CANADIAN WILDLAND FIRE & SMOKE

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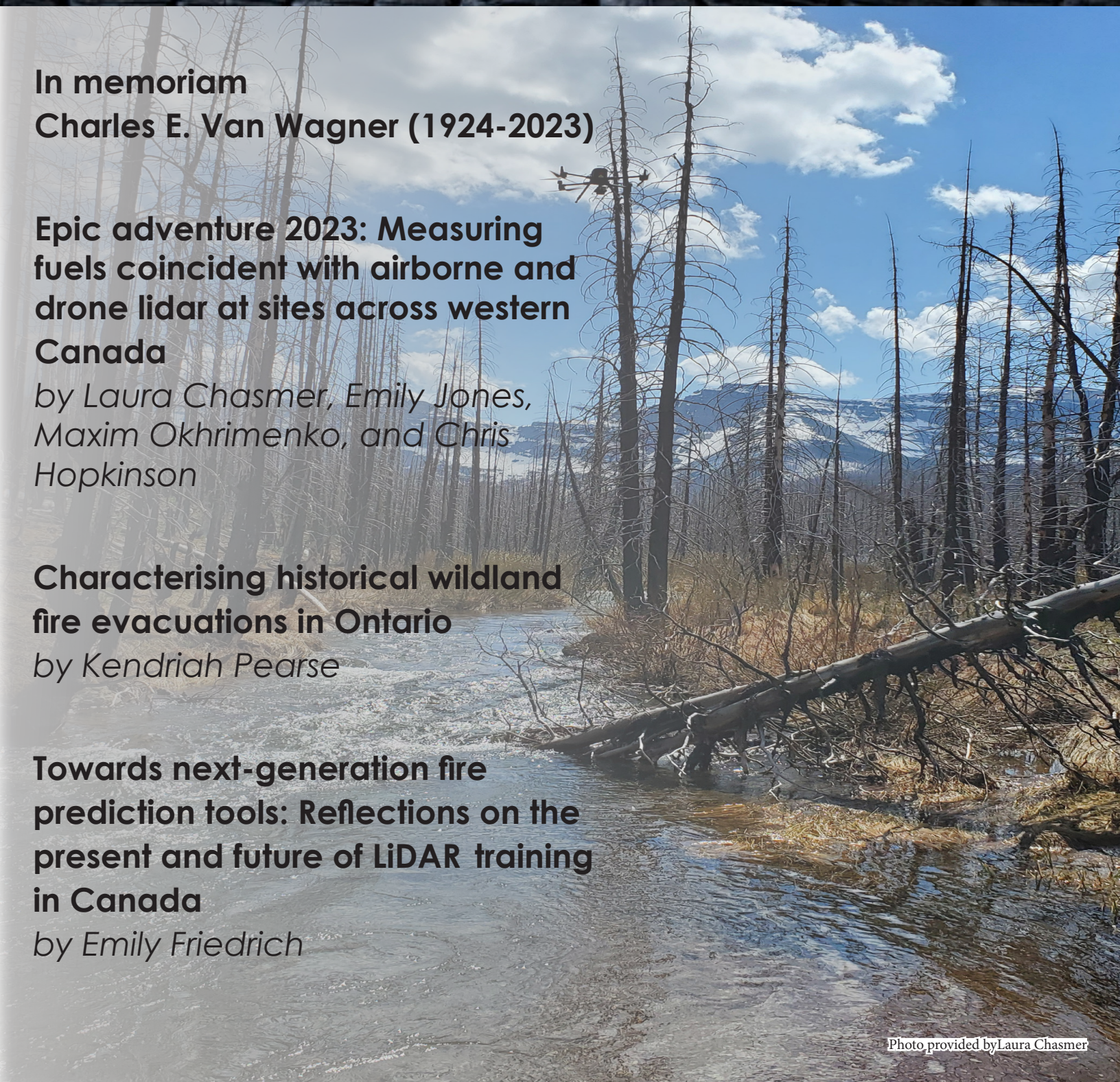

In memoriam
Charles E. Van Wagner (1924-2023)

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Photo provided byLaura Chasmer

In memoriam
Charles E. Van Wagner (1924-2023)

During his 30-year career (1961-1991) as a Senior Forest Fire Research Scientist with the Canadian Forest Service, Charles (Charlie) Van Wagner was the leading fire researcher in Canada and was immensely respected both nationally and internationally as an imaginative and innovative scientist. His contributions to fire science greatly influenced both his and succeeding generations of fire scientists throughout the world.

Charlie played a vital leadership role in visualizing and developing the current Canadian Forest Fire Danger Rating System (CFFDRS), a fire danger rating system that has served as a foundation for the most important fire management information systems and decision-support tools used across Canada since 1970, and a fire danger rating system that has been adopted in many countries internationally over the past several decades. The key component subsystems of the CFFDRS, namely the Fire Weather Index (FWI) System and the Fire Behavior Prediction (FBP) System, were developed after many years of dedicated and focused research by a number of Canadian fire scientists. Charlie was the acknowledged leader of that group and a person with the broad vision required throughout this process.

Charlie was the 2012 recipient of the Ember and Wright Awards at the Wildland Fire Canada Conference in Kananaskis, Alberta (L to R: Mike Wotton, Mike Flannigan, Charlie Van Wanger and Brian Stocks).

Van Wagner's pioneering studies in the area of fuel moisture physics laid the foundation for the moisture models within CFFDRS. These experiments typified his approach to model development and included extensive laboratory and field measurements of the moisture content of forest fuels, focusing on the relationship of temperature and relative humidity to both equilibrium moisture content and the drying rate of fuel layers in the forests, both critical to understanding and predicting fuel layer moisture exchange and ultimately fuel ignition probability.

A staunch advocate of field-based experimentation, he conducted over 100 experimental fires in various fuel types correlating fire behaviour parameters (e.g., spread rate, fuel consumption, and fire intensity) with on-site fire weather and fire danger conditions. When expanded to other forest types, this approach became fundamental to gathering the range of fire behaviour data (from surface to crown fires) necessary in the development of the FBP System and fostered experimental burning programs across Canada.

Van Wagner also conducted pioneering fire physics research on the measurement and theory of flame temperature and its variation with height above ground. He greatly expanded the theory of fire propagation through flame radiation, concluding that in crown fires, radiation occurs within the trunk space and crown layer. This finding led to his conclusion that the crowning phase in the most intense fires is unable to advance by itself and requires continuous convective heat from the surface fire below. This theory on the onset of crowning and the threshold between passive and active crown fire spread of crowning fires is used worldwide in most operational fire spread models that link surface and crown fire. It represents a large part of the scientific rationale for the effectiveness of stand treatment techniques (e.g., thinning, pruning, and surface fuel removal) in reducing fire intensity, an area of extensive activity and investment in 21st-century fire management.

