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The Alberta Wildland Fuels Inventory Program (AWFIP): data description and reference tables

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Key message: This document describes a dataset obtained from a field sampling program conducted in Alberta, Canada. Field data were used to describe the structure and composition of forest stands, including several fuel loads (e.g., surface, understory, canopy fuels). The dataset can be downloaded from https://doi.org/10.17605/OSF.IO/FZ8E4 and metadata is available at https://metadata-afs.nancy.inra.fr/geonetwork/srv/fre/catalog.search#/metadata/527efb49-43b4-43eb-88b2-70535ff99fc5

Abstract: We present a quality-checked and curated dataset obtained from a field sampling program conducted in the province of Alberta, Canada. Field data were used to describe the structure and composition of forest stands documented in 476 sampling events. Each sampling event record consists of 42 different variables, including several fuel loads (e.g., surface, understory, canopy fuels). The dataset has been created for operational and research applications including but not limited to fuel classification, estimation of fuel attributes from remote sensing technologies, fuel treatment planning, fire behavior prediction, and use in high resolution fire growth models.

Keywords: Fuel load, Fuel measurement, Fire behavior, Forest structure, Field inventory, Vegetation management, Fuel treatment

1 Background

The Alberta Wildland Fuels Inventory Program (AWFIP) collected data on forest structure and composition across the province of Alberta from 2007 to 2019. The program established 917 plots where 1313 sampling events occurred. Data collection procedures outlined in the AWFIP manual (Alberta Agriculture and Forestry 2015) were generally followed by field crews; however, sampling protocols changed over time, modified procedures were sometimes used to accommodate special data needs or time constraints, post-sampling data entry errors were sometimes made, and the manner in which missing values were recorded in the database was inconsistent.

