CANADIAN WILDLAND FIRE & SMOKE

NEWSLETTER

SPRING 2025

Evaluating Clean Air Shelters for Improving Wildfire Responder Health
by Jesse Wallace-Webb and Drew Lichty

The Canadian Forest Service's Northern Forest Mapping (NorthForM) Program
by Jessica Zerb, et al.
Article in English and French

For Those Who Walk the Hard Path: Building Leadership and Resilience Training Opportunities in Canada
by Emily Friedrich

Introducing `fireexposuR` v1.1.0
by Air Forbes

Photo: Alberta Wildfire crew supporting suppression efforts on the Eaton Fire during deployment to California by Ang Beaulac.

Evaluating Clean Air Shelters for Improving Wildfire Responder Health

By Jesse Wallace-Webb[1] and Drew Lichty[2]
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Background

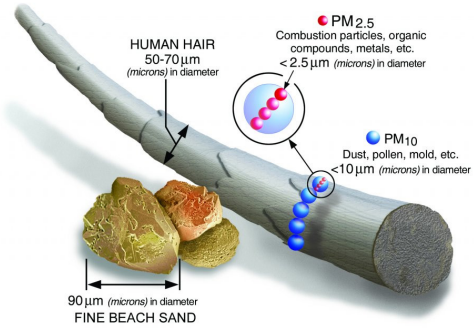
Wildland firefighters often face demanding conditions, including exposure to hazardous levels of wildfire smoke[1]. Wildfire smoke is a complex mixture of particles and gases containing harmful pollutants like particulate matter (PM), inorganic gases like carbon monoxide (CO), and volatile organic compounds (VOCs) such as benzene, formaldehyde, and polycyclic aromatic hydrocarbons[2] .

One critical component of smoke is $PM_{2.5}$, fine particles less than 2.5 micrometers in diameter[3]. These microscopic particles are dangerous because they can travel deep into the lungs and enter the bloodstream, increasing the risk of long-term health problems.

Concentrations of $PM_{2.5}$ above 100 µg/m^3 are classified as "very high[4]." Unfortunately, wildland firefighters may work without respiratory protection in areas where $PM_{2.5}$ levels reach ten times this limit, with some studies reporting exposure levels over 1000 µg/m^3 on the fireline—far exceeding recommended safety limits[5].

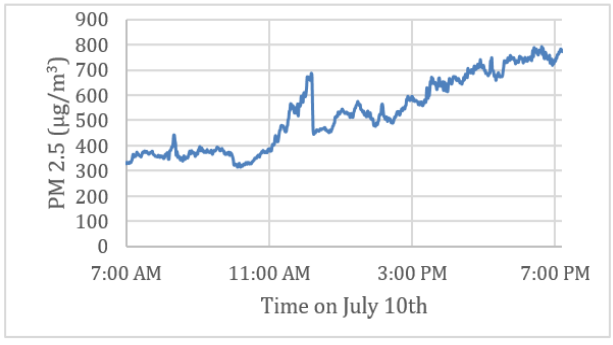
1-HOUR $PM_{2.5}$ (µg/m^3)	PROVINCIAL AQHI	AQHI RISK CATEGORY
0 – 10	1	LOW
11 – 20	2	
21 – 30	3	
31 – 40	4	MODERATE
41 – 50	5	
51 – 60	6	
61 – 70	7	HIGH
71 – 80	8	
81 – 90	9	
91 – 100	10	
101+	10+	VERY HIGH

$PM_{2.5}$ Level of Exposure Chart Source: BC Centre of Disease Control



Size comparisons for particulate matter. Source: U.S. Environmental Protection Agency

Even after their shift, wildland firefighters may return only to find their camp just as smoky as the fireline itself, leading to around-the-clock exposure.



$PM_{2.5}$ levels on July 10th, 2024 at fire a camp near Fort Nelson, BC

Photo taken at 4:45 pm on July 10th, 2024, at a fire camp near Fort Nelson, BC. $PM_{2.5}$ = 715ug/m^3. Credit: Ian Berglund

[1] Health Effects of Wildfire Smoke Exposure - PubMed (nih.gov)
[2] Woodsmoke health effects: a review - PubMed (nih.gov)
[3] $PM_{2.5}$ Size comparison: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM
[4] BC Health Wildfire Smoke Response Coordination Guideline.pdf (bccdc.ca)
[5] Working in Smoke: Wildfire Impacts on the Health of Firefighters and Outdoor Workers and Mitigation Strategies - PMC (nih.gov)

As wildfire seasons grow longer and more intense, the need to protect firefighters is increasingly important. One potential solution? *Clean air shelters*—spaces equipped with air filtration systems for personnel to eat, sleep, and recover in-between shifts.

Trial Objective:

The BC Wildfire Service Research and Innovation business area conducted a series of preliminary trials to evaluate the effectiveness of various clean air shelters in reducing exposure to fine particulate matter. The trials tested four shelter designs in real-world conditions, focusing on their ability to reduce $PM_{2.5}$ concentrations.

Two of these designs were prototypes developed by third-year product design students at Kwantlen Polytechnic University (KPU)[6] Wilson School of Design. The larger "Phoenix" shelter was designed for fire camp use, aiming to accommodate up to 12 people for a space to eat and rest. The smaller "O-Tent" was designed for one or two people and tailored for use closer to the fireline. Powered by a rechargeable battery, it has increased functionality in remote locations.

The third clean air shelter, designed in collaboration with BGE Indoor Air Quality Solutions Ltd[7], incorporated a 1000 CFM commercial-grade high efficiency particulate air filter (HEPA) and molecular filtration air purifier; the Purafil Purashield Smart 1000. HEPA units such as these have been shown to reduce $PM_{2.5}$ in residential clean air shelters, as well as lead to health benefits[8].

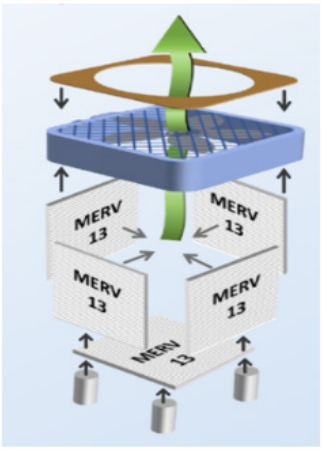
The final design incorporated a Do-It-Yourself (DIY) option; the Corsi-Rosenthal Box[9]. These DIY air cleaners, made with a box fan and MERV 13 filters, are considered a cost-effective method for reducing fine particulate concentrations indoors[10,11].

The Purafil Purashield Smart 1000 and Corsi-Rosenthal Box were tested inside a 14ft x 24ft "Ranger" wall tent. These multi-use tents are widely used at BC Wildfire Service fire camps for holding meetings and providing a place for crews to eat and relax after shift[12].

