

A Landscape Analysis of Nature-based Solutions in Canada



Abstract

- Nature-based Solutions can mitigate carbon emissions and provide multiple ecosystem services that improve the well-being of humanity. However, their performance is poorly understood.
- We assessed publicly available data from Canadian projects that could be considered Nature-based Solutions (NbS) according to the IUCN Nature-based Solutions framework.
- Across three sectors (government, industry, and Indigenous) we observed a general lack of standardized monitoring, reporting and verification (MRV), and high variability in funding mechanisms. This hinders NbS effectiveness, deters further financing and renders MRV difficult to properly integrate in Nationally-Determined Contributions.
- We also observed geographic and ecosystem coverage gaps that exclude key regions, stakeholders, and ecosystems within Canada.
- The effective participation of Indigenous Peoples and Local Communities (IPLC) is fundamental to equitable and effective climate and biodiversity action. Five principles are highlighted to promote effective NbS co-design and implementation with IPLC.
- Novel artificial intelligence and machine learning methods can also help overcome current gaps in the Canadian NbS landscape, but more research is needed to determine the full scope of limitations and benefits of these big-data driven approaches.



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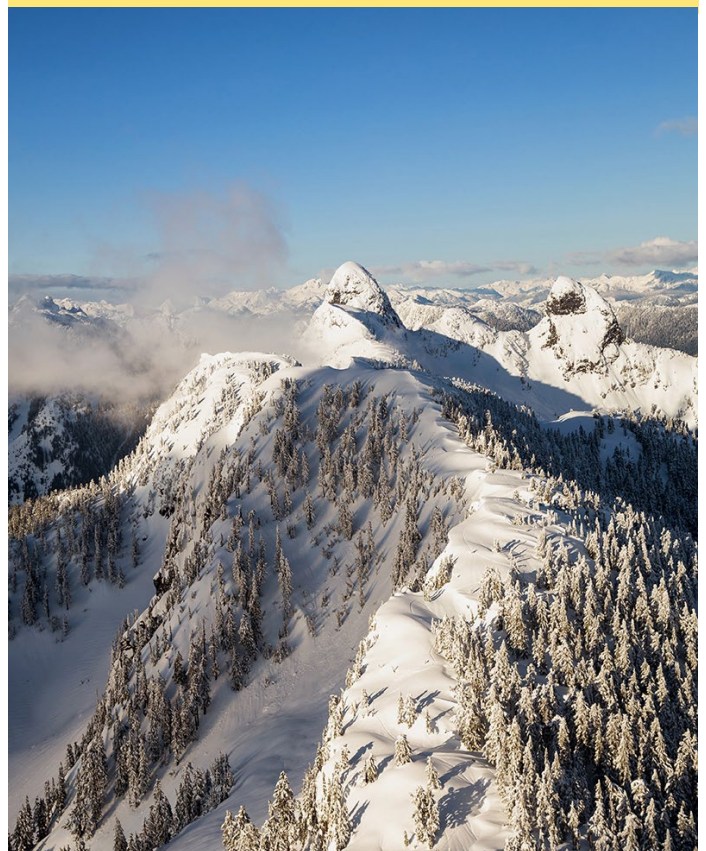
1. Nature-based Solutions, Canada's opportunity to meet climate goals

If Canada is to achieve net-zero emissions by 2050, a combination of emissions reduction and innovative carbon sequestration approaches are needed. Nature-based Solutions¹ (NbS) are promising, as they could help achieve up to 35% of Canada's 2030 carbon reduction commitment (Griscom et al., 2017, Drever et al., 2021). In addition, NbS can protect biodiversity and provide multiple ecosystem services that improve the well-being of humanity. However, their performance and long-term impacts are still poorly understood.

In this report, we aim to provide an improved understanding of Nature-based Solutions to help decision-makers prioritize actions that support carbon storage, biodiversity, resilience, and reconciliation goals.

The report presents an assessment of publicly available data from current NbS projects in Canada to outline opportunities for improved reporting, funding, and geographic distribution of NbS (Section 2). We present a rationale for the necessity of co-creating NbS with Indigenous Peoples and Local Communities (Section 3) and suggest ways to do so, based on consultation with over 100 stakeholders (Section 4). We also present potential applications of artificial intelligence and machine learning for NbS, based on a review of the literature (Section 5). Finally, Section 6 presents conclusions that weave all these considerations together, to enhance understanding of the current status and future potential for NbS in Canada.

This document uses the definition of Nature-based Solutions from the International Union for the Conservation of Nature: *Nature-based Solutions (NbS) are actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g., climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits* (Cohen-Shacham et al. 2016).



¹ There is overlap and divergence in the literature with the term "Nature-based Solutions" (as defined by Cohen-Shacham et al., 2016) and "natural climate solutions" (as defined by Drever et al., 2021). Both have merit and we use Nature-based Solutions in this report for simplicity.

2. Trends across sectors funding Nature-based Solutions in Canada

What we analyzed

We assessed 50 illustrative funding programs, spanning over 200 NbS project examples, to begin to identify trends across multiple categories (i.e., project monitoring, geographic distribution, ecosystem type, project funding). We searched publicly available websites of Indigenous communities, non-governmental organizations (NGOs), industry, and the Canadian government and compiled these into three NbS categories: Government, Industry, and Indigenous-led projects. As there are no standard criteria for monitoring NbS in Canada, this review included only programs that mentioned some mechanism to evaluate results.

