Assessing Climate Preparedness: A Comparative Analysis of Canada's Provinces and Municipalities

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Les changements climatiques représentent des risques environnementaux, économiques et sociétaux majeurs pour le Canada, comme en témoignent l'intensification et la fréquence accrues des feux de forêt, des inondations et des tempêtes. Bien que les efforts d'atténuation demeurent essentiels, cette étude souligne l'urgence d'une meilleure transparence des données afin de permettre des évaluations plus rigoureuses et de faciliter des stratégies d'adaptation plus globales. Nous évaluons le niveau de préparation de dix provinces canadiennes et de six municipalités face aux catastrophes naturelles liées au climat, en élaborant un indice composite intégrant des indicateurs financiers et qualitatifs issus des divulgations publiques. Au cours de notre analyse, nous avons constaté des lacunes persistantes dans la déclaration des dommages causés par les catastrophes naturelles, ainsi qu'un manque de normalisation des données — des insuffisances qui entravent l'établissement de comparaisons fiables et limitent la prise de décision éclairée. Nous formulons ainsi des recommandations visant à améliorer la qualité des rapports, de manière à orienter non seulement les décideurs politiques et les planificateurs communautaires, mais aussi à soutenir les investisseurs dans l'évaluation de la résilience climatique comme facteur de leurs choix d'allocation de capital et d'analyse des risques. En alignant les stratégies d'adaptation sur les profils de risque régionaux, en assurant une plus grande comparabilité des données et en intégrant des indicateurs de résilience dans les critères d'investissement, les parties prenantes peuvent mieux appréhender l'évolution des menaces climatiques et contribuer à bâtir un Canada plus adaptable et prêt pour l'avenir.

Mots clés : stratégies d'adaptation, Canada, base de données canadienne sur les catastrophes (BDC), préparation climatique, résilience aux catastrophes, évaluation des risques

Climate change poses environmental, economic, and societal risks to Canada, as evidenced by the increasing severity and frequency of wildfires, floods, and storms. While climate mitigation efforts remain paramount, this study underscores the urgent need for improved data transparency to enable better assessments and facilitate more comprehensive adaptation efforts. We assess the preparedness of ten Canadian provinces

and six municipalities for climate-related natural disasters by developing a composite index (score) that integrates both financial and qualitative indicators derived from public disclosures. During our analysis, we encountered persistent gaps in natural disaster damage reporting and noted a lack of standardized data—shortcomings that obstruct accurate benchmarking and hinder informed decision-making. We thus provide recommendations for enhanced reporting that can not only guide policymakers and community planners but also support investors in evaluating climate resilience as a factor in their capital allocation and risk assessments. By aligning adaptation strategies with regional risk profiles, ensuring greater data comparability, and integrating resilience metrics into investment criteria, stakeholders can more effectively navigate the evolving landscape of climate-related threats and foster a more adaptable, future-ready Canada.

Keywords: adaptation strategies, Canada, Canadian Disaster Database (CDD), climate preparedness, disaster resilience, risk assessment

Introduction

The escalating threat of climate change poses severe risks to environmental, economic, and social systems worldwide, with Canada being no exception. The country has witnessed an alarming increase in the frequency and intensity of natural disasters such as wildfires, floods, and storms. These events have inflicted substantial economic damage in Canada by disrupting communities, straining government resources, and driving up insurance costs (Public Safety Canada 2024). Although considerable resources are allocated to long-term climate mitigation efforts—such as reducing carbon emissions and transitioning to renewable energy—there is an equally urgent need for climate adaptation to address the immediate impacts of these disasters.

Governments have the option to invest in climate resilience either reactively, by funding recovery efforts after disasters strike, or proactively, by financing adaptation measures that mitigate future risks. Proactive adaptation spending offers a logical approach to minimizing the financial burden of future recovery efforts. For example, investing in climate adaptation infrastructure can yield substantial returns by preventing extensive damage and reducing the need for costly post-disaster repairs. In fact, every dollar allocated toward proactive measures has the potential to save multiple dollars in future recovery costs (Sawyer et al. 2022). However, despite these clear economic advantages, both public and private investments in climate adaptation remain limited. The financial strain of reactive spending, required frequently in the wake of disasters, often diverts critical funds away from essential public services such as health care, education, and infrastructure, thereby intensifying the socio-economic challenges posed by climate change.

Moreover, public opinion reflects a growing urgency for robust climate preparedness measures across Canada. According to a recent Nanos Research survey, 61 percent of Canadians believe the country is "not prepared" or only "somewhat prepared" for future emergencies, such as extreme weather, wildfires, and other natural disasters (CEPCA 2024). This sentiment highlights widespread concern regarding national readiness and the adequacy of existing response frameworks. Survey data further shows that Canadians overwhelmingly support stronger national initiatives, with 91 percent backing a volunteer disaster relief program and 82 percent supporting the establishment of a national disaster response agency. Moreover, almost half of participants think Canada should be investing more funding for emergency preparedness in 2024 and 2025. These findings emphasize a broad public mandate for enhancing Canada's climate adaptation infrastructure.

In 2024, Canada again experienced severe climate-related events, underscoring the critical importance of climate resilience at both the provincial and municipal level. The year began with a historic deep freeze across western Canada in mid-January, resulting in over C$180 million in insured damages (IBC 2024a). In July, Canada's largest city, Toronto, was struck by unprecedented torrential rainfall and flash flooding, which disrupted transportation networks, left over 167,000 people without power (Raveendran and Powers 2024), and inflicted an estimated C$940 million in insured damages (IBC 2024b). Meanwhile, a massive wildfire near Jasper, Alberta, ravaged over 30,000 hectares of land and forced many residents to evacuate (Snowdon and Frew 2024). According to the Insurance Bureau of Canada (IBC 2024c), the resulting insured losses amounted to approximately C$880 million, making it one of the costliest wildfires in Alberta's history. An analysis of these events, along with observed trends over time, underscores the urgent need for proactive climate adaptation strategies to mitigate the vulnerability of Canadian communities to future climate-related disasters. In this respect, multiple studies have identified significant gaps in Canada's current climate adaptation measures, including limited integration of adaptation into infrastructure planning, inconsistent implementation of municipal adaptation strategies, and

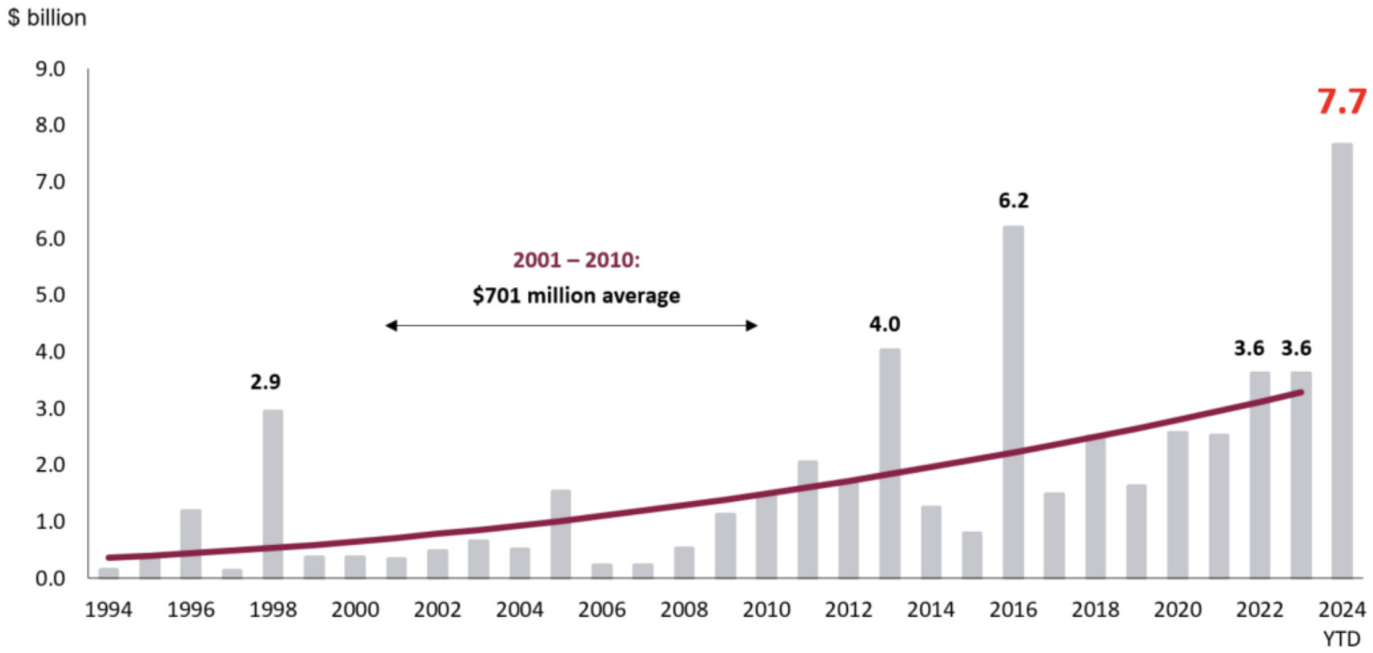


Figure 1: Insured Losses (Canadian Dollars in Billions at 2023 Value) Due to Extreme Weather Events in Canada (1994–2024)

Notes: This figure illustrates the annual insured losses resulting from extreme weather events in Canada between 1994 and 2024 (up to September 2024), adjusted to 2023 Canadian dollars sourced from the Insurance Bureau of Canada (IBC 2024d). Figure shows an upward trend in loss and loss adjustment expenses over time. While there is significant year-to-year variability, with peaks in certain years reflecting major catastrophic events, the overall trend indicates a steady increase in insured losses, highlighting the growing financial burden posed by climate-related disasters. The grey bars show "loss + loss adjustment expenses in 2023 dollars", and the estimated trend line is shown in red. Source: Insurance Bureau of Canada (2024d).

underinvestment in climate-resilient infrastructure. Enhancing adaptation requires stable, long-term funding, stronger policy integration across sectors, and robust monitoring to track implementation progress.

Figure 1 illustrates the annual insured losses from extreme weather events in Canada between 1994 and 2024, adjusted to 2023 Canadian dollars. The data reveals a clear upward trend in loss and loss adjustment expenses over time, with notable year-to-year variability. Certain peaks correspond to major catastrophic events, but the general trend shows a steady increase in insured losses, underscoring the growing financial impact of climate-related disasters. This upward trend in insured losses is consistent with previous research documenting how the increasing frequency and severity of natural catastrophes has placed mounting pressure on property insurance markets in Canada, contributing to rising premiums, coverage restrictions, and reduced availability in high-risk areas.

Insurers paid out C$701 million annually, on average, for severe weather losses from 2001 to 2010; however, 2024 losses to date (September 2024) are over ten times that number. It is important to recognize that these figures do not capture the range of indirect losses often associated with disasters, losses which may extend beyond measurable monetary impacts. In fact, evidence suggests that for every dollar of insured damages, there may be an additional three to four dollars of uninsured losses (O'Hara and Jones 2023). This disparity—commonly referred to as the "protection gap" (Swiss Re Institute 2018)— leaves a substantial gap in financial protection, ultimately burdening taxpayers and other stakeholders who must bear the costs that extend well beyond measurable, insured damages. These trends reinforce the urgent need for enhanced climate adaptation measures, as the economic burden of reactive spending continues to rise. Proactive investment in climate resilience could mitigate these mounting costs and reduce the financial volatility associated with natural disaster recovery efforts in Canada.

We aim to assess the climate adaptation and resilience levels of Canadian provinces and municipalities in relation to their unique natural disaster (ND) risk profiles. By developing a proprietary preparedness index based on publicly disclosed data, we evaluate the extent to which these regions have implemented measures to reduce the adverse impacts of climate-related disasters and improve their capacity for recovery. This extensive data collection process enabled us to create a novel index that captures the variation in climate adaptation efforts across

Canada's diverse geographic and economic landscapes. Moreover, the index facilitates a comparative analysis of preparedness across various provinces and municipalities, enabling a better understanding of how well different jurisdictions are equipped to manage the challenges posed by climate change. Throughout this paper, the terms "preparedness," "resilience," and "readiness" are used interchangeably to describe the capacity of provinces and municipalities to anticipate, withstand, and recover from climate-related disasters.

To inform our analysis, we rely on two main data sources, the Canadian Disaster Database (CDD) and the Emergency Events Database (EM-DAT). These resources provide comprehensive information on natural disaster occurrences, allowing us to construct ND risk profiles for each province. In hindsight, a notable contribution of this research is its emphasis on standardized, per-disaster-type reporting, which is essential for improving data granularity, comparability, and transparency. Our findings reveal significant gaps in the reporting of natural disaster impacts, thus highlighting the need for consistent data collection practices that can enable stakeholders to make more informed decisions. By encouraging a standardized approach to reporting, we aim to support policymakers, investors, and community leaders in identifying areas where additional resources and efforts are needed to enhance Canada's quality of databases and reporting standards.