Charlie also spent considerable time studying the ecological consequences of fire through long-term post-fire monitoring of his experimental and prescribed fires at the Petawawa Research Forest. In addition to influential studies on the "Height of crown scorch in forest fires" and "Age-class distribution and the forest fire cycle," this led to cooperating with Parks Canada extensively in developing their large landscape-scale prescribed burning program.

In his career, Charlie Van Wagner produced over 100 published papers in journals, conferences, symposia and government information reports, always publishing his research results quickly and concisely. His papers have garnered thousands of citations within the field of fire research and remain a common point of reference today. The measure of a scientist's contribution should not be the raw number of publications produced in a career but the influence of those publications and the legacy thus created. His enduring influence, the ongoing significance of his original research, its wide-reaching scope, and its integration into forest fire management underscore his profound impact on the field of fire science. He has been a true visionary.

- BJS, BMW, MDF

Epic adventure 2023: Measuring fuels coincident with airborne and drone LiDAR at sites across western Canada

By Laura Chasmer[1], Emily Jones[1], Maxim Okhrimenko[1], and Chris Hopkinson[1]
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From June 24 to July 11, 2023, undergraduate and graduate students (accompanied by faculty) from the University of Lethbridge and an MSc internship student from France completed an epic fire fuel field measurement and LiDAR survey across western Canada. Covering more than 8,000 km and six major field sites in Northwest Territories, Yukon, and across the eastern slopes of the Canadian Rockies (Figure 1), the team added 23 NG-CFFDRS (Next Generation Canadian Forest Fire Danger Rating System) fuel plots, completing a time series of almost 200 fuel and biomass/mensuration plots coincident with airborne LiDAR data. The broad overall objective of the research, proposed by PhD student Emily Jones, is to better understand the range of structural variations of fire fuels in peatlands, forested permafrost, and montane areas undergoing rapid climate-mediated change.

We started our trip in Lethbridge, with some students driving and some flying to Yellowknife, managing to avoid the various fires occurring across the provinces and territories. The first leg of the trip included installation of fuel plots near Fort Simpson and discussion with the Dehcho First Nations at the northern part of the Scotty Creek Research Basin. Identified plots were then surveyed by the University of Lethbridge (ULethbridge) ARTeMiS Lab multi-spectral airborne LiDAR and a drone-based LiDAR prior to measurement (as it is important that we don't trample the vegetation before the LiDAR survey is acquired). Plots were installed in forested uplands and peatlands to better understand the impacts of permafrost thaw and drying on canopy and understory fuels.

Next, we braved the bugs and drove on to Watson Lake, seeing various wildfires in the distance. Here, we collaborated with Yukon Wildfire to collect LiDAR data over masticated and replanted forest plots south of Whitehorse for BSc thesis research by Milan Lapres. Forested areas in the foothills surrounding Watson Lake were also surveyed, with additional plots added and airborne/drone-based lidar surveys completed. A single NG-CFFDRS fuel plot can take four hours to a day to measure, so we tested a new method for rapid measurement of tree structural attributes from drone LiDAR (while measuring other fuel attributes within

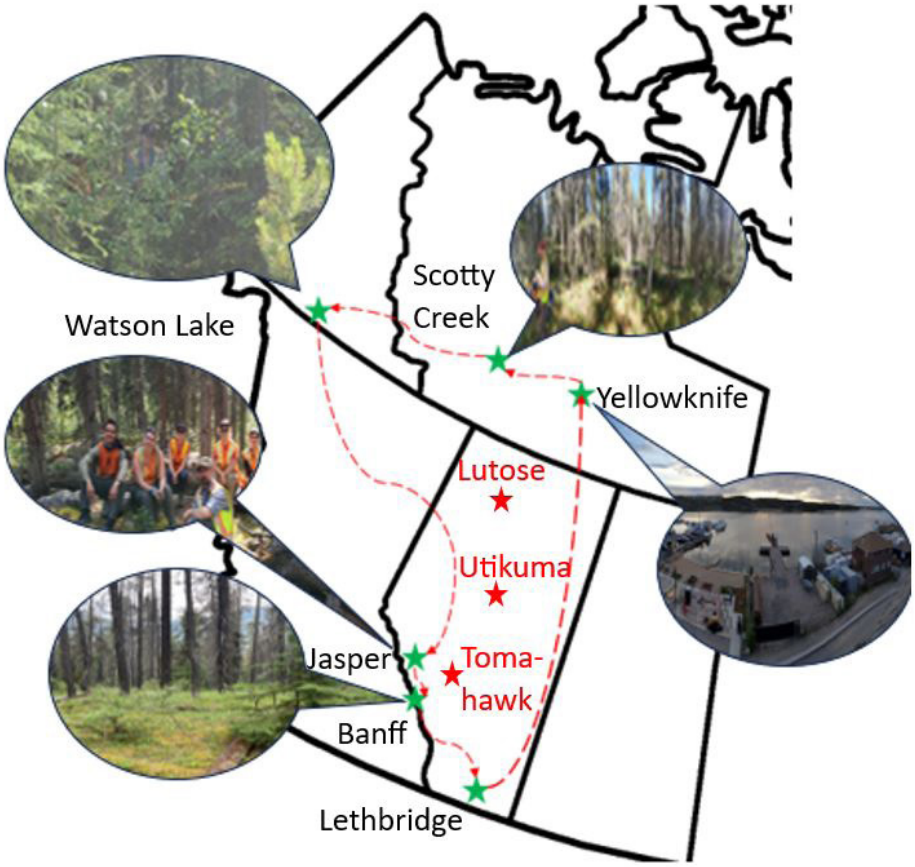


Figure 1. Map showing approximate site locations. Green stars indicate areas where field, drone LiDAR, and airborne LiDAR data were collected, while red stars represent sites where only airborne LiDAR data was collected. The dashed lines depict an artistic representation of the route travelled.

plots). This method reduced the measurement time to about 45 minutes within these 'hybrid' plots! From that discovery, we had to convince ourselves that measuring 'all' of the fuel attributes (by hand) was still important for modelling fuels from LiDAR data.

The trip from Watson Lake to Jasper was incredible, and if you have not travelled Hwy 97 through Coal River and Toad River to Fort Nelson, it is worth the trip! Here, we skirted a couple of small fires to arrive at idyllic villages with float planes and bison. After a close encounter with a bear at a local gas station, we were on our way again, staying overnight at Fort Nelson and then arriving late in the evening to Jasper.