We recognize this is not an exhaustive analysis of all the NbS projects in Canada. More work is needed to examine the full scope and breadth of projects, potentially with the aid of natural language processing. Trying to understand trends and success through government and industry websites and blog

posts may paint an incomplete picture of the current status of Nature-based Solutions, but we put forward this effort as a start.

What the trends tell us

Existing data on the Canadian NbS landscape is fragmented. Below we describe the main gaps and outline opportunities to address these gaps, based on trends observed in four categories:

- **Monitoring and Transparency**
- **Geographic Distribution**
- **Ecosystem Type**
- **Funding**

Gaps and opportunities are followed by example opportunities in Box 1. A detailed description of trends by project type can be found in the Appendix.



Monitoring and Transparency

It is not currently possible to evaluate the efficacy of NbS efforts in Canada, due to a lack of standardized performance metrics, transparency, and monitoring, reporting and verification (MRV) frameworks.

Trend: Across all projects, performance metrics were infrequently assessed and not standardized (see Appendix for details).

Gap

Since each NbS project uses its own performance metrics or individual monitoring framework (e.g., species inventory, change in forest cover, change in soil carbon, etc.), it is challenging to include the carbon mitigation potential of NbS in Nationally Determined Contributions, hindering an understanding of how NbS may contribute to climate goals.

Opportunity

Create a national framework for monitoring, reporting and verification (MRV)

An MRV framework will allow decision makers to:

- Measure NbS efficacy against standardized metrics
- Capture the diversity of NbS co-benefits
- Ensure national carbon reporting aligns with rapidly evolving global standards

Gap

The lack of national standardization is amplified by a lack of globally standardized carbon tracking metrics. Together, lack of national and international standards hinders further financing and action in this space.

Opportunity

Build a national NbS repository

A national repository for NbS could help:

- Guide more transparent investments
- Identify which NbS produce multiple co-benefits

Geographic Distribution

The current regional distribution of NbS projects in Canada does not adequately balance environmental needs, human well-being, and opportunities for impact.

Trend: Over half (60.6%) of Canada's NbS projects occur in British Columbia, Ontario, and Quebec. Peatlands NbS are funded predominantly in Quebec.

Gap

The current distribution of NbS projects (mainly BC, ON, QC) is to be expected, aligning with high regional economic activity, population, and project infrastructure capacity. However, this distribution reveals a gap in coverage for the remainder of Canada, failing to support those most vulnerable to climate change impacts, including Inuit and Northern communities, Atlantic Canada, regions prone to drought, floods and fire, and Métis and First Nations residing outside of BC, ON, QC.

Opportunity

Expand regional distribution of NbS to address climate vulnerability

Given that NbS should simultaneously protect ecosystems, address societal challenges, and provide human well-being, and given that Canada has lost \$15 billion dollars in the last ten years to natural disasters due to lack of preparedness [1] there is an opportunity to expand the distribution of NbS projects across Canada, based on a balance of regional capacity and vulnerability to climate change impacts.

Gap

Peatlands are critical global ecosystems because they store more carbon than all other vegetation types in the world combined. [2] While peatland NbS are mainly being funded in Quebec, the world's largest peatland carbon stock (~150 Gt of carbon) is located outside this province, between Ontario and Manitoba within Treaty 9 and Treaty 5 Indigenous lands. [3] Furthermore, peatland vulnerability to climate change is highest in Manitoba, Ontario, Northwest Territories, and Alberta. [4]

Opportunity

Increase coverage of peatland NbS to maintain critical carbon sinks

Canada houses 25% of the world's northern peatlands and the world's largest peatland carbon stock. Thus, peatland NbS investment across Canada has both national and international repercussions in the fight against climate change [5].

[1] Sawyer et al., 2020; [2] IUCN, 2021; [3] Hugelius et al., 2020; [4] Tarnocai, 2006; [5] Harris et al., 2021.

Ecosystem Type

By supporting NbS projects in agriculture, grasslands, and oceans, Canada can expand its 2030 mitigation potential.

Trend: Across all sectors, most NbS project types focused on aquatic and forest ecosystems. Other NbS types with high carbon mitigation potential, like agriculture, grasslands, and oceans, are less represented under current funding schemes.

Gap

Agricultural NbS represent the largest opportunity for CO² mitigation in Canada by 2030 (46.8% of total NbS mitigation potential [1]) yet our analysis found few Industry and Indigenous-led projects focused on agriculture.

Opportunity

Support more agricultural NbS

As agricultural NbS may provide food security and economic benefits beyond carbon uptake, increasing the number of agricultural NbS projects can significantly augment Canada's carbon mitigation potential, increase participation of Inuit and First Nations, strengthen self-reliance of communities, and enhance local food availability. This is particularly relevant in Nunavut, where the Food Security Coalition has proposed an increase in agricultural produce as one key part to counter the high food insecurity. [3]

Gap

Forests and aquatic ecosystems account for a 2030 carbon mitigation potential of 14.7% and 22% respectively. Grasslands NbS represent a similar mitigation potential (16.5%) yet are not a current priority for funders. Marine protected areas (MPAs) are also an effective tool for restoring ocean biodiversity and ecosystem services [2] yet marine and oceanic NbS are not currently well represented in the Canadian NbS landscape.

Opportunity

Explore blue carbon and grassland NbS

While forests and aquatic ecosystems are relatively well-studied in Canada, much collective work remains to be done on oceanic ecosystems (only 8% of Canada's offshore ecosystems are mapped to modern standards [4]) and grasslands NbS which hold mitigation potential on par with forests.

