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This chapter is an excerpt from the CCA report *Nature-Based Climate Solutions*. Information about the charge, the expert panel authors, the sponsor, other ecosystems, and references can be found in the full report.

The Panel's Summary Assessment of NBCSs

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NBCSs are increasingly recognized as practices that can help Canada and other countries achieve potentially significant reductions in atmospheric GHGs through the intentional enhancement of carbon sequestration. This growing awareness has led to a desire among researchers, policymakers, stakeholders, and communities to better understand how the protection, restoration, and management of ecosystems may aid in the enhancement of GHG sequestration (or reduced release of GHGs to the atmosphere). This chapter synthesizes the Panel's analysis and findings on NBCSs across different Canadian ecosystems and land-use types, summarizing key findings in relation to the Panel's charge. This synthesis provides a comparative analysis of all the NBCSs considered by the Panel according to the four main criteria used in its assessment: (i) GHG mitigation potential (in terms of either carbon sequestration or avoided emissions); (ii) constraints on continued sequestration and the permanence of carbon stocks; (iii) the costs and feasibility of implementation; and (iv) co-benefits and trade-offs. The Panel also outlines its findings on the need for meaningful and ongoing engagement with, and leadership by, Indigenous communities in relation to the potential success of NBCSs. Key sources of uncertainty, data gaps, and research priorities are identified and discussed. Moreover, the Panel's assessment takes into consideration various Indigenous perspectives on NBCSs so as to reflect a more comprehensive understanding of the potential benefits (or harms) associated with these activities.

7.1 Assessing the GHG Mitigation Potential of Canada's Carbon Sinks

Main Question

What is the potential for nature-based solutions to help meet Canada's GHG emission reduction goals by enhancing carbon sequestration and storage, and reducing emissions, in managed and unmanaged areas (e.g., wetlands, agricultural and forest systems, harvested wood, and as blue (marine) carbon), and taking into account the major non-CO_2 climate impacts that can be reliably estimated (e.g., non-CO_2 GHG emissions, albedo, and aerosols)?

NBCSs are affected by ecosystem responses to a changing climate, can produce additional climate effects, and have mitigation potentials that operate on different timescales

The GHG mitigation potential of NBCSs cannot be assessed in isolation from their impacts on other factors affecting the Earth's climate. As suggested in the Panel's charge, changes in land-use and land management practices may not only alter the rates of uptake or release of GHGs but can also alter the surface temperature of the Earth. In cases such as the expansion of forest area over land covered by snow seasonally, decreases in reflectivity (i.e., albedo) can offset a portion of carbon sequestration benefits (NASEM, 2019), thus reducing the overall mitigation potential. The release of volatile organic carbon compounds from forests and plants can also affect climate through the creation of aerosols and associated effects on cloud formation and radiative forcing, potentially enhancing mitigation benefits from NBCSs (Laothawornkitkul *et al.*, 2009; Després *et al.*, 2012).

Conversely, a changing climate also stands to impact the ability of ecosystems to sequester carbon or alter their GHG emissions rates. Increasing temperatures and changes in precipitation can lead to shifts in environmental conditions and associated ecosystem changes. Across much of Canada, higher temperatures and a lengthening fire season are expected to increase the likelihood and intensity of wildfires (Canadell *et al.*, 2021; Jain *et al.*, 2022), leading to larger releases of GHGs from Canada's extensive forests over time. In some areas of Canada, however, warming has led to increased productivity and maintenance of existing carbon stocks (if not increased carbon sequestration) (D'Orangeville *et al.*, 2016; Ziegler *et al.*, 2017).

Soils across the country will also be affected, as higher temperatures coupled with extreme precipitation events lead to the destabilization of carbon stocks. This is a result of increased soil redox fluctuations, alterations in microbial metabolism, and hydrology (including the form and timing of water input), all of which are key drivers of carbon fluxes, in turn regulating soil carbon stocks in forests (Section 3.3.1). More frequent and longer anoxic conditions increase CH_4 emissions in freshwater wetlands and aquatic systems affected by changes in land use, while heat and drought can encourage higher rates of decomposition of soil organic matter as freshwater wetlands grow drier, resulting in increased emissions of CO_2 and N_2O (Sections 5.4.3 and 5.4.4).

Furthermore, sea-level rise threatens to inundate some coastal areas, resulting in the loss of ongoing carbon sequestration in tidal wetlands and uncertain impacts on existing carbon stocks in submerged sediments (Section 6.4.1). In other areas of Canada, the threat of rising sea levels is lower due to continued post-glacial rebound (i.e., land uplift) and neotectonic activity (i.e., earthquakes). In general, these impacts may lessen the mitigation potential of NBCSs.

The timing of the mitigation potential of NBCSs varies. Some interventions result in immediate but short-term benefits such as the reduction of N_2O emissions with improved nutrient management of croplands (Chapter 4), while NBCSs involving land-use and ecosystem changes have impacts associated with gradual increases in carbon sequestration over longer timeframes (e.g., restoration of wetlands; Chapters 5 and 6). The sequestration and avoided emissions potential of forest management NBCSs varies, as some have limited initial impact (e.g., restoration of forest cover) while others yield immediate results (e.g., use of harvest residues in bioenergy) yet could result in net emissions over a longer timeframe (Section 3.3.2). NBCSs such as restoration of forest cover can even have net negative impacts on climate change mitigation in the years immediately following implementation due to albedo effects (Section 3.3.3), as could restoration of certain freshwater wetlands with increased CH_4 emissions immediately post-restoration (Section 5.3.1).

There are also temporal limits to some systems' abilities to uptake carbon. Some NBCSs involve ecosystems with no well-defined biophysical limits on carbon sequestration and can continue to sequester and store carbon indefinitely under favourable environmental conditions (e.g., avoided conversion of peatlands; Section 5.4.1). In others, sequestration can continue only up to a threshold, after which the net carbon flux reaches equilibrium (e.g., no-till agriculture; Section 4.4). All of these factors were considered by the Panel in its evaluation of the overall mitigation potential of NBCSs in Canada.

Table 7.1 provides a synthesis of the Panel's assessment of the overall potential associated with a range of NBCSs in forests, agricultural lands, grasslands, freshwater ecosystems, tidal wetlands, and seagrass meadows. The table indicates the extent of limits on sequestration and the vulnerability of stored carbon to atmospheric release (see the Appendix for additional details about the Panel's ratings and the scales for this assessment). Table 7.1 does not include consideration of all climate effects, but adjustments were made to account for albedo and CH_4 and N_2O emissions, where relevant to certain NBCSs. However, the Panel notes there may be uncertainty surrounding these climate effects, which are further explored in Chapters 3–6. Changes to land surface albedo, in particular, may alter the climate change mitigation benefits of increased carbon sequestration in terrestrial ecosystems. For example, the restoration of forest cover reduces the surface albedo of a given geographical area, thereby increasing the absorption of incoming solar radiation and in turn surface temperature (Section 3.3.3). The uncertainties related to the influence of climate effects should be considered when assessing the magnitude of sequestration potential of NBCSs.

