United Nations University
Institute for Water, Environment and Health

POLICYBRIEF
August 2026

From Carbon Accounting to Net Cooling: Securing the Albedo-Carbon Double Win in Canada's Boreal Forest

Key Messages

- Canada's large-scale afforestation and reforestation efforts are central to its climate commitments. Yet, the current practices measure carbon storage without fully accounting for surface heat absorption or wildfire vulnerability. This creates a strategic risk: forests may appear climate-positive in carbon accounting frameworks while delivering weaker or unstable long-term cooling.

- Long-term modelling studies in northern Canada show that forest design determines climate performance. Mixed-species forests that include 25-40 percent deciduous trees and are planted at moderate density (600-1400 trees/ha) consistently deliver stronger and more durable climate cooling than dense evergreen monocultures[1,2]. They store substantial long-term carbon, reflect more winter sunlight, and reduce fire intensity.

- Dense evergreen plantations, by contrast, absorb more solar radiation during snow seasons and intensify fuel continuity, increasing warming and wildfire risk[3,4]. In drought-prone zones, these forests may become unstable climate assets.

- Afforestation and reforestation investments would benefit from prioritizing mixed-species, moderate-density forests in hydrologically viable zones, while avoiding planting in high fire-risk margins.

- Canada is encouraged to shift from a carbon-quantity approach toward a Net Cooling standard that integrates carbon storage, surface reflectivity, and permanence screening.

- Climate leadership now depends not on planting more trees, but on planting forests that deliver durable cooling.

UNU
INWEH

unu.edu/inweh

Context

Canada's boreal forest is one of the world's largest terrestrial carbon stores. Yet it is being rapidly reshaped by warming temperatures, shorter snow seasons, and intensifying wildfire regimes[3].

Afforestation and reforestation remain central to national mitigation strategy. However, climate performance depends not only on the number of trees planted, but on forest design and landscape suitability.

Why the Status Quo Is a Fiscal and Climate Risk

Current reforestation policy largely treats all forests as equivalent climate assets. Dense evergreen monocultures are often favored because they maximize short-term carbon reporting. Yet, this approach carries three escalating risks:

- **Fiscal Risk:** Public funds may be invested in forests that increase surface heat absorption and face elevated fire reversal risk, weakening long-term climate returns.
- **Carbon Market Credibility Risk:** Carbon credits that ignore surface reflectivity and permanence may overestimate true mitigation impacts[4].
- **Climate Mandate Risk:** In a warming boreal system, wildfire is no longer a background disturbance. It is the primary constraint on carbon durability[3,5]. Without reform, Canada risks issuing low-integrity carbon credits and investing in unstable climate assets.

The strategic challenge is not a research gap. It is a policy failure to measure net temperature impact.

Problem Statement

The Hidden Warming Penalty and Accounting Failure: Dark evergreen forests absorb more winter sunlight than snow-covered or open landscapes, increasing surface warming[4]. Carbon-accounting frameworks that ignore this heat absorption may overstate net cooling performance and produce low-integrity carbon credits. Most offset frameworks count tonnes of carbon stored, but do not deduct surface warming effects or incorporate climate-adjusted permanence risk. This leads to inflated mitigation estimates and a systematic overstatement of reforestation's true climate value.

The Permanence Paradox: Wildfire as the Hard Limit: Wildfire is a critical factor in determining whether reforestation represents a safe and durable climate investment. High-density plantations increase water competition and fuel continuity, raising the probability of high-severity fire under drought conditions[5], transforming potential carbon sinks into catastrophic fire liabilities. Carbon stored today has limited climate value if it is released within decades. As the current