This study addresses the question: How prepared are Canadian provinces and municipalities for climate-related natural disasters, and what factors contribute most to their preparedness? The objectives are to (a) develop a comparative preparedness index for provinces and municipalities using quantitative and qualitative indicators; (b) identify key strengths and weaknesses in existing preparedness strategies; and (c) highlight data gaps and methodological considerations for future climate adaptation assessments. The rest of the paper is organized as follows: the next section ("Literature Review") reviews relevant literature, including a categorized summary of the most pertinent studies. The section after it ("Canadian Disaster Databases") discusses Canadian natural disaster data availability and provides a historical overview of the natural disaster landscape in Canada. This section is followed by ("Methodology") section that outlines the study's framework and methodology. The final rankings and analysis are presented in the next section ("Results"), which is followed by some concluding thoughts ("Conclusion").

Literature Review

Canada's varied geography and climate expose its provinces and municipalities to distinct natural hazards, necessitating targeted climate preparedness. For this reason, this literature review explores existing research on (a) the current state of climate adaptation financing; (b) the economic impacts of natural disasters; (c) challenges in financing adaptation efforts; and (d) the benefits of proactive adaptation and mitigation spending. Previous studies primarily examine the financial and macroeconomic impacts of disasters, government-led adaptation strategies, and often focus on specific regions or events in Canada. They highlight the critical need for provinces and municipalities to mobilize capital for climate resilience. However, to the best of our knowledge, there are no studies to date that conduct a comparative analysis of ND preparedness across different Canadian regions. Our study closes this gap and offers a first standardized, adaptable metric that incorporates each region's unique risk profile.

The Current State of Global and National Climate Change Adaptation Financing

The *Global Landscape of Climate Finance 2021* (Buchner et al. 2021) report indicates that global climate-related financial flows reached US$632 billion in 2019/2020, yet a substantial increase is required to meet the 2030 climate targets and mitigate severe climate impacts. Notably, adaptation financing lags behind mitigation, making up only 14 percent of public climate finance despite a 53 percent increase since 2017/2018 (Buchner et al. 2021). Canada, facing escalating climate risks, can draw insights from this report's findings on adaptation financing gaps, findings which suggest a pressing need for increased investment in climate resilience, particularly in vulnerable regions and provinces.

Addressing the capital requirements for climate adaptation requires a "whole-of-society action" approach to convert intentions into measurable outcomes (Environment and Climate Change Canada 2023). This objective hinges on effective governmental co-ordination of adaptation strategies by embedding climate resilience into policies, programs, and daily operations—a facet often neglected in the past. Economic downturns, for instance, have led governments to drastically reduce funding for proactive disaster measures; in 2015, Alberta slashed its FireSmart wildfire prevention program (a program that included cash for clearing brush and trees away from communities in forested areas) budget by C$6.5 million (Canadian Press 2015), leaving numerous communities unprepared for the devastating 2016 Fort McMurray Wildfire, one of Canada's most costly natural disasters. The economic case for climate adaptation is compelling, with projections suggesting climate impacts could cost Canada's economy C$78 billion annually by mid-century, even under low-emission scenarios (Sawyer et al. 2022).

Canada's general lack of disaster preparedness is further highlighted in Public Safety Canada's (2024) white paper, which examines national disaster risks and deficiencies in emergency management, especially regarding earthquakes, floods, and wildfires. The report emphasizes the need for nationwide co-ordination in disaster readiness and response, particularly in integrating climate adaptation with emergency strategies. Addressing interjurisdictional inconsistencies is thus crucial to strengthening Canada's disaster resilience, as the report also notes a pervasive lack of public awareness about disaster risks and emergency response protocols.

Moreover, Exell and Parry (2023) argue that the Disaster Financial Assistance Arrangements (DFAA), which has operated as a recovery program for the past 50 years, lacks mechanisms to incentivize future disaster prevention by provincial governments effectively. The program's fragmented, piecemeal approach has fostered provincial reliance on federal support, generating a moral hazard where some provinces in high-risk areas opt out of insurance, instead depending on DFAA funds to cover the majority of disaster-related costs (Public Safety Canada 2022). Additionally, inconsistent and unclear reporting standards across provinces indicate that the DFAA's framework may inadequately encourage proactive disaster planning, thus leaving significant room for improvement in how the program motivates comprehensive disaster preparedness and mitigation efforts.

An important consideration is the political economy of disaster management. Recovery spending often enjoys greater political support than proactive adaptation, as post-disaster aid is highly visible and provides immediate benefits, whereas adaptation measures yield less tangible benefits over longer time horizons (Healy and Malhotra 2009; Kousky 2014). This visibility gap can reinforce a reactive policy bias and divert resources toward recovery rather than toward measures that could reduce the scale and cost of future disasters.

The Economic and Financial Impacts of Natural Disasters

Natural disasters have profound economic and financial implications for affected regions, influencing both short-term recovery and long-term development trajectories. Their economic impacts encompass direct damages to infrastructure and assets, as well as indirect effects such as disruptions to economic activities and losses in income. Benson and Clay (2004) provide a comprehensive analysis of how natural disasters disrupt economic activity and lead to declines in GDP, increases in public debt, and shifts in trade balances. They emphasize the importance of understanding these impacts to develop effective risk management strategies.

Studies have also shown that natural disasters can significantly impede economic growth. Noy (2009) finds that disasters negatively affect GDP growth, particularly in developing countries with lower resilience and adaptive capacity. Similarly, Loayza et al. (2012) observe that while moderate disasters might have minimal or even positive effects due to reconstruction efforts stimulating the economy, severe disasters generally have detrimental impacts on economic growth. The financial markets also react to natural disasters. Worthington and Valadkhani (2004) note that disasters can lead to increased market volatility and reduced investor confidence. In the context of Canada, U-Din, Nazir, and Sarfraz (2022) find that weather catastrophes negatively impact stock market returns and increase volatility, with substantial losses observed on the day after the event.

Similarly, the fiscal consequences of natural disasters are substantial. Governments often face increased expenditures for emergency response, recovery, and reconstruction that are coupled with decreased revenues due to disrupted economic activities (Melecky and Raddatz 2011). This situation can lead to higher public debt and fiscal deficits, constraining future public investment and social spending (Mochizuki et al. 2014).

At the household level, natural disasters can exacerbate poverty and inequality. Hallegatte et al. (2017) highlight that disasters disproportionately affect the poor, who often lack adequate resources for recovery and are more vulnerable due to precarious living conditions. This vulnerability can trap households in cycles of poverty and undermine long-term development goals. Mortgage delinquencies also increase in areas severely damaged by natural disasters. Ho et al. (2023) show that financial institutions and mortgage insurers face spillover effects, highlighting the need to consider climate risk in lending decisions. Businesses, particularly small and medium-sized enterprises (SMEs), face significant challenges following disasters. The loss of assets, supply chain disruptions, and decreased consumer demand can lead to business closures and unemployment. Without sufficient insurance coverage or access to credit, recovery can be prolonged.

At the country level, the extent of economic impacts depends on various factors, including the magnitude of the disaster, the affected country's economic structure, and the effectiveness of pre-disaster preparedness and post-disaster response (Kousky 2014). Countries with robust institutions, diversified economies, and effective risk management strategies tend to recover more quickly and mitigate adverse effects.

Financial Challenges in Climate Adaptation

Federal and provincial climate change actions in Canada primarily focus on ambitious goals such as achieving

carbon neutrality and transitioning to renewable energy sources. However, the escalating financial burden of natural disasters requires significant capital reallocation towards disaster-recovery expenditures, which are often unplanned and inefficient (Eyzaguirre and Warren 2014; Henstra 2017). These unanticipated expenditures impede progress toward long-term climate change goals and increase provincial and federal debt levels, adversely affecting their financial risk profiles (Sawyer et al. 2022).

To assist municipalities in adapting to climate change, the federal government of Canada introduced a C$530 million program in 2023 labelled the National Adaptation Strategy (Environment and Climate Change Canada 2023). This program aims to bolster local resilience by funding infrastructure improvements in response to extreme weather events. Additionally, the government announced the Disaster Mitigation and Adaptation Fund (DMAF) in 2018, a fund which provides C$2 billion over ten years to support large-scale infrastructure projects that help communities better manage the risks of disasters triggered by natural hazards (Housing, Infrastructure and Communities Canada 2023). However, these funding amounts may be insufficient to adequately prepare for climate risks.

Concerns have also been raised about the adequacy and fairness of federal support among Canadian municipalities. The maximum grant amounts offered to local governments may not align with the significant costs required for effective climate adaptation measures, leaving municipalities under-resourced (Ewart, Coffee, and Miller 2023). If climate catastrophes remain unaddressed, fiscal pressures on governments to respond to growing climate costs will intensify. Governments may be compelled to raise taxes, accrue additional public debt, or cut essential services to finance disaster recovery efforts (Sawyer et al. 2022). Climate change impacts also pose affordability risks for households in Canada, with income losses materializing from slower economic growth and higher taxes needed to maintain services and pay for repairs. These concerns illustrate the systemwide financial impact of natural disasters, from government fiscal constraints to reduced household incomes and purchasing power.

Investing in climate adaptation projects is crucial to mitigate these impacts. Studies suggest that every dollar spent on adaptation can save more dollars in future recovery spending. Adaptation costs vary by disaster type and region; however, without proactive adaptation spending, the future costs for disaster recovery could increase dramatically, as indicated by a comprehensive study conducted by the US National Institute of Building Sciences (Multi-Hazard Mitigation Council 2019). Additionally, adaptation costs vary across Canada. Notably, the top four communities with the highest natural disaster adaptation costs are coastal communities, highlighting the vulnerability of these areas to climate change impacts (Feltmate, Moudrak and Bakos 2020).

Despite the significant economic benefits of adaptation, public and private capital flows toward climate adaptation investments remain insufficient. For this reason, municipalities and private landowners bear most of the financial burden associated with natural disasters. To adequately adapt to increasing disaster severity, municipalities must not only retrofit existing infrastructure—such as strengthening buildings, upgrading drainage systems, and improving flood barriers—but also invest in nature-based solutions, bolster emergency response capacities, and enhance long-term planning for land use and development. This multifaceted approach encompasses risk assessment, community education, and policy reforms, ensuring that adaptation efforts are holistic, resilient, and capable of mitigating future climate-related challenges. However, many lack the financial capacity to undertake major infrastructure upgrades beyond regular maintenance. Under the current budgeting structures, provinces also face challenges in meeting capital requirements for adaptation projects, prompting calls for increased private sector investment (Ewart et al. 2023). This underinvestment highlights the need for innovative financing mechanisms and stronger collaboration between public and private sectors to mobilize the necessary capital for climate adaptation.

Benefits of Proactive Adaptation and Mitigation Spending

Proactive climate adaptation and mitigation investments have been shown to yield significant economic benefits by reducing the costs associated with natural disasters. Empirical studies consistently demonstrate that the financial returns on such investments far exceed the initial expenditures, thus providing both short-term relief and long-term economic resilience (Sawyer et al. 2022).

Multiple studies have quantified the benefit–cost ratios of climate adaptation infrastructure projects, with findings ranging from 3:1 to as high as 15:1. This suggests that for every dollar invested in climate adaptation, governments can save between three to fifteen dollars in disaster-related damages (Multi-Hazard Mitigation Council 2019; Sawyer et al. 2022). A comprehensive 2019 study by the National Institute of Building Sciences (NIBS) evaluated the effectiveness of mitigation efforts for various building classes in the United States. The study reported benefit–cost ratios of 7:1 for riverine floods, 5:1 for strong winds, and 3:1 for earthquakes and wildfires (Multi-Hazard Mitigation Council 2019). These findings are instrumental for Canadian provinces in benchmarking future climate mitigation spending.