Table 7.1 Summary Assessment of NBCS Mitigation Potential, Permanence, and Feasibility

	GHG Mitigation Potential[31]		Permanence		Feasibility	
NBCS	**Annual reduction** Mt CO_2e /yr in 2030	**Annual reduction** Mt CO_2e /yr in 2050	**Biophysical vulnerability to atmospheric release**	**Socioeconomic vulnerability to atmospheric release**	**Cost** mean MAC in 2030[32] (\$/t CO_2e)	**Barriers to implementation and enhanced use of NBCSs**
Forest						
Improved forest management	5 – 15††	>25††	Moderate**	High**	\$57†††	Major*
Restoration of forest cover	0 – 1††	15 – 25††	Moderate**	Moderate*	\$1,203††† (\$96 in 2050)	Major***
Avoided forest conversion	1 – 5†	1 – 5†	Moderate**	Low*	\$90†††	Moderate***
Urban canopy cover	0 – 1†††	1 – 5†††	Low*	Moderate*	\$150††	Moderate*
Agriculture & Grasslands						
Crop management	5 – 15††	5 – 15††	Moderate**	Low**	\$63 – 103††	Minor**
Soil management	5 – 15 ††	5 – 15 ††	Moderate**	Low**	\$74 – 150††	Moderate**
Nitrogen management	5 – 15†††	5 – 15†††	–	–	\$56††	Moderate***
Agroforestry	5 – 15†	5 – 15†	Low**	High***	\$11 – 3,874††	Moderate**
Avoided grassland conversion	5 – 15†	1 – 5†	Moderate*	High**	\$144††	Moderate*
Grassland restoration	0 – 1†	0 – 1†	Moderate*	Low*	\$102††	Moderate*
Improved grassland management	0 – 1†	0 – 1†	Moderate*	Low*	\$40††	Minor**

(Continues)

31 Mitigation potential is cumulative across all areas of opportunity determined by Drever *et al.* (2021). Assumptions about area of opportunity are discussed in Sections 3.3, 4.3, 5.3, and 6.3.

32 Costs are only available to 2030; NBCSs with long-term sequestration potential, including restoration of forest cover, have a lower cost per tonne in 2050.

	GHG Mitigation Potential		Permanence		Feasibility	
NBCS	**Annual reduction** Mt CO_2e /yr in 2030	**Annual reduction** Mt CO_2e /yr in 2050	**Biophysical vulnerability to atmospheric release**	**Socioeconomic vulnerability to atmospheric release**	**Cost** mean MAC in 2030 (\$/t CO_2e)	**Barriers to implementation and enhanced use of NBCSs**
Inland Freshwater Aquatic Systems						
Wetland restoration (peatlands)	0 – 1††	0 – 1††	Moderate**	Low*	$403†	Moderate***
Avoided conversion (peatlands)	5 – 15†	1 – 5†	Moderate**	High*	$363†	Moderate***
Wetland restoration (freshwater mineral)	0 – 1††	0 – 1††	High***	Moderate*	$497††	Moderate***
Avoided conversion (freshwater mineral)	1 – 5††	0 – 1††	Moderate***	Low*	$29††	Minor**
Coastal Zone						
Tidal wetland restoration	0 – 1††	0 – 1††	Moderate**	Low**	$89†	Moderate**
Tidal wetland conservation	–	–	Moderate**	Low***	–	–
Seagrass restoration	0 – 1†	0 – 1†	Moderate***	Moderate*	$150†	Moderate*
Seagrass conservation	0 – 1†	0 – 1†	Moderate*	Moderate*	$150†	Minor*

Evidence Scale rating: *Limited **Moderate ***Robust
Panel Confidence Scale rating: †Limited ††Moderate †††High

Estimates of mitigation potential are organized into five categories (0–1, 1–5, 5–15, 15–25, and >25 Mt CO_2e /yr) to characterize the likely range of annual GHG mitigation (sequestration or avoided emissions), based on Drever *et al.* (2021) at both 2030 and 2050, as detailed in Tables 3.2, 4.4, 5.2, and 6.2. Costs are the mean marginal abatement costs (MAC) for 2030, as reported in Cook-Patton *et al.* (2021), with the exception of restoration of forest cover, which also includes an estimate of the 2050 mean MAC in parentheses. The remaining columns are based on the Panel's assessment framework outlined in Section 1.2.3, which includes consideration of factors impacting permanence and feasibility (here indicated as barriers to implementation and enhanced use of NBCSs). Each column was assessed in terms of either quality of evidence (represented with *) or the Panel's confidence in the estimate provided (represented with †). Full details and definitions for rating scales are presented in the Appendix.

Successful implementation of NBCSs can meaningfully contribute to climate change mitigation, however, they will not achieve Canada's GHG reduction targets on their own

The NBCSs considered by Drever *et al.* (2021) were estimated to have the technical potential of approximately 78 Mt CO_2e/yr in 2030, ranging between 41 and 115 Mt CO_2e at a 95% confidence interval. In contrast, data for Canada extracted from Roe *et al.* (2021) provide an estimated total technical mitigation potential for a similar set of interventions as ~1,286 Mt of CO_2e/yr between 2020 and 2050. The disparity between Roe *et al.* (2021) and Drever *et al.* (2021) is primarily driven by differences in constraints on where wetland and forest NBCSs can be implemented and/or harnessed. In the Panel's view, this results in significant overestimation in many cases of mitigation potential by Roe *et al.* (2021). As such, the Panel notes that estimates by Drever *et al.* (2021) generally provide a more credible and useful baseline for Canadian policymakers, although the assumptions or evidence underlying some estimates may similarly result in over- or underestimation, or may be influenced by short-term time constraints (i.e., to 2030).

> "Even achieving the approximate 6% reduction via NBCSs will require aggressive policy support."

According to these estimates, it is unlikely that NBCS emissions mitigation in Canada could exceed 115 Mt CO_2e/yr by 2030, even with aggressive support and deployment. A credible estimate of the overall cost-effective mitigation potential (e.g., carbon sequestration or emissions reductions achievable at \$100 per tonne or less) is approximately 40 Mt CO_2e/yr in 2030 (Cook-Patton *et al.*, 2021). This value translates to approximately 6% of Canada's current annual emissions — estimated at 672 Mt CO_2e in 2020 (ECCC, 2022b) — or the equivalent of removing approximately 25.4 million cars from Canadian roads,[33] suggesting that NBCSs would play a supporting and meaningful role in achieving national emissions reduction goals. They would need to complement other stringent policies aimed at reducing emissions from fossil fuel combustion and other sectors to achieve Canada's targets. Even achieving the approximate 6% reduction via NBCSs will require aggressive policy support.