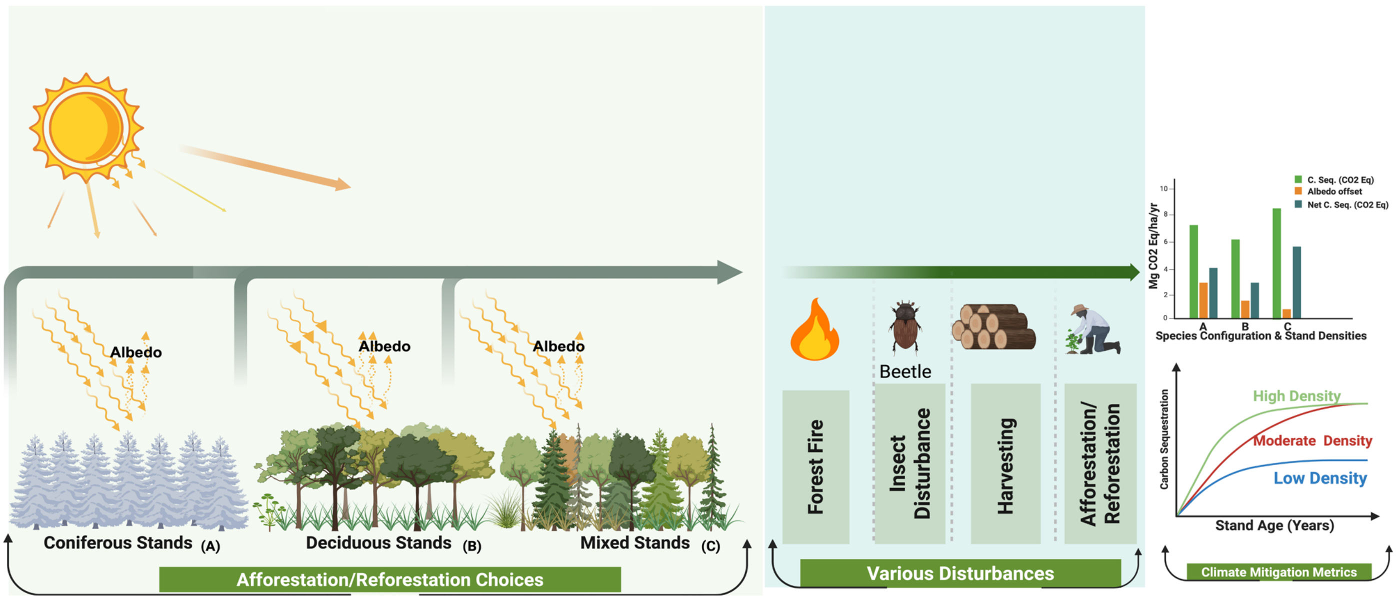

Figure 1: Afforestation and reforestation choices determine net climate forcing in Canada's Boreal forests. Mixed-species afforestation and reforestation with a meaningful deciduous component and moderate planting density deliver the strongest and most durable benefit by combining high long-term carbon storage with net surface cooling. In contrast, dense evergreen monocultures reduce winter surface reflectivity, increasing warming and vulnerability to disturbance. Policy-aligned afforestation and reforestation should therefore prioritize species diversity, moderate density, and active restoration of under-stocked lands. Created in BioRender.

model prioritizes carbon quantity over climate quality, Canada would benefit from directing reforestation investments toward forests that deliver both carbon storage and long-term resilience.

Policy Recommendations

1. Reform Carbon Accounting to Integrate Albedo Effects

The common practice of carbon-only accounting significantly overestimates the climate benefit of dense evergreen monocultures. Evidence from the Taiga Plains shows that heat absorbed by dark spruce forests can offset 6-20 percent of their reported carbon gains[1]. To ensure reforestation delivers genuine climate cooling, Canada would benefit from establishing a Net Cooling Standard. Under this standard, carbon credit verification would account for the Albedo Penalty associated with darker canopies. Climate performance should be assessed based on net climate impact rather than gross carbon storage alone, shifting policy from maximizing carbon volume to minimizing net warming[2,4].

2. Prioritize Mixed-Species Stands at Moderate Density

While monocultures are operationally simpler, they are less resilient and deliver weaker long-term climate returns. Long-term modelling studies in northern Canada show that mixed forests with a meaningful deciduous component, such as approximately 25 percent aspen, generate stronger and more durable climate cooling than conifer-only stands by combining rapid early growth with sustained carbon retention[1]. Moderate planting densities further strengthen this performance by reducing drought stress and limiting competition for soil moisture. In contrast, dense plantations intensify the competition for water, heighten drought vulnerability, and increase the likelihood of high-severity wildfire during dry years. Forestry and climate policy should therefore prioritize mixed-species, moderate-density forest design as the default public investment model, reserving high-density planting only for clearly justified, site-specific objectives.