The first part of our activities in Jasper National Park was to revisit the Chetamon Fire (Figure 3). Here, we measured composite burn indices of the paleo-vegetation plots that were described by Dr. Raphael Chavardez (Canadian Forest Service) and Dr. Lori Daniels (University of British Columbia) (Chavardes and Daniels, 2016). These sites have pre-fire airborne LiDAR data, which we re-surveyed again post-fire. Though Raphael was across the country in Nova Scotia working on the impacts of the fires there, we explored ideas related to fire return intervals and burn severity, led by Natalie Krizan (NSERC Undergraduate Student Research Award recipient and hopeful future MSc student). This work was followed by installation of additional NG-CFFDRS plots in areas that were not impacted by Mountain Pine Beetle. The purpose was to measure fuels in reference to pine/spruce and mixed sites, which will help us better understand how mountain pine beetle impact fuel distribution – a project that we are working on with the

Figure 2. Chris Hopkinson with DJI Matrice drone with laser scanner (left), distant fire burning in northern BC visible from highway 97 in BC, early July 2023 (top right), colourized point cloud from drone (bottom right).

Figure 3. Photograph of the Chetamon Fire, Jasper National Park taken looking north.

Foothills Research Institute, Jasper National Park, Dr. Patrick James (University of Toronto), and Dr. Jonathan Boucher (CFS). Always keeping in mind how easy it is to survey plots with drone-based LiDAR, we continued to do airborne and drone-based LiDAR surveys prior to our vegetation plots.

During our operations in Jasper National Park, we maintained our collaboration with Raphael through virtual means and continued to receive support from Dr. Chris Watson, who works at Parks Canada. Additionally, our team (Figure 4), initially comprising five members on the ground, Dr. Chris Hopkinson operating the drone, and PhD student Maxim Okhrimenko in the air, has now grown with the inclusion of two more students, providing an opportunity to separate tasks and complete two plots at once, further streamlining the activities.

Remaining plots were added to Banff Natioinal Park along the Icefields Parkway, where we first installed forest plots with

Figure 4. Undergraduate and graduate student team involved in plot measurements at Jasper National Park, including Dr. Chris Watson from Jasper National Park (right).

LiDAR data in 2002, and Waterton Lakes National Park (where we are measuring post-fire regeneration following the Kenow fire). In between field and LiDAR plots in the National Parks, LiDAR-operator and PhD student Maxim managed to survey another area near Utikuma Lake, Alberta. A new fire burned towards the site from the east, where fires burned in 1956, 2011, and this year. In collaboration with Dr. Sophie Wilkinson and Dr. Koreen Millard, we also surveyed the Tomahawk-managed peatland area (burned in 2021) and another harvested peatland area to the north, which burned this year. These surveys will support a new ULethbridge MSc student, Amanda Bakalarczyk and upcoming students of Drs. Sophie Wilkinson and Koreen Millard through an NSERC Alliance grant.

While these have taken considerable time, we are grateful to the NSERC/CFS Canada Wildfire Strategic Network, Foothills Research Institute, Parks Canada, and the various communities and agencies for enabling us to do this research. Finally, while all of this is highly academic, we recognize the importance of operationalizing these findings and developing tools. An early version of a rapid fuel assessment has been showcased (using our fuel and LiDAR data) by Hatfield Consultants with support from NRCAN. You can find an overview of the project here: arboSense Fuels (https://storymaps.arcgis.com/stories/8eaaab1537fd493094cd1007dd82b02f). To hear more about the 2023 field season and the great working ongoing at the Univeristy of Lethbridge, check out this Canada Wildfire Webinar.

We look forward to sharing the data in the near future and continuing to work across various entities using these valuable datasets.

Panoramic photo showing fuel plot installation and measuring trees near Fort Simpson, NWT.

Characterising historical wildland fire evacuations in Ontario

By Kendriah Pearse, MScF, kendriah.pearse@mail.utoronto.ca
University of Toronto, Ontario, Canada

In Ontario, wildland fire evacuations are commonly used to protect the public from the direct threat to a community or the indirect threats associated with smoke. In my master's thesis, completed this past December, I characterized the situational factors (e.g. Fire Weather Index (FWI) System outputs, distance, direction and fire load) associated with fires that caused evacuations around communities in Ontario compared to those that did not cause evacuations.

Throughout this process, which began during the height of COVID (being fully remote for my first year of my master's thesis), I was blessed with a wealth of perspectives and support from my master's committee. My committee consisted of a combination of fire research scientists and a representative from a provincial fire management agency (Mike Wotton, Xianli Wang, Mike Flannigan and Dan Johnston). The goal of this research was to provide an initial exploration of the characteristics associated with wildland fire evacuations in Ontario and the physical conditions that may drive evacuation decisions.