33 The average emissions for passenger cars in Canada between 2010 and 2020 was 36.45 Mt CO_2e/yr (ECCC, 2022c). The number of motor vehicles (not including farm, off-road, or construction vehicles) is 23.421 million (averaged between 2009 and 2019) (StatCan, 2020, 2022). NBCSs, which were estimated to have a mitigation potential of 39.6 Mt CO_2e, would then be equivalent to the emissions reduction of removing 25.4 million passenger cars from Canada's roads.

Forest, agricultural land, grassland, and peatland NBCSs have the highest GHG mitigation potentials nationally between now and 2050

Practices in forest, agricultural land, grassland, and peatland NBCSs have the greatest potential to sequester additional carbon or reduce GHG emissions in the next three decades, though the dynamics and temporal aspects of these NBCSs differ significantly. In the short term, actions that avoid emissions in demonstrably at-risk areas tend to lead to immediate mitigation benefits; these include avoided conversion of forests, grasslands, and peatlands. Yet the Panel notes that, in many instances, demonstrating the additional nature of avoided conversion can be problematic, especially when projecting into the future of mid- to long-term timescales. For example, despite having a relatively high mitigation potential, avoided conversion of peatlands is largely uncertain due to assumptions around the future demand for oil, gas, and minerals (Section 5.3.3). Issues surrounding additionality and leakage may arise as certain areas become protected, and industry moves to use unprotected but still vulnerable areas elsewhere.

Over decades, however, the impacts of improved management and restoration actions become more significant. Restoration of forest cover on managed and unmanaged land has the theoretical potential to sequester more than 25 Mt CO_2e/yr by 2050 in Canada (Table 3.2), though the adoption of these NBCSs at larger scales is subject to many implementation challenges (e.g., access to remote areas for planting, environmental and anthropogenic pressures on land available). The expansion of forest cover may also have slight negative implications as decreased albedo from expanding canopy — and thus surface warming — occurs early, while biomass accumulation from growth accrues slowly over decades as forests mature (Section 3.3.3). In contrast, in agricultural areas, interventions in crop and soil management practices can lead to benefits in soil organic carbon concentrations or emissions reductions on shorter timescales; however, the rate of soil carbon accumulation gradually diminishes over time, eventually reaching a saturation point, and atmospheric fluxes eventually become net neutral (Section 4.4).

Wetland restoration pays off in the long term and at the regional scale

When evaluated at the national scale, the opportunity for increased carbon sequestration in restored coastal and freshwater wetlands is comparatively low with most NBCSs, likely leading to less than 1 Mt CO_2e/yr in additional sequestration. For freshwater wetlands, this largely reflects increased CH_4 emissions in the initial years post-restoration, though once the radiative forcing from CH_4 diminishes (due to its shorter atmospheric lifetime compared with CO_2), these systems will convey greater carbon sequestration in future decades

(Section 5.3.1). Moreover, both peatland and freshwater restoration can yield large CO_2e sequestration on a per-hectare basis, but the area of opportunity in Canada is relatively small compared to other NBCSs, resulting in a smaller national potential.

For marine coastal wetlands, the area of opportunity for restoration may be smaller than other national-scale NBCSs, but the local impacts of restoration may be substantial. For avoided conversion of marine coastal wetlands, existing no-net-loss policies in Nova Scotia, New Brunswick, and Prince Edward Island mean that wetland conservation fails to satisfy the additionality criterion (Section 6.5.2). However, regional differences in the opportunities for these NBCSs are significant (i.e., differences in climate, local hydrology, vegetation, and policy); such NBCSs could still play an important role in regional GHG mitigation actions, while simultaneously enhancing the ecosystem services and other co-benefits that flow from these systems.

7.2 Assessing NBCS Uncertainties, Including Considerations of Permanence and Feasibility

What are key uncertainties, and to what extent may achievement of enhanced sequestration be affected by impacts of climate change, carbon leakage (e.g., displaced elsewhere), non-additionality (e.g., sequestration would have happened anyway), impermanence (e.g., due to wildfires, drought, or land conversion) and other implementation issues?

National-level estimates of NBCS mitigation potential in Canada are based on limited evidence and many remain subject to high levels of uncertainty

Evidence of changes in GHG fluxes specific to Canadian NBCSs and carbon sinks is often limited, and studies based on similar ecosystems in other regions are not always applicable. Impacts on ecosystem processes associated with the higher latitude of Canadian terrestrial and coastal ecosystems can make studies from elsewhere in North America (or other temperate areas) less relevant (e.g., seagrass meadows; Chapter 6). Uncertainties are magnified when attempting to estimate the national GHG mitigation potential of these practices across Canada. These estimates rely on the ability to calculate the area over which such practices can be deployed and often depend on underlying assumptions that are open to debate (Sections 3.3, 4.3, 5.3, and 6.3). These include considerations and constraints related to jurisdictions and regulatory controls, the feasibility of access, the acceptability of impacts on other sectors or economic activity, the ecological and environmental suitability of regions or areas for a given intervention, social and behavioural barriers to adoption, and the need for intergovernmental coordination.

Even excluding considerations related to socioeconomic feasibility, existing geographical and environmental data are insufficient, in some cases, to identify areas over which NBCSs can be implemented or expanded. For example, the absence of adequate knowledge regarding the extent of seagrass meadows (such as a clear baseline or historical data) results in high uncertainty when estimating the scope of seagrass restoration (Section 6.3.4). While the availability of geographic and environmental data significantly enhances the certainty of an NBCS's potential, the Panel notes that complete datasets are unlikely to be acquired. Thus, the full extent of the area of opportunity for an NBCS is not necessarily required for successful implementation — rather, what is needed is improved monitoring of GHG mitigation and ecosystem processes associated with NBCSs to better understand the potential for implementation.

The vulnerability of Canada's carbon stocks represents a significant climate change liability that could easily counteract any identified mitigation potential

The Panel assessed all carbon stocks associated with NBCSs as potentially vulnerable to being emitted to the atmosphere due to biophysical and socioeconomic factors. Biophysical threats to natural carbon stocks stem from changing temperature and precipitation patterns, as well as sea-level rise. Aboveground forest biomass is vulnerable to release due to increasing risks of wildfire and insect disturbance; wildfires also pose a risk to soil carbon sequestered in forests and peatlands (Sections 3.4 and 5.4). In some cases, coastal wetlands are likely to be "squeezed" between ongoing coastal development and rising sea levels (Section 6.4.1). These impacts vary regionally and are offset by neotectonics and post-glacial rebound on Canada's west and northern coasts, respectively, reducing the rate of sea-level rise and accumulation of tidal wetland soil.