KPU Prototypes: Purple "O-Tent" shown in front of "Phoenix"

BC Wildfire Service Ranger Tent[12]

Purafil Purashield Smart 1000[8]



Corsi-Rosenthal Box[11]

[6]KPU: https://www.kpu.ca/news/2024/05/07/kpu-students-design-tents-protect-firefighters-wildfire-smoke
[7]BGE: https://bgecleanair.com/
[8]HEPA: http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-environment/WFSG_EvidenceReview_CleanAirShelters_FINAL_v3_edstrs.pdf
[9]Corsi-Box: https://cleanaircrew.org/box-fan-filters/;
[10]Corsi-Box: https://www.epa.gov/air-research/research-diy-air-cleaners-reduce-wildfire-smoke-indoors
[11]Corsi-Box: Impact of DIY air cleaner design on the reduction of simulated wildfire smoke in a controlled chamber environment
[12]Ranger Tents: https://www.100milefreepress.net/news/100-mile-house-fire-camp-is-like-a-small-city-5403580

Methods

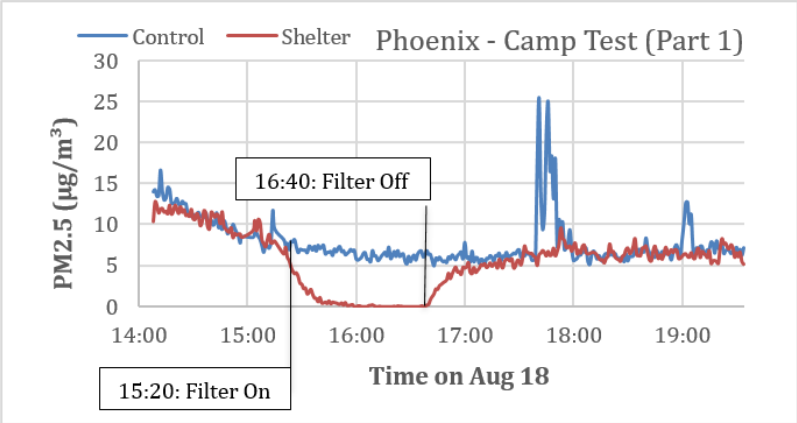
Five trials, including eight testing sessions, were conducted in August 2024 at the Slocan Lake Complex fire camp. Two real-time air quality sensors[13] were used to measure $PM_{2.5}$ levels inside the shelters compared to outdoor conditions.

- Trial 1: Tested the KPU "Phoenix" and "O-Tent" prototypes at a camp near Winlaw, BC. Phoenix testing was split over 2 days to get sufficient data.
- Trial 2: Conducted at a staging area closer to the Ponderosa FSR wildfire in an attempt to capture heavier smoke exposure. These sessions used the Phoenix shelter because it performed better in Trial 1.
- Trials 3 & 4: Tested the Purafil Purashield Smart 1000 and Corsi-Rosenthal Box prototypes at camp.
- Trial 5: Tested air quality inside an idling truck at fire camp, as trucks are sometimes used as a temporary shelter when crew personnel are exposed to heavy smoke in the field. For this trial, a sensor was placed inside an idling Dodge Ram 3500 with air-recirculation turned on.

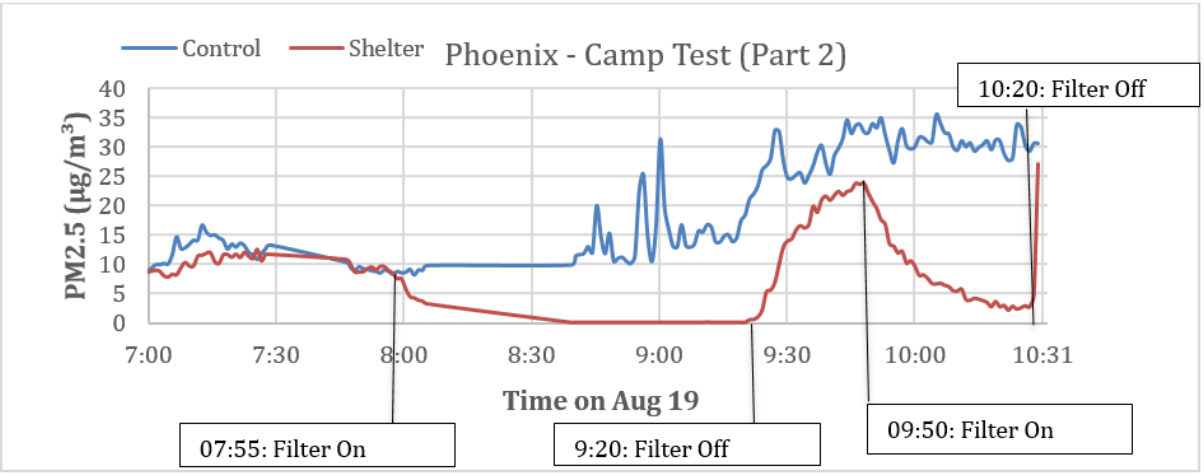
Results

All clean air shelter designs significantly reduced $PM_{2.5}$ concentrations, consistently bringing them from "moderate" to "low" levels as defined by the Smoke-optimized Air Quality Health Index (AQHI-Plus)[14]. This section presents graphs of $PM_{2.5}$ levels over time for each of the five trials, along with a table showing percent reduction. These visual summaries are followed by a more detailed discussion and analysis in the subsequent sections.

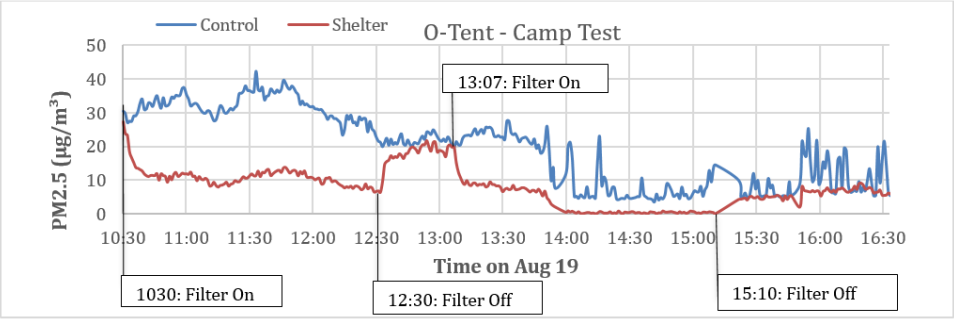
Trial 1: KPU Shelters at Camp



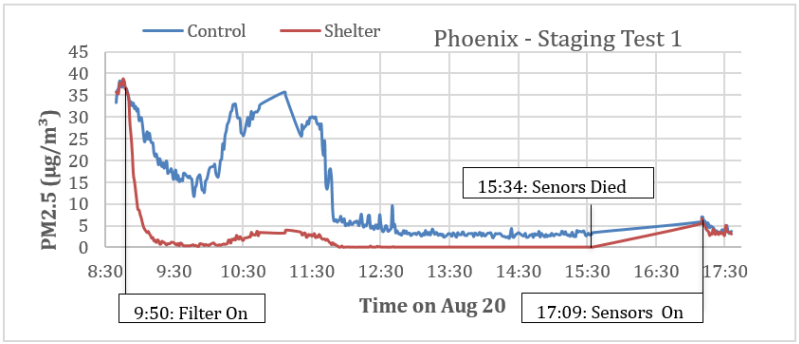
Both of the KPU prototypes reduced particulate matter during low to moderate levels of smoke exposure. The Phoenix shelter reduced $PM_{2.5}$ by an average of 84%, while the O-tent averaged a 69% reduction.



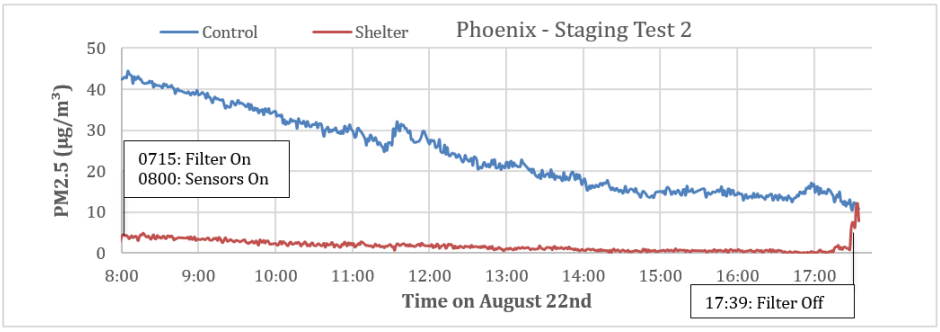
[13] Air Quality Egg: https://airqualityegg.com/home
[14] BC Health Wildfire Smoke Response Coordination Guideline.pdf (bccdc.ca)



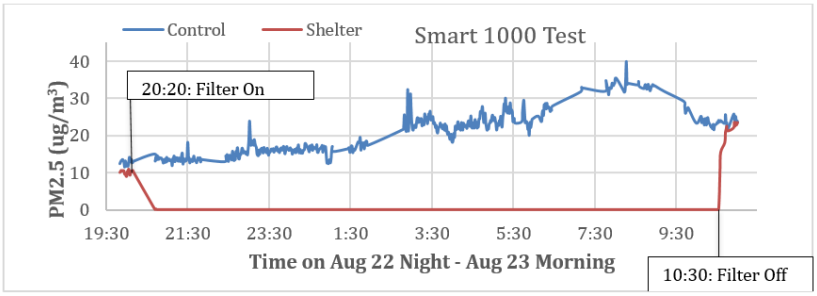
Trial 2: Phoenix Shelter at Staging Area



The Phoenix shelter reduced $PM_{2.5}$ by an average of 91% during low to moderate levels of smoke.