The opportunity costs of allocating capital toward disaster recovery are significant. Funds used for recovery

Table 1: Overview of Recent Academic and Professional Reports on Natural Disaster Risks in Canada

	Reports on Emergency Management	Reports on the Costs of Climate Change Adaptation and Disaster Damages	Reports on the Benefits of Adaptation and Mitigation Spending	Other Reports/ Academic Studies
Article/Report	Public Safety Canada (2024): The National Risk Profile	(1) Federation of Canadian Municipalities (2020): *The Cost of Climate Adaptation at the Local Level* (2) Raikes and McBean (2016): *Responsibility and Liability in Emergency Management to Natural Disasters: A Canadian Example*	(1) Sawyer et al. (2022): *Damage Control: Reducing the Costs of Climate Impacts in Canada* (2) Multi-Hazard Mitigation Council (2019): *Natural Hazard Mitigation Saves: 2019 Report*	(1) Agrawal et al. (2021): "Disaster Risk in Canada—A Data-Driven Discussion" (2) Ewart et al. (2023): *Mobilizing Private Capital for Climate Adaptation Infrastructure*
Scope and findings	Overviews national disaster risks and highlights gaps in Canada's emergency management system for earthquakes, floods, and wildfires	(1) The estimated annual adaptation cost at the municipal level is C$5.3 billion, equal to 0.26% of Canada's GDP (2) Municipalities and private landowners bear most of the financial burden in natural disasters, with limited and discretionary assistance from provincial governments	(1) High estimate: Prevention spending has a benefit–cost ratio of up to 15:1, reducing GDP losses by 75% (2) Low estimate: benefit–cost ratios are 7:1 for floods, 5:1 for winds, and 3:1 for earthquakes and wildfires	(1) Understanding past disasters and socio-economic factors is critical for long-term resilience (2) Provinces face funding challenges, making private capital (and individual preparedness) essential for adaptation

Notes: This table summarizes key recent academic, professional, and governmental reports on various aspects of natural disaster risks in Canada, including emergency management, the costs of climate adaptation, benefits of mitigation spending, and other critical studies. It highlights the scope and findings of each report, underscoring the financial, operational, and resilience challenges and opportunities related to natural disasters.
Source: Authors.

efforts could otherwise support critical priorities such as health care, education, or research and development in climate technologies. Proactive adaptation measures not only prevent extensive damage but also reduce the financial burden on governments and taxpayers. This view is supported by Sawyer et al. (2022), who show that compared to emission reduction policies, proactive adaptation yields immediate financial benefits regardless of the emissions trajectory.

Understanding past disasters and their associated socio-economic implication is essential for building long-term resilience. In this respect, Agrawal, Adjikari, and Yiu (2021) highlight the importance of addressing underlying vulnerabilities to minimize the long-term effects of natural disasters on communities. By analyzing the impacts of natural disasters on individual provinces and assessing their preparedness levels, policy-makers can better evaluate the potential financial ramifications within each province's specific risk context. This approach facilitates the development of tailored adaptation strategies that effectively mitigate risks and optimize the allocation of resources.

Table 1 provides a concise summary of recent key reports and studies that address various facets of natural disaster risk management in Canada, including emergency management, climate adaptation costs, the benefits of adaptation and mitigation spending, and other relevant academic studies. The table captures the scope and significant findings of each report and reveals critical insights into Canada's challenges and opportunities in building resilience against natural disasters. By summarizing, we offer readers a comprehensive foundation to understand the financial, operational, and resilience-related aspects essential for addressing natural disaster impacts in Canada.

Canadian Disaster Databases: Comparisons, Limitations, and Justifications for Data Selection

We start by analyzing data from two main publicly available databases—Canadian Disaster Database (CDD) and Emergency Events Database (EM-DAT)—to estimate the natural disaster risk exposure of ten Canadian provinces (i.e., Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Ontario, Prince Edward Island, Quebec, Saskatchewan). Moreover, in what follows, we briefly show the limitations of EM-DAT data for damage estimations compared to CDD, leading us to use just CDD as it is the most reliable source for our provincial damage

estimations (while showing and comparing information contained in EM-DAT for reference).

Based on the geographical identifiers, disaster type classifications, and damage estimations provided by CDD (2000–2020, as 2020 is the most recent year available in CDD), we calculate the average annual damages for each of the ten provinces. We also identify the top three disaster types (e.g., flood, wildfire) in terms of total damages affecting each province, data which is required for calculating our preparedness score (index). Unfortunately, we cannot estimate the average annual damages for the six municipalities (i.e., Montreal, Ottawa, Peel Region, Toronto, Vancouver, and York Region) examined in this study considering dataset limitations. However, we can still identify the top three disaster types affecting them and calculate their preparedness score regardless of the damage amount that is caused by natural disasters in those municipalities.

Canadian Disaster Database (CDD)

Managed by Public Safety Canada, the CDD is a centralized database that catalogs disaster events occurring within Canada. It provides extensive information on each disaster, including the type, date, duration, location, and economic impacts, thereby enabling detailed analyses at the provincial level. The inclusion of financial indicators, such as insurance claims and payments under the Disaster Financial Assistance Arrangements (DFAA), positions the CDD as a critical resource for economic impact assessments of natural disasters in Canada.

Advantages of the CDD

The granularity of the CDD is its primary strength. The dataset captures detailed event-specific data, including injuries, evacuations, fatalities, and estimated economic losses, thereby facilitating comprehensive analyses of the direct and indirect impacts of disasters. This level of detail is invaluable for province-level research, as it allows for more accurate tracking of disaster frequency, intensity, and associated financial burdens on regional economies.

Additionally, the inclusion of insurance and DFAA payments allows researchers and policy-makers to examine economic losses, offering a nuanced perspective on the financial implications of disaster events. This data enables assessments of the financial resilience of provinces and municipalities and aids in identifying gaps in disaster response mechanisms. For example, by analyzing how provinces utilize federal Disaster Financial Assistance Arrangements (DFAA) disbursements recorded in the CDD, researchers can better understand the financial pressures on regional governments in the aftermath of disaster events. Here, "provincial expenditure through the DFAA" refers to provincial spending of federally provided funds, not to independent provincial disaster assistance programs, which are not captured in the CDD. However, it should be noted that the reporting of these variables is very limited in scope, and enhancing database quality is of utmost importance for researchers.

Limitations of the CDD

Despite its detailed coverage, the CDD is limited by certain structural and operational issues. First, the dataset lacks complete information for various disaster events, leading to significant data gaps that hinder comprehensive analyses. This incompleteness is exacerbated by irregular updates: the database has not been systematically updated since 2020, thus limiting its relevance for recent studies. Another limitation is that DFAA data reported in the CDD primarily reflects recovery of municipal/public infrastructure, while other impacts (e.g., destroyed homes) fall under provincial DFA programs or insurance and are not captured.

Moreover, the CDD does not adhere to a standardized data collection or reporting format, creating inconsistencies across provinces. This lack of uniformity complicates efforts to compare data over time and across jurisdictions, a significant challenge for researchers aiming to conduct comparative analyses. The values are reported in Canadian dollars and the latest year that dollar value can be normalized to is 2016. (Therefore, we had to adjust the values based on CPI reported by Statistics Canada to 2023 values on our own.) In addition, the CDD lacks straightforward data extraction options by province, further limiting usability and accessibility for research and policy-making purposes. We used the locations of the events (e.g., regions, municipalities) reported by CDD to extract province-level data.

Emergency Events Database (EM-DAT)

The EM-DAT, maintained by the Centre for Research on the Epidemiology of Disasters (CRED), offers a global perspective on disaster events, allowing for cross-country comparisons and international benchmarking. With standardized definitions and thresholds for inclusion, EM-DAT provides a reliable source of data for global analyses of disaster frequency and impact.

Advantages of EM-DAT

The primary advantage of EM-DAT is its adherence to consistent, internationally recognized definitions and thresholds, thereby enhancing the comparability of disaster data across countries. This feature makes EM-DAT an invaluable tool for researchers conducting global or interregional analyses. Moreover, the database is updated regularly, ensuring that recent events are accounted for in analyses, a feature which is crucial for time-sensitive disaster studies.

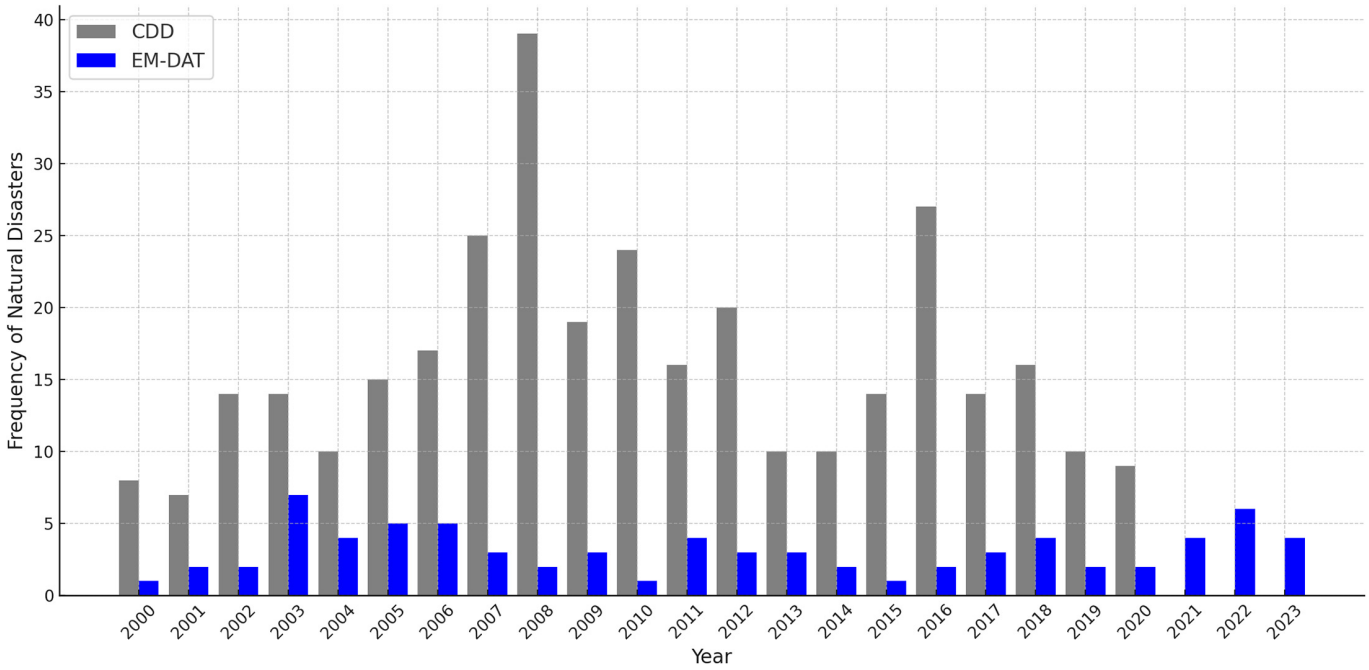


Figure 2: Comparison of Natural Disaster Frequency in Canada (2000–2023): CDD vs. EM-DAT

Notes: This figure compares the frequency of natural disasters in Canada reported by the CDD and EM-DAT from 2000 to 2023. The CDD provides detailed province-level data, capturing 338 events (natural "Meteorological–Hydrological" disasters) during this period, with variables such as disaster type, location, costs, injuries, and fatalities. In contrast, EM-DAT, with its global coverage, reports fewer events for Canada (75). The discrepancies stem from differences in data collection methods, thresholds, and definitions used by each database. Both databases also suffer from missing data, especially regarding total disaster costs, and updates may lag—CDD was last updated in 2020. EM-DAT data before 2000 should be considered of lesser quality due to time bias (EM-DAT Documentation n.d.).
Source: Data taken from CDD and EM-DAT records.

Limitations of EM-DAT

EM-DAT's strict inclusion criteria restrict its utility for localized disaster assessments within Canada. Smaller, region-specific disasters are frequently excluded due to EM-DAT's focus on larger-scale events that have significant human or economic impacts at the international level. For instance, between 2000 and 2023, EM-DAT includes only 75 recorded events for Canada, while the CDD records 338 events within the same period. This discrepancy arises from EM-DAT's exclusion of less catastrophic events, which often lack international implications but still bear significant local consequences.

Another limitation of EM-DAT is its use of US dollars for damage amounts, requiring researchers to convert values into Canadian dollars for accurate financial analysis. Adjustments for inflation and currency exchange rates add further complexity to economic assessments. Finally, EM-DAT lacks detailed subnational breakdowns, something which limits its usefulness for provincial or municipal-level analyses critical for Canadian policy-making and localized disaster response planning.

Figure 2 presents a comparative analysis of the frequency of natural disasters in Canada as reported by the CDD and the EM-DAT from 2000 to 2023. The CDD (indicated by the grey bar) records a significantly higher number of natural disasters—338 events within the specified period—compared to the 75 events reported by EM-DAT (represented by the blue bar). This disparity highlights the differences in reporting criteria, geographical focus, and inclusion thresholds between the two databases and shows the challenges in compiling comprehensive disaster data in Canada.