Carbon losses from peatlands due to wildfire and drought may be offset by longer growing seasons and CO_2 fertilization; however, there is significant uncertainty about the implications of permafrost thaw in peatlands, in particular, as it may increase carbon sequestration or enhance carbon losses from the current soil stocks (Section 5.4.3). Similarly, the longer thermal stratification periods in lakes and reservoirs may lead to prolonged anoxic conditions and increased CH_4

emissions from aquatic systems (Section 5.4.4). In the agricultural sector, the primary biophysical threat is drought (as dry conditions result in soil erosion and degradation), but these systems (much like peatlands in areas of high potential resource extraction) are also at higher risk of losing stored carbon due to socioeconomic factors such as changes in market conditions, policy regimes and incentives, or landowner preferences, which can lead to losses of previously stored carbon (Section 4.4).

NBCSs are also not uniform in the way they affect the vulnerability of carbon stored in these systems. For example, some forest management NBCSs (fire management activities, including Indigenous cultural burning; Box 3.3) may decrease the risk of large losses of stored carbon (Section 3.6.1). Alternatively, some management practices (e.g., restoration of forest cover with single species) may reduce resilience to future disturbances (e.g., insect-related disease outbreak) and are less likely to effectively store carbon over longer time periods (Section 3.3.2). The Panel notes that increased release of carbon from natural sources may reduce the efficacy of NBCSs, and thus, the protection and/or conservation of these systems is imperative to achieve successful climate mitigation.

> "Increased release of carbon from natural sources may reduce the efficacy of NBCSs, and thus, the protection and/or conservation of these systems is imperative to achieve successful climate mitigation."

A comprehensive assessment of carbon sink potential requires factoring in political and socioeconomic aspects related to feasibility and cost of implementation

Estimates of mitigation potential can be misleading given costs, jurisdictional challenges, and socioeconomic barriers to the implementation of NBCSs in some sectors (Section 2.3). Understanding the practicalities of implementation requires consideration of both the direct costs of these interventions, as well as related factors such as opportunity costs associated with other potential land-uses, social and cultural barriers to adoption, the risks of emissions leakage, and the availability of suitable policy and regulatory tools for supporting deployment (e.g., markets, payments for ecosystem services) (Sections 3.5, 4.5, 5.5, and 6.5). Drever *et al.* (2021) estimated that the cost-effective potential GHG mitigation of NBCSs in Canada is roughly half (51%) of their estimated total technical potential. Roe *et al.* (2021) estimated that ~30% of their estimated technical GHG mitigation potential in Canada is below the cost-effective threshold of \$100/t CO_2e.[34] Cost estimates underlying these calculations are based on limited evidence, often extrapolated from a few studies focusing on specific regions or contexts. Limited consideration of factors such as leakage, commodity market effects, efficacy of policy instruments, additionality, transaction costs, and behavioural or social resistance to the adoption of new practices means that they are more likely to be underestimated than overestimated. In the Panel's view, more research assessing these factors is needed.

In the Canadian context, lower-cost abatement opportunities averaging less than \$50/t CO_2e include most agroforestry NBCSs, as well as avoided conversion of mineral wetlands and adding legumes to pastures (Table 7.1). The Panel notes that, although agroforestry practices are estimated to be relatively cost-effective, these costs are likely to be underestimated and will be affected by uncertainties, such as issues of reversibility and unaccounted-for nuisance costs. NBCSs achievable at slightly higher costs — between \$50 and \$100/t CO_2e — with relatively short-term mitigation effects include improved forest management, avoided forest conversion, cover crops, reduced or no-till practices, and nutrient management; most of these NBCSs are included in the Highest Overall Promise category of Figure 7.1.

For some of these NBCSs, implementation may even be associated with lower cost or even no-cost opportunities, depending on local soil and environmental characteristics (e.g., nitrogen management). Other NBCSs in this cost bracket have either a low mitigation potential on a national scale, or their effects are only realized at long timescales. For example, tidal wetland restoration (with an average marginal abatement cost (MAC) of \$89/t CO_2e) has a regionally limited mitigation potential and low Panel confidence in the MAC itself. In the short term, restoration of forest cover has a very high MAC (\$1,203/t CO_2e in 2030); however, when considered over the long term, the costs are reduced to \$96/t CO_2e and the mitigation potential increases as trees gradually sequester carbon, offsetting initial capital expenditures associated with their implementation over a longer timeframe (Section 3.5.1). The high costs associated with the remainder of NBCSs most commonly stem from opportunity costs associated with forgone revenues (e.g., avoided peatland conversion).

34 In this case, the largest difference between the cost-effective and technical potential comes from the restoration of forest cover, of which only 12% of the total technical potential was estimated as cost-effective.

Highest Overall Promise

Scientifically well understood to provide moderate to high CO_2e sequestration or emissions reduction, with low to moderate socioeconomic barriers to implementation and biophysical risks to permanence

Crop management

Soil management

- ⊖ Biochar has a high cost

Nitrogen management

Improved forest management

- ⊖ High socioeconomic vulnerability to release

Restoration of forest cover

- ⊖ Low potential and high cost in 2030
- ⊖ Major barriers to implementation

Improved forest management

- ⊖ High socioeconomic vulnerability to release

Avoided freshwater mineral wetland conversion

Improved grassland management

Grassland restoration

Tidal wetland restoration

- ⊕ Moderate scientific understanding of magnitude and low socioeconomic vulnerability to release
- ⊖ Some socioeconomic barriers to implementation

Seagrass restoration

- ⊕ Moderate scientific understanding of magnitude
- ⊕ Limited scientific understanding of area of opportunity
- ⊖ Moderate costs

Lower Risk, Lower Reward

Low sequestration or emissions reduction potential, and low to moderate scientific understanding, but with low to moderate socioeconomic barriers to implementation and biophysical risks to permanence

Positive ⊕ or Negative ⊖ Deviation from the Grouping

Figure 7.1 Categorization of NBCSs to 2050 at a National Scale

The Panel's groupings of NBCSs (to 2050) based on four criteria: (i) magnitude of sequestration/emissions reduction potential at the national scale, (ii) socioeconomic barriers to implementation, (iii) biophysical risks to permanence, and (iv) scientific understanding of categories (i)–(iii). Categorization of NBCSs is based on the evidence presented in Chapters 3–6 and the Panel's corresponding assessment, using the same criteria as Table 7.1. The positive (+) or negative (-) sign represents instances in which one of the identified criteria deviates from the overall category the NBCS has been placed within.