3. Restore Under-Stocked Lands Where Climate Benefits Are Durable

Large areas of Canada's boreal forest remain under-stocked due to past wildfire, pest outbreaks, and unsustainable harvesting. While targeted replanting can enhance long-term climate returns[1], the decisive factor is site suitability. Reforestation is most effective when limited to landscapes with sufficient and stable soil moisture to sustain durable forest growth. In moisture-secure zones, restoration strengthens carbon stability and reduces disturbance risk. In contrast, planting in arid margins or drought-prone sites increases water stress, accelerates fuel accumulation, and elevates the probability of high-severity wildfire[2,3]. Under these conditions, additional biomass becomes a fire liability rather than a climate asset. Publicly supported reforestation should not proceed where hydrological and wildfire-risk screening indicates that durable carbon storage and net cooling cannot be maintained.

4. Adopt Climate-Smart Harvesting and Replanting Practices

Clearcutting creates sharp carbon losses and increases landscape volatility, weakening long-term climate stability. Long-term modelling studies in northern Canada indicate that partial harvesting, followed by prompt mixed-species replanting, maintains stronger and more stable climate returns than full clearcut cycles[1]. By preserving structural continuity and limiting fuel build-up, this approach reduces disturbance intensity and improves resilience under warming conditions. Forest management policy should therefore incentivize partial harvest-and-replant systems as the default climate-aligned practice, reserving large-scale clearcutting for clearly justified and site-specific cases.

5. Leverage Spatial Planning and Real-Time Monitoring

Reforestation outcomes vary significantly across landscapes depending on soil moisture, permafrost stability, and wildfire exposure. Uniform planting targets are therefore insufficient under rapidly changing climate conditions. Spatially differentiated reforestation planning that screens sites for hydrological viability and fire risk prior to investment approval offers a more robust and climate-aligned approach[1]. In addition, a satellite-supported national monitoring platform tracking soil moisture, fuel accumulation, surface reflectivity, and post-fire recovery in near-real-time would strengthen accountability and enable adaptive management[2]. Continuous monitoring ensures that publicly funded forests maintain durable cooling performance over time, and dynamic oversight is critical to aligning reforestation investment with long-term climate stability.

Final Remarks

Afforestation and reforestation remain powerful natural climate solutions. However, climate success in Canada's boreal forests requires moving beyond carbon quantity toward measurable net climate outcomes. In snow-affected regions, forest design determines

Winter mixed birch–spruce forest showing exposed snow beneath leafless deciduous trees and darker evergreen foliage. The contrast illustrates how species composition and canopy openness can influence winter surface reflectivity and net climate outcomes. Photo by Dmitry Potashkin/iStock via Getty Images.

whether reforestation delivers durable cooling or unintended warming.

Mixed-species, moderate-density forests planted in moisture-secure zones provide the strongest and most stable climate returns. They store substantial carbon, reflect more winter sunlight, and reduce wildfire intensity. Dense evergreen monocultures in drought-prone landscapes increase heat absorption and fire vulnerability, weakening long-term climate performance.

To secure the Albedo-Carbon Double Win, three immediate implementation priorities are:

1. Establish a Net Cooling standard that deducts the Albedo Penalty and integrates wildfire permanence screening into all publicly supported reforestation.
2. Restrict restoration to hydrologically viable under-stocked landscapes where long-term cooling can be sustained.
3. Implement adaptive, landscape-level monitoring of soil moisture, fuel accumulation, and surface reflectivity to safeguard climate durability under changing conditions.

By aligning forest design with net temperature impact and permanence limits, Canada can protect public investment, strengthen carbon market credibility, and ensure its boreal strategy delivers durable, verifiable cooling.

References

1. Ofosu, E. et al. Climate benefits of afforestation and reforestation with varying species mixtures and densities in north-western boreal lands. Environ. Res. Lett. 20, 124026 (2025).