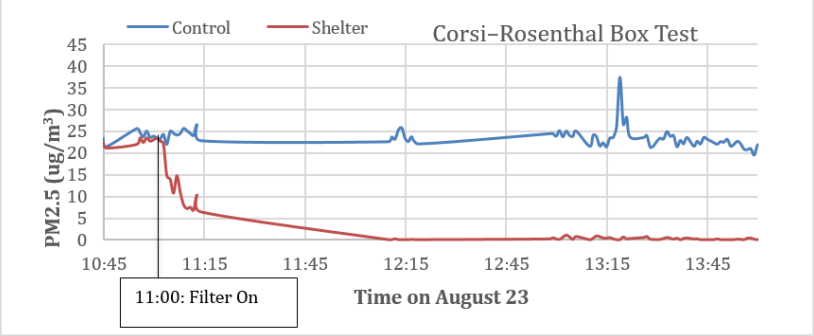


Trial 3: Purafil Purashield Smart 1000 Shelter at Camp



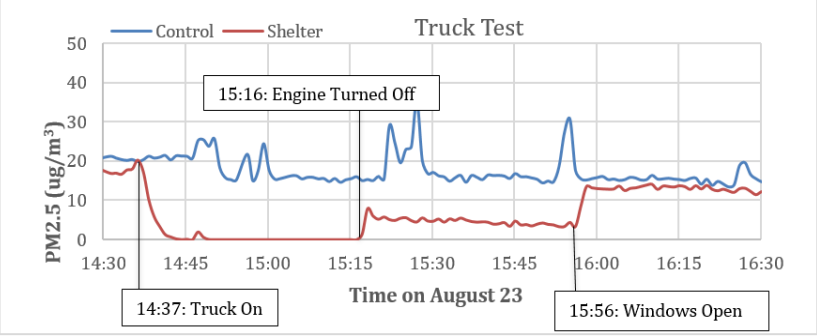
The Purafil Purashield Smart 1000 shelter reduced $PM_{2.5}$ by an average of nearly 100% during low to moderate levels of smoke.

Trial 4: Corsi–Rosenthal Box Shelter at Camp



The Corsi–Rosenthal Box shelter reduced $PM_{2.5}$ by an average of 91% during low to moderate levels of smoke.

Trial 5: Truck at Camp



The "Truck" shelter reduced $PM_{2.5}$ by an average of 96% during low to moderate levels of smoke.

Table 1. Percent Reductions for All Exposure Metrics in Each Testing Session

Testing Session	Shelter	Sensor	PM2.5 (µg/m³)	% Diff	PM1.0 (µg/m³)	% Diff	PM10 (µg/m³)	% Diff	CO (ppm)	% Diff	VOC (ppb)	% Diff
1	KPU Phoenix	Shelter	0.9	↓87%	0.48	↓89%	0.91	↓87%	0.75	↑177%	10.04	↓56%
		Control	6.6		4.27		6.74		0.27		23.04	
2	KPU Phoenix	Shelter	4.2	↓80%	2.72	↓81%	4.27	↓81%	0.62	↑81%	25.21	↑14%
		Control	20.9		14.45		22.00		0.34		22.13	
3	KPU O-Tent	Shelter	7.1	↓69%	4.79	↓69%	7.20	↓70%	0.72	↑122%	20.76	↓10%
		Control	22.7		15.52		24.29		0.32		23.07	
4	KPU Phoenix	Shelter	1.3	↓89%	0.74	↓90%	1.26	↓89%	5.52	↑1207%	35.07	↑51%
		Control	11.5		7.76		11.93		0.42		23.18	
5	KPU Phoenix	Shelter	1.7	↓93%	0.83	↓95%	1.76	↓93%	0.66	0%	23.37	↓2%
		Control	24.5		15.36		26.54		0.66		23.94	
6	Smart 1000	Shelter	0.001	↓99.996%	0.0003	↓99.997%	0.00	↓99.99%	0.29	↑19%	22.48	↓10%
		Control	20.8		12.37		21.78		0.25		24.88	
7	Corsi -Box	Shelter	2.2	↓91%	1.17	↓92%	2.26	↓91%	0.40	↑35%	23.51	↓1%
		Control	23.6		14.98		24.22		0.30		23.82	
8	Truck	Shelter	0.7	↓96%	0.39	↓97%	0.67	↓97%	0.62	↑121%	118.57	↑279%
		Control	18.5		11.98		19.04		0.28		31.27	

Discussion

These trials demonstrated the effectiveness of clean air shelters in reducing fine particulate matter concentrations. All of the tested prototypes showed a marked improvement in $PM_{2.5}$ levels when tested under moderate conditions of air pollution.

Key Findings

- KPU Phoenix Shelter: Outperformed the O-Tent during initial testing, consistently keeping $PM_{2.5}$ levels below 5µg/m³ under moderate smoke conditions ($PM_{2.5}$ up to 40µg/m³ outdoors).
- Purafil Purashield Smart 1000: Achieved the highest reductions due to its commercial-grade HEPA filter, eliminating nearly 100% of particles over 0.1 micrometers in size.
- Corsi-Rosenthal Box: Offered an affordable and scalable air filtration system that effectively reduced fine particulate matter, which is in line with previous research studies[15]. The simplicity and ease of construction makes this solution rapidly deployable in nearly any fire camp location and is particularly suitable for remote or resource-limited situations.

Considerations for Future Research

Based on the findings of these trials, the following could be explored as potential strategies to reduce smoke exposure during wildfire deployments. These are not formal recommendations, but rather areas that may warrant further investigation and discussion:

1. Real-Time Air Quality Monitoring: Fire camps could benefit from exploring the use of real-time air quality monitors, which could alert safety officers when $PM_{2.5}$ levels exceed certain thresholds.
2. Establishing Smoke Exposure Thresholds: There may be value in exploring preliminary guidelines for acceptable smoke exposure levels, which could serve as a foundation for future discussions on managing smoke at fire camps.
3. Exploring Smoke Reduction Interventions: Promising smoke reduction measures, such as the use of Corsi-Rosenthal Box systems, could be trialed when $PM_{2.5}$ concentrations surpass certain thresholds.

It is important to emphasize that these ideas are intended as exploratory suggestions and would require further evaluation and consultation before any broader implementation.

Other Considerations

It is important to acknowledge all of the current trials were conducted under low to moderate smoke conditions. Further testing in heavy smoke conditions is necessary to fully evaluate the various clean air shelters' performance. However, it is worth noting here that previous research on the Corsi-Rosenthal Box showed minimal variation in effectiveness across a wide range of $PM_{2.5}$ concentrations (11 to 161 µg/m³).

In terms of instrument calibration, the air quality sensor used in these trials has been validated with a collocated gravimetric sample and it showed similar results (correction factor = 0.89 at $PM_{2.5}$ of 38 µg/m³).