The Panel notes, however, that these MACs represent only the mean value of the economic cost for each NBCS, and real costs may vary significantly depending on local and regional factors. Further, the costs presented below, calculated by Cook-Patton *et al.* (2021), do not include values associated with transaction or monitoring costs. Grafton *et al.* (2021) estimated that transaction and monitoring costs could add an additional 9–47% to the overall cost of an NBCS. In addition, Cook-Patton *et al.* (2021) assumed that land is permanently allocated for NBCS use in the opportunity cost analyses, while, in reality, some land could be switched out of NBCS use if lower-cost mitigation options become available, or if decarbonization of the economy sufficiently advances.

Outside of costs, the Panel evaluated feasibility based on a categorical scale measuring the severity of barriers to adoption and deployment. Of the NBCSs assessed, four were found by the Panel to have relatively minor barriers to adoption: crop management, improved grassland management, avoided conversion of freshwater mineral wetlands, and avoided conversion of seagrass meadows. The feasibility challenges in other NBCS categories are more significant for various reasons, including behavioural and sociocultural factors that may slow adoption rates on private land (e.g., agroforestry NBCSs). Among forest NBCSs, feasibility challenges stem from a variety of factors, including access, consistency with current timber harvesting and forest management practices, and potential conflicts with other public land management objectives (Section 3.5). Restoration of forest cover was deemed by the Panel to have high initial costs, and implementation may be regionally constrained due to a variety of factors, including agricultural demand, infrastructure development, and extractive industries (Section 3.5.1).

However, as the price of carbon increases, economic investment in the restoration of forest cover may become increasingly viable in Canada, so long as mechanisms are available for forest managers to realize these benefits and there is agreement among the complex assessments of land-use changes and decisions at the agriculture-forestry interface (Section 3.5). Current biophysical barriers associated with expanding restoration of forest cover in remote and northern areas may be impacted due to warming conditions and extending growing seasons, though ultimately these climate changes will alter boreal forest species composition and result in a lagged increase in tree canopy (Section 3.4). However, some forest management practices (e.g., changing use of harvest residue and harvested wood products) and avoided peatland conversion also face notable barriers to deployment based on costs and other implementation challenges within existing forest management and harvesting systems (Sections 3.5 and 5.5).

Indigenous self-determination is a precondition and catalyst for the implementation, adoption, long-term deployment, and success of NBCSs

All carbon stocks across Canada are on the traditional territory of Indigenous Peoples and these communities are critical to the long-term success of many NBCSs. As such, the Panel notes that the story of carbon sequestration in Canada is intrinsically interconnected with ongoing Indigenous-led land and resource management (and by extension, reconciliation). This is seen most explicitly in the concept of *all my relations* (Section 2.4), which acts as a reminder that everything is connected, including the air we breathe, the water we drink, and the land we walk on (Nandogikendan, n.d.). The ecosystems within which communities exist are conserved and cared for — a natural extension of the respect one gives to any relation. As a result of this care, the carbon stored within these ecosystems has also been conserved. Thus, in the Panel's view, the benefit of enhanced carbon sequestration in many of these ecosystems is the direct result of Indigenous stewardship over land and water.

Advancing the self-determination of Indigenous Peoples has the potential to enhance carbon sequestration and emissions reductions and, in turn, contribute to Canada's environmental targets, such as GHG emissions reduction goals. When communities themselves engage in ecosystem management efforts, in accordance with their traditions and values, decision-making processes for sustained NBCS use may be enhanced (Sections 3.2, 4.2, 5.2, and 6.2). The Panel believes that Indigenous governments and communities are best placed to effectively manage the natural environment in ways that both strengthen the conservation of current carbons stocks as well as enhance the ongoing sequestration of atmospheric carbon and reduction of emissions.

As agreements extending beyond local ecosystems to the broader issues of self-determination and land sovereignty, existing and future IPCAs may be effective in respecting Indigenous communities, their relationships to the land, and the environment more generally. While the Panel notes that IPCAs may not always be established in areas facing an imminent threat of land-use conversion (resulting in their inability to be considered additional), the main purpose of IPCAs is not to enhance NBCSs but rather to codify self-determination for Indigenous communities (Sections 5.2 and 6.2). Although this acknowledgement and respect for self-determination may result in increased carbon sequestration, as discussed above, it ought not to be considered a requirement in the application and approval processes. At their most fundamental, IPCAs represent land and water management agreements that function within the boundaries of a community's goals; only when a community chooses to enter into partnerships with federal, provincial, or territorial governments for the purpose of enhanced carbon sequestration or emissions reductions do these practices become potential NBCSs (Section 2.4). As such, it is important for the federal government to be aware of the multifaceted nature of these Indigenous-led relationships, to ensure that IPCAs remain a tool of self-determination rather than colonization.

Another example of collaborative and respectful relationships between Indigenous and non-Indigenous communities are Indigenous Guardians programs (Section 3.2). As Indigenous-led bodies that collaborate and engage with land-users, industry representatives, researchers, and governments directly, Indigenous Guardians ensure communities have the capacity to make well-informed decisions based on the values and priorities they choose. By fostering self-determination and ensuring that free, prior, and informed consent is achieved in all land management decisions, Indigenous Guardians can serve to ensure that self-determination and Indigenous governance structures are respected and upheld when discussing potential NBCSs (Section 2.4). Other initiatives, such as the Buffalo Treaty in the prairie provinces (Section 4.6.2) and Indigenous-led carbon credit programs in British Columbia (Box 3.2), further reinforce the idea that, when traditional ways of being and knowing are centred in land management decision-making processes, carbon sequestration and emissions reductions may result from the increased economic autonomy and enhanced livelihoods of community members. In the Panel's view, these are all attributes that will increase the likelihood of sustained management and monitoring of NBCSs.

"While many NBCSs may have high technical and economic potential, there is no guarantee of high adoption rates due to the context-dependent nature of individual decision-making."

Behavioural barriers are a significant but uncertain element in determining the feasibility of NBCSs

Behaviours in the form of cognitive, emotional, and social characteristics of a given individual, community, organization, or institution can negatively impact the feasibility of an NBCS. Behavioural barriers are therefore also uncertain. While many NBCSs may have high technical and economic potential, there is no guarantee of high adoption rates due to the context-dependent nature of individual decision-making (Section 4.5.2). Certain behaviours can impede acceptance of NBCSs despite high mitigation potential and cost-effectiveness. Land-use change for restoration of forest cover, for example, may be resisted due to the perceived value and prioritization of land for agricultural production over forested area, as well as potential difficulties associated with negotiating contracts for such practices on public land (Section 3.5). In the agricultural sector, farmers may be particularly risk-averse, viewing the potential of reduced crop yields as outweighing the environmental and economic benefits of improved nitrogen management (Section 4.5.2).

Additionally, the Panel notes there is a potential for optimism bias — the tendency for individuals to believe they are less likely to experience negative outcomes than others. This bias could impede the acceptance of NBCSs; though individuals may view practices to mitigate potential harm as beneficial, they may not view them as necessary for the success of their particular project. Overall, behavioural barriers represent a critical element in feasibility considerations despite their considerable uncertainty.