The CDD, managed by Public Safety Canada, is tailored to Canada's specific disaster landscape and captures a wider range of events, particularly those with localized impacts that may not meet EM-DAT's criteria. In addition to recording event frequency, the CDD includes detailed province-level information that encompasses disaster type, location, estimated costs, insurance payouts, injuries, and fatalities. This depth of data is essential for localized disaster analysis but is hindered by data gaps and inconsistent updates, with the last systematic update occurring in 2020. The database's irregular update frequency and the absence of a standardized reporting framework result in missing data for some variables, particularly economic losses, an outcome

Table 2: Summary Statistics for Natural Disasters in Canada (2000–2023): EM-DAT vs. CDD

Panel A: Summary Statistics for Natural Disasters in Canada (2000–2023): EM-DAT Data (75 Obs.)					
Variable Names	Observations	Mean	SD	Minimum	Maximum
Total deaths	33	29.94	141.44	1	815
No. Injured	6	33.17	53.53	2	140
No. Affected	45	9,910.22	21,878.26	170	100,000
No. Homeless	4	1,941.50	3,386.96	30	7,000
Total affected	50	9,078.50	20,903.24	3	100,000
Total damages ('000 USD)	32	733,403.50	1,220,158.19	10,000	5,700,000
Total damages, adjusted ('000 USD 2023)	32	940,659.69	1,569,241.36	16,564	7,455,449
Panel B: Summary Statistics for Natural Disasters in Canada (2000–2020): CDD Data (338 Obs.)					
Variable Names	Observations	Mean	SD	Minimum	Maximum
Fatalities	258	3.69	33.70	0	455
Injured/Infected	230	2.18	13.09	0	140
Evacuated	266	2,134.53	9,862.24	0	100,000
Estimated total cost ('000 CAD)	149	130,856.79	430,997.20	31.01	4,066,678
Estimated total cost ('000 CAD 2023)	149	167,619.90	538,297.40	48.72	4,978,110

Notes: This table provides a comparison of summary statistics for natural disasters in Canada based on data from the EM-DAT (2000–2023) and the CDD (2000–2020). The CDD includes more observations, while EM-DAT has fewer observations but spans more recent years. Both datasets have missing or incomplete data for various variables (as noted by *Observations* for each variable), which may impact the accuracy of the statistics presented. EM-DAT provides adjusted amounts of total damages in 2023 US dollars. To adjust estimated total costs provided by CDD to 2023 Canadian dollars, CPI reported by Statistics Canada (CANSIM Table No. 326-0021) is used.
Source: Data taken from EM-DAT and CDD records.

which further complicates longitudinal and comparative analyses.

In contrast, EM-DAT, maintained by the CRED, adopts a global perspective by applying strict inclusion criteria that often exclude smaller or more regionally specific disasters. This approach is evident in the comparatively low number of Canadian events recorded by EM-DAT, which focuses on disasters with significant human and economic impacts that are likely to attract international attention or necessitate external assistance. The discrepancy between the two databases is most noticeable in peak years, such as 2005, 2008, and 2016, where CDD reports sharp increases in disaster frequency, reflecting specific national events not captured by EM-DAT.

Figure 2 highlights the complexities and challenges associated with compiling a comprehensive record of natural disasters in Canada. The discrepancies between CDD and EM-DAT show the importance of standardized reporting practices and the need for databases that not only capture local nuances but are also regularly updated to reflect current trends in disaster occurrence and impact. Both datasets suffer from limitations, notably missing or delayed data updates, which impact the accuracy and timeliness of disaster analysis. CDD's lag in updates past 2020 restricts its utility for recent events, while EM-DAT's reliance on international reporting can introduce time biases, especially for data prior to 2000, which may lack the reliability of more recent entries.

Table 2 presents a comparative summary of natural disaster statistics in Canada that draws from both the CDD and the EM-DAT. The differences between these datasets reveal significant insights into their respective strengths and limitations. The CDD dataset, which includes 338 observations from 2000 to 2020, is markedly larger than EM-DAT's 75 observations covering 2000 to 2023. This disparity highlights the CDD's capacity to capture a wider range of disaster events, including smaller and localized incidents that may not meet EM-DAT's more stringent inclusion criteria. As a result, the CDD provides a more comprehensive dataset for examining the frequency and impacts of natural disasters across Canada.

The contrast between the datasets is also evident in the mean values reported for fatalities, injuries, and economic impacts. In the case of fatalities and injuries, the CDD reports an average of 3.69 fatalities and 2.18 injuries per event, figures which are substantially lower than EM-DAT's averages of 29.94 fatalities and 33.17 injuries. In this way, EM-DAT's focus on larger-scale disasters with significant human impacts may skew the dataset towards more catastrophic events. By including events with smaller fatality and injury counts, the CDD offers a more nuanced view of the localized human impacts of disasters. This granularity is particularly valuable for analyzing regional vulnerabilities and the cumulative effects of smaller yet recurrent disasters on Canadian communities.

The variable of evacuations further exemplifies the limitations of EM-DAT in capturing localized disaster responses. The CDD provides evacuation data with an average of 2,134 individuals evacuated per event, although there is considerable variability, as shown by the high standard deviation. This information is essential for understanding the scale of displacement caused by disasters across different regions in Canada. EM-DAT, however, does not report evacuation data, thus limiting its utility for studies that require detailed assessments of human displacement and community-level responses.

Economic impact assessments also reveal significant discrepancies between the two datasets. The CDD records economic damages in Canadian dollars, with an average estimated cost of C$167.61 million per event, whereas EM-DAT's reported damages are much higher, averaging US$940.66 million per event (both adjusted to 2023 values). This difference can largely be attributed to EM-DAT's emphasis on high-impact events and the exclusion of smaller-scale disasters, which typically incur lower financial costs. Although the CDD has incomplete economic data, as indicated by its 149 observations out of 338 events for total costs, it still offers critical insights into the financial impacts borne by Canadian regions.

Both datasets suffer from incomplete information for certain variables, as illustrated by the number of observations available for each measure. CDD has more missing data on economic damages, while EM-DAT provides damage estimates for only 32 events, further limiting its applicability for a thorough economic analysis of disaster impacts in Canada. This missing data complicates the task of achieving a comprehensive and accurate picture of disaster costs—which is essential for effective policy-making and resource allocation.

Given these observations, the CDD is a more suitable choice for an in-depth analysis of provincial and municipal disaster preparedness in Canada. The CDD's larger dataset and its detailed records of smaller and localized events allow for a more granular and regionally focused analysis. This level of detail is essential for understanding disaster patterns and assessing preparedness across Canada's diverse provinces and territories, which may be disproportionately affected by smaller-scale events not captured by EM-DAT.

While EM-DAT's global scope and strict inclusion criteria are useful for cross-country comparisons, its limited Canadian data, higher thresholds for event inclusion, and lack of detailed subnational breakdowns make it less suitable for this study's objectives. The CDD aligns more closely with Canadian policy needs by offering provincially focused data that supports localized decision-making and preparedness strategies. Therefore, this study will rely primarily on the CDD as the main data source for analyzing natural disasters in Canada, using EM-DAT only as a supplementary reference where necessary to extend coverage or provide an international benchmark.

Overview of the Natural Disaster Landscape in Canada

Both the CDD and EM-DAT aggregate damage data across multiple provinces when the natural disaster is not limited to one region, posing challenges for province-level analyses. To address this issue, we distribute the total disaster cost across affected provinces equally, thereby providing a rough estimate of the regional impacts. Although imperfect, this method offers a standardized approach to disaggregate the data and facilitate more targeted assessments of disaster impacts within specific provinces.

This approach, however, highlights a fundamental need for provincial breakdowns in financial data. Without this granularity, assessments remain incomplete and may overlook disproportionate impacts on certain provinces or municipalities. As a result, policy-makers are less equipped to direct resources effectively or plan region-specific resilience strategies. It should be emphasized that all our analyses will be based on the available standardized information.

Figure 3 illustrates the total economic damages and occurrence frequency of major natural disaster types in Canada based on EM-DAT records from 2000 to 2023. The chart reveals that floods and wildfires are particularly costly, with floods showing the highest total damages among all disaster types. In terms of frequency, storms are the most common event after floods, although they have a lower associated economic burden compared to wildfires. Extreme temperatures, while less frequent, exhibit relatively low economic impact, but it also has a devastating human impact (e.g., the high number of fatalities often stems from heat events). This figure shows the uneven distribution of both financial costs and occurrence rates across disaster types, reflecting distinct patterns in how various disasters impact Canada economically and operationally over time.

Figure 4 provides a comparative analysis of total economic damages and frequency of major natural disaster types in Canada based on CDD data from 2000 to 2020. Consistent with EM-DAT data, floods emerge as the costliest disaster type, while wildfires also show significant financial impact. Winter storms and general storm events are frequent but result in comparatively lower total damages. This figure underscores the high economic burden that certain disasters, particularly floods and wildfires, impose on Canada, while also reflecting the challenges of incomplete damage reporting.

Figure 5 provides a compelling visualization of the economic toll that various natural disasters have imposed on Canadian provinces from 2000 to 2020, as

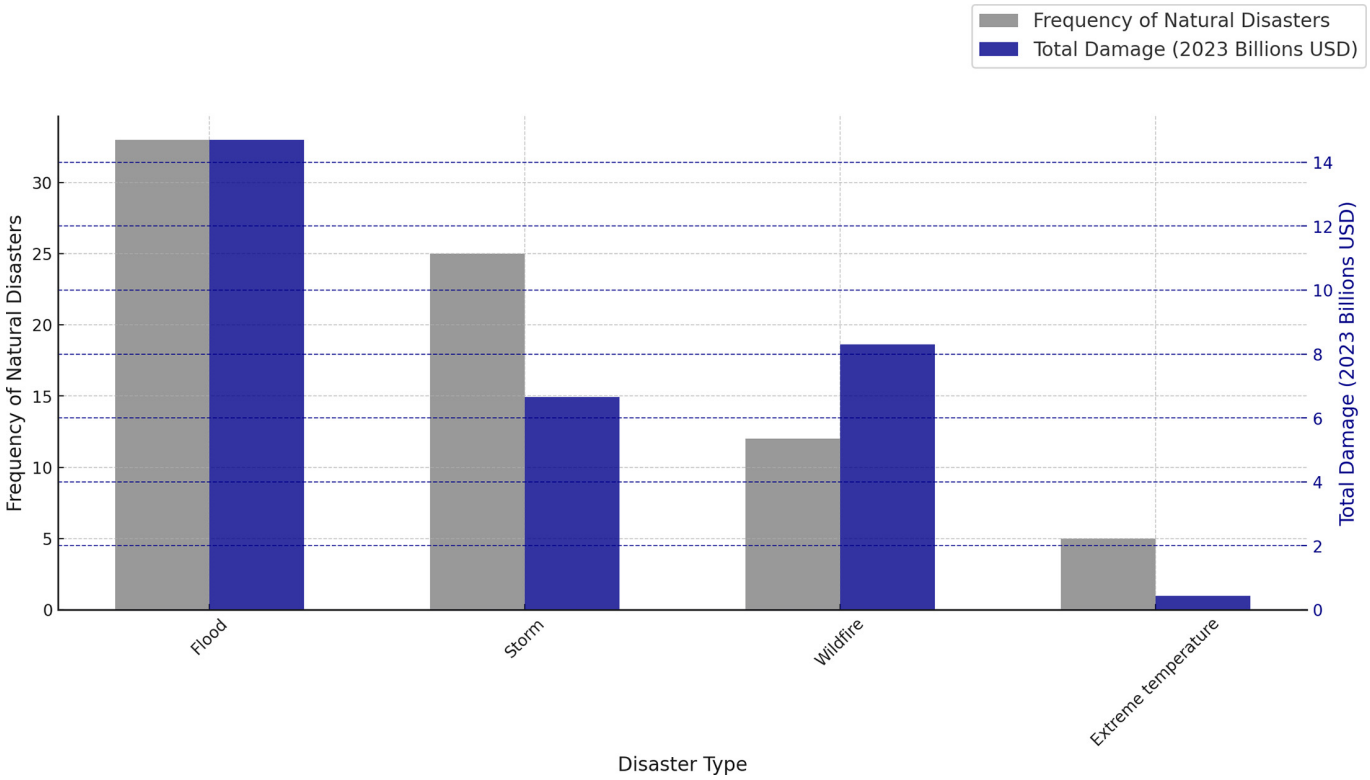


Figure 3: Total Damages by Natural Disaster Type (2000–2023): EM-DAT Records

Notes: This bar chart compares the total economic damages and occurrence frequency for each major natural disaster type in Canada based on EM-DAT records covering the period between 2000 and 2023. The blue bars represent the total damages (in billions of US dollars, adjusted to 2023 values) associated with each disaster type, while the grey bars show the frequency of occurrence. This visualization highlights the economic burden and prevalence of various disaster types, with floods and wildfires showing most significant financial impact. The data includes a total of 75 events, of which 32 report specific damage estimates.
Source: Data taken from EM-DAT records.

recorded in the CDD. In Panel A, each disaster type is represented by a stacked bar, with colours distinguishing the damages incurred by individual provinces, figures which are further aggregated to showcase total costs in billions of Canadian dollars (adjusted to 2023 values). In Panel B, the exact dollar values are reported for each province.