To date, only relatively small subsets of the AWFIP data have been analyzed and used in research studies (e.g., Wilkinson et al. 2018; Thompson et al. 2020; Cameron et al. 2021, 2022a, 2022b), primarily due to the above-noted data quality challenges that rendered broad-scale analyses infeasible. The primary purpose of this work is to document a quality-assured, stand-level subset of the AWFIP records that is suitable for analysis. The curated dataset consists of 476 sampling events concentrated in three Natural Regions (Natural Regions Committee 2006; Fig. 1): Boreal Forest (253 records), Rocky Mountain (134 records), and Foothills (89 records). Thus far, the quality-checked dataset has been used to cluster forest stands into groups with similar forest structure and expected wildland fire behavior (Phelps N, Beverly JL: Classification of forest fuels in selected fire-prone ecosystems of Alberta, Canada - implications for crown fire behaviour prediction and fuel management, in review). In the following sections, we
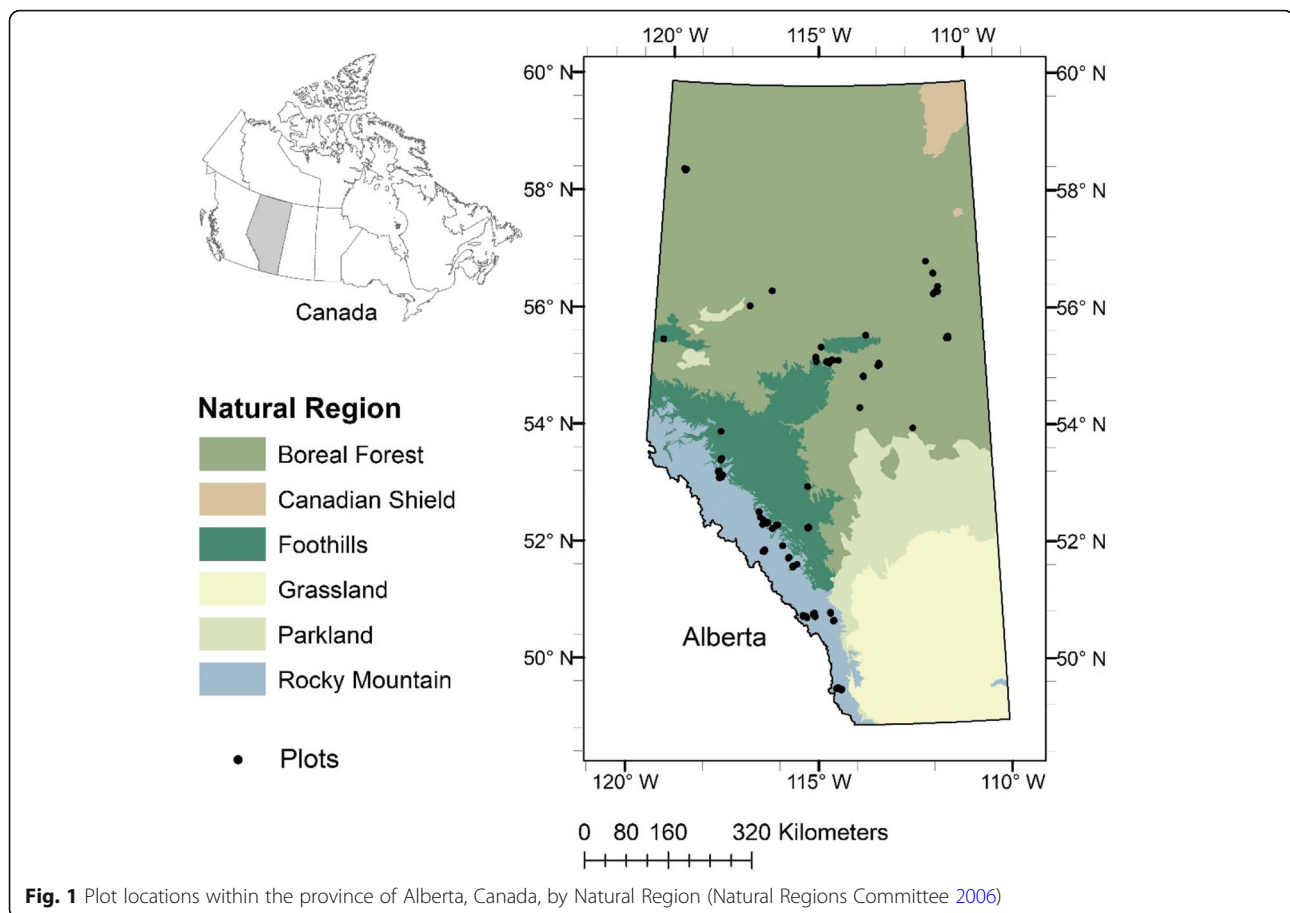
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Fig. 1 Plot locations within the province of Alberta, Canada, by Natural Region (Natural Regions Committee 2006)

document the following: the database contents and structure, database computations, and associated cleaning and filtering steps that were undertaken to ensure the data is suitable for use in research studies and fire management applications.