Increased monitoring of NBCSs is needed to realize their full potential

The Panel identified accurate and sustained monitoring of NBCSs as critical and necessary across all ecosystems and action types, although approaches will vary. Many of the NBCSs discussed in this report rely on sparse or coarse datasets, some of which may not represent the complexities and variances associated with carbon stocks and fluxes (Novick *et al.*, 2022). This lack of data results in uncertainties at the policy level, where issues of additionality or permanence may be overlooked and the benefits and impacts of NBCSs may not fully be understood (Novick *et al.*, 2022). In the agricultural sector, for example, the need for comprehensive, centralized, and accessible data for understanding soil organic matter and soil organic carbon trends, in relation to land-use practices and climate change, has been identified as a priority for providing a benchmark for assessing human impacts on soils (Harden *et al.*, 2018). While the International Soil Carbon Network has been promoted as an avenue for achieving this goal (Harden *et al.*, 2018), the Panel believes that Canada could develop a better-resolved monitoring network and platform to help track the relationship between Canadian NBCSs and soil carbon. This would establish the necessary baselines with which to track progress of NBCSs and their responses to climate change (e.g., connecting the National Forest Inventory to the study of climate responses and NBCSs; Section 3.5.3).

Monitoring would ideally also extend to the implementation and practice of policy mechanisms in place, which are meant to support and ensure the success of NBCSs. No-net-loss policies associated with wetlands along the Atlantic coast offer a good example of this issue. Policies requiring that loss of wetlands be offset through the creation or restoration of other wetland areas have the potential to incentivize the conservation of existing coastal wetlands and the associated carbon stocks (Section 6.5.2). However, under this policy approach, a long-term carbon stock could be lost while a new wetland is created that cannot replace the carbon that was lost. Furthermore, policies of this sort have not been uniformly enforced, resulting in ineffective protection and a reduction in the practice's overall magnitude of sequestration potential (Section 6.5.2).

In the Panel's view, comprehensive monitoring and enforcement of policies (provincial/territorial and federal) related to the conditions of an NBCS's operation are critical in ensuring the benefits of each practice are truly realized. Moreover, in ensuring that monitoring is comprehensive, the Panel believes additional benefits may be gained from NBCSs, such as increased knowledge of the ecosystems in which these actions are being carried out. This increase in knowledge may further benefit decision-makers by increasing overall confidence in how well-informed decisions may be.

Increased monitoring of NBCSs will also improve knowledge about the cost-effectiveness of these activities. In many instances, cost estimates are based on synthetic calculations of amounts landowners are paid for the delivery of NBCSs (Section 2.3.1). More information about the successes (or shortcomings) of NBCSs would allow decision-makers to better assess the true costs of these actions, which may be different than the simulated costs. This is critical if carbon-related markets are to be established. However, the Panel notes that increased NBCS monitoring does not come without added costs, which must also be considered in assessing the feasibility of any given project or activity.

7.3 Assessing NBCS Co-Benefits and Trade-Offs

> *What are the implications, benefits, or risks of implementing nature-based solutions focused on enhancing carbon sequestration, including for biodiversity, ecosystem services, economic factors, and Canada's GHG emissions?*

Many NBCS co-benefits have been described in this report: positive impacts on biodiversity, promotion of soil health, protection from hazards such as flooding, and space for social and cultural activities. Similarly, trade-offs to the implementation of certain NBCSs have been discussed, including risks to livelihoods, climate impacts and feedbacks (excluding impacts on CH_4 and N_2O fluxes and changes in albedo of land cover), though competing land-use priorities are unavoidable in many contexts. When considering all NBCSs, several common themes emerge that can inform decision-making about which NBCSs are most appropriate for implementation in specific places.

Wider implementation of many NBCSs in Canada may be desirable due to their co-benefits, even in the absence of the additional carbon sequestration they provide

Many NBCSs are associated with well-documented positive co-benefits in terms of ecosystem services, biodiversity protection, cultural value, and climate change adaptation. They can provide tangible social and economic co-benefits, including those associated with property values (e.g., scenic/aesthetic amenities, water quality improvements), avoided flood damages, improvements in recreation experiences, and improvements in threatened species' conditions (Sections 3.6, 4.6, 5.6, and 6.6). Even where GHG mitigation benefits are low, these co-benefits alone may justify wider adoption of such practices. For example, despite a relatively low potential for carbon sequestration, the restoration and preservation of marshes in the Prairie Pothole Region have a multitude of positive effects, including habitat for endangered species, flood protection, maintenance of water quality, and recreational services (Section 5.6). Similarly, the climate mitigation effects of urban forests are relatively minor, and the costs far outweigh the benefits if carbon sequestration is the only consideration. Yet, urban forests contribute to reducing temperatures in cities, with the potential to save lives by reducing the urban heat-island effect (Section 3.3.2). Protection and restoration of coastal wetlands contribute to climate change adaptation by protecting coasts and communities from storm surges and erosion; proper management of these ecosystems can translate to significant savings from disaster impacts (Section 6.5.1). These examples illustrate the importance of considering opportunities to co-fund or implement NBCSs in conjunction with actors or decision-makers with responsibilities outside of carbon sequestration, although the Panel notes that, in such circumstances, carbon sequestration (or reduced emissions) should be considered a co-benefit itself rather than the motivation for conservation or restoration.

However, these co-benefits will vary depending on the location of the NBCS activity and the surrounding natural and human environments. They will also depend on other factors that affect land use, such as human population growth, urbanization, and economic conditions of the energy, agricultural, and forestry sectors. This variation is reflected in the economic valuation ranges for ecosystem services. Relatively little is known about the economic value of ecosystem services in Canada (Olewiler, 2017); though many exist, the overall number of studies per year has not increased since 1975, and there are many research gaps in terms of certain resources (such as air quality) and location (with very few studies in the territories) (Macaskill & Lloyd-Smith, 2022). Despite this, the demand for environmental valuation research remains. To properly estimate the value of NBCS co-benefits, further study is warranted in: up-to-date and regionally distributed studies, promising practices in non-market valuation methods, changes to peoples' behaviours and preferences, as well as to the state of the environment itself (Macaskill & Lloyd-Smith, 2022).