[1] Drever et. al. 2021; [2] Sala et al., 2021; [3] Nunavut Food Security Coalition, 2014; [4] Locke, 2019.

Funding

Funding length, amount, and access are highly variable, creating barriers for fair and long-term distribution of funds based on needs.

Trend: Funding timeframes varied (usually five years or less). Funding ranged from hundreds of thousands to billions and many funding programs required matching funds. Projects are more frequently motivated by compliance than by co-benefits.

Gap

While the majority of NbS projects have access to short term funding (<5 years), many of the benefits of NbS projects are seen over the medium to long term (>5 years). Long-term funding, however, is difficult to justify due to inadequate performance measurement (see monitoring above).

Opportunity

Create inclusive funding schemes based on data

Both government and industry can make more informed decisions on project funding based on evidence gathered via standardized performance monitoring schemes. With such data, more inclusive funding schemes can be created, such as funding for Indigenous-led projects outside of Indigenous lands and increasing the number of open calls supported by industry. There is also an opportunity to increase overall understanding of the long term return on investment when projects with co-benefits are supported, in combination with an ongoing role for regulatory or compliance-based mechanisms.

Box 1: Example opportunities addressing the implementation gaps for Nature-based Solutions in Canada

Monitoring and Transparency

Digitally-enhanced MRV: The Canadian Forest Service is currently using an open-source MRV initiative ([Full Lands Integration Tool \[FLINT\]](#)) to track greenhouse gas emissions and removals from forestry, agriculture and other land uses. Recent calls for the creation of standardized MRV frameworks have also been proposed in the [Carbon Call](#) and the [WBCSD Business Manifesto for Climate Recovery](#).

Centralized NbS repositories: The [Nature-based Solutions Initiative](#), the [Urban Nature Atlas](#), and the [Nature-based infrastructure database](#) are useful guiding references for centralized repositories.

Geographic Distribution

Improving monitoring of peatland areas is key for carbon mitigation: McMaster University, WWF Canada, and the [Mushkegowuk First Nations](#) (communities within Ontario peatlands) are joining efforts to map and monitor the carbon stored in their traditional territory. By intertwining climate science and Indigenous Knowledge Systems, this initiative is helping advance Indigenous-led conservation, while improving satellite data monitoring of peatlands with on-the ground-measurements.

Ecosystem type

Investing in agricultural NbS to complement efforts of forest and aquatic projects: The federal government recently announced a 10-year, \$185 million fund for [Agricultural Climate Solutions – Living Labs](#). These labs will support the development of a Canada-wide network of farmers, scientists and other participants working together to develop, test, and implement farming practices to tackle climate change. These labs could also serve as a model for industry-funded agricultural NbS.

Funding

Closing the funding gap: Approximately US\$133 billion per year is currently directed towards NbS; (86% public financing and 14% private sector finance). There is a massive opportunity to boost private sector funding in NbS towards the estimated annual US\$536 billion that is required to meet the UN's cross-cutting climate and biodiversity goals (Commonwealth Secretariat, 2021).

3. Importance of co-creating Nature-based Solutions with Indigenous Peoples and Local Communities

The convergence of multiple knowledge systems has been highlighted as necessary to reach climate and biodiversity goals (Garnett et al., 2018). Hence, Indigenous Knowledge Systems are increasingly being brought into present-day environmental science and land management practices. Yet, Indigenous Peoples have long developed their approaches to climate change, which facilitated carbon storage for thousands of years (ICA, 2021, Artelle et al., 2019). Failing to centralize these approaches in the development and implementation of NbS will result in perpetuated acts of colonialism, continued seizure of territories from Indigenous communities, and the continued erosion of Indigenous sovereignty over knowledge and resources (M'sit No'kmaq et al. 2021; Prosper et al. 2011; Townsend et al., 2020). Further, Indigenous territories span all of Canada and occupy large segments of land outside large urban centers, with most being currently explored for NbS implementation (Artelle et al., 2019). Thus, scaling up Nature-based Solutions in Canada must proceed in a direct co-creative process with Indigenous Peoples and Local Communities (IPLC). Here, we explore three important elements that underscore the importance of designing NbS with IPLC to maximize carbon and biodiversity benefits.

Boundaries and stewardship on Indigenous lands for improved ecosystem management

Globally, Indigenous land boundaries and land uses are poorly understood and quantified. Still, it is estimated that Indigenous communities, despite comprising less than 5% of the world's population, protect 80% of the world's biodiversity (Raygorodetsky, 2018) and retain sovereignty of approximately 40% of the remaining intact ecosystems (Garnett et al., 2018). This is likely an underestimate given that many

Indigenous communities maintain ties to landscapes lost to colonial land grabs.

Canada is no exception. Around 7% of Canada is federally legislated for reserves, land claim settlements, and Indian Lands (Gocke, 2013; Artelle et al., 2019). Yet, it is increasingly evident that Indigenous rights, titles, and responsibilities apply to a far greater portion of Canada. When considering all the land depicted under Indigenous treaties between the Crown and First Nations in Canada (Aboriginal and Treaty Rights Information System (ATRIS), 2021) and recognizing that communities have maintained ties to land lost during colonial times, Indigenous lands account for over 80% of Canada's landmass. The western concept of marking exclusive ownership or use rights is also problematic. Euro-Canadian cartography and mapping of lands solidified the borders and boundaries of colonial governments, ignoring the ways in which Indigenous Peoples had already mapped their land (Hunt & Stevenson, 2017).