It is worth noting that despite showing promise in reducing fine particulate concentrations, none of the shelters were able to reliably reduce volatile organic compounds (VOCs) or carbon monoxide (CO). In fact, levels of CO appeared to be higher in the clean air shelters compared to outside air. This was seen to varying degrees but was most notable in the 4th testing session. The relatively high CO levels during this session is suspected to be caused by the generator being placed directly adjacent to the Phoenix shelter, which seemed to disproportionately accumulate CO inside the shelter compared to outside. Although levels of CO remained below established health exposure limits (10ppm), further research and testing is nonetheless warranted to ensure undesirable pollutants aren't generated or accumulated during clean air shelter operation.

Similarly, it was noticed during the 8th testing session that VOC concentration was much higher inside the truck compared to outside air. This is suspected to be due to the truck being idled, as further inspection revealed that VOCs immediately decreased from ~130ppb to under 30ppb as soon as the truck engine was turned off. Though notable, these VOC levels are difficult to interpret from a health standpoint because VOC exposure limits vary widely depending on the specific compound[17]. It is also important to note that not all vehicles are equipped with cabin air filters. Wildfire responders should check their vehicle's specifications before relying on it as a shelter during heavy smoke events.

Conclusion

These clean air shelter trials highlight the potential of these systems for providing respite during smoke events. Despite varying levels of moderate smoke throughout the trial period, most shelters successfully maintained $PM_{2.5}$ levels well below the lowest exposure threshold of 10 µg/m³. With further research and wider adoption, these shelters could offer significant health benefits for wildfire responders, especially during prolonged deployments in smoky camp conditions.

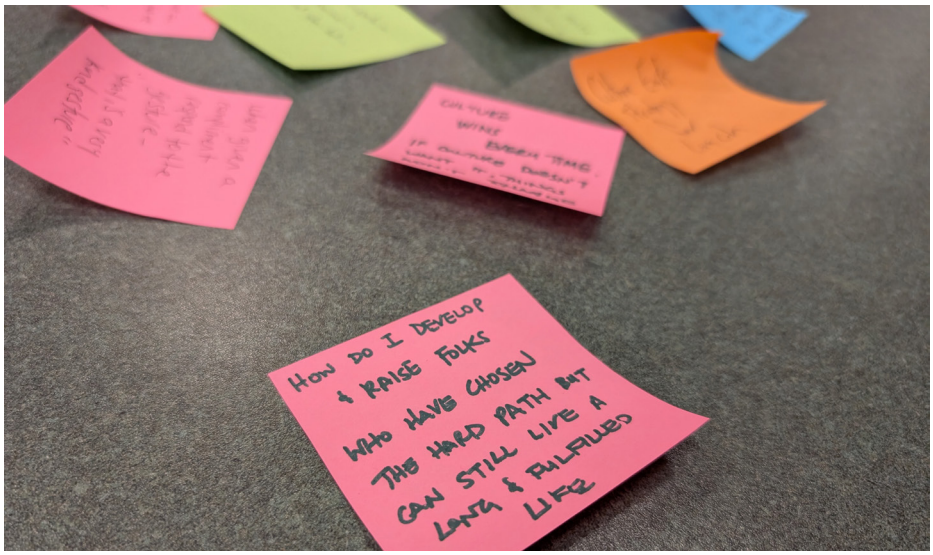
[15] Impact of DIY air cleaner design on the reduction of simulated wildfire smoke in a controlled chamber environment
[16] Residential Indoor Air Quality Guideline: Carbon Monoxide - Canada.ca
[17] Indoor Air Reference Levels - Canada.ca

For Those Who Walk the Hard Path: Building Leadership and Resilience Training Opportunities in Canada

In this changing fire landscape, how do we support our teams? Offering new tools, a supportive community, and a mental reset is a start.

By Emily Friedrich, efriedri@ualberta.ca
Knowledge Translation & Mobilization Specialist, Canada Wildfire, Alberta, Canada

In December 2024, Canada Wildfire piloted Mission Critical Team Leader Training (MCTL), a four-day workshop addressing one of the most pressing challenges facing emergency and critical response agencies: staff burnout and resilience in high-pressure environments. The training focuses on mission critical teams—small, integrated groups that adapt to complex, time-sensitive problems where failure can result in catastrophic loss. After gathering participant feedback during and after the pilot, we're excited to share insights on needs, successes, and opportunities, including the next MCTL offering scheduled for December 2025.



Attendees reflect on challenging questions during the first Mission Critical Team Leader Training (MCTL) in Hinton, AB, from December 9-12, 2024. MCTL will be offered a second time on December 8-11, 2025. Photo: Emily Friedrich, December 2024.

Meeting a critical need

MCTL was developed in response to an urgent community need. In previous years, Canada Wildfire had hosted two free webinars on mental health and resilience featuring Dr. Preston Cline from the Mission Critical Teams Institute (MCTI). Following these sessions, numerous messages poured in from wildfire management and other emergency response groups across Canada expressing the need for targeted support and tools. For these teams, failure (even perceived failure) can have long-lasting detrimental impacts on decision-makers and the teams assigned to the incident or campaign.

These colleagues identified several critical needs:

- Equipping leaders and decision-makers for high-pressure situations in a rapidly changing environment, both in shifting norms and increased public scrutiny.
- Managing acute and cumulative mental strain, avoiding and countering burnout, and improving long-term retention and health.
- Breaking down silos and connecting with colleagues across agencies.
- Finding cost-effective, collaborative solutions that avoid the one-size-fits-all approach to mental health support that often leaves many without accessible resources.

Seeking to help fill this gap, Canada Wildfire partnered with the Mission Critical Teams Institute (MCTI) to offer research-backed

resilience and leadership training specifically tailored for Canadian first and critical response professionals. Led by Director Dr. Preston Cline, MCTI's experienced instructors work with mission critical teams worldwide that face complex, high-impact problems every day, including urban and wildland fire, tactical law enforcement, military special operations, NASA, and emergency medicine.

The course was held at the Hinton Training Centre in Alberta, which provided on-site training, meals, and accommodations. Course registrations met an ideal instructor-to-participant ratio for the pilot, with approximately 30 registrants from wildfire, policing, and all hazard emergency response agencies. Participants came from 8 provinces/territories and 14 organizations, with over half currently working in leadership or training delivery positions.

Seeking to promote equitable access to opportunities, Canada Wildfire partnered with Michelle Vandevord, Amy Cardinal Christianson, and the Canadian Interagency Forest Fire Centre to help ensure groups who may not otherwise hear about or easily access the training were notified. Four scholarships were provided to individuals based on their outstanding community involvement and commitment to emergency response and coordination. Amy and Michelle were instrumental in guiding the scholarship process and selection.

New approaches made a lasting impact

MCTL broke away from typical professional development by focusing on the human aspects of learning, sharing, decision-making, and psychological health. The result was a lively and personal four days that deeply resonated with participants, both in content and delivery.

The human side of teams

Training content focused on the personal elements of navigating uncertainty and high-impact environments, including processing mental residue from challenging experiences and walking the hard path of critical environments. Participants also learned about communicating and teaching tacit knowledge, nuances between routine and critical communication in different contexts, and how to facilitate and lead meaningful After Action Reviews (AARs) and debriefs that genuinely support team well-being and learning.

For many, the course offered a much-needed reset—a path back to living and thriving after mental strain or burnout. Many noted that it helped them find a healthier perspective on their profession and work-life balance, while reaffirming or even introducing the importance of integrating self-care along with supporting others. Participants learned to detect, recognize, react, respond, and recover from the radical change events caused by high-impact environments—in other words, to live a long and fulfilling life during and after a challenging career.

Attendees learned and connected with each other at round tables in a bright, non-traditional "classroom" overlooking the Rocky Mountains. Photo: Emily Friedrich, December 2024.

Collaborative and informal in-person learning

Instructor Preston Cline facilitated the course using collaborative inquiry. This research and teaching approach combines the expertise of facilitators and participants to participate in research and learning with, rather than on, the people who will use the outcomes. This discussion-oriented format encourages more engagement than a traditional classroom approach.