Several of the benefits discussed in previous chapters are more intangible than the perceived trade-offs. For example, a study of the behavioural aspects required for the conversion of shelterbelts found that the costs for planting and upkeep of trees were weighed much more heavily by landowners than the potential long-term benefits of shelterbelts (Section 4.5.2). These long-term benefits include carbon sequestration, improved aesthetics, and enhanced biodiversity, and are all more difficult to quantify than start-up and maintenance costs. Certain forest management practices (i.e., restoration of forest cover) have similar challenges, where the carbon benefits may only be seen decades in the future, while implementation may require upfront costs (Section 3.5.1). Conservation and restoration of wetlands is also subject to this tension. High upfront costs to restore or protect a wetland are juxtaposed with benefits such as flood protection (which may not be apparent in the short term) or benefits to biodiversity (which may take years to manifest and whose value is subjective). Additionally, restoration of mineral-soil freshwater wetlands may result in upfront increases in CH_4 emissions — a notable trade-off in terms of climate mitigation, with the contribution to atmospheric cooling felt only decades after implementation (Section 5.3.2). As such, the Panel believes it is important to ensure consideration is given to both relevant co-benefits and costs when assessing the value of NBCSs — costs and/or related trade-offs for practices must take into account the various additional benefits that may be accrued with successful implementation; however, any co-benefit itself must similarly be evaluated against the costs of the action, as well.

A better understanding of the value of co-benefits, supported by policy, can help reduce perceived market-related trade-offs

Negative market-related effects, and the uncertainties associated with them, are primary trade-offs when implementing NBCSs. Loss of yield in crops or wood products, reduction in profits, and risks to employment are all cited as significant concerns to those considering NBCSs. For example, reducing fertilizer use can have direct impacts on the growth of crops, thereby affecting yield and profits among agricultural producers who are increasingly pressured by markets and demand for food (Section 4.5.1). Reducing horticultural peat extraction or preventing the expansion of oil, gas, and mineral exploration or mining activities in peatlands will directly impact industries, reducing employment opportunities and significantly affecting profits (Section 5.6). Reducing the harvest of forests and avoiding forest conversion will inherently reduce yield in forestry operations and can potentially heavily impact communities that depend on logging for employment (Section 3.6.2). These trade-offs should be carefully considered when implementing NBCSs but should not act as a deterrent — while initial costs may increase, some costs may be temporary (e.g., employment adjustments). More importantly, making strides to better quantify co-benefits, and using policy mechanisms and funding programs to incentivize the adoption of NBCSs and mitigate some of these trade-offs, can help reduce the overall negative market-related effects.

Although an exhaustive review of policies, programs, and regulations for the implementation and continued use of NBCSs across Canada is outside of the scope of this report, the Panel discussed several avenues that may hold promise for achieving the goals of carbon sequestration through NBCSs. For example, the integration of forest-based resources into climate policy frameworks, clarity on policy mechanisms that incentivize sequestration or avoided conversion, the alignment of reporting requirements among different sectors, no-net-loss policies, and policies to value intact ecosystems can all work to advance NBCS uptake in Canada (Sections 3.5.2, 5.5.2, and 6.5.2). Carbon credit programs in the agricultural sector and cross-compliance within Business Risk Management programs have been suggested as ways to advance NBCSs in Canada, though not without drawbacks and trade-offs (Section 4.5.2). Other programs and agreements, such as Indigenous Guardians and IPCAs, offer the potential to conserve at-risk carbon stocks while advancing Indigenous self-determination, as discussed in Section 7.2.

When choosing appropriate policies for implementing NBCSs, the Panel emphasizes the importance of assessing both private and public costs and benefits, particularly when dealing with private landowners. Decision-making structures for choosing among policy options underscore the complexity of private vs. public benefits and employing the most effective policy designs and incentives or penalties for striking a balance between them (Section 2.3.2). Critically, policies for advancing the use of NBCSs must be designed for geographic and environmental characteristics unique to the ecosystems, regions, and political contexts in which they are deployed.

This regional variation does not preclude action on a national scale. The Panel emphasizes that, despite the regional variability of many of the solutions discussed throughout this report, there are opportunities for decision-makers to make progress on implementing NBCSs across jurisdictions. For example, the *Declaration of the Premiers of Canada* includes commitments to "promote actions that support intergovernmental and cross-sector linkages in addressing climate change and that are inclusive of all sectors of the economy; implement programs and measures to adapt to climate change and reduce GHG emissions; [and]

implement policies to reduce GHG emissions," among others (Premiers of Canada, 2015). These pledges are relevant to NBCSs and provide a potential avenue to implement, monitor, and improve them nationally while maintaining regional specificity and mitigation. Nevertheless, the design, development, and evaluation of policies for cost-effective implementation of NBCS programs remain key uncertainties associated with the future of such programs in Canada and, in the Panel's view, deserve further research.

Some NBCSs are incompatible with each other or other land management objectives, while others are complementary

Additional considerations in the implementation of NBCSs are their interactions with broader land management objectives, as well as with each other. In the forestry sector, for example, assessing the balance of co-benefits and trade-offs is complex and subject to higher levels of uncertainty due to the often-incongruent nature of NBCSs with many current land management goals. Intensively managing forests in support of the production of harvested wood products (HWPs) could jeopardize other forest management priorities (e.g., providing habitat for wildlife, or ensuring forest diversity, resilience, and climate adaptation), depending on assumptions about the GHG emissions associated with maintaining, harvesting, and using HWPs. However, there is uncertainty in accounting for carbon stored in HWPs (Section 3.3.1). Furthermore, actions that require increased harvesting, such as the use of HWPs and harvest residue for biofuels, are directly at odds with other forest NBCSs, such as extended rotations, which sequester carbon through reduced harvesting (Section 3.3.2). This demonstrates that there are many pathways to reducing emissions or sequestering carbon, but not all contribute to other policy and land management objectives.

NBCSs can also be complementary. Nitrogen management, and fertilizer management in general, will not only have direct impacts on N_2O emissions from fields and croplands where fertilizer is applied but also help reduce emissions from downstream freshwater and marine ecosystems (Section 4.6.1). The management of fertilizers is related to the wider concept of watershed management, where decisions around land uses consider all downstream effects for rivers, lakes, and wetlands (including control over harmful algal blooms). Employing nutrient management on a watershed scale conveys widespread environmental benefits, both for emissions reduction and for water quality and ecosystem health.

7.4 Contributions to Global Emissions Pathways and Warming

To what extent do Canadian carbon sinks and potential enhanced sequestration influence or contribute to future global emission pathways and warming, consistent with the Paris Agreement goal of holding global average temperature increases to well below 2°C?

NBCSs can play a modest but important role in contributing to Canada's GHG mitigation goals and targets

It has been suggested that, on national and international scales, NBCSs can provide emissions reductions of up to one-third of the total current annual global emissions, either through the intentional enhancement of carbon sequestration or reduction in GHGs released to the atmosphere (Griscom *et al.*, 2017; Roe *et al.*, 2021). Such practices, alongside fossil fuel emissions reductions, will contribute meaningfully to meeting the goal of the Paris Agreement of holding the global average temperature increase to between 1.5–2°C. In Canada, there is awareness of the opportunities for carbon sequestration and emissions reductions offered by ecosystems across the country, as evidenced by the Government of Canada's strengthened climate action plan and commitment to invest over $3 billion in NBCSs over 10 years (ECCC, 2020a).