Globally, degradation and fragmentation by developed nations have reduced the number of pristine ecosystems. Suppression of Indigenous stewardship actions have led to catastrophic consequences in many Canadian ecosystems that are still being felt today. As such, there is a need to work towards common perceptions of land management responsibilities to capture all opportunities Canada has to preserve, promote, and support the historical and active Indigenous stewardship of carbon and ecosystems.

Irrecoverable carbon on Indigenous lands

Stored carbon may be considered irrecoverable if the timeframe to recovery exceeds necessary emission

targets (Noon et al., 2021). In Canada, the amount of irreplaceable carbon within Indigenous boundaries varies greatly, but we estimate that 80% of carbon-rich peatlands occur within the bounds of Indigenous lands (Government Canada, 2021a). ([Interactive map of Irrecoverable Carbon within Indigenous Treaties in Canada](#)). Indeed, Indigenous Treaty 9 and Treaty 5, which overlap with the Hudson Bay Lowlands in Ontario and Manitoba, contain one of the largest peatland and carbon pools on Earth (Packalen et al., 2014). Based on our calculations of irrecoverable carbon contained in Canadian peatlands (using data from Noon et al. 2021), we estimate that 4.8 Gt of carbon exists in lands defined by Indigenous Treaties. This represents three orders of magnitude more carbon than the annual Canadian carbon emissions (780Mt). Despite this, only 1 of the 62 projects federally funded to establish Indigenous Protected Areas² (IPA) in Canada overlaps with Ontario’s part of the Hudson Bay lowlands.

To maximize the irrecoverable carbon and biodiversity benefits on Indigenous lands, we need to understand: a) what are the current spatial and temporal distributions of Indigenous management activities and land uses that impact carbon storage, biodiversity,

and resilience? b) what are the direct and indirect impacts of Indigenous land management activities on carbon storage, biodiversity, resilience, and human health? c) how can this data be obtained working together with Indigenous Peoples and respecting their data sovereignty?

Carbon potential beyond federally protected areas in Canada

In Canada, federally protected areas (i.e., national, provincial, territorial parks, and Indigenous Protected Areas) account for only 12.5% of land area and 13.8% of marine area (Government of Canada, 2021b). Further, we estimate that less than 20% of Canadian peatlands are federally protected, accounting for only 1.2 Gt of stored carbon. Therefore, major opportunities exist for carbon-driven NbS beyond federally protected lands, to increase both carbon uptake and land/marine coverage.

Questions to help determine regions to prioritize include: What is the extent of all carbon rich habitats in Canada, such as peatlands, grassland, forests, and wetlands? How can we improve our estimates of extent and health within and across habitat types?

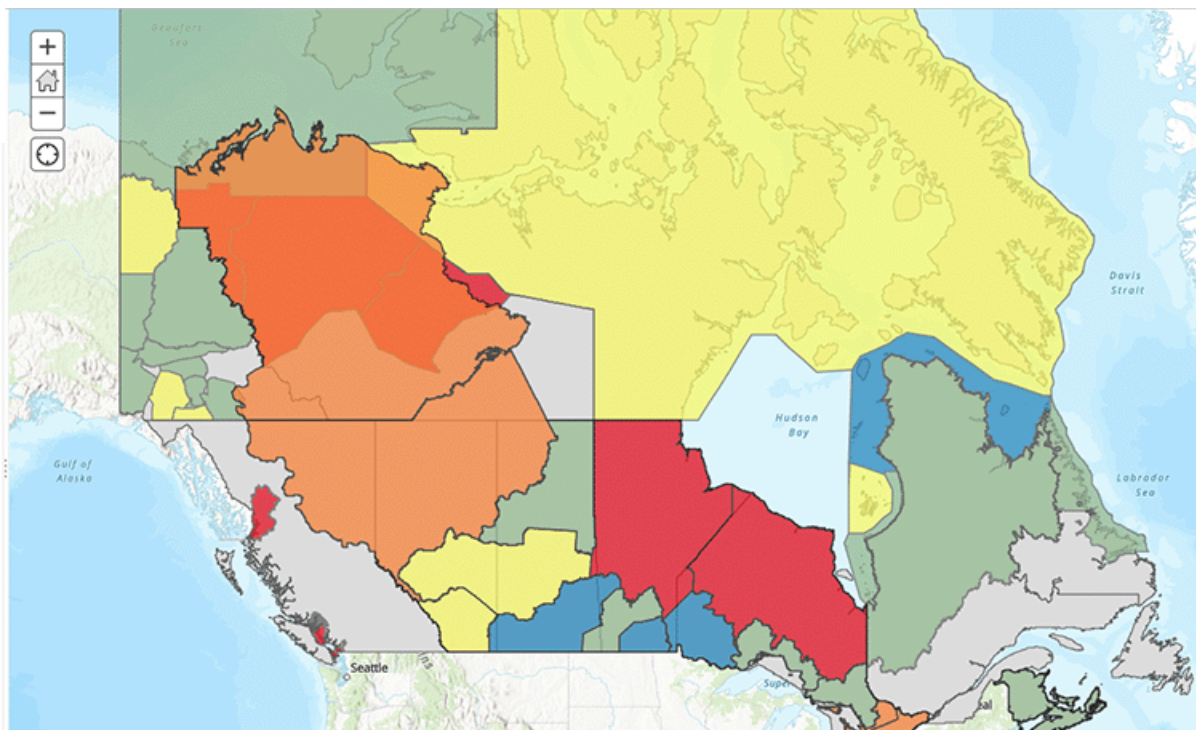
Figure 1: Irrecoverable Carbon in lands under Indigenous Treaties

Legend

Mean carbon (MgC/Ha)

- 20.000001 - 85.000000
- 15.000001 - 20.000000
- 10.000001 - 15.000000
- 5.000001 - 10.000000
- 0 - 5.000000

Canadian Federal Boundaries



2 The term Indigenous Protected Areas is a regulatory term that encompasses established or proposed protected areas under Indigenous stewardship, within federal lands (Government Canada, 2021a).