An early-set expectation of confidentiality allowed participants to more openly share their experiences and connect with their colleagues across different agencies on a deeper level, as did the shared on-site meals, recreational facilities, accommodations, and learning location outside of a traditional classroom. Integrated storytelling, both stories from the instructor and developing their own, offered participants memorable ways to recount their experiences with their colleagues back home.

Feedback for the course was very encouraging. Over 95% of participants said that they can better process challenging experiences, lead in complex and chaotic situations, and build community, and 100% would recommend the training to others or attend another similar course. Participants noted feeling re-energized, ready to bring back new tools to their teams and integrate changes into their personal and professional lives.

What's next for MCTL?

As part of our mandate to bridge organizational gaps and support critical new training opportunities, Canada Wildfire aims to continue offering MCTL annually. The Canada Wildfire team will continue donating administrative and labour costs, ensuring registration fees directly cover event expenses.

This year, we are pursuing exciting opportunities to expand MCTL's scope and reach, seeking to welcome more participants from diverse agencies and sectors. Thanks to the Supporting Psychological Health in First Responders grant program with the Government of Alberta, we're excited to offer an extra full day of instruction, an additional instructor, an extra night of accommodations (and meals), and a post-course follow-up. The grant has also allowed us to cut the cost of registration by almost 20%, as well as offer a limited number of scholarships for Albertan residents.

Looking ahead to a busy fire season, Canada Wildfire also looks forward to (re)connecting at MCTL to collectively reset and work towards processing our experiences. We're hopeful that strengthening our teams will support a culture change in mental health support for first and critical responders.

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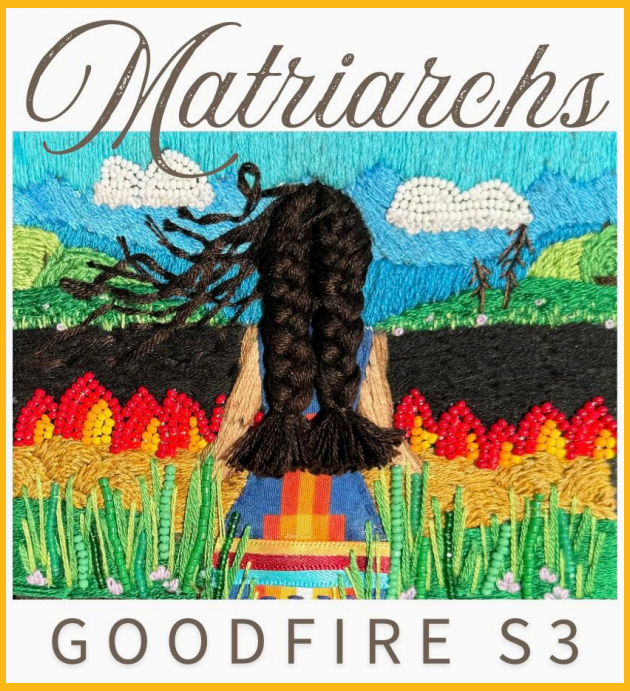
Mission Critical Team Leader Training 2025 will be offered in Hinton, AB from December 8-11, 2025. Learn more on the course website at bit.ly/mctl25.



Have you listened to the latest season of the Good Fire Podcast?

The Good Fire podcast shares stories of Indigenous fire stewardship, cultural and social empowerment, and environmental integrity. This season, Matriarchs, highlights the central role of Indigenous matriachs in fire, with powerful reflections on leadership, generational knowledge, healing trauma, and land stewardship.

Hosted by Amy Cardinal Christianson and Matthew Kristoff. Tune in wherever you find your podcasts, or at canadawildfire.org/podcasts

The Canadian Forest Service's Northern Forest Mapping (NorthForM) Program

By Jessica Zerb[1], Byron Smiley[2], Chris Bater[2], Jonathan Boucher[3], Anne-Cotton Gagnon[3], Sébastien Dagnault[3], Maxime Nolan[3], Samuel Lacarte[1], Graham Stinson[2], Chris Stockdale[1]
[1]Northern Forestry Centre, Canadian Forest Service, Natural Resources Canada, Edmonton, AB, Canada
[2]Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, Victoria, BC, Canada
[3]Laurentian Forestry Centre, Canadian Forest Service, Natural Resources Canada, Québec, QC, Canada
Corresponding author: jessica.zerb@nrcan-rncan.gc.ca

English version (French version below)

Accurate forest fuel mapping is a critical component of wildfire hazard assessment and fire behaviour prediction. Fire behaviour is primarily influenced by three key factors: fuel, topography, and weather; however, in Canada's northern forests, limited availability of reliable fuels information introduces uncertainty into fire behaviour predictions. This impedes the accuracy of wildfire risk assessments and constrains efforts to strengthen community wildfire resilience in these remote and often undersampled regions.

Fuel mapping in Canada is commonly based on the Canadian Forest Fire Behavior Prediction (FBP) System fuel type classification (Forestry Canada Fire Danger Group 1992; Taylor and Alexander 2018). This system defines 18 discrete fuel types (Canadian Forest Service Fire Danger Group 2021, Appendix A), typically derived from provincial and territorial forest resource inventory (FRI) datasets. While these inventories are the best available source of fuel information for forest management planning, they are often outdated, limited in spatial extent, and rarely cover areas outside of active forest tenures. In the absence of complete FRI coverage, fuel mapping in northern Canada has relied on moderate-resolution satellite remote sensing (e.g., Beaudoin et al. 2014) supported by National Forest Inventory (NFI) sample plots. However, low NFI sampling density in the North and remote sensing classifications trained on these data can misrepresent fuel conditions in the northern boreal forest, particularly in areas with mixed or transitional vegetation types.

The Northern Forest Mapping (NorthForM) program was launched to address these data gaps by generating high-resolution, up-to-date forest fuel maps specifically focused on Canada's northern boreal forests. The program aims to produce spatially continuous fuel attribute maps suitable for the Next-Generation Canadian Forest

Image 1. A Northern Forestry Centre field crew measuring a plot in northern Saskatchewan. One field crew member is inputting data through the NorthForM Survey123 application and the other field crew member is collecting subcanopy tree information. Photo credit: M.P. Ouellet-Pariseau.

Image 2. A top-down photograph collected at a NorthForM plot in Northwest Territories. This photograph is showing a regeneration microplot along one of the north-south transect tapes.

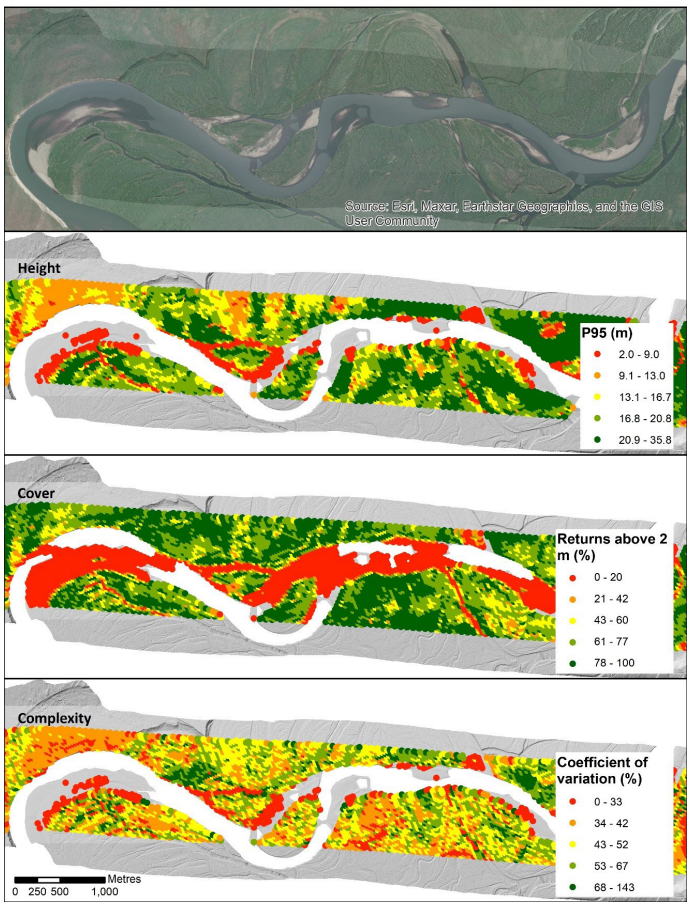


Image 3. Examples of ALS-derived vegetation metrics characterizing height, cover, and vertical complexity. Each point represents a 30 x 30 m cell in which a suite of area-based metrics is calculated.