While the opportunities presented by NBCSs are real, they should be considered in the context of the overriding need to decarbonize energy systems and reduce emissions. Based on the review and estimates of Drever *et al.* (2021), NBCSs that are cost-effective in the short term (between now and 2030) are unlikely to offset more than 6% of Canada's current GHG emissions. And while the potential of these solutions may increase (or decrease) in the long term, there is currently no available evidence to accurately determine their influence beyond 2050. Accordingly, NBCSs cannot be fully relied upon to achieve international climate commitments such as the Paris Agreement, especially as many of the solutions identified throughout this report are not currently included in Canada's national emissions accounting framework (Section 2.1.5). Instead, NBCSs offer one approach among many to effectively reduce GHG emissions, and their role in international climate policy is best considered as a supporting element. Success in meeting climate mitigation goals and targets will require a suite of other actions by foreign governments, most importantly those achieving ongoing, deep, and sustained reductions in emissions from fossil fuel combustion.

Canada can foster greater awareness and knowledge about NBCSs through their implementation, accelerating their deployment elsewhere and leading to additional emissions mitigation benefits

Although the climate impacts of NBCSs within Canada are small in a global context, more widespread adoption of these approaches can yield co-benefits related to international carbon sequestration efforts. Canada is one of the most ecologically diverse countries in the world, featuring extensive deciduous and coniferous forests, native grasslands, inland waterways and wetlands, Arctic tundra, and vast coastlines; as such, it is in a unique position for implementing and promoting NBCSs across multiple ecosystems. In their analysis of increasing support for NBCSs in the European Union, Faivre *et al.* (2017) outlined four critical components required for such promotion to be successful: "building the evidence base," creating a "repository of best practice examples," "creating [an NBCS] community," and "creating [widespread] awareness." Canada is well positioned to fulfill these goals.

In the Panel's view, increased use and monitoring of NBCSs domestically will allow for innovation, experimentation, and expansion of concepts, providing new evidence and helping to identify promising practices across different ecosystems and land-use sectors. Knowledge gained by Canadian researchers and practitioners can, in turn, be shared among governments and practitioners in other jurisdictions, enhancing Canada's readiness and resilience to climate change. It may even benefit further as this community of practice expands and NBCS knowledge-sharing across borders increases. Such learning-by-doing is critical if the higher levels of NBCS mitigation potential estimated by some studies (e.g., Griscom *et al.*, 2017; Roe *et al.*, 2021) are to be achieved. Additionally, as the practice of these NBCSs expands globally, the evidence required to support them will likewise increase, and many of the identified knowledge gaps and uncertainties may be resolved (e.g., area of opportunity).

Applying NBCSs can help lessen the risks of rising GHG emissions from Canadian ecosystems, which are of global significance and represent a liability to successful global climate change mitigation

The global climate risks associated with increasing (and accelerating) emissions from Canada's terrestrial, aquatic, and coastal ecosystems are substantial — in contrast with the more modest mitigation benefits of NBCSs. Wildfires have been responsible for hundreds of Mt of CO_2e emissions from Canadian forests and peatlands in recent years (Sections 3.3.1 and 5.4.3), and such fires are predicted to become more common and intense as the temperature rises. Wetlands across Canada are also threatened by increasing temperature, which may lead to heightened atmospheric emissions (Section 5.4.3). While subject to considerable

> "Limiting warming to 1.5–2°C will likely only occur in the face of forward-looking climate mitigation policies that move rapidly to reduce anthropogenic emissions across sectors, since Canadian NBCSs will not be able to single-handedly safeguard carbon within such ecosystems."

uncertainty in terms of magnitude, permafrost thaw in northern Canada has the potential to increase carbon emissions far beyond that which can be sequestered through current NBCSs (Box 2.2).

These emissions could have globally significant impacts, turning current natural carbon sinks into significant carbon sources and contributing to climate feedback loops that may amplify and accelerate warming in an irreversible manner (Collins *et al.*, 2013; IPCC, 2014a). In crossing critical climate thresholds, NBCSs may become less effective, sequestering (or reducing emissions of) negligible amounts of carbon in comparison to rising emissions from terrestrial, aquatic, and coastal stocks in response to changing environmental and climatic conditions (Cooley & Moore, 2018). Preserving and protecting Canada's current carbon stocks is of significant importance in combatting global climate change. The Panel recognizes that Canada cannot unilaterally preserve all its current carbon stocks; preservation of which requires a reduction in overall GHG emissions. Limiting warming to 1.5–2°C will likely only occur in the face of forward-looking climate mitigation policies that move rapidly to reduce anthropogenic emissions across sectors, since Canadian NBCSs will not be able to single-handedly safeguard carbon within such ecosystems. However, they can play a role in both contributing to additional carbon sequestration and preserving current stocks from release.

7.5 Panel Reflections

In response to its charge from Environment and Climate Change Canada, the Panel reviewed a wide range of literature on the various NBCSs found across Canada's numerous ecosystems. Beyond reflecting on the technical mitigation potential of the NBCSs identified, the Panel's review resulted in an overall assessment of the various elements that are critical to the design, implementation, and exercise of NBCSs as tools for climate mitigation in Canada, moving forward. These elements, which include the permanence and feasibility of the actions explored, as well as considerations of additionality and the various co-benefits and trade-offs associated with them, all influence the projected success of NBCSs and are thus critical for well-informed decision-making.

The Panel notes that, despite the technical potential of many of the practices identified, attempts to enhance carbon sequestration in ecosystems across the country will not succeed without meaningful cooperation among multiple levels of government as well as various industry and community stakeholders. This includes the incorporation of Indigenous knowledge and leadership as well as the intentional enhancement of Indigenous stewardship over land and water, especially as it relates to self-determination, self-governance, and local environmental control. Because NBCSs are inherently land- and water-based, and because many are closely related to Indigenous land management practices, their relationship with Indigenous Peoples is fundamental, and the expertise, involvement, and leadership of Indigenous Peoples in the design, planning, and execution of these actions is of the utmost importance. Without such involvement, the full potential of many NBCSs may not be realized, and the various co-benefits attached to these practices may not be attained.

Overall, the Panel believes that Canada's — and the world's — future depends on the success of a host of actions across all sectors to mitigate climate change, including, but clearly not limited to, those associated with NBCSs. In the Panel's view, the question moving forward should not be solely about the extent to which rates of natural carbon sequestration in Canada's various ecosystems can be enhanced, but rather about how carbon stocks can be protected in order to enhance the efficacy of the NBCSs identified. Ultimately, natural carbon stocks in Canada will create feedbacks that can be either beneficial or adversarial to our future; in order for NBCSs to be most effective, a pathway of strong climate mitigation must be undertaken.