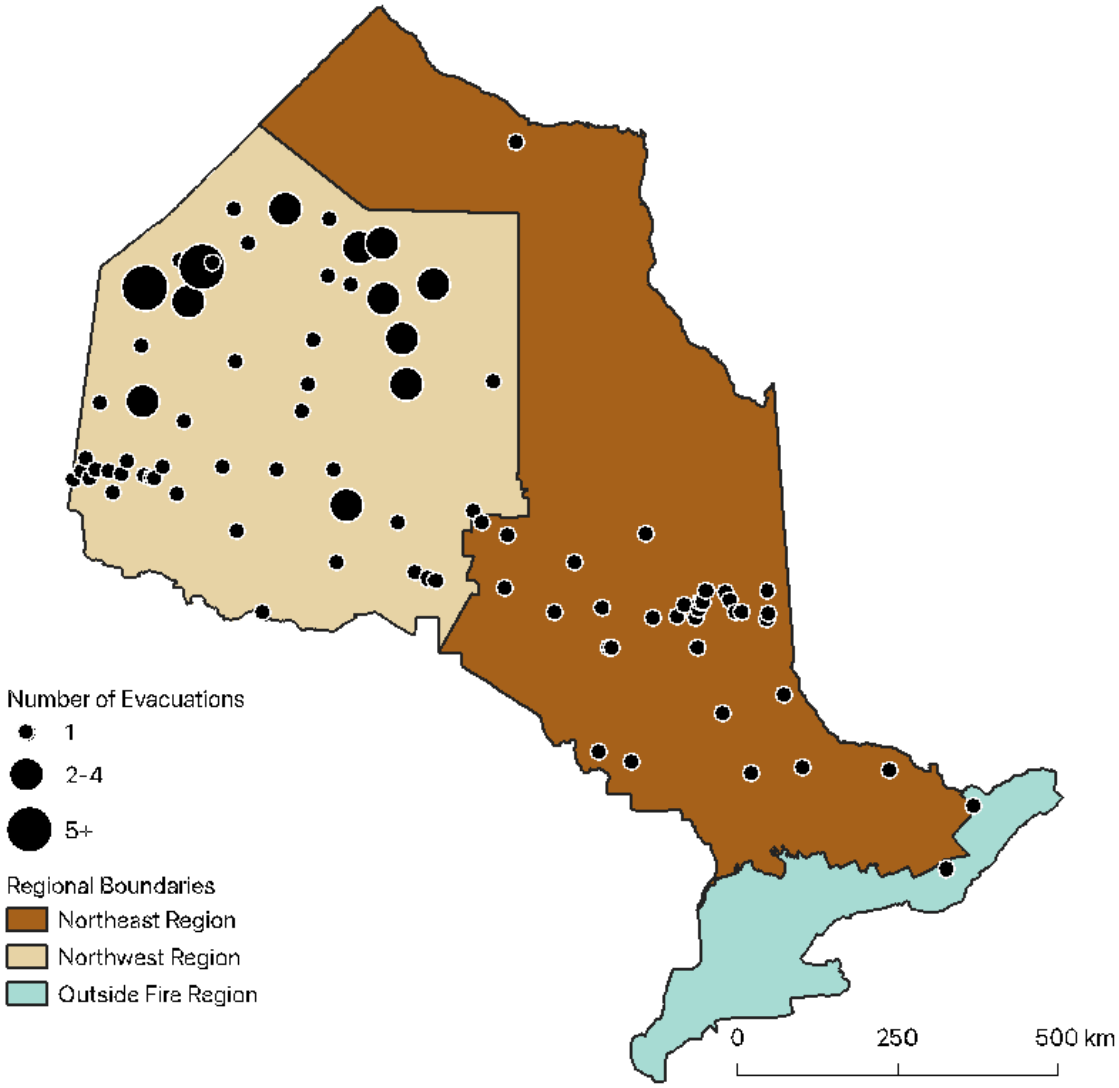


Figure 1. Evacuation locations which experienced one or more wildfire evacuations in Ontario between 1980-2020. Map only displays evacuation locations where the corresponding fire's estimated ignition point was within 80km.

For my analysis, I obtained wildland fire evacuation information for Ontario from the Canadian Wildland Fire Evacuation Dataset for 1980-2020. Evacuations are highly impactful on people. Although wildfire spread and smoke production are physical environmental processes that could potentially lead to evacuation, the decision to evacuate is heavily influenced by social and jurisdictional factors. Upon initial exploration of the data, it was clear some data was missing. I was able to improve the sample size through direct contact with the Ontario Ministry of Natural Resources and Forestry fire management to find evacuations that were not within the original dataset.

To begin my analysis, I looked at the general characterization of the year-to-year variability of evacuations in Ontario. I did this to get a sense of the general characteristics of annual evacuation occurrence between 1980 and 2020. Through my examination of these baselines, I was able to quantify the annual variation in evacuations over the last 40 years. Albeit simple, this allowed me

to understand the annual ranges we can expect and how variable evacuations are from year to year, ranging from none to, at the highest, 15 evacuations in 2019. Four evacuations occur on average per year in Ontario, a number that is much higher than I had anticipated. Although rare to most communities, evacuations are not rare in Ontario.

The first section of my thesis focused on a very broad descriptive analyses of general yearly trends in evacuation occurrence. In the next section, I compared factors of fires that caused evacuations versus those that did not while also assessing if these factors differed for each evacuation type (smoke versus direct threat of fire). Here, I will focus on the second section of my thesis.

Methods

In this analysis, only fires with a size of >5ha and <80km from a previously evacuated community were included (Figure 1). Initially, 21 independent variables were explored, such as the maximum Build-up Index (BUI), Initial Spread Index (ISI), and number of spread events over the lifetime of the fire, as well as the distance, direction (relative to a community), and final size of the fire. In the analysis, there were a total of 138 evacuations (42 smoke, 96 direct threat), with 12,754 fires included in the analysis.

Initially, univariate models of each independent variable were created, and model fit was assessed using binned residuals and area under the receiver operator curve (AUC). After this, a supervised forward stepwise logistic regression was used to develop two main models. The first, Model A, looked at the absolute probability that a fire led to an evacuation of either type. The dependent variable here was evacuation occurrence (smoke and threat combined). The second, Model B, was a conditional model in which I only included the subset of fires which caused evacuations. This was done to identify factors which could help to discriminate between if an evacuation occurred due to smoke or a direct threat with the dependent variable being evacuation type. The third and final model, (Model C), was simply the multiplicative combination of Model A and the conditional Model B to get the absolute probability of a threat evacuation and of a smoke evacuation (see Figure 2 for more info).

Description of models:

Model A: Absolute probability that a fire leads to an evacuation of either type

Model B: Conditional probability that if an evacuation occurred, it was due to a direct threat (instead of smoke)

Model C: Model A* Model B: Absolute probability that a fire leads to a direct threat evacuation

Model C': Model A* (1- Model B): Absolute probability that a fire leads to a smoke evacuation

Figure 2. Description of models.

Results

The final multivariate model for Model A consisted of the independent variables: final fire size, distance to evacuation location, maximum BUI over the lifetime of a fire, direction, and an interaction between distance and final fire size (see Figure 3). Distance and final fire size were the two main drivers influencing evacuation probability; however, other factors, such as extreme BUI and an ignition location northwest of communities were associated with increased evacuation probability.

In the final model for Model B, the distance between the fire and the community was the only variable that was found to distinguish between evacuation type. Fires located close to communities were associated more with threat evacuations, but the probability of a smoke evacuation increased as the distance increased (see Figure 4).