Fire Danger Rating System (NG-CFFDRS). These products will be made available as open, interoperable datasets to support wildfire planning, management, and risk reduction efforts in northern communities.

Field data collection is conducted following the NorthForM protocol, which was developed to support consistent and scientifically rigorous sampling of fuel attributes in Canadian forests. The protocol was authored by Boucher, J., Cotton-Gagnon, A., Dagnault, S., Zerb, J., Smiley, B., Russo, G., and Nolan, M. (June 2024) and is available through the NFI website. It provides standardized procedures for sampling fuel strata, stand structure, and site conditions relevant to NG-CFFDRS fire behaviour models. To support both practical implementation and scientific development, the NorthForM program is structured into two working groups: an Operations Committee and a Science Steering Committee. The Operations Committee oversees field planning, logistics, coordination with provincial and territorial agencies, airborne laser scanning (ALS) acquisitions, and data pipelines. The Science Committee—comprised of wildfire, remote sensing and forest inventory research scientists from across the Canadian Forest Service (CFS)—guide methodological/protocol development, data interpretation, and integration with the NG-CFFDRS fire behaviour modelling frameworks.

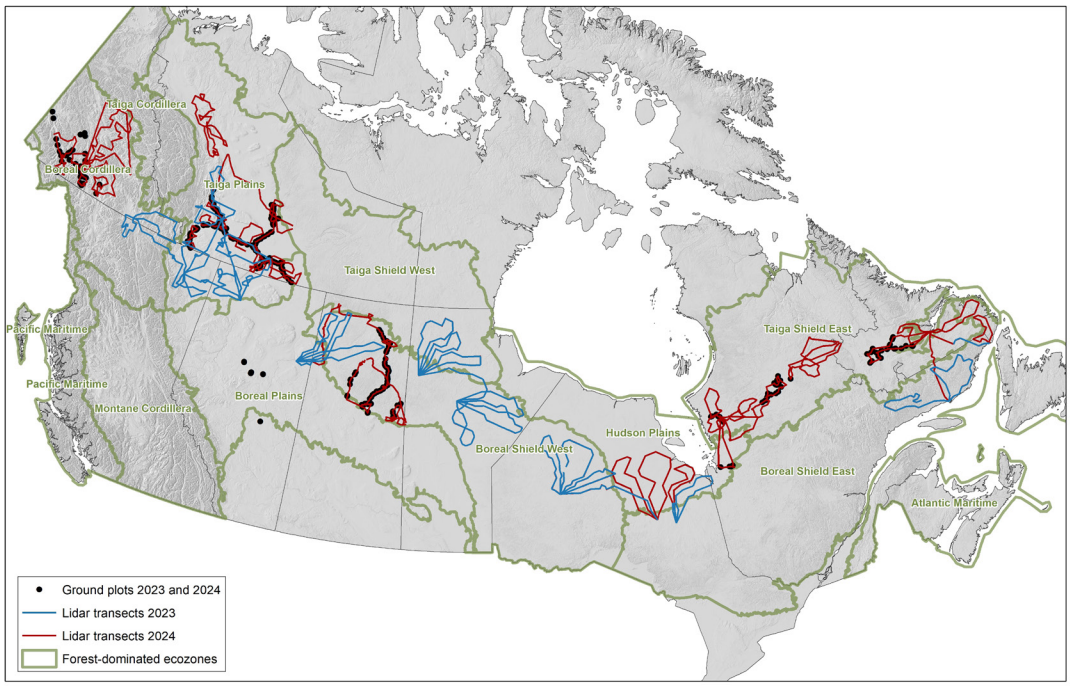


Image 4. Ground plot and ALS transect locations collected in 2023 and 2024. Approximately 620 ground plots are co-located within 43,000 km of linear ALS samples.

NorthForM is now in its third year of field data collection. In 2023, field plots were measured in the Northwest Territories, Labrador, and Alberta. The 2024 field season expanded sampling to include northern Saskatchewan, Yukon, and Quebec. In 2025, data collection will continue in Yukon and Quebec and expand into northern Manitoba. To date, more than 600 ground plots have been measured, and coincident ALS transects have been acquired across a range of northern forest fuel types. These datasets form the empirical basis for calibrating and validating models used in the production of fuel classification and attribute maps.

One of the expected outcomes of the program is wall-to-wall satellite information products related to wildfire fuels. Satellite imagery provides information on land cover and change; however, structural attributes are difficult to estimate without additional measurements. Sample transects of ALS, can provide direct measurements related to height, cover, and vertical complexity. Lidar transects spanning Canada's northern forests were acquired in 2023 and 2024. The transects are 20,000 and 23,000 km long, respectively and 500-800 m in width with 12 points/m^2 minimum point densities. The transects capture the ~620 co-located ground plots established within the same time frame. By linking ground plot measurements, lidar-derived structural metrics, and wall-to-wall satellite data, models can be developed to estimate several of the fuels attributes described in Boucher et al. (2024).

The success of the program is reinforced by strong collaboration with provincial and territorial partners, as well as the assembly of experienced and diverse field crews. Internal field teams from the CFS's Northern Forestry Centre and the Laurentian Forestry Centre include highly skilled recent graduates with academic backgrounds in conservation biology, geography, and forestry. These interdisciplinary teams bring a broad range of expertise to data collection in complex and remote environments. In addition to CFS-led efforts, provincial and territorial partners have supported the program via contractors who measure NorthForM plots within their jurisdictions. This collaborative model ensures robust data coverage while fostering capacity building and interagency knowledge exchange.

The NorthForM program is a crucial initiative to improve wildfire risk assessments and enhance community resilience across Canada's northern boreal forest. By addressing data gaps in fuel mapping, accurate fuel type classifications and attributes,

NorthForM will equip wildfire managers, local communities, and policymakers with the tools necessary to better understand and mitigate fire behaviour in these remote and vulnerable regions. The program's multi-year, collaborative approach that integrates expertise from various fields and jurisdictions, ensures that the data collected are scientifically rigorous and operationally relevant. As the project progresses into its third field season, the integration of field measurements with ALS and wall-to-wall satellite imagery will continue to refine fuel mapping capabilities, offering valuable insights for fire management agencies. With ongoing support from both internal CFS teams and jurisdiction partners, NorthForM is positioned to provide critical, long-term contributions to wildfire science and the sustainable management of Canada's northern forests.

Version française - Le Programme de cartographie des forêts du Nord (Northern Forest Mapping (NorthForM) Program) du Service canadien des forêts

La cartographie précise des combustibles forestiers est un élément essentiel de l'évaluation des aléas d'incendie et de la prévision du comportement des incendies. Le comportement des incendies est principalement influencé par trois facteurs clés : le combustible, la topographie et les conditions météorologiques. Cependant, dans les forêts nordiques du Canada, la disponibilité limitée d'informations fiables sur les combustibles introduit une incertitude dans les prévisions du comportement des incendies. Cela nuit à la précision des évaluations des aléas d'incendies et limite les efforts visant à renforcer la résilience des communautés face aux incendies dans ces régions éloignées et souvent sous-échantillonnées.