2 Methods

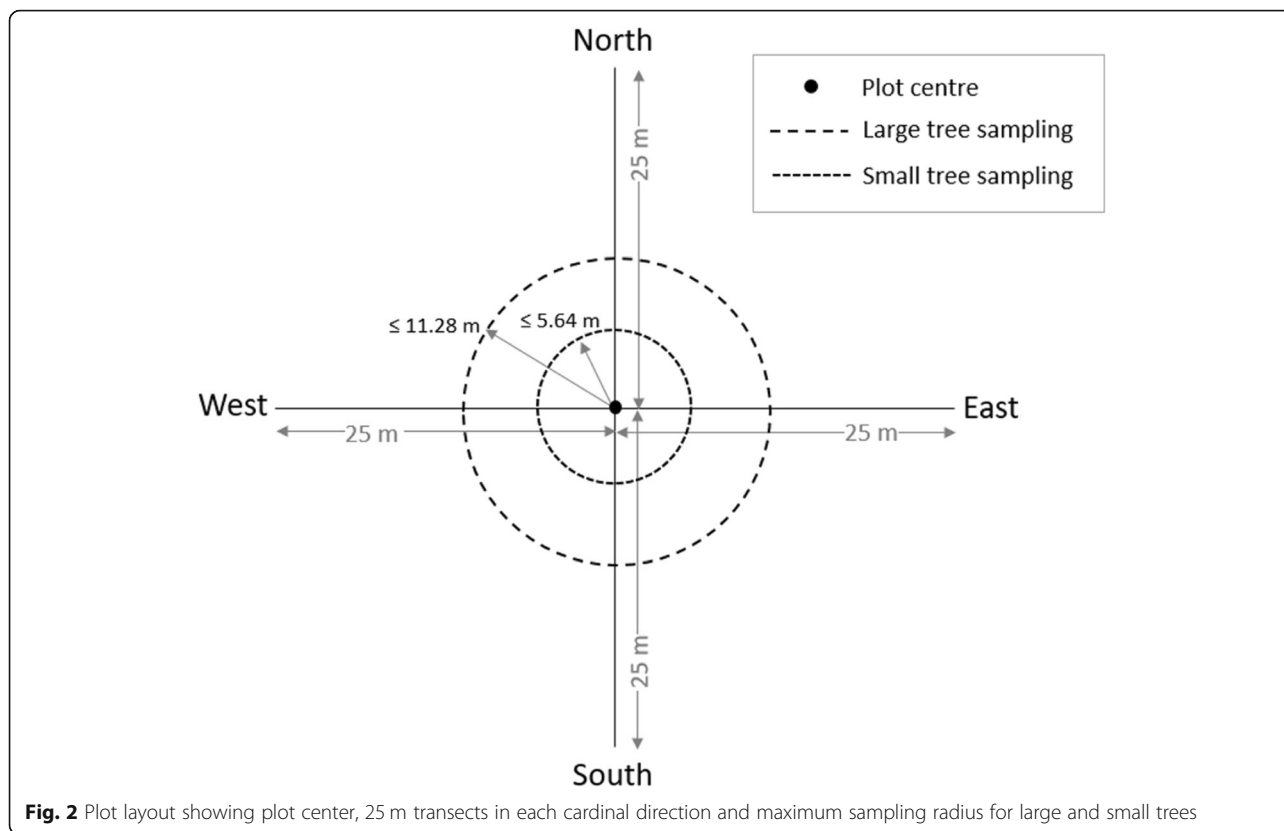### 2.1 Field measurements and database structure

Field measurements were collected in accordance with the AWFIP sampling manual (Alberta Agriculture and Forestry 2015). Plot center was documented with a commercial-grade Global Positioning System unit with a mean accuracy of 4.88 m. Coordinates for some plots were acquired with more sophisticated locational equipment, as detailed by Cameron et al. (2021); however, methods for enhanced locational accuracy were not standard for all plots.

At each site, 25 m transects in each of the four cardinal directions extended from plot center (Fig. 2), and data were collected for shrubs, dead and down woody material, and ground cover. Destructive samples were also collected along these transects for litter, duff, forbs, grass, and mulch, when present. Additionally, data were collected for trees, which were divided into three classes

based on tree height and diameter at breast height (DBH, 1.3 m). Seedlings were defined as trees less than 1.3 m tall. Trees 1.3 m tall or taller with a DBH < 9 cm were defined as saplings, whereas those with DBH ≥ 9 cm were defined as large trees. During the initial 2 years of data collection, the criterion used to define a large tree was a DBH > 7 cm, and these inconsistent data were removed from the referenced database. Stem inventories were conducted with a variable plot radius designed to ensure a minimum of 20 trees were documented.

Documented plot-level attributes included tree age, which was measured using an increment borer with a minimum of two samples per tree species and a minimum of four samples per plot. Plot moisture regime was classified by field crews using relative ratings of available moisture supplies, which are detailed in the province's *Ecological Land Survey Site Description Manual* (Resource Data Branch 2003) and include the following classes: Hydric, Subhydric, Hygric, Subhygric, Mesic, Submesic, Subxeric, Xeric, and very Xeric.

Field measurements were recorded manually by hand and hardcopy datasheets were later compiled and input to a Microsoft Access database in a two-step process that introduced opportunities for errors. Other data

Fig. 2 Plot layout showing plot center, 25 m transects in each cardinal direction and maximum sampling radius for large and small trees

inconsistencies were introduced by sampling protocols that were occasionally altered to accommodate unique circumstances such as the requirements of a local research study.