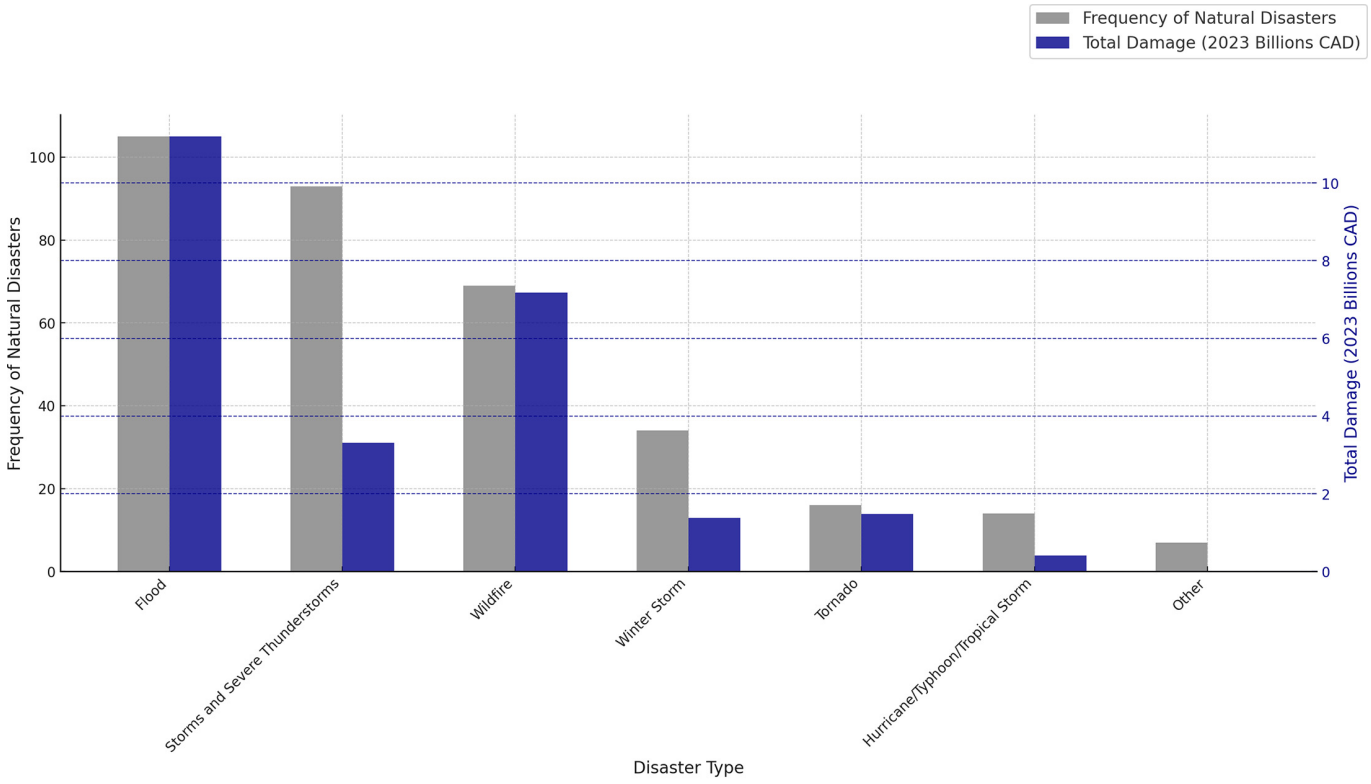
Floods and wildfires stand out as the most financially devastating disasters across Canada, with floods displaying the highest cumulative damages by a substantial margin. This impact is notably concentrated in provinces such as Alberta (AB), British Columbia (BC), and Manitoba (MB), where severe flooding/wildfire events have led to substantial economic losses. These regions are known for frequent and intense wildfire activity due to their forested landscapes and susceptibility to dry conditions.

The chart also reveals interesting nuances in disaster impacts across provinces. For example, while hurricanes, tornadoes, and winter storms contribute to the economic burden, they are less financially disruptive compared to floods and wildfires. This pattern reflects the varied geographic and climatic vulnerabilities of each province; Alberta, for instance, incurs heavy costs, while eastern provinces like Nova Scotia (NS) and Newfoundland and Labrador (NL) experience relatively lower disaster costs.

In cases where a disaster affected multiple provinces, the total damage cost was divided equally among them, allowing for a balanced representation of shared financial impacts. This approach emphasizes the interconnected nature of disaster resilience and response across provinces. Overall, Figure 5 shows the importance of province-level analysis in understanding Canada's disaster preparedness needs, as different regions face unique disaster profiles that influence their economic vulnerability and resilience.

Recommendation for Standardized Reporting: Lessons from the Canadian National Fire Database (CNFDB)

To improve disaster data reporting, we propose the establishment of a standardized reporting method that includes disaster-specific categorization and intensity



Note 1: Avalanche (2 records), Drought (2), and Heat Event (3) are categorized as 'Other' with no estimate on the damages.
Note 2: Storm-Unspecified (18 records), and Storm Surge (5) categories in CDD are grouped with 'Storms and Severe Thunderstorms' in the above figure.

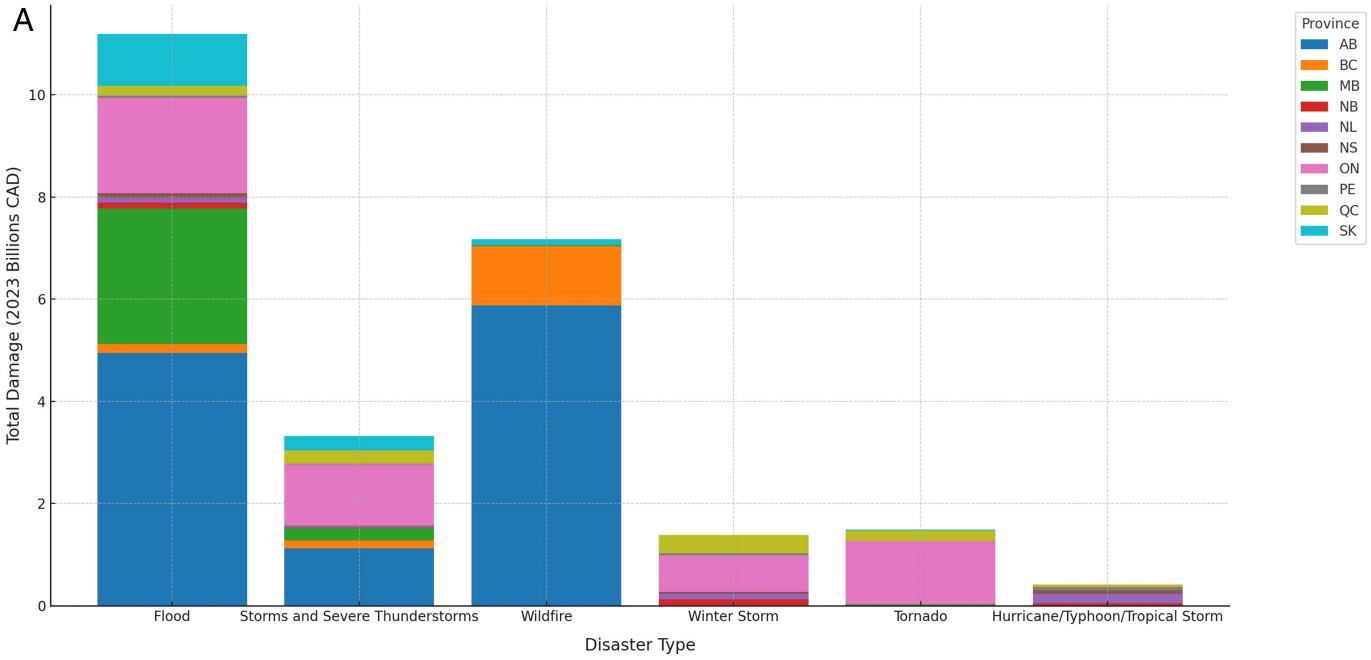
Figure 4: Total Damages by Natural Disaster Type (2000–2020): CDD Records

Notes: This bar chart presents a comparative view of the total economic damages and frequency of major natural disaster types in Canada based on data from the CDD covering the period between 2000 and 2020. The blue bars represent total damages in billions of Canadian dollars, capturing the financial impact of each disaster type, while the grey bars show the frequency of occurrences. The economic impact values reflect the year of each disaster without inflation adjustments. While CDD provides normalized damage data adjusted to 2016-dollar values, this adjustment introduces additional missing values, yielding qualitatively similar insights but reducing the completeness of the dataset. This visualization highlights both the economic burden and prevalence of disasters, with floods and wildfires incurring high costs. The data includes a total of 338 events, of which 149 report specific damage estimates.
Source: Data taken from CDD records.

scales. The National Forestry Database (NFD) serves as a model for this approach. The NFD records data on wildfires categorized by size, location, and cause, offering a highly granular and accessible dataset that is conducive to in-depth analyses. This standardized method minimizes pre-processing requirements, thus enhancing the dataset's utility for researchers and policymakers alike.

The benefits of this system are evident: by providing a standardized, per-event breakdown, the NFD allows for longitudinal analyses of wildfire trends and enables researchers to track the frequency and intensity of fires over time. This approach is particularly useful for studying economic impacts since it eliminates the need for complex data transformations and permits direct comparisons across provinces and time periods. However, similar to the CDD, the NFD faces issues with incomplete data, particularly concerning property loss estimates, and it has not been updated since 2021.

Figure 6 provides an example of standardized data reporting through the Canadian National Fire Database (CNFDB) and the National Forestry Database (NFD), both of which track the frequency and severity of wildfires in Canada from 1980 to 2019. Both databases exhibit similar trends in wildfire occurrence and area burned, demonstrating consistency across datasets, despite occasional discrepancies that may result from minor differences in data collection and reporting criteria. This level of alignment, with reliable annual records of total fires and areas burned, underscores the advantages of standardized data practices. Unlike the CDD, which suffers from inconsistent updates and gaps in reporting, the CNFDB and NFD exemplify how uniform data standards can improve data completeness and comparability over time. This standardization model could serve as a basis for improving other disaster databases like the CDD in order to enable more reliable, cohesive analysis



B

Total Damage per Province for Each Disaster Type (2023 Millions CAD)

Disaster Type	AB	BC	MB	NB	NL	NS	ON	PE	QC	SK
Flood	$4,950.50	$171.68	$2,649.98	$124.35	$85.19	$93.61	$1,868.51	$39.31	$196.02	$1,017.96
Storms and Severe Thunderstorms	$1,123.11	$151.37	$246.15	$11.02	$27.76	$10.80	$1,201.15	$6.15	$258.46	$282.67
Wildfire	$5,876.56	$1,162.53	$20.99	N/A	$0.73	N/A	N/A	N/A	N/A	$114.50
Winter Storm	N/A	N/A	N/A	$126.41	$104.24	$40.55	$716.21	$37.87	$353.91	N/A
Tornado	$5.57	N/A	$24.81	N/A	N/A	N/A	$1,233.97	N/A	$204.91	$17.85
Hurricane/Typhoon/Tropical Storm	N/A	N/A	N/A	$49.00	$184.44	$67.58	N/A	$67.58	$48.07	N/A

Figure 5: Total Damages per Province by Disaster Type in Canada (CDD 2000–2020, Where Damage Data Is Available)

Notes: This figure displays the total disaster-related damages across Canadian provinces based on data from the CDD covering the period between 2000 and 2020. Out of 338 recorded disasters, 149 had available information on damages. Damage values are presented in billions of Canadian dollars (in Panel A), with distinct colours representing each province, and in millions of Canadian dollars (in Panel B) providing a comparative view of economic impacts across provinces and disaster types. In cases where a disaster hit multiple provinces, the total damages are divided by the number of provinces affected to calculate each province's damages.
Source: Data taken from CDD records.

across regions and support enhanced policymaking and preparedness efforts.

Implications for Research, Policy, and Investors

The absence of consistent, up-to-date, and complete data poses a substantial challenge for evaluating disaster preparedness and resilience at the provincial level. Without standardized, accessible, and recent data, researchers and policy-makers are limited in their ability to conduct accurate assessments of disaster impacts and to formulate data-driven preparedness strategies.

This analysis sheds light on the importance of investing in a standardized, comprehensive disaster database that includes province-level breakdowns and is updated regularly. Improved data collection and reporting standards will enhance the quality and comparability of disaster data across provinces, ultimately supporting a more effective national disaster preparedness strategy. Until these changes are implemented, the CDD, despite its limitations, offers the most detailed source for localized Canadian disaster data and will therefore serve as the primary database for this research.