2. Dsouza, K.B. et al. Assessing the climate benefits of afforestation in the Canadian northern boreal and southern Arctic. Nat. Commun. 16, 6699 (2025).

3. Huberman, Y. et al. The state of Northwest Territories forests in the wake of climate change: Baseline conditions and observed changes to forest ecosystems. Information Report NOR-X-430 (Natural Resources Canada, 2022).

4. Hasler, N. et al. Accounting for albedo change to identify climate-positive tree cover restoration. Nat. Commun. 15, 2275 (2024).

5. Lee, J. H., AghaKouchak, A., Kieft, J., Matin, M., & Madani, K. (2025). Beyond planting trees: Taking advantage of satellite observations to improve forest carbon management and wildfire prevention. United Nations University Institute for Water, Environment and Health (UNU-INWEH), Richmond Hill, Canada.

Authors

Dr. Enoch Ofosu is a Postdoctoral Research Scientist in the Department of Earth and Environmental Sciences at the University of Waterloo, Canada, specializing in ecosystem carbon dynamics and the climate impacts of boreal afforestation.

Dr. Kevin Bradley Dsouza is a Postdoctoral Research Scientist in the Department of Earth and Environmental Sciences at the University of Waterloo, Canada, focusing on biogeochemical and biogeophysical modeling of northern ecosystems.

Mr. Daniel Chukwuemeka Amaogu is a PhD candidate at the Sustainable Infrastructure and Geoengineering Lab (SIGLab) at Polytechnique Montréal, Canada, with research interests in sustainable forest management and geoengineering solutions.

Mr. Jérôme Pigeon is a PhD candidate at the Sustainable Infrastructure and Geoengineering Lab (SIGLab) at Polytechnique Montréal, Canada, where his work integrates geotechnical and ecological engineering for climate resilience.

Mr. Richard Boudreault is an affiliate researcher in the Department of Earth and Environmental Sciences at the University of Waterloo and at Polytechnique Montréal.

Professor Nima Shokri is Executive Co-Director of the UNU Hub on Engineering to Face Climate Change and a Professor at Hamburg University of Technology (TUHH), Germany, working at the intersection of geo-hydroinformatics, resource management, and sustainable development.

Professor Juan Moreno-Cruz is a professor at the School of Environment, Enterprise and Development of the University of Waterloo, Canada. His research focuses on environmental economics, climate policy, and the integration of technological and natural solutions for climate mitigation.

Dr. Mir Matin is the Manager of the Head, Research and Training at the United Nations University Institute for Water, Environment and Health (UNU-INWEH), working on the application of earth observation and geoinformation solutions to mitigate risk and enhance resilience.

Professor Kaveh Madani is the Director of UNU-INWEH and a Research Professor at the City University of New York's Remote Sensing Earth Systems (CUNY CREST) Institute with expertise in modeling complex human-nature systems to advise policy.

Professor Pooneh Maghoul is Lead for Sustainable Infrastructure in Cold Regions at UNU-INWEH and a Professor of Civil Engineering and Director of the International Science Diplomacy Research Chair for Arctic and Space Cooperation at Polytechnique Montréal, Canada.

Dr. Yuri Leonenko is an Associate Professor of Geological Engineering at the University of Waterloo, Canada. His research specializes in the capture and geological storage of CO_2 to mitigate climate change.

doi: 10.53328/INR26RPM001
ISBN: 978-92-808-6142-6

Recommended Citation: Ofosu, E., Dsouza, K. B., Amaogu, D. C., Pigeon, J., Boudreault, R., Shokri, N., Moreno-Cruz, J., Matin, M., Madani, K., Maghoul, P., and Leonenko, Y. (2026). From Carbon Accounting to Net Cooling: Securing the Albedo-Carbon Double Win in Canada's Boreal Forest. United Nations University Institute for Water, Environment and Health (UNU-INWEH), Richmond Hill, Canada. doi: 10.53328/INR26RPM001

@30
30TH ANNIVERSARY
UNU-INWEH
2026