Au Canada, la cartographie des combustibles est généralement basée sur la classification des types de combustibles de la Méthode canadienne de prévision du comportement des incendies de forêt (Méthode de PCI) (Forestry Canada Fire Danger Group 1992 ; Taylor et Alexander 2018). Ce système définit 18 types de combustibles distincts (Canadian Forest Service Fire Danger Group 2021, Annexe A), généralement dérivés des données d'inventaires des ressources forestières (IRF) des provinces et territoires. Bien que ces inventaires constituent la meilleure source d'information sur les combustibles pour la planification de la gestion forestière, ils sont souvent obsolètes, limités dans leur étendue spatiale et couvrent rarement les zones situées en dehors des tenures forestières actives. En l'absence d'une couverture complète des IRFs, la cartographie des combustibles dans le nord du Canada s'est appuyée sur la télédétection satellitaire à résolution modérée (p. ex., Beaudoin et al. 2014) soutenue par des parcelles d'échantillonnage de l'Inventaire forestier national (IFN). Cependant, la faible densité d'échantillonnage

Image 1. Une équipe de terrain du Centre de foresterie du Nord mesure une parcelle dans le nord de la Saskatchewan. Un membre de l'équipe de terrain saisit des données à l'aide de l'application NorthForM Survey123 et l'autre membre de l'équipe de terrain recueille des informations sur les arbres du sous-bois. Crédit photo : M.P. Ouellet-Pariseau.

Image 2. Photographie de haut en bas prise dans une parcelle de NorthForM dans les Territoires du Nord-Ouest. Cette photographie montre une microplacette de régénération le long d'un des rubans de transect nord-sud.

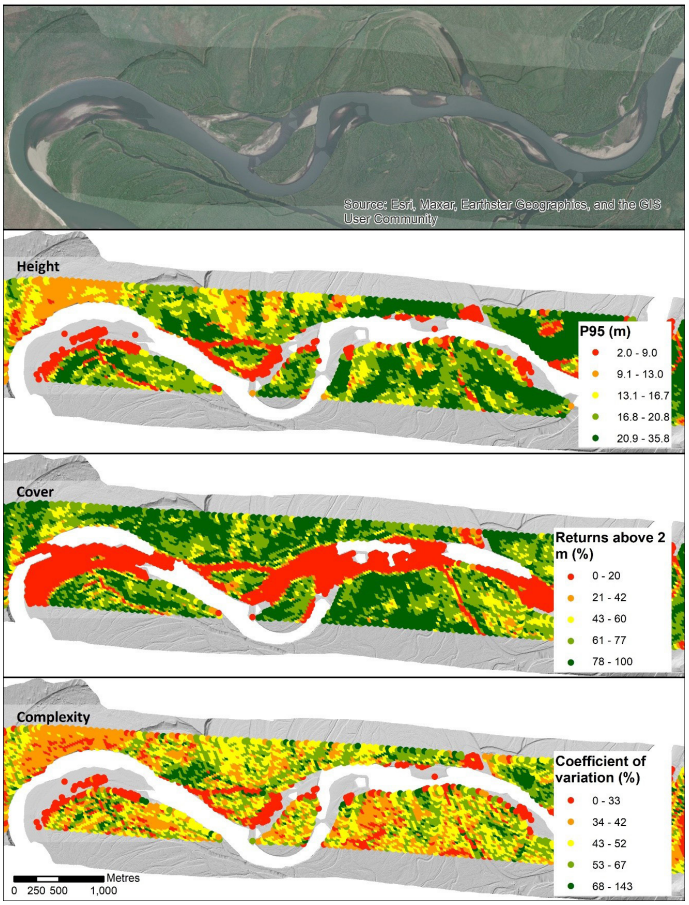


Image 3. Exemples de mesures de la végétation dérivées de l'ALS caractérisant la hauteur, la couverture et la complexité verticale. Chaque point représente une cellule de 30 x 30 m dans laquelle une série de mesures basées sur la surface sont calculées.

de l'IFN dans le Nord et les classifications de télédétection formées à partir de ces données peuvent donner une image erronée des conditions de combustible dans la forêt boréale nordique, en particulier dans les zones où les types de végétation sont mixtes ou transitoires.

Le Northern Forest Mapping (NorthForM) program (« Programme de cartographie des forêts du Nord ») a été lancé pour combler ces lacunes en produisant des cartes à haute résolution et à jour des combustibles forestiers, spécifiquement axées sur les forêts boréales nordiques du Canada. Le programme vise à produire des cartes d'attributs de combustibles spatialement continues, adaptées à la prochaine génération de la Méthode canadienne d'évaluation des dangers d'incendie de forêt (PG-MCEDIF). Ces produits seront mis à disposition sous forme de jeux de données ouverts et interopérables afin de soutenir les efforts de planification, de gestion et de réduction des risques liés aux incendies de forêt dans les communautés nordiques.

La collecte de données sur le terrain est effectuée conformément au protocole NorthForM, qui a été élaboré pour favoriser un échantillonnage cohérent et scientifiquement rigoureux des attributs des combustibles dans les forêts canadiennes. Le protocole a été rédigé par Boucher, J., Cotton-Gagnon, A., Dagnault, S., Zerb, J., Smiley, B., Russo, G. et Nolan, M. (juin 2024) et est disponible sur le site Web de l'IFN. Il fournit des procédures normalisées pour l'échantillonnage des couches de combustibles, de la structure

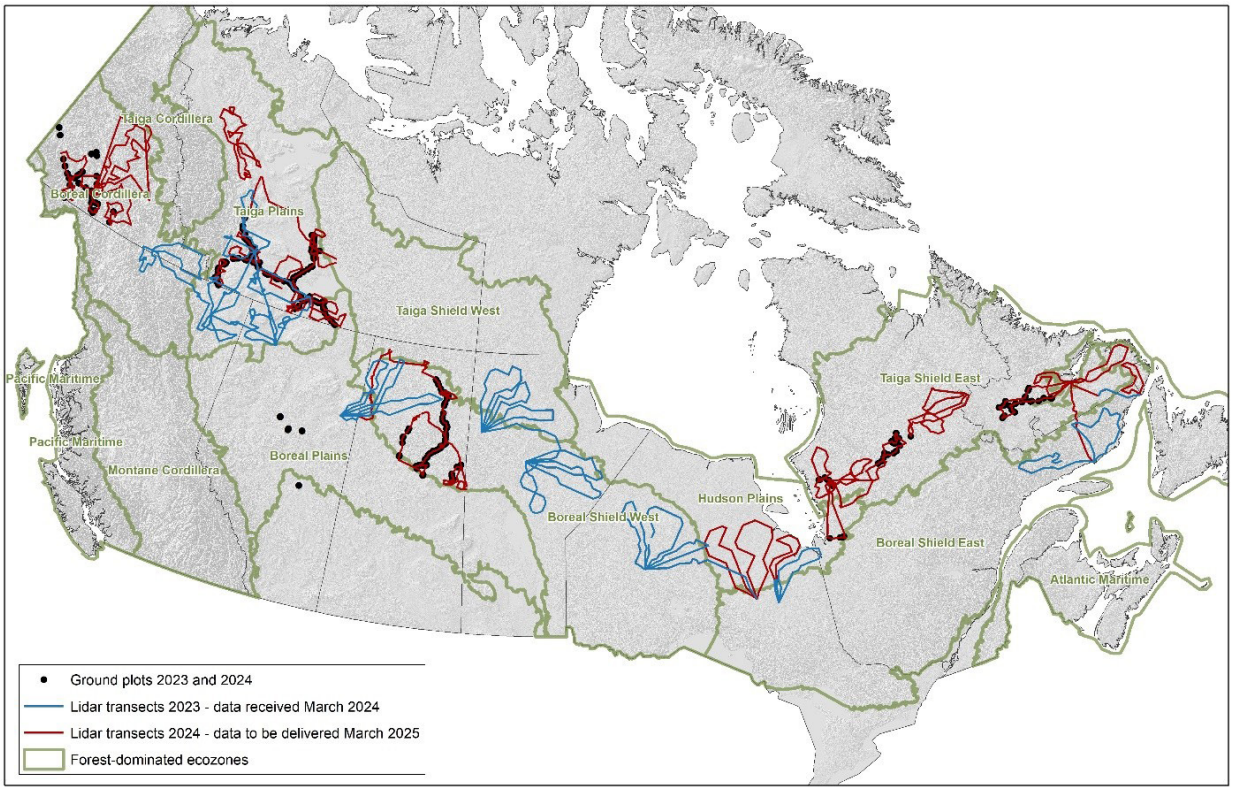


Image 4. Emplacements des placettes et des transects ALS collectés en 2023 et 2024. Environ 620 placettes sont situées dans un rayon de 43 000 km d'échantillons ALS linéaires.