Improved data quality and standardization also hold significant implications for investors. Detailed, up-to-date, and comparable information on disaster frequency, severity, and economic consequences enables investors to more accurately price climate-related risks and opportunities in their portfolios. With clear province-level data, investors can identify regions and sectors that have proactively invested in resilience measures and mitigated the threat of sudden loss or asset damage. Such transparency fosters greater confidence and may encourage increased capital allocation toward resilient infrastructure projects, climate-smart technologies, and

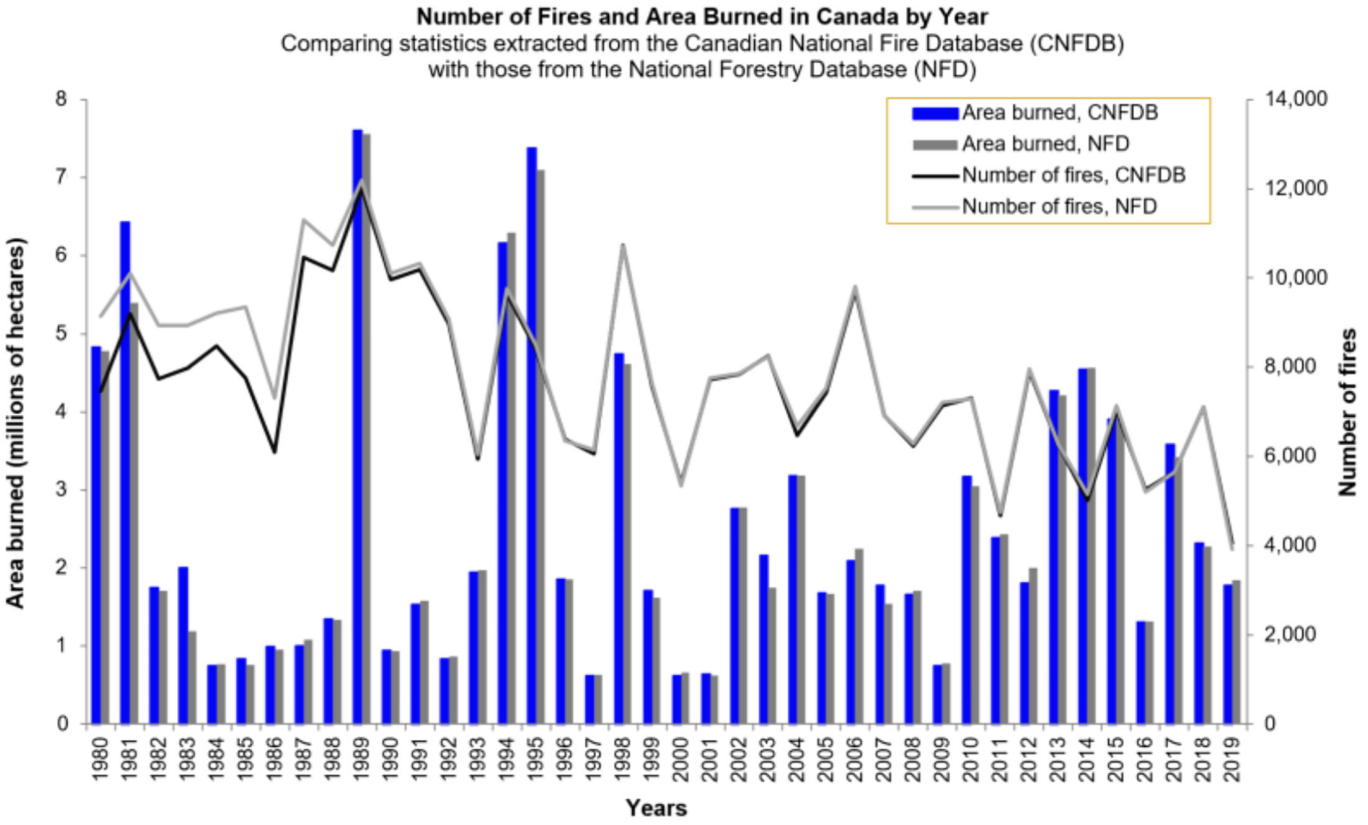


Figure 6: Comparison of Wildfire Frequency and Severity in Canada (1980–2019): CNFBD vs. NFD Databases

Notes: This figure compares statistics extracted from the Canadian National Fire Database (CNFDB) with those from the National Forestry Database (NFD) for the number of fires and area burned annually in Canada, sourced from Natural Resources Canada (n.d.). The two databases show very similar trends, with few discrepancies, a fact which may be attributed to differences in data collection methods and reporting criteria between the two databases. The data contained in these databases are not complete nor are they without error and updates may lag.
Source: Statistics taken from CNFBD and NFD records.

adaptive urban planning. Ultimately, better data empowers investors to make more informed, risk-adjusted decisions, supporting a virtuous cycle where robust adaptation efforts attract long-term investment and drive further resilience-enhancing initiatives.

Methodology

This study pursues multiple objectives: (a) to examine the landscape and trends of natural disaster damages across Canadian provinces and municipalities; (b) to highlight the shortcomings of existing disaster databases and the associated data gaps; and (c) to evaluate preparedness levels for natural disasters in relation to unique regional risk profiles. Recognizing the limitations in available data and the varying financial capacities of provincial and municipal governments, we have developed a proprietary preparedness index that incorporates both quantitative and qualitative factors derived from budgets and public disclosures. By integrating insights from the broader assessment of disaster damages, identifying data limitations, and applying the preparedness index, this approach offers a more holistic understanding of climate adaptation needs in Canada that extends beyond traditional financial metrics into strategic planning, governance, and resource allocation.

To construct this index, we began by analyzing data from the CDD to identify and rank the top three disaster types for each province and municipality based on historical frequency and impact. This initial step ensured that our assessment focused on the most significant risks faced by each region. We then collected relevant fiscal reports, action plans, and educational materials, examining the latest public accounts and budget documents for disclosures related to natural disaster initiatives and spending. Table 3 summarizes our scoring criteria.

The preparedness index assesses five key criteria, each reflecting critical aspects of disaster preparedness: initiatives and action plans, associated budgets, timelines, local and regional integration, and education plans.

Table 3: Evaluation Criteria for Action Plan, Budget, Timeline, Regional Integration, and Educational Outreach

Action Plan	Budget	Timeline	Regional Integration	Education
Do they have clear initiatives and are they realistic?	How many relevant accounts do they have?	Do they have time-oriented goals?	Do they understand the communal risk profiles?	Do they educate residents?
Does the action plan address their risk profile?	Are the amounts diluted among other non-relevant items?	How granular is the timeline; how many years ahead do they forecast?	Are they in touch with their communities?	Does the province consult with experts?

Notes: This table outlines key evaluation questions across five primary areas—*Action Plan*, *Budget*, *Timeline*, *Regional Integration*, and *Education*. Each area includes specific questions designed to assess the effectiveness, relevance, and community integration of provincial planning efforts. The questions focus on areas such as financial accountability, goal setting, risk understanding, actionable planning, and public education, offering a comprehensive framework for evaluating local governance strategies.
Source: Authors.

These criteria were carefully selected to provide a holistic evaluation of preparedness and consider both financial commitments and strategic planning. The top three identified disaster threats for each province by total estimated damages (estimated in this study) are summarized in Table 4.

The five components/criteria—*Action Plan*, *Budget*, *Timeline*, *Regional Integration*, and *Education*—were identified through a review of existing preparedness and adaptation frameworks (e.g., Ford and King 2015; Gilissen et al. 2016; Henstra 2017; Jamieson 2016). These sources emphasize that effective preparedness requires (a) formalized and actionable strategies; (b) dedicated and sustainable funding; (c) defined timelines for implementation; (d) cross-jurisdictional coordination to ensure policy coherence; and (e) public engagement and education to build risk awareness and adaptive capacity. The chosen components also reflect the indicators for which comparable, publicly available data could be obtained across Canadian jurisdictions, thus ensuring both conceptual relevance and practical measurability.

Table 5 evaluates the preparedness using the top three identified disaster threats for each province. The first criterion, *Action Plan*, focuses on the existence and quality of climate adaptation action plans and/or initiatives that include strategies directly responding to unique regional risks. The existence and quality of climate adaptation action plans is a central criterion in our index, as such plans provide a structured road map for risk reduction and long-term resilience. Research has shown that while the prevalence of local climate adaptation plans is increasing, there is substantial variation in their quality, scope, and implementation (Fu and Li 2022; Guyadeen et al. 2019; Reckien et al. 2018; Stults and Woodruff 2016). In the Canadian context, many municipal plans score highly on ambition but face challenges in execution and integration with other policy domains. Similar patterns are found internationally, underscoring the importance of evaluating both the presence and quality of such plans as a measure of preparedness. Action plans are essential for translating aspirations into concrete initiatives, and this criterion is thus given the weight of 20 percent. The scoring for this criterion ranges from 0 to 1 and is evaluated based on the comprehensiveness and specificity of the plans.

The second criterion, *Budget Score*, examines whether provinces or municipalities allocate budget accounts toward recovery or adaptation spending in their yearly public account reports. This practice serves as a baseline requirement for climate adaptation and indicates acknowledgment of losses and proactive capital allocation. A score of 1 is assigned if initiatives are disclosed, and 0 otherwise, reflecting a 40 percent weight in the overall index. This criterion is given the highest weight

Timeline constitutes the third criterion, emphasizing the importance of long-term planning in demonstrating a sustained commitment to embedding climate adaptation into core operations. This proactive approach is critical for addressing evolving climate risks and ensuring that adaptation efforts are integrated into ongoing governance and decision-making processes. Provinces or municipalities with multi-year strategies for resilience are awarded additional points, with scores ranging from 0 to 5 based on the extent and clarity of long-term goals and capital allocation strategies. This criterion holds a 20 percent weight in the index.

The fourth criterion, *Regional Integration*, assesses local and regional integration for provinces and local engagement levels for municipalities. Recognizing that municipalities often bear the brunt of recovery costs and increasingly require federal assistance to meet financial burdens, this criterion evaluates the degree of municipal government involvement and the quality of strategies, hazard maps, and risk profile initiatives for municipalities or localities. The quality was assessed by reviewing the clarity, accessibility, and integration of hazard infor-

Table 4: Top Three Natural Disasters per Province with Weights

Province	Disaster Type	Total Damages (2023 millions CAD)	Weight (%)
AB	Wildfire	5876.56	49.18
AB	Flood	4950.50	41.43
AB	Storms and severe thunderstorms	1123.11	9.40
BC	Wildfire	1162.53	78.25
BC	Flood	171.68	11.56
BC	Storms and severe thunderstorms	151.37	10.19
MB	Flood	2649.98	90.72
MB	Storms and severe thunderstorms	246.15	8.43
MB	Tornado	24.81	0.85
NB	Winter storm	126.41	42.17
NB	Flood	124.35	41.48
NB	Hurricane/typhoon/tropical storm	49.00	16.35
NL	Hurricane/typhoon/tropical storm	184.44	49.33
NL	Winter storm	104.24	27.88
NL	Flood	85.19	22.79
NS	Flood	93.61	46.40
NS	Hurricane/typhoon/tropical storm	67.58	33.50
NS	Winter storm	40.55	20.10
ON	Flood	1868.51	43.42
ON	Tornado	1233.97	28.67
ON	Storms and severe thunderstorms	1201.15	27.91
PE	Hurricane/typhoon/tropical storm	67.58	46.68
PE	Flood	39.31	27.16
PE	Winter storm	37.87	26.16
QC	Winter storm	353.91	43.30
QC	Storms and severe thunderstorms	258.46	31.62
QC	Tornado	204.91	25.07
SK	Flood	1017.96	71.93
SK	Storms and severe thunderstorms	282.67	19.97
SK	Wildfire	114.50	8.09

Notes: The table presents the top three natural disasters by total damages for each province, measured in 2023 millions of Canadian dollars. It includes the type of disaster, the corresponding monetary damages, and the disaster's weight as a percentage of the total damages of the top three disasters in that province. The data highlights the most impactful natural disasters across provinces, offering insights into regional vulnerabilities and the proportional significance of each disaster type.
Source: Data taken from the CDD.

mation into decision-making processes. This approach reflects evidence that effective hazard communication improves public understanding and response (Stephens et al. 2024), that multi-hazard maps are most impactful when developed with stakeholder engagement and clear usability goals (Dallo et al. 2020), and that regional policy frameworks strongly influence municipal adaptation planning (Bonnett and Birchall 2023). The score ranges from 0 to 3 and is weighted at 10 percent, reflecting its essential role in tailoring preparedness strategies that address local vulnerabilities effectively.

The last criterion, *Education*, examines efforts to educate residents about procedures and actions to minimize natural disaster damages. The reason for including it is that effective public education can significantly reduce human and physical losses during disasters. In this way, an educated government and population understand how to assess climate risk when building new infrastructure, which industries are most affected by severe natural disasters, and where to deploy capital. A maximum score of 1 is assigned if proactive educational programs, such as workshops and seminars, are offered. Conversely, a score of 0 is given if reliance is solely on national programs that may not address community-specific risks and needs. While such programs are important for fostering an "intent to act" and building a culture of preparedness, awareness alone does not consistently translate into concrete adaptation behaviours. For this reason, the education criterion carries a weight of 10 percent in the index, reflecting its supporting—rather than primary—role in determining overall preparedness. The weights assigned to each criterion were carefully considered to reflect their relative importance in effective disaster preparedness.