Model A and B were combined to produce Model C, an estimate of the absolute probability of a direct threat evacuation, and Model C', an estimate of the absolute probability of a smoke evacuation. The absolute probability of an evacuation decreases

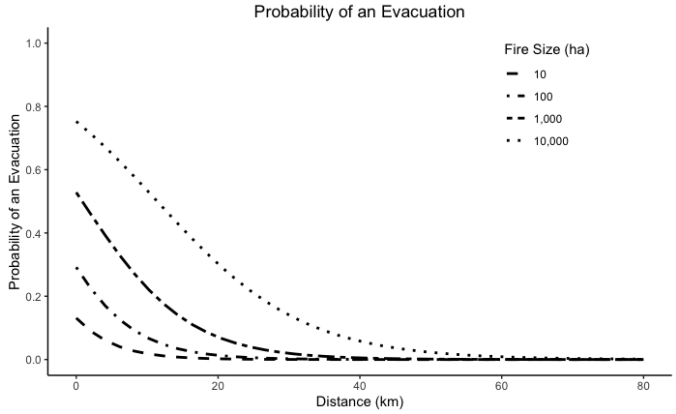
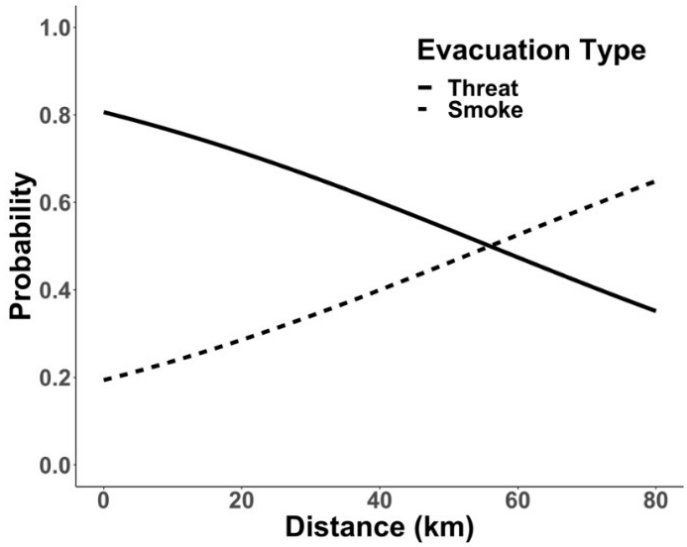


Figure 3. Model A results of the probability of an evacuation as a function of final fire size as the distance from the fire to evacuation location increases. The Max BUI function was held constant at 55, and only NW direction is shown.



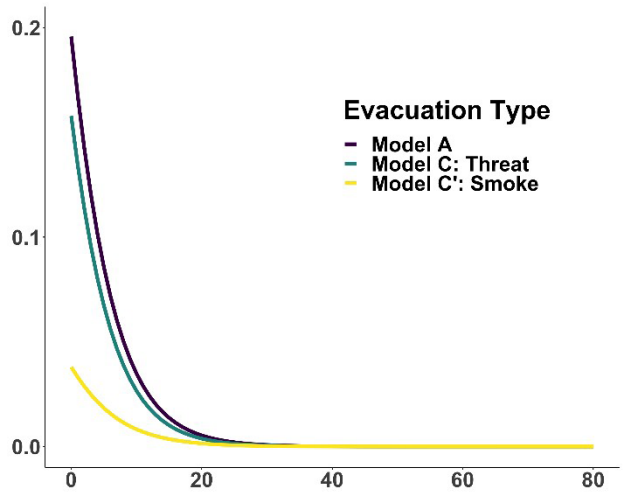


Figure 4 (left). Model B results of the change in probability of a threat and smoke evacuation as a function of distance of fire ignition location to evacuation location. Figure 5 (right). Visual representation of the conditional probability of each evacuation type. The purple line is the probability of an evacuation of either type (Model A), the blue line (Model C) is the probability of a threat evacuation given that there is a fire within 80km of a previously evacuated location (P(threat=1) = Prob(evac=1)*Prob (threat | evac=1)), and the yellow line (Model C') is the probability of a smoke evacuation given that there is a fire within 80km of a previously evacuated location (P(smoke=1) = Prob(evac=1)*(1.0 - Prob (threat | evac=1))).

significantly after 20km, and the probability of a smoke evacuation is almost always lower than that of a threat evacuation (Figure 5). The probability of a smoke evacuation surpasses that of a threat evacuation around 57km (see Figure 4); however, at this point, the overall probability of an evacuation is so low that this difference is visually indistinguishable.

Discussion

In Model A, I estimated the probability that given a new fire is occurring on the landscape in the 80km radius (and it ends up >5ha), it will lead to an evacuation. Given these assumptions, the attributes associated with an increased probability of an evacuation were: large fires, northwest of and close in proximity to communities, and spreading during extreme BUI conditions (Figure 3).

Of the fire environment variables, the BUI, which is related to fuel consumption and, therefore, a reasonable indicator of smoke production, was the only variable found to influence evacuations. However, the only variable that was statistically significant in distinguishing evacuations by type was the proximity of a fire to an evacuation location. If a fire is far away from a community, it is probably a smoke caused evacuation; this is what Model B tells us.

Although I did not find associations between the other FWI System variables and evacuation occurrence or type, it does not mean that such relationships do not exist. This dataset was quite small, with 138 evacuation occurrences. And as we know, evacuations are driven by many situational and social factors. I explored several general environmental factors, but additional factors could also be considered in future studies.

Although I found statistical significance within my models, this does not mean such models should be translated into predictive models for operational purposes in evacuation situations or during wildfire seasons. Instead, the aim of my research was to identify potential patterns that may exist in factors typically used by wildfire management in day-to-day decision-making to inform and add to the general understanding of evacuations in Ontario. Having a representative from a provincial fire management agency on my committee ensured that the factors I analyzed made sense in real-world applications and allowed for operationally relevant perspectives and hypotheses to be explored that would otherwise not have been. It also means having a regular reality check throughout the thesis research process. I highly recommend this to other graduate students. To bridge the gap that often occurs between academia and fire management, seek out individuals within fire management. A practical understanding of the operational fire management business makes for more applicable research. View full thesis here.

Towards next-generation fire prediction tools: Reflections on the present and future of LiDAR training in Canada

Amid shifting Canadian ecosystems, predicting fire activity requires next-generation environment mapping. Canada Wildfire reflects on partnering with the University of Lethbridge to offer a world-class LiDAR training course.

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

It's been jokingly suggested that forests on Canadian roadsides could be some of the most-sampled forests on the planet. Plot-scale measurements have been the foundation for forest surveys and reporting for over 200 years (Newnham et al., 2015), and scientists will often wade into the bush to take these measurements after stopping on the side of the highway.

But what about for larger, variant, and evolving fuels and terrain? That's where technologies like Light Detection and Ranging (LiDAR) have filled the gap. Identified in Canada's Blueprint for wildland fire science (2019-2029) as a priority technology for addressing urgent operational and research needs, LiDAR plays a pivotal role in informing next-generation fire behaviour prediction tools.