In addition to localized procedural modifications, adjustments to program-wide sampling protocols were sometimes implemented. Unfortunately, the timing and extent of procedural changes during the life of the fuel inventory program were not systematically documented. Deficient documentation combined with high numbers of missing values and the expansive size of the database (i.e., 1313 sampling events each with dozens of recorded field observations) meant that considerable time and effort was required to screen the data and identify potential sources of error. When possible, these errors were corrected; alternately unreliable or incomplete records were removed. This systematic filtering and cleaning process was completed prior to computing quality-assured attributes of interest from the raw field observations and is detailed in sections that follow.

2.2 Imputing missing values

Missing values in the AWFIP database were a persistent issue throughout the life of the program. Occasionally, DBH values for large trees were missing and were therefore imputed using the mean DBH of large trees from the sampling event of the same species and vegetation status (i.e., live or dead).

If the vegetation status of either a large tree or sapling was missing and tree species was unknown, status was assumed to be dead. When species was identified, but status was missing, the tree's live crown base height (LCBH) was used to determine its status. Live crown base height was measured as the height above ground of the lowest live crown fuels that have the ability to move fire higher in the tree (Lutes et al. 2006). Presence of an LCBH measurement indicated a live tree whereas a dead crown base height (DCBH) but no LCBH indicated a dead tree. For any remaining trees, vegetation status was assigned to match the majority of other like trees in the sampling event.

In cases where the LCBH was missing for live large trees, no attempt was made to impute these values. The LCBH of a large tree only contributed to computing the average LCBH of the large trees in the stand, so imputing individual entries was not necessary. The missing values were excluded from this computation, which was equivalent to assuming that a tree had the average LCBH for large trees from that sampling event.

Measurement of LCBH for saplings was initiated in 2015, during the later stages of the AWFIP program. To estimate LCBH values for pre-2015 sampling events, a linear regression model based on the 2015–2019 data

was built for each tree species, regressing LCBH on tree height and treatment status. Treatment status indicated if the tree came from a natural stand or one that had been altered mechanically, typically with the intention of raising the LCBH, and was only included in the model if it was found to be significant at a significance level of 0.05. For each species, square root and logarithmic transformations of LCBH were considered. After analyzing the fit of each model, one of the three models was selected for a given species. In some cases, the fit of the model was not particularly good (e.g., R^2 as low as 0.34), and it was possible for the model to predict a negative LCBH. If a stand's average LCBH for saplings in its canopy was negative, then it was assigned a value of zero.

Measurements of LCBH are used for assessing fire behavior potential and statistical models for estimating LCBH were therefore developed solely for flammable conifer species in the stand: black spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), tamarack larch (*Larix laricina*), and jack pine (*Pinus banksiana*). Other species were present in the database in limited numbers such that model development was not possible, and trees of these species without an LCBH were omitted from the canopy base height (CBH) calculation for the stand.

2.3 Cleaning and filtering
An exhaustive data cleaning and filtering process was undertaken, which included manually reviewing original field datasheets where necessary and implementing over 250 corrections to the database records. Due to the labor-intensive nature of this work, priority was given to sampling events with all or nearly all (e.g., missing just one) key data fields: trees, soil, dead and down woody material, shrubs, and herbaceous material. Although mulch is also a key data field, it was not considered in this filtering process because mulch fuels are limited to stands that were subjected to fuel reduction treatments.

2.3.1 General approach to missing, duplicate, and mislabeled data
In several cases, data for an entire data field (i.e., not just an individual sample) on the hardcopy datasheet had been omitted from the database and were therefore digitized retrospectively during the cleaning process. In some cases, field datasheets or individual records were missing, and the sampling event was either removed or missing values were treated as true zeroes based on data collected from other sampling events at the same location.

For some sampling events, field data collection for one or more of the transects was omitted due to time constraints or site conditions. Sampling events with one or more omitted transects for all of the sample types (i.e.,

fine woody debris, coarse woody debris, destructive samples) were removed.

2.3.2 Forb, grass, litter, and duff samples
In isolated cases, destructive samples were entered without a tray weight, which was corrected when the datasheet weight record was available. Duplicate destructive samples were sometimes entered or single-sample weights were entered in error (e.g., a litter sample assigned the weight of a nearby duff sample). Sampling events were screened to identify any cases where two samples had equivalent tray and sample weights, with confirmed errors corrected.

