Natural Climate Solutions for Canada FAQ

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1. **What are natural climate solutions?**

Natural climate solutions (NCS) are actions beyond business-as-usual that can help limit global warming by avoiding emissions of greenhouse gases or increasing sequestration in natural and managed forests, grasslands, wetlands or agricultural lands. NCS are a complement climate action to deep cuts in use of fossil fuels and increased renewables and energy efficiency.

2. **What are pathways?**

Pathways are actions related to conservation, restoration, or improved land management that can avoid emissions from land use change or enhance the ability of natural systems to sequester **CO_2** from the atmosphere. The NCS Canada study examined four ecosystems and 24 pathways that, undertaken in the next decade, have the potential to cut Canada's greenhouse gas emissions by an amount equal to 11% of our current annual emissions.

3. **How are the specific pathways defined?**

Avoided freshwater mineral wetland conversion. Avoided CO_2e emissions of above- and belowground biomass and soil carbon due to prevention of drainage, dredging, eutrophication, or other anthropogenic activities in freshwater mineral wetlands (29,335 ha/yr). We account for differences in CH_4 and N_2O between converted and unconverted wetlands.

Avoided grassland conversion. Avoided emissions of CO_2 by preventing conversion of 2.5M ha over 10 years of native and tame grassland and shrubland to cropland. We quantify avoided emissions from soil and roots in grassland to 30-cm soil depth, as well as aboveground biomass in shrublands, based on the historical rates and patterns of conversion.

Avoided loss of shelterbelts. Avoided emissions of CO_2e from aboveground biomass and of forgone carbon sequestration through avoided loss of shelterbelts across Canada's three Prairie provinces (586 km/yr).

Cover crops. Increased sequestration of CO_2e into agricultural soils from growing additional cover crops in late summer-fall with or after the cash crop, in early spring before planting the cash crop, or on fallow areas. We model additional adoption of cover crops over 20.5M ha (63% of land in Canada with annual cash crops) where growing conditions and cash crop type did not preclude cover crop adoption. Mitigation includes soil organic carbon (SOC) storage, as well as avoided direct and indirect N_2O emissions from the field and avoided emissions from fertilizer manufacture where relevant (see Supplementary Materials).

Crop residue – Biochar. Increased sequestration of CO_2 in soil carbon by amending agricultural soils with biochar produced by converting crop residue to recalcitrant carbon (i.e., charcoal) through pyrolysis. We limited the source of biochar production to crop residue that can be sustainably harvested. We assumed biochar carbon persists longer than 100 years and has no effects on soil emissions of N_2O or CH_4.

Improved forest management. Additional CO_2e storage in forests or harvested wood products relative to a business-as-usual scenario. We modelled mitigation associated with set-asides of old growth forests, enhanced forest regeneration in post-harvest stands, and utilization of harvest residues (logging slash) that would have otherwise been burned for bioenergy, as well as increased use of saw logs for long-lived wood products. Net mitigation includes changes in carbon storage in all forest ecosystem pools and wood products, the albedo effect of old growth set-asides and temporary land cover transitions, and substitution benefits of wood for energy and building materials.

Nutrient management. Avoided N_2O emissions (reported in CO_2e) due to implementation of the "4R" best practices (right source, right rate, right time, and right place) for use of nitrogen fertilizer. We project business-as-usual growth in fertilizer use in Canada as 2.8% annually by 2030 and then assess additional mitigation of a full 4R implementation scenario compared to this baseline. We account for avoided N_2O emissions in the field due to more efficient use of nitrogen fertilizer as well as avoided emissions from fertilizer manufacture.

Reduced tillage. Increased sequestration of CO_2 in soil carbon from expanded use of no-till or reduced tillage practices in croplands. We model expansion of no-till on 1.4M ha and reduced tillage on 2.2M ha of crop areas relative to a business-as-usual scenario based on 2016 tillage levels.

Restoration of forest cover. Additional e sequestration from restoration of forest cover with locally adapted native tree species in areas where forests historically occurred and where planting is not an obligation under existing forest management regimes, e.g. after forest harvest. Our analysis excludes tree establishment in grass-dominated biomes because these plantings are often not successful, can reduce biodiversity, and can adversely affect soil carbon. We also exclude urban areas and areas alongside major roads, as well as crop and pasture lands except those with severe limitations on agricultural production. We do not include recently harvested forest lands, peatland areas, or areas burned by wildfire. Plantable areas are only included if they lie within 1 km of existing roads. We calculate net carbon accumulation in all forest ecosystem pools, assuming planting of 3.8M ha between 2022 and 2030 and discounting the mitigation benefit to account for changes in albedo.

Freshwater mineral wetland restoration. Increased sequestration of CO_2e from restoring freshwater mineral wetlands (25,000 ha/yr for 10 years) through restoration of hydrological function (rewetting) or topography, moss layer transfer, fertilization, nutrient management, vegetation management, or disturbance management. We account for differences in CH_4 and N_2O between restored and unrestored wetlands.

Riparian grassland restoration. Increased CO_2 sequestration in soils to 30-cm depth gained by restoring cropland to grassland or shrubland in areas with severe limitations on agricultural production (265,500 ha). We modelled establishment of 30-m riparian grassland buffers around all water bodies, including prairie pothole wetlands, in all agricultural lands within areas that would not naturally support forests.