Figure 1. Instructor Chris Hopkinson demonstrates a Remote Piloted Airborne System (RPAS) drone to students during a field experience day at Waterton Lakes National Park, AB. [Photo courtesy of Laura Chasmer, May 2023.]

As part of our mandate to train the next-generation of highly qualified wildfire personnel, Canada Wildfire partnered with the University of Lethbridge in May 2023 to offer a world-class airborne LiDAR course in generating three-dimensional representations of fuels and terrain. Leading the instructor team was Dr. Chris Hopkinson, Research Chair in Terrestrial Ecosystems Remote Sensing at the University of Lethbridge and NSERC/CFS Canada Wildfire Strategic Network member. A blend of undergraduate and graduate students and public sector staff was guided through an intense, integrated format that challenged participants in an immersive learning environment. Over five days, participants learned how to plan, collect data, model forest resources, and assess after a fire through lectures, labs, and field experiences. The course provided invaluable experience in the technologies vital to understanding fire activity in today's shifting ecosystems.

LiDAR at work for wildfire science

While LiDAR is not a new technology, capturing, understanding, and using the data has expanded significantly in the last couple of decades. As it becomes more integrated into modern academic and operational contexts, training is required for those new to it or with a more traditional background in remote sensing.

Illuminating the field

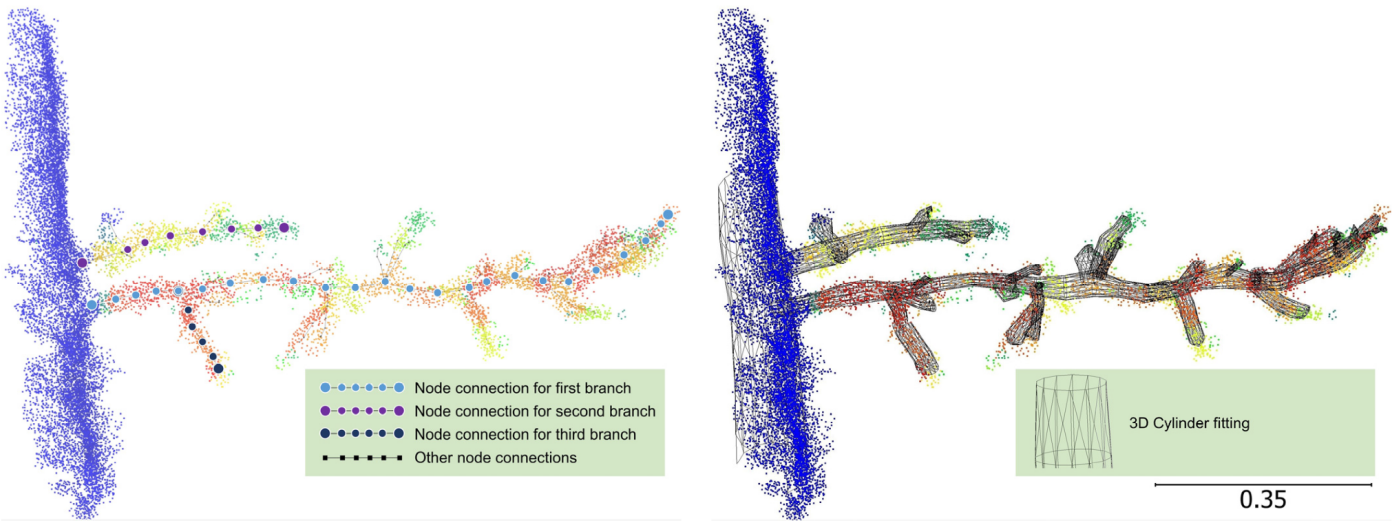
Since the early 2000s, LiDAR has been used to generate accurate, 3D representations of physical environments. A typical system includes a laser, a scanner, and a specialized Global Positioning System (GPS) receiver mounted on an airplane or helicopter (airborne-based systems), although drones or ground-based systems are also standard platforms. Each provides a different view perspective and data density.

The process initiates thousands to millions of laser pulses per second that travel out from the sensor until they reflect or return to

the LiDAR sensor after encountering an object or surface. The sensor measures the time each pulse takes to return. Given that the speed of light is constant, the timing data can be converted into distance, creating intricate, detailed, and highly accurate 3D images or topographic maps. Traditional Geographic Information System (GIS) or remote sensing, which is rooted in two-dimensional spatial data analyses like maps, satellite imagery, and aerial photos, don't capture the third dimension (height/depth) as intricately.

Although invaluable for various academic research and operational tasks, the LiDAR technology and systems involved can be costly, from obtaining the equipment and software to flying the aircraft. Access to one–or several–LiDAR systems in an educational setting is a rare opportunity for acquiring hands-on experience.

Modelling the landscape



(a) (b)

Figure 2. An example of reconstructing a tree branch using a terrestrial LiDAR system demonstrates how data points reveal the surface of objects (Xi et al., 2023). [Image courtesy of Zhouxin Xi, September 2023.]

LiDAR data is stored in a dense 3D point cloud architecture, where individual points sample the surface contours of an object or landform, providing a detailed snapshot of the object's morphology. Each point has an XYZ coordinate address denoting exactly where it's located on the Earth's surface. Points also contain additional information, such as its real-world colour or laser signal strength, or other attributes describing the timing and view geometry of the pulse that produced the point. Combined, this provides a high-resolution representation of surfaces with many useful pieces of information that can help with interpretation.

A cross-disciplinary approach, integrating computer science, environmental sciences, engineering, and geospatial science, forms the foundational knowledge that goes into capturing, understanding and working with LiDAR. For those accustomed to traditional data from remote sensing techniques, understanding the 3D dense point cloud structure can require new skill sets in mathematics, software use and programming, or even hardware operations.

In the context of wildfire science and management, LiDAR data can create a granular understanding of fuel load distribution and terrain characteristics. Importantly, it can accurately reflect changes in vegetation and shifting ecosystems. This is instrumental in predicting, managing, and mitigating wildfire impacts in academic and operational contexts.

Canadian expertise, next-generation knowledge

With a breadth and depth of subjects to cover in the LiDAR course, it really was all-hands-ondeck. Innovative approaches to teaching were needed to make the course useful in real-world applications for a large variety of students, from academics to practitioners.

It takes a village

Course lead Dr. Chris Hopkinson and one of his co-instructors, fellow NSERC/CFS Canada Wildfire Strategic Network member Dr. Laura Chasmer, have been at the forefront of using, expanding, and pioneering LiDAR research for over 20 years. They worked on prototypes and early systems going back to 1999. Nowadays, Drs. Hopkinson and Chasmer are leaders in cutting-edge approaches and applications of LiDAR, and they offer a range of teaching and mentoring opportunities to pass on their skills.