4. Structuring successful NbS with Indigenous and local partners

On October 26, 2021, Sustainability in the Digital Age and Future Earth held a series of virtual, expert convenings to inform the scale-up of equitable Nature-based Solutions in Canada. The convenings took place over three, half-day sessions and engaged over 100 expert participants (75% from Canada, 25% international including US, South America, Africa, and Europe). The workshops gathered actors representing the private sector, research communities, Indigenous communities, and nonprofits, and included over 20 Indigenous leaders, Elders, experts, and Chiefs. Each half-day explored one of three central themes:

1. Exploring the connection of Indigenous worldviews and technology through digital technologies
2. Enabling equitable Nature-based Solutions (NbS) for climate change mitigation and ecosystem resilience to climate change.
3. Leveraging digital technology for innovating, strengthening, and upscaling Nature-based Solutions

The outcomes from all three workshops were then synthesized with other background research and evaluated with the Indigenous Elders, experts, and Chiefs that attended the workshops. The following 5 principles can be followed to successfully work together with Indigenous partners in the implementation of Nature-based Solutions:

1. **Include, consult, and partner with Indigenous Peoples and Local Communities**

The only way Canada can reach climate and biodiversity goals equitably is by building NbS

in a direct co-creative process encompassing collaboration and consent of Indigenous communities. Over 600 Indigenous communities live within Canada, representing First Nations, Inuit, and Métis Peoples, each with teachings grounded in their own localities (Townsend et al., 2020). As such, any co-development of NbS or technological applications must be developed locally and be culturally relevant to those it is meant to serve. Information used for these purposes must be validated by Elders and Knowledge Holders from the community to ensure authenticity and proper representation (Bartlett, Marshall, & Marshall, 2012; Berkes & Berkes, 2009). Lastly, NbS needs to support the resurgence and revitalization of Indigenous Peoples from the effects of colonialism. This means funding for Indigenous communities to lead their own solutions, supporting language revitalization, and the return of Indigenous lands. All projects implemented together with Indigenous partners should aim to strengthen their land and resource rights, their institutions, organizations, and networks to support concerted action to protect their land, nature.

Example: The [Elephant Hill Riparian Restoration Project](#) follows this principle as it exemplifies collaboration between First Nations, private landowners, government, and other stakeholders, and is training Secwepemc technicians for surveys and in-stream habitat improvement interventions to collect 5-year time series data.



2. Prioritize synergistic goals by working bottom-up



To ensure NbS can be implemented inclusively and equitably, precision in framing the goal before a project begins is crucial. Considerations of human rights protection, food security, access to potable water, biodiversity conservation, land conservation, cost of implementation and maintenance, and ability to co-design with impacted communities, should all be weighed along with carbon uptake potential at the outset of any decision to invest in each NbS. Since all these considerations can only be assessed when working with specific communities, projects must be implemented from a bottom-up approach. Admittedly, because NbS often addresses many societal challenges simultaneously, prioritizing some in a goal-setting process will inevitably lead to trade-offs between competing goals. Yet, decision-making should be based on the “no regret” principle, where the priority is to minimize harm before optimizing certain benefits (Rizvi et al., 2014) and where NbS projects should minimally aim to maintain biodiversity and ideally to increase it in concert with prioritizing benefits for impacted communities (IUCN, 2020) to pursue and maintain sustainable livelihoods.

Example: The [Indigenous Guardians](#)

program is a successful example of addressing multiple goals encompassing societal, economic, and biodiversity issues. The program shifted the conversation to one where Indigenous and Crown representatives came together to collaborate on land and biodiversity conservation, strengthening communities, and fostering local and regional economic development. It helped the West Moberly and Sauleau First Nations in British Columbia's Peace region expand protected areas from 4.2% to 6.7% of the landscape providing protection for endangered species, increasing the protection of the carbon pools, and supporting a caribou penning project, all within the spirit of reconciliation (Cox, 2020).

3. Consider who will be impacted by the project, from local to global scales



Working with the beneficiaries of the NbS projects during the project design phase is crucial to ensure that projects can be responsive to both local and global needs (Beaudouin, 2020). The granularity of data must first reflect local context and place-based needs. Only then can it be used to link global benefits with local needs and vice versa. Carbon uptake and food security are two examples of how local and global needs can align under one project. While carbon is an issue of planetary scale, food security is more localized, and considering them together offers a balanced approach.

Example: In Nunavut, 78.7% of children live in food-insecure households and, overall, northern territories have the highest food insecurity across all Canadian provinces (Tarasuk & Mitchell, 2020). Rather than aiming to solve a global issue (e.g. carbon uptake) in this context, it is important to consider how an NbS could first provide local food security, without necessarily sacrificing global needs. For example, research by Unc et al., (2021) shows that the conversion of northern lands to agriculture may generate a 76% loss of carbon currently stored in vegetation and soils. However, interdisciplinary approaches such as agricultural NbS, may allow for selection of superior carbon fixing crops, providing higher food security while still limiting the carbon release of this land conversion (Nesshöver et al., 2017).