During data entry, destructive samples were sometimes assigned to the wrong biomass material, transect, or distance from plot center. Observed sample counts were compared with expected sample counts based on field procedures to screen for potential mislabeling of biomass categories (i.e., forb, grass, litter, or duff). This process did not identify samples that were entered for the wrong transect or distance, but such errors would have no impact on forb or grass categories, which are summed across the entire sampling event. For litter and duff, samples entered incorrectly with respect to transect number or distance could impact some of our computations, which prompted additional quality control measures for these biomass types.

A common issue with litter and duff destructive samples involved determining if a missing value was a true zero (i.e., no sample was recorded because there was no sample to collect) or a false zero (i.e., a sample could not be taken, a sample was lost between the field and the laboratory, or a data entry error). Destructive litter and duff samples, along with measurements of their depth, were taken at 10 m and 20 m along each transect, but litter and duff depth measurements were also recorded every 5 m along each transect. To determine if the missing sample was a true zero or false zero, we looked at the field datasheets and consulted both depth measurements. If either of these depths were non-zero or a reason was given for a sample not being taken (e.g., due to a safety issue such as bees), it indicated that the sample was a false zero. Sampling events with false zeros were then manually inspected to determine if the false zeros were caused by a data entry error. Entering a sample with the wrong transect number or distance created an apparent missing sample and manual review of these cases limited the frequency of incorrect entries.

In some cases, destructive samples were collected but their depths were either missing or subject to typographical errors during digitization, such as omitting or miskeying a decimal point. Samples without a depth were removed and treated as a false zero. Some typographical errors were found by searching for depths that were

impossibly large and were then updated upon confirmation of the true depth with the field datasheet.

Litter and duff samples were sometimes interchanged, on either the field datasheet or during digitization. Normalized values (i.e., values with a mean of zero and standard deviation of one) for litter and duff samples were computed for each sampling event to identify potential errors. Since duff samples were typically heavier than litter samples, litter samples with a normalized mass greater than 1.5 and duff sample with a normalized mass less than – 1.5 were flagged. These sampling events were assessed individually and a determination was made as to whether or not the values had been inverted and required correction.

2.3.3 Fine woody debris

For fine woody debris, the transect length was sometimes recorded incorrectly, leading to the removal of those sampling events. To calculate fine woody debris fuel load, an estimate of the percent species composition of woody material was required, which we obtained from overstory tree composition. For some sampling events, these data were omitted during digitization and subsequently entered upon discovery. In other cases, duplicate entries of a single tree species were discovered and removed to correct double counting of some fine woody debris fuel.

2.3.4 Shrubs

Almost all shrubs had a vegetation status of either live or dead, but a small number had other labels that indicated a data entry error, which was corrected when possible. To calculate shrub fuel load, a standard 25 m transect length was used. When the recorded transect length deviated from the 25 m standard, the record was removed.

2.3.5 Trees

Tree data were also subject to errors. Tree heights of zero were reviewed, leading to one data entry correction and removal of several sampling events where sapling tree heights had been omitted due to time constraints. A tree entry was considered erroneous if it had an LCBH greater than its height, if it was a large tree with a DBH < 7 cm, which accommodated measurements within 2 cm of the 9 cm DBH threshold for large trees, or if it was a sapling with a DBH > 9 cm. These discrepancies sometimes led to data entry corrections. Sampling events with errors in 10% or more of their large tree or sapling records were removed. For the remaining samples, we assumed the impact of the errors was immaterial.

2.3.6 Mulch treatments

Some sampling events occurred following highly heterogenous fuel management treatments, referred to as *strip* or *cluster* mulch treatments. Resulting stand structures undermined the accuracy of field sampling, which assume certain (i.e., natural) distributions and variability (Keane 2015), and were therefore removed from analysis. The sampling protocol for strip mulched stands differed from the protocol for other stands (Alberta Agriculture and Forestry 2015), and these differences enabled identification and removal of the associated data. The remaining sampling events with mulch present were either broadcast mulched stands or forest stands that had been thinned and mulched as a FireSmart treatment. At these locations, mulch sampling along each transect occurred at 10 m and 20 m, and sometimes also at 15 m.