Drs. Hopkinson and Chasmer were joined by a team of instructors who offered their expertise in technology, applications, and data-handling concepts. Formal Teaching Assistants and co-instructors Emily Jones and Linda Flade were supported by Celeste Barnes, Dr. Zhouxin Xi, Maxim Okhrimenko, and Jared Sisco, all current or former students and postdoctoral fellows in Dr. Hopkinson's or Dr. Chasmer's labs. They offered demonstrations and seminars ranging from surveying to software programs, taking a blended and interdisciplinary approach. Most importantly, the instruction team offered passion for the subject. They encouraged discussion, provided personalized attention, and shared their enthusiasm for future applications in the field.

Figure 3. Co-instructor Emily Jones provides expertise in LiDAR calibration and validation surveys, key tools for wildfire risk and biofuel measurements. [Photo courtesy of Laura Chasmer, May 2023.]

Blended learning

Course lead Dr. Hopkinson admits that organizing a course with such a range of participants–undergraduate to doctoral students, credit to non-credit, and academics to professionals and practitioners–was experimental and had its challenges. However, that variety made the course exciting, allowing for collaboration and interaction to meet the students' diverse needs.

Doctoral candidates, graduate students, and undergraduate students from the University of Lethbridge were joined by students from other institutions, including the universities of Toronto, Alberta, and Victoria. Practitioners also attended from various government agencies, including the Government of the Northwest Territories, the Government of British Columbia, and a former member of Natural Resource Canada, now a graduate student. Canada Wildfire sponsored four NSERC Network students as part of their training.

Each student arrived with their own learning agenda; while some attended for

Figure 4. LiDAR course participants and instructors pose for a photo in Waterton Lakes National Park. Sitting on a bridge over Cameron Creek, they are immediately downstream from post-fire recovery monitoring plots, where Canada Wildfire researchers regularly collect field plots, drone data, and airborne LiDAR data. [Photo credit: Chris Hopkinson, May 2023.]

credit and others did not, each had their own applications for the data in mind. Understanding student motivations was crucial, as some standard tools or workflows for prepping LiDAR data and deriving useful outputs require specific approaches.

On the academic side, students wanted to get a solid foundation of the fundamentals, which include data cleaning, managing large datasets, and labelling, sorting, and organizing data (for example, using point classification and feature extraction/segmentation). Meanwhile, practitioners usually have more targeted needs. They often dive right into the specifics of how to turn a set of data into the product they need, how to understand the level of uncertainty in the data, or even how to reduce operational costs while maximizing output. Instructors accounted for this combination of theory and case-based application through personalized attention.

While the course offered an opportunity to learn more about instructing such a diverse group, the feedback was overwhelmingly positive. Public sector staff were especially outspoken about the high value of the comprehensive yet hands-on course. The instructors were kept on their toes, but took full advantage of the unique opportunity.

Hands-on experience

For instructor Chris Hopkinson, getting out of the classroom–into nature or a working situation like a hangar or lab–is invaluable for teaching and learning. After the Kenow fire of 2017, the forest of Waterton Lakes National Park, Alberta, has been the site of one of his and Dr. Chasmer's post-fire recovery monitoring plots. Their team regularly collect field plot, drone, and airborne LiDAR data at this site. It provided the perfect location for hands-on experience for the students, where some of the theory could be practised in a fun and relaxed setting.

While airborne LiDAR was the focus of the course, there were also demonstrations of operations and data handling for two other types of LiDAR systems: Terrestrial Laser Scanning (TLS) on the ground, and Remote Piloted Airborne System (RPAS) mounted on drones. These newer complementary technologies offer more detailed scans and are simpler to deploy than their airplane-based counterpart.

Other field demonstrations included forest fuel plot data collection and post-fire assessments. Demonstrations in survey-grade differential Global Navigation Satellite System (GNSS), a type of GPS more accurate and reliable than consumer-grade devices, were crucial for teaching students how to obtain accurate data samples from (square or circular) plots and (straight-line) transects. It was memorable for both students and instructors—one of the best ways to make new knowledge stick.

Students came away with an unmatched understanding of how these complex systems—mathematics, software,

Figure 5. One of the thousands of felled trees from the Kenow fire of 2017 at Waterton Lakes National Park. Already dead when the fire swept through the area, the log shows unique patterning. [Photo credit: Laura Chasmer, May 2023.]

hardware, and complementary field techniques—come together to make airborne LiDAR surveys happen from start to finish.

What's next for LiDAR in Canada?

The application of LiDAR technology in Canada is expected to expand significantly. As wildfire management experts retire, there is an urgent need to sustain their knowledge; at the same time, there is an opportunity to take new directions.

Accelerating research

NSERC/CFS Canada Wildfire Strategic Network research leads like Drs. Hopkinson and Chasmer continue to apply and advance LiDAR in their lab and fieldwork. Their University of Lethbridge Network teams evaluate fire impacts and changes in vegetation, using technologies such as LiDAR to improve efficiency in data collection. Work is ongoing across several locations, including Waterton Lakes, Banff, and Jasper National Parks, and is assisted through collaborations with over 20 individuals across Canada.

In Dr. Chris Hopkinson's lab, they believe that airborne, drone-based, and terrestrial LiDAR can be more widely applied in environmental monitoring than has traditionally been the case. Traditional Digital Elevation Models (DEMs) offer information about the physical landscape but do not capture the dynamic nature of ecosystems, especially those that undergo seasonal, lifecycle, and climatic changes like forests and wetlands. LiDAR can offer more comprehensive monitoring and data analysis of living ecosystems, offering a 3D view with time as a fourth dimension (Hopkinson, 2022). Monitoring these changes is crucial for understanding ecosystem health, productivity, carbon balance shifts, and wildfire risks.

As research accelerates, it will rely on increasingly complex inferences and parsing of large datasets. Adopting artificial intelligence methods, such as deep learning, shows promise for enhancing and creating prediction-based data upscaling (Xi et al., 2020). For example, forests in Jasper National Park, affected by mountain pine beetle, were analyzed using deep learning methods from TLS data. Detailed 3D models of the trees and branches revealed the fire fuel at different heights and locations in the forest, including the "ladder trees" that

Figure 6. Students acquire hands-on experience in key considerations for using specialized GPS for locating mapping plots, including canopy, timing, and optimal location for connecting to the satellite. [Photo courtesy of Laura Chasmer, May 2023.]