4. Recognize all knowledge systems are equal



The co-development of goals by non-Indigenous and Indigenous groups and communities should also happen within collaborative spaces, where all knowledge systems are respected. There are multiple conceptual frameworks to achieve this, such as the *ethical space of engagement* for discussions around Indigenous and Canadian legal systems (Ermine, 2007) and the vast diversity of long-standing Indigenous frameworks of knowledge coexistence (Reid et al., 2021). One widely used framework known as Two-Eyed Seeing, can also help operationalize ways of coming together from distinct knowledge systems (Bartlett et al., 2012; Reid et al., 2021). While this process may not be straightforward, shifting and adjusting to different factors requires time and effort to ensure the universality is replaced with the equality of different systems (Indigenous Council of Experts (ICE), 2018; Ermine 2007). This process can help to ensure that everyone can work towards goals effectively and ethically.

Example: The [Climate Atlas of Canada](#) is a new tool explicitly designed for cross-epistemological conversation, using a Two-Eyed Seeing approach that equally values climate science and Indigenous Knowledge Systems. Using dynamic and statistical downscaling methods, the Atlas integrates climate models with Indigenous stories, Indigenous place names, and local priorities to identify where action is needed for effective climate change planning.

5. Nothing about us without us



Ultimately, whatever the means used to upscale equitable Nature-based Solutions, the principle of, “nothing about us without us” should be at the core of any project to ensure equity in the design process and implementation.

Example: Since 2002, Coastal First Nations and the Government of British Columbia have negotiated government-to-government agreements to steward the Great Bear Rainforest, 6.4 million hectares of coastal temperate rainforest. The project takes a holistic approach to land and water management to benefit climate change mitigation, biodiversity, and human wellbeing, and runs one of the largest carbon offset programs in Canada.



5. Potential applications of artificial intelligence and machine learning

Recent developments in artificial intelligence (AI) and machine learning could play a significant role in the planning, implementation, scaling, and monitoring of Nature-based Solutions in Canada. There is already much remote sensing data readily available and some of Canada's ecosystems are mapped extensively, in part via government frameworks. However, through our background research, we gathered over 60 examples of new types of satellite data (examples available on request) and found that many datasets in their current form are not useful for implementing NbS. In some cases, missing years or missing pixels (due to cloud interference, for example) make a dataset less useful. Some landscape features (e.g., understory vegetation and secretive wildlife) cannot be detected without on-the-ground surveys. Scale is also vital, and many recent datasets are only available at global scales. A lack of dataset interoperability is also problematic. Similar limitations hold true for carbon metrics which we also inventoried (data available on request). Measurements do not exist at a relevant scale and would also require additional processing.

Approaches to closing the data gaps

Novel machine learning data processing and classification techniques can help to downscale satellite data and fill in gaps, so that the new layers are appropriate for answering specific research questions. For example, correlative machine learning classification models, such as MaxEnt and Random Forest, can forecast invasive species range expansions (Srivastava et al. 2020), as well as peatland depth across large spatial scales (Hugelius et al. 2020). Machine learning models, such as the multilayer perceptron neural network models, variations of adaptive neuro fuzzy inference systems (Zhu et al. 2018) and the OceanParcels models – Computationally Efficient Lagrangian Simulator – (Kaandorp et al.,

2022), may also be useful for predicting water temperatures and tracking particle movements in oceans, vital metrics of ecosystem health that impact biodiversity and carbon storage, when limited data exist. Machine learning initiatives like Microsoft Azure FarmBeats are also tackling the issue of dataset interoperability by building models on fused datasets coming from sensor, satellite, and drone imagery. Ultimately a combination of big-data techniques with on-the-ground and satellite monitoring is the ideal scenario to collect and enhance data.

Novel digital technologies can enable rapid implementation of NbS, but these tools should not be treated as a panacea, nor displace traditional ecological knowledge. There are well-documented limitations with machine learning (e.g. models can be computationally intensive, highly sensitive to noise, may not be transferable) so further analysis is needed to assess how NbS could best benefit from big-data driven approaches.

This includes exploring how NbS monitoring and implementation can draw on conceptual frameworks like Two-Eyed Seeing that equally value technology and Indigenous Knowledge Systems. Building from others' work such as the [Indigenous Futures Research Centre \(IFRC\)](#) and the efforts of the [Indigenous AI Protocol Working Group](#), ensures that novel AI solutions draw on Indigenous epistemologies and ontologies. For instance, while cloud-based platforms (e.g. Google Earth Engine) are able to perform large scale analysis, data holders (including Indigenous communities and others) may require more stringent policies of data privacy and data ownership, to house sensitive information, such as locations of cultural sites and medicines. Thus, there are opportunities for cloud-based platforms to tailor new services to meet the needs of Indigenous Peoples or local communities in this area of research.

6. Conclusion

Nature-based Solutions (NbS) have the potential to contribute up to 35% of Canada's 2030 carbon reduction target (Griscom et al., 2017), yet NbS performance and long-term impacts are poorly understood. This report presents an analysis of the current NbS landscape in Canada. We reviewed 50 funding programs spanning over 200 NbS project examples to identify preliminary trends across the government, industry, and Indigenous sectors. We also conducted a series of stakeholder workshops on equitable Nature-based Solutions in Canada, that convened 100 expert participants worldwide, including 20 Indigenous Elders, experts, and Chiefs. Finally, based on a literature review, this report touches on the role of AI and machine learning to support the monitoring of Nature-based Solutions in Canada. Combining the findings of these three streams of exploration, this report makes the following conclusions.