des peuplements et des conditions du site pertinentes pour les modèles de comportement des incendies de la PG-MCEDIF. Pour soutenir à la fois la mise en œuvre pratique et le développement scientifique, le programme NorthForM est structuré en deux groupes de travail : un comité des opérations et un comité de pilotage scientifique. Le comité des opérations supervise la planification du terrain, la logistique, la coordination avec les agences provinciales et territoriales, les acquisitions par balayage laser aéroporté (airborne laser scanning; ALS) et les pipelines de données. Le comité scientifique - composé de chercheurs.ses en incendies de forêt, en télédétection et en inventaire forestier de l'ensemble du SCF - oriente l'élaboration des méthodes et des protocoles, l'interprétation des données et l'intégration avec les cadres de modélisation du comportement des incendies de la PG-MCEDIF.

NorthForM en est à sa troisième année de collecte de données sur le terrain. En 2023, des parcelles de terrain ont été mesurées dans les Territoires du Nord-Ouest, au Labrador et en Alberta. La saison de terrain 2024 a permis d'étendre l'échantillonnage au nord du Saskatchewan, au Yukon et au Québec. En 2025, la collecte de données se poursuivra au Yukon et au Québec et s'étendra au nord du Manitoba. À ce jour, plus de 600 placettes ont été mesurées et des transects ALS coïncidents ont été acquis dans toute une gamme de types de combustibles forestiers nordiques. Ces ensembles de données constituent la base empirique pour l'étalonnage et la validation des modèles utilisés dans la production de cartes de classification et d'attributs des combustibles.

L'un des résultats escomptés du programme sera la production de produits d'information satellitaire mur à mur sur les combustibles utilisés dans les incendies de forêt. L'imagerie satellitaire fournit des informations sur la couverture et le changement des terres ; cependant, les attributs structurels sont difficiles à estimer sans mesures supplémentaires. Les transects d'échantillonnage de l'ALS peuvent fournir des mesures directes de la hauteur, de la couverture et de la complexité verticale. Des transects LiDAR couvrant les forêts nordiques du Canada ont été acquis en 2023 et 2024, et mesurent respectivement 20 000 et 23 000 km de long. Les transects avaient une largeur de 500 à 800 m et la densité minimale de points était de 12 points/m^2. Les

transects capturent les ~620 placettes colocalisées établies au cours de la même période. En reliant les mesures des placettes, les mesures structurelles dérivées du LiDAR et les données satellitaires mur à mur, des modèles peuvent être développés pour estimer plusieurs des attributs des combustibles décrits dans Boucher et al. (2024).

Le succès du programme est renforcé par une collaboration étroite avec les partenaires provinciaux et territoriaux, ainsi que par la constitution d'équipes de terrain expérimentées et diversifiées. Les équipes de terrain internes du Centre de foresterie du Nord et du Centre de foresterie des Laurentides sont composées de jeunes diplômés.ées hautement qualifiés.ées ayant une formation universitaire en biologie de la conservation, en géographie et en foresterie. Ces équipes interdisciplinaires apportent un large éventail de compétences à la collecte de données dans des environnements complexes et éloignés. En plus des efforts déployés par le SCF, les partenaires provinciaux et territoriaux ont soutenu le programme par l'intermédiaire d'entrepreneurs.euses qui mesurent les parcelles de NorthForM sur leur territoire. Ce modèle de collaboration assure une couverture robuste des données tout en favorisant le renforcement des capacités et l'échange de connaissances entre les agences.

Le programme NorthForM est une initiative cruciale visant à améliorer l'évaluation des risques d'incendie de forêt et à renforcer la résilience des communautés dans la forêt boréale nordique du Canada. En comblant les lacunes dans les données relatives à la cartographie des combustibles, à la classification précise des types de combustibles et à leurs attributs, NorthForM dotera les gestionnaires des incendies de forêt, les communautés locales et les décideurs.euses des outils nécessaires pour mieux comprendre et atténuer le comportement des incendies dans ces régions éloignées et vulnérables. L'approche pluriannuelle et collaborative du programme, qui intègre l'expertise de divers domaines et juridictions, garantit que les données collectées sont scientifiquement rigoureuses et pertinentes d'un point de vue opérationnel. Alors que le projet entre dans sa troisième saison de terrain, l'intégration des mesures de terrain avec l'ALS et l'imagerie satellite mur à mur continuera à affiner les capacités de cartographie des combustibles, offrant des informations précieuses aux agences de gestion des incendies. Grâce au soutien continu des équipes internes du SCF et des partenaires gouvernementaux, NorthForM est en mesure d'apporter des contributions essentielles et à long terme à la science des incendies de forêt et à la gestion durable des forêts nordiques du Canada.

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Canada Wildfire

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Introducing `fireexposuR` v1.1.0

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`fireexposuR` is an open-source package for computing and visualizing wildfire ignition exposure (v1.1.0; Forbes and Beverly 2025) written in the R programming language (R Core Team 2024). The development of `fireexposuR` was inspired by the increased interest in conducting the wildfire ignition exposure and directional vulnerability assessments that have been introduced in a number of publications (Beverly et al. 2010, Beverly et al. 2021, Forbes and Beverly 2023) and reference materials (Firesmart Canada 2018). Before the release of this package, it was challenging for the methods to be replicated by interested parties without prior spatial analysis skills. This barrier to access has now been reduced significantly with the added assurance and verification from originating authors that the computation functions are generating the expected results. The package does require knowledge of the R programming language and environment, but there are many free resources available online to reduce this barrier. I recommend the first two chapters of this online book as a great place to start.

There have been a number of opportunities to learn more about wildfire ignition exposure methods and the fireexposuR package in the past year. A workshop with an early development version of the software was offered at the Wildland Fire Canada Conference in September 2024, and the first iteration of EXP100: Wildfire Exposure and Directional Vulnerability Assessments: Methods and Applications course was offered in February 2025. Over 70 participants worked through example exercises to assess wildfire exposure and directional vulnerability. Future offerings of EXP100 and more advanced courses (EXP200, EXP300) are in development and will be advertised here.

In January of 2025, I also presented about the project during a Canada Wildfire webinar; the recording is available here. Since the webinar, the `fireexposuR` package has completed the peer-review process. The package is now hosted on the ROpenSci repo and available for easy installation through R-Universe. For users that have installed the development version from github in the past, it is recommended that you follow the new installation instructions to make sure you are using the latest version. The documentation in the current package version has been expanded and is updated frequently to improve clarity.

The package will continue to be maintained and improved over its lifespan. Any feedback, suggestions, and contributions are welcome and encouraged; they can be raised on github or emailed to Air Forbes (amforbes@ualberta.ca). A full-length publication that will dive into the nitty-gritty details is also in preparation. News and updates about the package and paper will be posted on the package website, the Wildfire Analytics website, and LinkedIn. I have thoroughly enjoyed hearing from researchers and practitioners who have used the package for their own projects. If you have used the package yourself, I would love to see how you use it and, with your permission, share your projects on the package website!

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