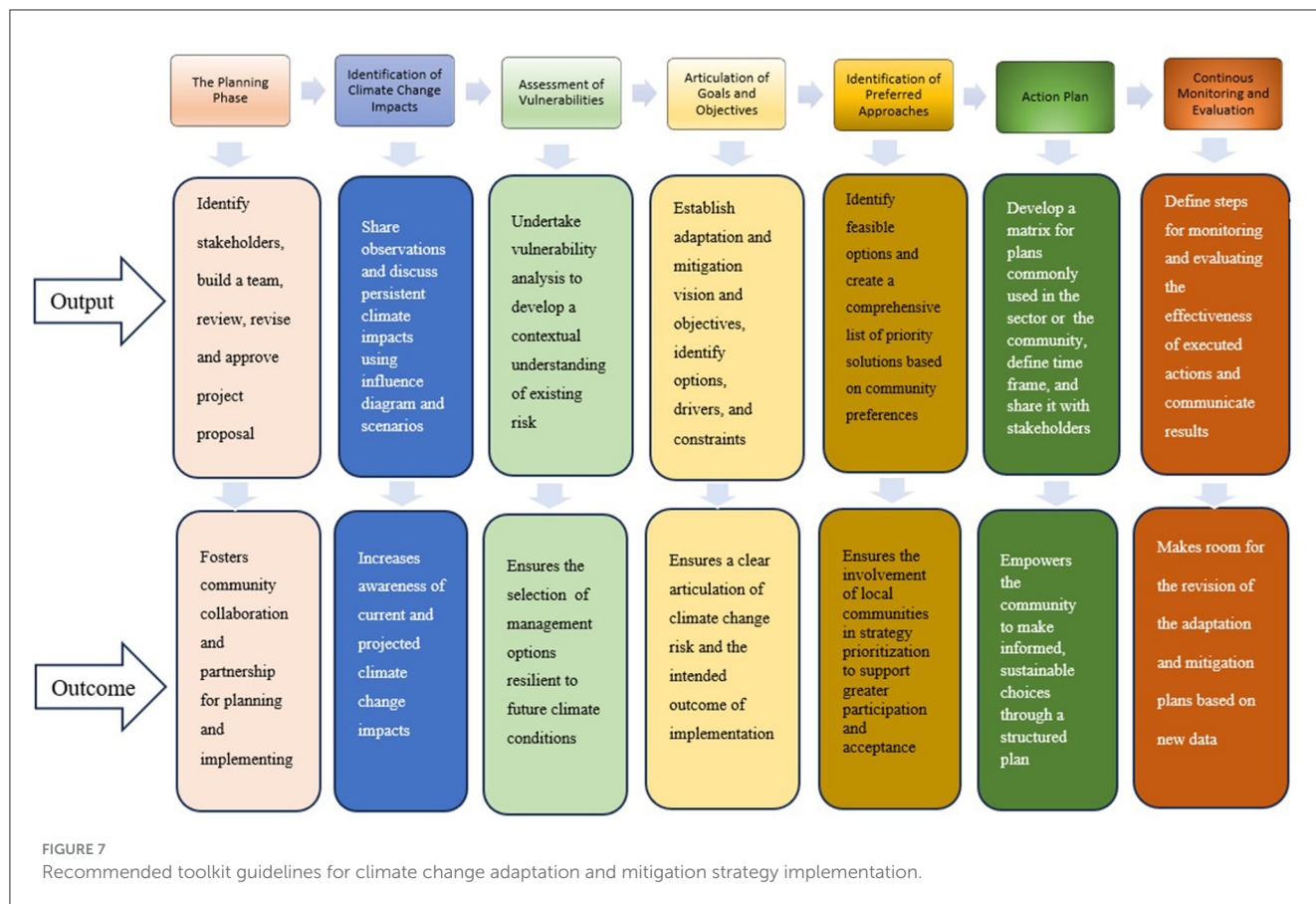
ideal process. Achieving this requires a broad understanding and mapping of climate issues, implementation options, as well as best practices for monitoring and evaluation of action plans.

Most forest sector climate change toolkits reviewed required that seven stages be present: planning, identification of climate change impacts, assessment of vulnerabilities, articulation of goals and objectives, identification of preferred approaches, development of an action plan and monitoring and evaluation. Although all stages are important, monitoring the effects of climate change, identifying the consequences for the forest sector and local residents, and understanding the potential impact of adaptation and mitigation strategies should occur at different stages throughout the process of implementation. This makes room for revisiting assumptions, objectives, and strategies, as well as changing perceptions, values, and priorities of the forest sector.

Implementation of these steps requires the active involvement of local residents and stakeholders, including Indigenous and non-Indigenous communities. This approach creates a platform to contextualize and align the guidelines to the specific needs of various components of the forest sector. Significantly, six of the toolkits reviewed were Indigenous-led, highlighting the importance of developing place and culturally specific toolkits to advance effective climate action. Toolkits developed with such cultural specificity can be useful for the communities concerned but may not be appropriate to other or broader contexts.

Through this review, we have also learned that there are several challenges that can hinder the development and implementation of toolkits. Some of these include financial constraints, difficulty incorporating diverse perspectives and the complexities of predicting impacts. Overcoming these hurdles requires a collaborative, adaptive, and stakeholder-inclusive approach to ensure the toolkit's efficacy in promoting sustainable practices and addressing the multifaceted issues facing forest ecosystems. Beyond overcoming these challenges, it is also important to note that most toolkits tend to be context-specific; thus, transferring the processes or outcomes to a different context would require significant adaptations and modifications to make them relevant. Hence, developing an ideal toolkit for the forest sector in Canada would need to consider the caveats and challenges identified in this paper.

Several advantages have been identified through the review for policy development and implementation around climate change adaptation and mitigation in the forest sector. The review provides evidence-based analysis of the climate change adaptation and mitigation toolkits for the forest sector to inform the development of an ideal toolkit by drawing on the lessons learned in the development of reviewed toolkits. The evidence provides strong justification for the need for a standardized document to guide communities and forest managers on the best way to implement strategies in adapting and mitigating climate change. The review provides a scientific basis for making decisions around the development and implementation of climate change adaptation and mitigation strategies with



Indigenous and non-Indigenous communities. The reported funding challenges provide potential funding opportunities for institutions to support climate change initiatives. The review also identified the need for policy integration around climate change strategies and Indigenous-led resource management in designing a comprehensive toolkit for the forest sector. Finally, the review provides guidelines for developing strategies to adapt to climate and actions to mitigate climate change. This will inform the development of an ideal toolkit for the Canadian forest sector forest sector after consultation with various stakeholders including scientists, Indigenous and non-Indigenous communities.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Author contributions

EA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AD: Conceptualization,

Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JB-D: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. EF-R: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. HM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. PY: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fclim.2025.1578605/full#supplementary-material>

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