Expanding NbS in Canada to cover peatlands and agriculture will help address current regional imbalances, increase co-benefits, and capitalize on high carbon mitigation potential.

- **Peatlands:** One of the largest peatland carbon pools on Earth is found in Canada, specifically across Indigenous Treaty 9 and Treaty 5 Lands, overlapping with the Hudson Bay Lowlands in Ontario and Manitoba. Efforts here, such as accurate mapping and ground truthing of satellite data, in collaboration with the Mushkegowuk First Nations and all provincial stakeholders, is thus critical for both the national and international fight against climate change.

- **Agriculture:** Agricultural NbS represents Canada's largest NbS carbon mitigation opportunity for 2030 (more than forest and aquatic ecosystems combined). In Nunavut, promising opportunities have been proposed to increase northern agriculture guided by machine learning monitoring, increasing both food security and carbon uptake in this area most vulnerable to climate change. Across other regions of Canada, the federal government has made a significant commitment to agricultural NbS so there is an opportunity now for parallel investments from the industry and Indigenous sectors.



Improving monitoring, reporting and verification (MRV) for NbS efforts in Canada will help evaluate the efficacy and long term impacts of NbS. This can lead to more transparent distribution of funds and better integration of NbS carbon mitigation potential into Nationally Determined Contributions.

- **Standardize and centralize NbS monitoring and evaluation data:** A standardized MRV framework and central repository of NbS efforts can provide the needed data to assess NbS efficacy and performance, guide future NbS policies and funding, and enable needs-based distribution of NbS across Canada.

- **Continue to explore big-data driven approaches:** There is a role for big-data driven approaches to improve NbS data collection and monitoring, especially when co-developed with and complemented by the communities conducting on-the-ground monitoring, as evidenced by examples throughout this report.

The right balance of technology, public and private investment, and meaningful collaboration with Indigenous communities, especially in key areas like peatlands and agriculture, can accelerate Canada's efforts to achieve net-zero and 2030 conservation targets. Standardized metrics, in combination with digital tools and inclusive stakeholder participation, have great potential to restore balance to ecosystems, optimize carbon capture, increase biodiversity, promote community resilience, and provide opportunities for reconciliation of past colonial harms.



Appendix

We assessed 50 illustrative funding programs, spanning over 200 NbS project examples, to begin to identify trends across multiple categories (i.e., project monitoring, geographic distribution, ecosystem type, project funding). We searched publicly available websites of Indigenous communities, non-governmental organizations (NGOs), industry, and the Canadian government and compiled these into three NbS categories: Government, Industry, and Indigenous-led projects. As there are no standard criteria for monitoring NbS in Canada, this review included only programs that mentioned some mechanism to evaluate results.

Table 1 presents an analysis of trends across Government, Industry, and Indigenous-led Nature-based Solutions. This analysis categorized government-led projects as those funded by the federal or provincial government. The three main government

NbS projects analyzed were the Coastal Restoration Fund, the Natural Heritage Conservation Program, and the Canada Nature Fund for Species at Risk. This analysis considered Indigenous-led programs as those implemented and available only to Indigenous Peoples. Note that government-led programs can fund Indigenous communities but are not exclusively for Indigenous communities. We did not find any private funding initiatives directed exclusively to Indigenous Peoples' projects; all projects categorized here as Indigenous-led are federally funded. Among the most representative Indigenous-led NbS, we identified the Indigenous Guardians Pilot, First Nations Adapt Program, and the Indigenous Community-Based Climate Monitoring Program. Finally, we assessed three large-scale industry-led programs funded by three private companies: Walmart, Aurora Cannabis Inc., and Shell Oil.



Table 1. Trends across NbS funding types

Category	Trend (overall and by funder type)		
Monitoring and Transparency	<ul style="list-style-type: none"> • Overall, few projects published transparent funding reports and monitoring schemes. When monitoring was mentioned, details are vague, not quantifiable or monitoring data is not publicly available. • No common performance standards across initiatives are clearly stated. Each NbS project uses its own performance metrics or individual monitoring framework (e.g., species inventory, change in forest cover, etc.) and reports directly back to the funding body. • Industry-led projects lack the most transparency among the three groups. Government-led projects were the most transparent, with reporting and monitoring done to some extent. 		
	<p>Government-led projects</p> <ul style="list-style-type: none"> • Data or metrics used are not publicly available. • Data regarding federal funding is more prevalent than provincial. • Project monitoring appears to be conducted by project funders (i.e. no external verification). 	<p>Industry-led projects</p> <ul style="list-style-type: none"> • Publicly available information is usually basic. Almost no project has publicly available monitoring data. • In limited cases, companies state the frameworks used to monitor project effectiveness. • Reporting is done directly to the related authorities and is not public. 	<p>Indigenous-led projects</p> <ul style="list-style-type: none"> • Project monitoring and transparency are variable. Some: <ol style="list-style-type: none"> include long-term monitoring with publicly available data of the project's progress, state vaguely the type of monitoring that would be in place but with no accessible data, did not mention any clear monitoring schemes. • Most projects will need additional funding to continue monitoring efforts. Unclear whether funding will be renewed.