Table 5: Disaster Preparedness and Recovery Evaluation Criteria for Calculating Provinces and Municipalities Preparedness Scores

Top 3 Disasters by Total Estimated Damages	Action Plan (0 or 1)	Budget Score for Adaptation (0 or 1) or Recovery (0 or 1)	Timeline Graded by Number of Years Projected (Max Score = 5)	Regional Integration Specified in the Action Plan (Max Score = 3)	Education (1 or 0)
Threat 1	1	2	5	3	1
Threat 2	1	2	5	3	1
Threat 3	1	2	5	3	1
Sum	3	6	15	9	3
Score	100%	100%	100%	100%	100%
Weight	20%	40%	20%	10%	10%
				Score	100%

Notes: This table evaluates the preparedness for the top three identified disaster threats by total estimated losses. Each threat is assessed across five key criteria: existence of an initiative and/or presence of an action plan with an associated budget, timeline for implementation, number of regions/municipalities covered in the action plan, and availability of an educational initiative. Threats refer to top three most damaging natural disasters affecting the province historically (2000–2020). Scores for each criterion are assigned based on specific benchmarks, with total scores and weights provided to indicate relative importance. The final overall score reflects a weighted evaluation of disaster readiness and resilience.
Source: Authors.

The preparedness index (PI) is calculated as

$$PI = \sum_{i=1}^{5} W_i * S_i,$$

where W_i is the weight assigned to criterion i and S_i is the score for that criterion on a scale of 0 to 100. The five criteria—action plan, budget, timeline, regional integration, and education—were scored independently by three researchers, then they were weighted (20%, 40%, 20%, 10%, and 10%, respectively) to produce the overall PI. This structure is related and draws on established evaluation approaches, such as the adaptation readiness framework (Ford and King 2015) and disaster risk reduction evaluation frameworks (Gilissen et al. 2016; Henstra 2017; Jamieson 2016), which emphasize multi-dimensional models to capture institutional and operational readiness.

This study's preparedness index does not include historical recovery losses as a scoring criterion. While such losses could indicate potential deficiencies in resilience or adaptation, they were excluded to maintain a focus on proactive measures documented in public disclosures and to avoid biases arising from incomplete or uneven loss reporting across provinces and municipalities.

To ensure objectivity and consistency in the scoring process, three research assistants independently reviewed the public documents, by utilizing predefined keywords and criteria for each scoring category. Specific terms related to each criterion were searched within the documents to identify relevant content. Scores were assigned based on the presence and quality of information corresponding to each criterion's parameters. The individual scores from all three assistants were then averaged for each criterion to obtain the final score for each province or municipality. This approach mitigates individual biases and enhances the reliability of the assessment.

Following the scoring, individual criterion scores were multiplied by their respective weights and summed to produce the overall preparedness score. These scores were then compared across provinces and municipalities to identify patterns, strengths, and areas for improvement. This comparative analysis provides valuable insights into the effectiveness of current strategies and highlights opportunities for enhancing disaster preparedness at both provincial and municipal levels.

While this methodology offers a structured and comprehensive approach to assessing natural disaster preparedness, certain limitations should be acknowledged. Variations in fiscal reporting and the availability of public documents may affect the comparability of scores across different regions. Additionally, despite efforts to mitigate bias through multiple evaluators and predefined criteria, some subjectivity in qualitative assessments is unavoidable. Preparedness levels may also change rapidly due to new policies or events, so the scores represent a snapshot based on the most recent data available. Lastly, reliance on publicly disclosed information may overlook internal initiatives not reported in accessible documents.

This methodology provides a nuanced understanding of regional preparedness levels by combining quantitative data with qualitative analysis and involving multiple evaluators. It offers a valuable tool for policy-makers, stakeholders, and communities to assess and enhance

natural disaster preparedness, ultimately contributing to greater resilience and safety across Canadian provinces and municipalities.

Results

Building upon our methodology, we applied the preparedness index to assess and rank the provinces and municipalities. The results, detailed in Table 6, reveal significant variations in disaster preparedness levels across regions, which are categorized by percentage ranges. A prominent trend emerges wherein municipalities generally demonstrate better integration of climate adaptation considerations compared to provinces.

Ottawa and Vancouver occupy the highest preparedness tranche among municipalities. Ottawa stands out with a perfect score of 100 percent, indicating an exceptionally well–co-ordinated disaster preparedness strategy. This score reflects Ottawa's comprehensive long-term action plan, efficient resource allocation, strong community involvement, and effective educational initiatives aimed at raising awareness and enhancing citizen readiness. Despite this exemplary performance, there are opportunities for improvement. Enhancing the accessibility and clarity of Ottawa's natural disaster reports could further strengthen its preparedness. While detailed budgets and projections are available, the complexity and volume of these reports may reduce their usability and visibility for stakeholders and the general public.

Table 6: Calculated Preparedness Scores of Canadian Provinces and Municipalities

Region	Score (%)	Category
Municipalities		
Ottawa	100	Very High
Vancouver	80	High
Montreal	73	High
Peel Region	55	Moderate
York Region	50	Moderate
Toronto	45	Low
Provinces		
Newfoundland and Labrador	70	High
Quebec	68	High
New Brunswick	67	High
Ontario	65	Moderate
Alberta	64	Moderate
British Columbia	60	Moderate
Saskatchewan	55	Moderate
Manitoba	50	Moderate
Nova Scotia	45	Low
Prince Edward Island	40	Low

Notes: This table presents resilience and preparedness scores for selected municipalities and provinces, categorized by performance level. Scores are expressed as percentages and are grouped into categories—*Very High*, *High*, *Moderate*, and *Low*—based on specific criteria assessing readiness, response capabilities, and resilience against potential disasters. The table provides a comparative view of municipal and provincial readiness, highlighting areas with differing levels of preparedness across Canada.
Source: Authors.

Vancouver follows closely with a preparedness score of 80 percent, showcasing significant efforts in disaster readiness and climate adaptation. This high score underscores Vancouver's commitment to proactive planning and community engagement. Montreal also performs commendably, achieving a score of 73 percent. These municipalities have integrated climate adaptation into their core operations, although there remains room for advancement, particularly in refining long-term strategies and expanding educational programs.

Conversely, Peel Region, York Region, and Toronto fall within the 40 to 60 percent preparedness range. These lower scores suggest heightened vulnerability regarding disaster response, and they stress the need for these municipalities to bolster their preparedness efforts. Enhancements could include developing more comprehensive action plans, allocating adequate budgets for adaptation measures, and increasing local and regional integration and public education to address local vulnerabilities effectively.

At the provincial level, the majority of provinces exhibit moderate to low readiness. Newfoundland distinguishes itself as the only province with a higher preparedness score of 70 percent, reflecting proactive approaches in its disaster preparedness and climate adaptation strategies. Provinces within the 60 to 70 percent range include Quebec with 68 percent., New Brunswick with 67 percent, Ontario with 65 percent, Alberta with 64 percent, and British Columbia with 60 percent. While these scores indicate a moderate level of preparedness, they also signify substantial opportunities for improvement. Strengthening long-term planning, enhancing local and regional integration, and expanding education initiatives could elevate their readiness levels.

Alberta, in particular, requires urgent attention. Despite being highly exposed to natural disasters the preparedness score remains moderate at 64 percent This discrepancy accentuates the critical need for the province to intensify its preparedness strategies. By developing more detailed action plans, improving resource allocation, and fostering stronger community involvement, Alberta can better mitigate future risks and enhance its resilience against natural disasters.

Alarmingly, Prince Edward Island is the lowest performer with a preparedness score of only 40 percent. This low score suggests significant vulnerabilities and implies that the province may face severe consequences when disasters occur. For this reason, strengthening disaster preparedness strategies and improving governance

Table 7: Provincial Disaster Impact: Total and Damages per Capita (Canada, 2000–2020)

Province	Total Damages (2023 Billions CAD)	Population	Damages per Capita (2023 CAD)	Avg. Annual Damages per Capita (2023 CAD)
AB	11.9557	4,888,723	2,445.58	116.46
BC	1.4856	5,698,430	260.70	12.41
MB	2.9419	1,494,301	1,968.77	93.75
NB	0.3108	854,355	363.75	17.32
NL	0.4024	545,247	737.93	35.14
NS	0.2125	1,076,374	197.45	9.40
ON	5.0198	16,174,116	311.32	14.82
PE	0.1509	178,550	845.21	40.25
QC	1.0614	9,056,044	117.20	5.58
SK	1.4330	1,239,865	1,155.76	55.04

Notes: This table presents comprehensive data on disaster impacts by province in Canada from 2000 to 2020, detailing total disaster-related damages, population estimates, damages per capita, and calculated average annual damages per capita in Canadian dollars.
Source: Data taken from the CDD and Statistics Canada's July 2024 provincial population estimates.

integration are imperative for Prince Edward Island. Focusing on creating actionable plans, securing appropriate funding, and implementing effective educational programs can substantially improve the province's capacity to respond to and recover from natural disasters. The details of the score calculations are provided in the Online Appendix.

These climate adaptation scores serve a crucial role in raising awareness about the integration of climate adaptation needs at both provincial and municipal levels. By assessing the five key criteria—action plans and associated budgets, timelines, local and regional integration, and education plans—regions can identify their weakest areas and prioritize improvements. It is of utmost importance for areas with high-risk profiles to further develop their disaster preparedness and resilience measures. As natural disasters increase in frequency and severity, proactive adaptation and comprehensive preparedness become essential components of safeguarding communities.

Table 7 provides a detailed overview of disaster impacts across Canadian provinces between 2000 and 2020. The data encompass total disaster-related damages, population estimates, and damages per capita, offering insights into the economic burden of natural disasters on both a total and per capita basis. Additionally, the table presents the average annual damages per capita in 2023 Canadian dollars, a metric that helps contextualize the ongoing financial impact of disasters on each province's population.

Figure 7 provides a visual representation of disaster-related financial impacts across Canadian provinces from 2000 to 2020, as recorded in the CDD. The bar chart presents both total disaster-related damages in 2023 Canadian dollars (indicated by the grey bars) and per capita damages (represented by the blue bars) for each province, offering a comprehensive comparison of the absolute and individual financial burdens associated with natural disasters.

The dual *y*-axes highlight the disparities between overall economic losses and per capita impacts, with the left axis showing total damages and the right axis reflecting damages per capita. For instance, Alberta shows the highest total and per capita disaster-related damages, underscoring its significant exposure to natural disasters. However, Manitoba, Saskatchewan, and Prince Edward Island, while showing much lower total damages, experiences a notably high per capita impact due to their smaller population size. This visualization emphasizes both the regional concentration of damages and the substantial burden placed on individual residents in less populated provinces.

The chart includes only the recorded events with reported damage estimates, encompassing 149 incidents out of a total of 338 events documented in the CDD. Population estimates used to calculate per capita impacts are based on Statistics Canada's July 2024 provincial population data, ensuring an up-to-date reflection of individual risk exposure across Canada. This comparative view indicates the need for region-specific adaptation strategies, highlighting provinces with both high total damages and significant per capita impacts as areas requiring urgent resilience-building efforts.

The interpretation of preparedness scores should be considered alongside historical loss patterns and hazard exposure profiles, as outlined in Table 4. For example, Alberta's substantial population in the boreal forest increases wildfire exposure, while Ontario's dense urban areas heighten vulnerability to urban flooding. Such underlying exposure factors mean that even well-prepared jurisdictions may continue to experience significant losses. The findings from this assessment highlight the varying degrees of preparedness across Canada and emphasize the necessity for continued efforts to enhance