Riparian tree planting. Increased CO_2e sequestration from planting trees in 30-m riparian buffers around all water bodies in agricultural zones where forests are the natural land cover (200,319 ha). We included carbon storage in above- and belowground biomass and soil, and deductions for the albedo effect of transitioning from hay to full deciduous cover. To avoid double counting, we removed overlap with the area of opportunity for restoration of forest cover.

Salt marsh restoration. Increased sequestration of CO_2e from restoring coastal salt marshes in NB, NS and QC (4,413 ha/yr for 10 years), through activities such as restoration of hydrological function (rewetting) or topography, moss layer transfer, fertilization, nutrient management, vegetation management, or disturbance management. We accounted for differences in CH_4 and N_2O between restored and unrestored wetlands.

Silvopasture. Increased CO_2e sequestration from expansion of practices that integrate trees and livestock in the same area to manage simultaneously for tree crops, livestock grazing and forage. We assumed each ruminant farm in Canada could establish an average of 20 ha of silvopasture in existing pasture lands (985,518 ha). We included carbon storage in above- and belowground biomass and soil, and deductions for the albedo effect of transitioning from hay to partial deciduous cover of 111 trees/ha.

Tree intercropping. Increased CO_2e sequestration from additional trees planted in rows among crop and hay lands. We included carbon storage in above- and belowground biomass and soil, as well as deductions for the albedo effect of transitioning from crop or hay to partial deciduous cover of 111 trees/ha. We modelled expansion of tree intercropping across all crop and hay lands with Class 3 soils in Ontario and Quebec (797,298 ha), because these soils have moderate to severe limitations on production and are less likely to be used for high value crops. We did not include other provinces given the prevalence of large machinery that precludes intercropping.

4. How was mitigation potential estimated?

The NCS for Canada study is based on a collaborative research effort [link] by Nature United, our global affiliate, The Nature Conservancy, and experts from 16 other institutions. The mitigation estimate for each pathway was the result of combining areas of opportunity for implementation with the expected change in greenhouse gas emissions or carbon sequestration. For pathways related to protection (avoided conversion), mitigation potential was quantified as the total amount of carbon in carbon dioxide equivalent (**CO_2**e) that would be absorbed by natural systems if conversion (at a given annual rate) was halted for 10 years. For management or restoration pathways, mitigation potential was estimated as the amount of carbon that would be absorbed by restoring degraded natural areas or placing them under a new management regime over the 2021-2030 period.

5. How were mitigation costs estimated?

For each NCS, we constructed a marginal abatement cost (MAC) curve from available studies in the literature. A marginal abatement cost curve represents the monetary expense of achieving one additional tonne of sequestered **CO_2**e or avoided emissions. It indicates the total quantity of net GHG reductions that can be achieved at different price points. We estimated the abatement available per tonne of **CO_2**e at price points relevant to Canada's system of carbon pricing, namely ≤ $10, ≤ $50, ≤ $100/t **$CO_2$**e, as expressed in 2018 Canadian dollars. The costs included implementation costs (e.g.

growing seedlings for tree planting, new machinery for manure management) as well as opportunity costs (e.g. foregone revenue from transition of marginal agricultural land to forest).

In general, we consider mitigation available at ≤ $100/t **$CO_2$**e to be cost effective. This price point is what many policy makers consider as the social cost of carbon, i.e. an estimate of the cost to society of an additional tonne of **CO_2**e emitted into the atmosphere, such as paid through flood damages, lost crops due to extreme weather, or human health impacts. Therefore, spending up to $100/t **$CO_2$**e can be considered cost effective as it saves society the cost of additional emissions.

6. **Why are there only 15 pathways shown in the Canada Mapper?**

The analysis in the NCS Canada study considered 24 pathways; however, detailed spatial data for provincial-scale estimates were available for 15 pathways (Avoided forest conversion, Avoided freshwater wetland conversion, Avoided grassland conversion, Avoided loss of shelterbelts, Cover crops, Crop residue – Biochar, Freshwater mineral wetland restoration, Improved forest management, Nutrient management, Reduced tillage, Restoration of forest cover, Riparian grassland restoration, Riparian tree planting, Salt marsh restoration, Silvopasture, and Tree intercropping).

The pathways not included in the Canada Mapper (Avoided forest conversion, Avoided peatland conversion, Avoided seagrass loss, Increased legume crops, Legumes in pasture, Manure management, Peatland restoration, Seagrass restoration, and Urban canopy cover) are either not spatially explicit or only available at a national scale and cannot be disaggregated by province. These pathways represent 20.3 Mt **CO_2**e/yr in 2030.

7. **What are the limitations of the data in the Canada Mapper?**

The goal of the Canada Mapper is to provide high-level estimate of potential Natural Climate Solutions at national and provincial levels. The estimates should be interpreted as a starting point for deeper dives to more precisely assess their real NCS related activities potential to reduce emissions and help mitigation climate change. The provincial estimate of mitigation at each price points are proportional to the national estimates, so should be considered as initial estimates that bear refinement.

8. **Where can I find information on the science behind the Canada Mapper?**

The study is available here (link to Science Advances). The supporting data can be found here (link to data repository).