Category	Trend (overall and by funder type)		
Geographic Focus	<ul style="list-style-type: none"> • Across all sectors, more than half of the projects (60.6%) occur either in British Columbia (BC), Ontario (ON), or Quebec (QC), provinces that together, contribute up to two thirds of Canada's GDP (Statistics Canada, 2021). • The territories (Northwest Territories, Nunavut, Yukon) account collectively for less than 9% of the projects funded but represent over 44 % of Indigenous lands (Government of Canada, 2021a). 		
	Government-led projects <ul style="list-style-type: none"> • Majority (68%) of projects funded occur in QC, ON, and BC. • Most projects funding peatland restoration and conservation are in QC. 	Industry-led projects <ul style="list-style-type: none"> • Majority of projects (82%) tend to be funded in the areas where companies base their operations, these areas being mostly within QC, ON, AB, and BC. 	Indigenous-led projects <ul style="list-style-type: none"> • Majority of projects funded (53%) occur in QC, ON, and BC. • Largest and most-funded projects take place in BC.
Type of NbS and Targeted Ecosystems	<ul style="list-style-type: none"> • Overall, restoration and protection NbS projects were far more prevalent than management NbS. • Across all sectors, we found that most NbS project types focused on aquatic and forest ecosystems. • Oceanic ecosystems represent the least funded ecosystems. Grasslands are also poorly represented. • The majority of projects had an element of biodiversity protection and conservation. • Government was the largest investor by far in agricultural NbS with over half-billion investment from 2020 to 2030 (Agriculture Canada, 2021). 		
	Government-led projects <ul style="list-style-type: none"> • Tend to focus on restoration and protection, with less emphasis on management. • Carbon sequestration and biodiversity protection are common themes. • Over 70% of the projects target forests or aquatic ecosystems. 	Industry-led projects <ul style="list-style-type: none"> • Typically centered around reforestation or afforestation, but also include clean water and community-based initiatives. • Invested the least on management NbS when compared with other project types. 	Indigenous-led projects <ul style="list-style-type: none"> • Primarily focused on protection and ecosystem management, with a theme of resilience, capacity building, and biodiversity protection. • Strong tendency to center around management and protection of aquatic habitats.

Category	Trend (overall and by funder type)		
Funding Length	<ul style="list-style-type: none"> • Variable funding timeframes with most funding available up to 5 years or less. • No specific intent to fund projects long-term based on project success (attributed to a lack of monitoring). 		
	<p>Government-led projects</p> <ul style="list-style-type: none"> • Very variable, but overall longer funding period (from 1 to 5 years). • Most 'renewed' across funding types. 	<p>Industry-led projects</p> <ul style="list-style-type: none"> • Most programs give a one-time funding payout; projects have continued yearly funding, but it is usually not long-term (less than five years). 	<p>Indigenous-led projects</p> <ul style="list-style-type: none"> • Many projects were granted funding for a pilot period despite long-term monitoring and resilience goals. • Several projects are still ongoing, with information lacking on the scheduled end or renewal date.
Funding Amount	<ul style="list-style-type: none"> • Funding ranges vary, from the hundred thousand dollars to billions per large initiative or program, with smaller amounts for smaller projects. 		
	<p>Government-led projects</p> <ul style="list-style-type: none"> • Typically the largest amount of funding per initiative. • The single largest investment (to our knowledge) is the 2 billion tree project. 	<p>Industry-led projects</p> <ul style="list-style-type: none"> • Extremely variable ranging from \$250,000 to \$6,000,000 CAD. • Exact amounts of funding are often unavailable, and only partnerships with funded organizations are publicized. • Highest funding for individual projects (vs larger program). 	<p>Indigenous-led projects</p> <ul style="list-style-type: none"> • Usually large amounts (10s of millions) for overarching projects that are divided into smaller amounts (100s of thousands) for individual initiatives. • The average fund amount for smaller projects is \$200,000.

Category	Trend (overall and by funder type)		
Access to Grant Money	<ul style="list-style-type: none"> • Many funding programs require matching funds. • Targeted regions or themes are decided mainly by funder. 		
	<p>Government-led projects</p> <ul style="list-style-type: none"> • Grants are open to non-profits, industry, community and Indigenous groups. • Most grants are matching fund grants, restricted to priority government actions and objectives. 	<p>Industry-led projects</p> <ul style="list-style-type: none"> • We did not find evidence of open calls in over 90% of the sampled projects. The way the interested company funds a project is privately arranged. • Funding is predominantly allocated to the top 5 largest conservation NGOs (OECD, 2020). • Often, the funded organization acts as an intermediary deciding which projects are funded. 	<p>Indigenous-led projects</p> <ul style="list-style-type: none"> • 95% of the funding programs are limited to actions within Indigenous territories. • 40% of the funding programs available are fund-matching.
Motivation for Funding	<ul style="list-style-type: none"> • Projects are more frequently motivated by compliance than by co-benefits. • Ecosystem services are very seldom mentioned in any investment/monitoring effort apart from Indigenous Projects. 		
	<p>Government-led projects</p> <ul style="list-style-type: none"> • Meeting international emissions commitments as well as political campaign commitments (Tomlinson, 2021). 	<p>Industry-led projects</p> <ul style="list-style-type: none"> • Carbon credits, carbon neutrality for the company, public image. • Cheaper way to meet regulatory requirements and risk avoidance for projects. 	<p>Indigenous-led projects</p> <ul style="list-style-type: none"> • Protection of habitat, wildlife, flora, clean water, and the provision of ecosystem services. • Motivation aligns with cultural and historical significance of the areas as well as value for subsistence.

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