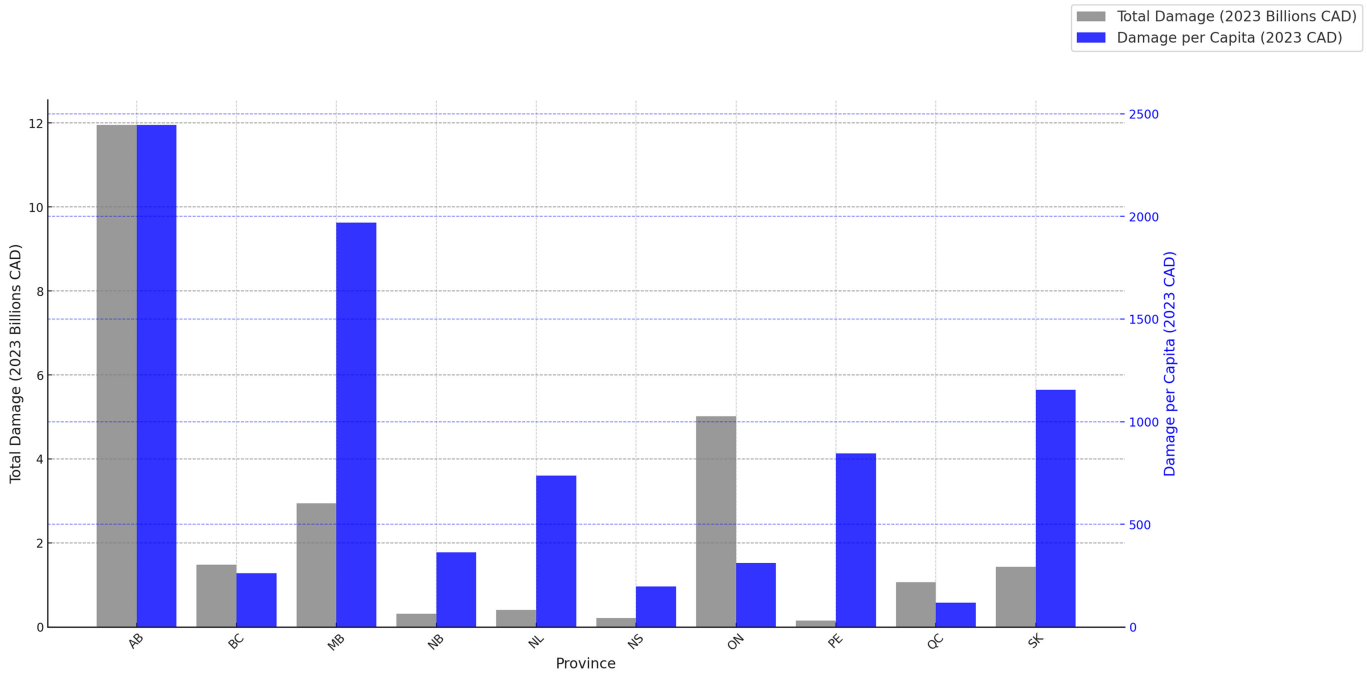


Figure 7: Provincial Disaster-Related Damages and Impact per Capita in Canada (CDD 2000–2020, Where Damage Data Is Available)

Notes: This bar chart illustrates the total disaster-related damages (in Canadian dollars) and damages per capita across Canadian provinces from 2000 to 2020, based on data from the CDD. The damages presented reflect only the recorded events with reported damage estimates, totalling 149 out of 338 incidents. Population estimates, used to calculate per capita impacts, are based on Statistics Canada's July 2024 provincial population estimates. The dual *y*-axes allow for a comparative view of overall financial impact and individual per capita burden.
Source: Data taken from the CDD and Statistics Canada's July 2024 provincial population estimates.

disaster readiness. Municipalities like Ottawa and Vancouver exemplify effective strategies and could serve as models for other regions aiming to improve their preparedness levels. Provinces and municipalities with lower scores should consider revisiting their current strategies by focusing on long-term planning, allocating sufficient resources, and engaging communities through education and participation.

Figure 8 presents a scatter plot illustrating the relationship between provincial preparedness scores (out of 100) and the average annual disaster damages per capita (in Canadian dollars) across Canadian provinces from 2000 to 2020. Each province is represented by a unique marker, with labels for easy identification. The chart incorporates reference lines at intervals of C$40, C$80, and C$120 on the *x*-axis for average annual damages per capita and at scores of 50, 60, and 70 on the *y*-axis for preparedness scores. These benchmarks facilitate a clearer interpretation of each province's position relative to others in terms of financial vulnerability and preparedness.

The scatter plot reveals a range of relationships between damages per capita and preparedness scores. Provinces like Newfoundland and Labrador, Quebec, and New Brunswick, positioned near the top of the chart with scores close to 70, indicate higher levels of preparedness despite facing low to moderate per capita damages. This result suggests that these provinces have made significant efforts to improve disaster resilience even as they continue to experience substantial disaster-related impacts. Alberta, while having a relatively high average annual damages per capita, achieves only a moderate preparedness score of 64. This position highlights a potential gap between Alberta's exposure to disasters and its level of preparedness, underscoring the need for enhanced resilience measures in a high-impact context.

Manitoba and Saskatchewan stand out as provinces with high per capita damages while having a relatively low preparedness score. Prince Edward Island (PEI), located at the far bottom of the chart with a relatively high average annual damages per capita, stands out as an area of concern. PEI's low score, combined with its high per capita damages, indicates a high level of vulnerability and suggests a critical need for improvement in its disaster preparedness and resilience strategies. This result contrasts with provinces such as Ontario and Quebec, which demonstrate moderate scores paired with low per capita damages, placing them in a more stable position

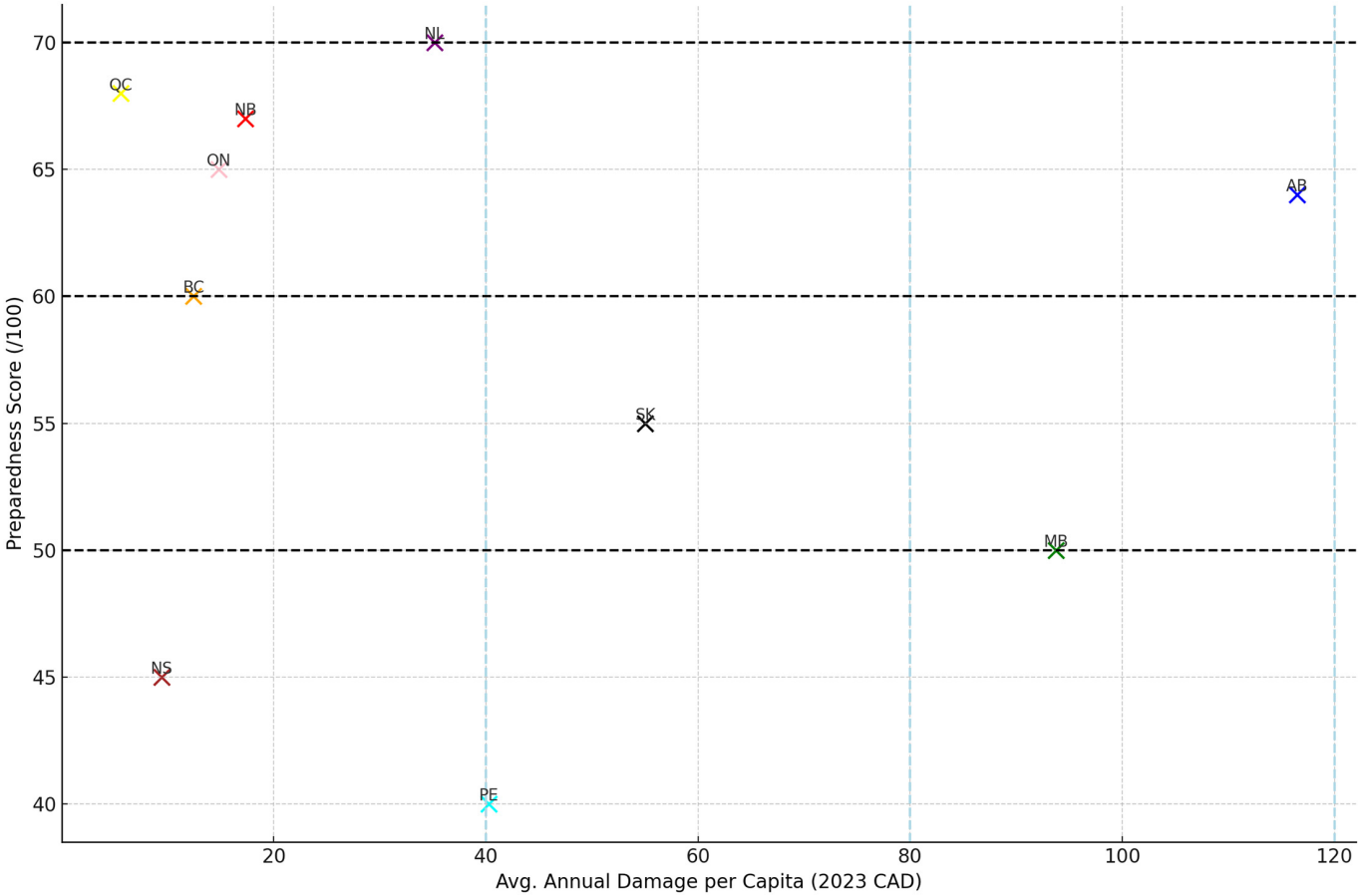


Figure 8: Provincial Preparedness Scores vs. Average Annual Disaster Damages per Capita in Canada

Notes: This scatter plot illustrates the relationship between provincial preparedness scores (out of 100) and average annual disaster damages per capita (2023 CAD) across Canadian provinces from 2000 to 2020. Provinces are represented by unique markers with names indicated directly on the chart for clarity. Vertical reference lines at C$40, C$80, and C$120 per capita and horizontal lines at scores of 50, 60, and 70 provide visual benchmarks.
Source: Data taken from the CDD and Statistics Canada's July 2024 provincial population estimates.

regarding disaster preparedness relative to their lower exposure.

Overall, the scatter plot in Figure 8 provides a visual synthesis of how provinces balance disaster preparedness with their financial exposure to natural disasters. Provinces with higher scores and moderate damages, such as Quebec and Newfoundland and Labrador, serve as examples of effective preparedness, while those with lower scores and high per capita damages, such as Manitoba, Saskatchewan, and Prince Edward Island, illustrate the pressing need for enhanced adaptation efforts. In this way, the chart emphasizes the diverse landscape of disaster readiness across Canada and points to specific areas where targeted improvements in preparedness could mitigate the impacts of future natural disasters. This final analysis highlights the importance of aligning preparedness efforts with regional risk profiles to foster greater resilience across Canadian provinces.

Conclusion

This study provides a comprehensive assessment of climate-related disaster preparedness among Canadian provinces and municipalities, culminating in the development of a proprietary preparedness index. By integrating both qualitative and quantitative measures—such as initiatives, action plans, timelines, local and regional integration, and public education—we offer a nuanced evaluation of regional readiness. Alongside these findings, our analysis of available disaster data sources, particularly the CDD and EM-DAT, reveals significant gaps and inconsistencies in the recording, reporting, and disclosure of natural disasters and related preparedness measures.

The results underscore several key areas for improvement. First, there is a clear lack of standardized, consistent, and timely disclosure on both disaster impacts and preparedness strategies at the provincial and

municipal levels. This shortfall makes it challenging to accurately benchmark resilience efforts and identify best practices. As a call to action, provinces and municipalities should enhance the frequency, clarity, and comparability of their climate preparedness disclosures. Doing so will empower policymakers, citizens, and investors to make more informed decisions and drive more effective climate adaptation initiatives.

Second, we highlight the challenges arising from reliance on third-party vendors and government agencies for disaster data. Inconsistent methodologies and incomplete datasets hinder meaningful comparisons and robust trend analysis. A logical next step would be increased collaboration between federal agencies, subsovereign entities, and data providers to adopt uniform reporting standards and methodologies. Such harmonization would yield higher-quality data, thus enabling more accurate assessments, facilitating better risk management strategies, and supporting more transparent market analyses.

Notwithstanding these limitations, our study successfully combines imperfect data from provincial and municipal disclosures and the CDD/EM-DAT to produce a preliminary preparedness index. This success demonstrates the feasibility of developing comparable metrics of resilience even with current data shortcomings. We encourage stakeholders—particularly market participants—to periodically recreate and refine this index as new, improved data become available. Regular updates would maintain its relevance and strengthen its role as a decision-making tool.

From an investment perspective, the preparedness index highlights varying degrees of climate-related vulnerabilities and provides investors with insights to guide their capital allocation, risk management, and stewardship activities. Investors can leverage these metrics as part of their due diligence, incorporating climate resilience into their ESG engagements and encouraging greater transparency and accountability from provincial and municipal issuers. As investors have influenced corporate reporting standards in the past, their proactive involvement could similarly enhance data quality and drive improvements in sub-sovereign climate preparedness.

Another limitation is that reported preparedness measures may not fully reflect actual adaptive capacity. Broader socio-economic factors—for example, high levels of economic growth, which can enable households and businesses to absorb disaster losses without state assistance—are not captured in the index. As a result, some jurisdictions may appear less prepared on paper than they are in practice, and vice versa. A further limitation is the absence of consistent, publicly available data on Indigenous communities, despite evidence that many experience heightened vulnerability to disaster impacts. The lack of standardized, disaggregated data prevents their inclusion in the preparedness index and represents a critical gap for future research and policy development.

Lastly, our brief examination of green bond issuances by government reveals that proceeds are predominantly funnelled into mitigation measures, with limited attention to adaptation. Given the growing severity of natural disasters, we urge provinces and municipalities to reconsider their capital allocation strategies within these financing instruments. Reorienting a portion of green bond proceeds toward adaptation measures would not only strengthen local resilience but also align with investors' evolving focus on comprehensive climate solutions.

In sum, this study highlights critical data and disclosure gaps, demonstrates the viability of integrating disparate data sources into a preparedness index, and calls for collaborative efforts among governments, data providers, and investors. By prioritizing transparent disclosures, harmonized reporting standards, strategic use of green financing, and continuous refinement of resilience metrics, Canada's provinces and municipalities can bolster their readiness for a changing climate and foster a more resilient and sustainable future.

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