Figure 7. A stand of trees in the Waterton Lakes National Park forest. The forest has begun to regenerate and is a source of frequent data samples for the University of Lethbridge NSERC Network lab teams. [Photo courtesy of Laura Chasmer, May 2023.]

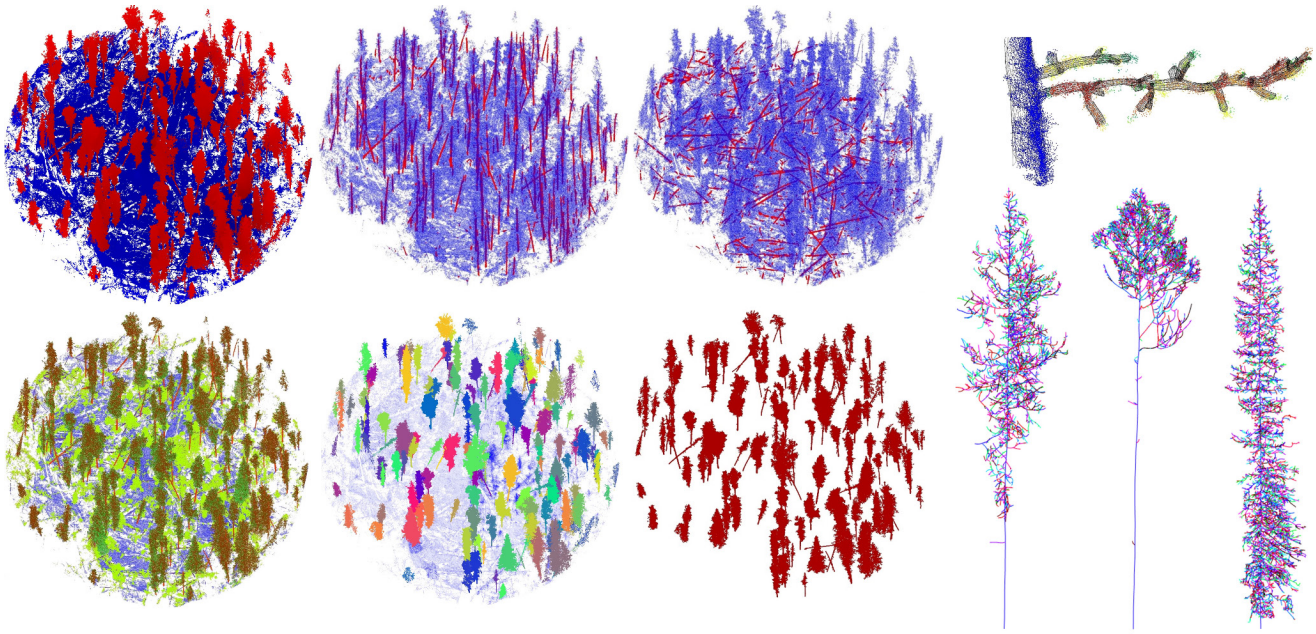


Figure 8. Detailed 3D models of Jasper National Park trees and branches produced by deep learning methods using TLS LiDAR data. [Image courtesy of Zhouxin Xi, September 2023]

accelerate vertical fire spread (Xi et al., 2023). Deep learning can also identify individual treetops or "crowns," which is important for understanding both big-picture ecology and small-scale tree health (Xi & Hopkinson, 2020). Moving beyond traditional vegetation fire science approaches requires taking advantage of new knowledge and changing contexts.

Research also relies on the wide availability of data. Open-source datasets from LiDAR scans, such as those uploaded to the Federal Research Data Repository (FRDR), will be crucial for training, research, and innovation. Canada Wildfire will continue to explore avenues for making data visible and available.

Bringing LiDAR to the everyday

Making geospatial tools like LiDAR more widely accessible to practitioners and public agencies can significantly augment their operations. Dr. Hopkinson sees great potential for further operationalizing airborne, terrestrial, and drone-based LiDAR for wildfire fuel risk assessment, as well as in FireSmart planning and assessment.

To get there, adding operational user interfaces for better usability is the next milestone, along with additional capabilities like quickly compiling and producing maps. Doing so requires user-friendly tools and standard practices. For research and development outcomes, Drs. Hopkinson and Chasmer engage with private and public sector partners like Teledyne Optech on hardware products, Hatfield Consultants on new applications and services, and the Canadian Forest Service on societal needs and advancing the science.

As adoption becomes even more widespread, partnerships between academic, operational, and private sector users and developers will benefit from further two- or three-way collaboration. As science is useful to practise and as practice informs science, LiDAR will continue to become more accessible, understandable, and ready to use.

Meeting increased training demand

To meet emerging training needs, the University of Lethbridge will be establishing a new Institute for Geospatial Inquiry, Instruction, and Innovation (i4Geo[1]) with funding from TECTERRA, a Canadian geomatics technology innovation support centre. Led by Dr. Hopkinson, i4Geo aims to develop innovative training, business development, and research partnership opportunities in 4D geospatial technology, environmental monitoring, and natural hazards.

The May LiDAR course was intended as a pilot for new micro-credential modules at the University of Lethbridge aimed at practitioners who need focused skills or knowledge without the formality of full-time student status. Working with the Canada Wildfire community, they hope to be able to provide similar geospatial technology and modelling courses in the future. The support of Canada Wildfire was instrumental in helping the University of Lethbridge team pilot and evaluate the blended delivery method.

[1] i4Geo will be formally announced in January 2024.

Canada Wildfire continues to foster reciprocal connections between organizations that can open up new opportunities for wildfire management research in Canada. By supporting and funding students, training equipment, and collaborations, Canada Wildfire will continue to prioritize state-of-the-art training for the next generation of highly qualified personnel.

Hands-on experience with emerging technology for personnel across sectors and disciplines will remain vital to integrating LiDAR further into fire management. Through continued training and collaboration, Canada Wildfire will be there to support along the way.

To learn more about the institute or future course offerings, contact Dr. Chris Hopkinson at c.hopkinson@uleth.ca. To learn more about future Canada Wildfire offerings, contact wildfire@alberta.ca.

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Remembering Resilience: Honoring Lives Lost in Canada's Challenging Fire Season

In the wake of an extraordinarily challenging fire season in Canada, our hearts are heavy with the collective grief and loss that has touched the lives of so many. Together, we remember those who have left us, honouring their memory with a deep gratitude for the resilience and unity that emerged during these trying times. As we reflect on the unwavering spirit of our nation, may we draw comfort from the realization that, even in times of hardship, the resilience of our community fosters hope and mutual support among us all.

Canada Wildfire

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