2.3.7 Treatment status

The treatment status (i.e., natural or treated) of each sampling event was verified with agency vegetation management records. In some cases, the treatment status recorded in the database differed from this secondary source. Standard photographs taken by AWFIP field crews at the time of each sampling event were used to verify treatment status in cases where the accuracy of the database entry was uncertain. This process confirmed that the treatment status recorded in the AWFIP database was reliable and it was retained for use. The photo verification process also led to removal of samples deemed unsuitable for analysis, such as stands subjected to the previously described strip mulch fuel treatments.

2.3.8 Exclusion of other sampling events

Some sampling events were excluded due to anomalous stand conditions, such as those without at least one live large conifer tree with a recorded LCBH and those with evidence of burning (i.e., presence of ash, charcoal, burnt shrubs, burnt coarse woody debris, or scorch marks). Samples taken in 2007 and 2008 were also excluded because they predated changes to data collection protocols.

2.4 Computing stand-level features
2.4.1 Identifying canopy and understory trees

All large trees were considered part of the canopy fuel strata. Due to the stunted stature of some northern boreal tree species, tree size alone could not be used to assign saplings to a given fuel strata. To determine if a sapling belonged to the canopy or understory, the following approach was used: for large live conifer trees, average LCBH was computed and compared to each sapling's height to determine if the sapling's crown extended vertically into the large tree canopy. If sapling height was greater than or equal to average LCBH plus

3 m, then the sapling was considered part of the canopy. Otherwise, the sapling was assigned to the understory strata.

Inclusion of saplings as part of the canopy was dependent on a relatively extended 3 m overlap with the canopy fuel strata. This approach accounted for the uneven vertical distribution of crown fuels. Vertical fuel profile graphs (e.g., Alexander et al. 2004) have shown that the top portion of conifer stems contribute little fuel weight relative to the remainder of the tree crown, such that vertical continuity of fuels could not be assumed without sapling heights that extended well into the canopy fuel strata.

2.4.2 Canopy fuel load (CFL)

The definition of CFL is not consistent across wildland fire literature (Arroyo et al. 2008), and can include live foliage alone (e.g., Van Wagner 1977) or in combination with roundwood (e.g., Alexander et al. 2004). We computed CFL using the allometric equations from Lambert et al. (2005) and Ter-Mikaelian and Korzukhin (1997) (see Table 1). Although small branchwood contributes to CFL (e.g., Stocks et al. 2004), we computed CFL using foliage equations because branch biomass equations by diameter class were unavailable for all tree species. Estimates produced with Table 1 equations were summed for all live conifer trees and saplings in the canopy strata and divided by the area sampled to obtain the CFL.

The readily available allometric equations in Table 1 that we used to estimate CFL can introduce error when stand conditions are inconsistent with those used to derive the applied equations. Direct measurement of CFL by destructive sampling and development of site-specific allometric equations would reduce potential sources of error but is impractical for large-scale fuel inventory programs due to the time and cost involved.

Allometric equations used for CFL calculations are for natural, untreated crown morphologies. In managed stands that have been subjected to fuel reduction treatments, CFL is reduced by thinning (i.e., tree removal) and pruning the lower branches of large trees, typically to a height of 2 m (Beverly et al. 2020). While the effects of thinning are accounted for in our CFL calculations, the effects of pruning in treated stands are not. This is due to the lack of pre-treatment measurements of LCBH, which made it impossible to calculate the extent to which a given tree's crown length had been altered during pruning. For a small subset of the data, Cameron et al. (2022b) modeled the relationship between field-measured tree height and LCBH to estimate the pre-treatment crown base height for each tree in managed black spruce stands; however, there was insufficient data for estimating these relationships for all conifer tree species included in the dataset.

2.4.3 Assigning Canadian Forest Fire Behavior Prediction (FBP) System fuel type

FBP System fuel types are described qualitatively and were designed to enable classification based on forest inventory type descriptions (Forestry Canada Fire Danger Group 1992). Due to natural variability, a given forest stand may not align with any of the available 16 FBP System fuel types and managed stands are not represented at all in the FBP System. It is therefore common for fuel types to be assigned based on the best available option for both operational and research purposes. We assigned a representative FBP System fuel type to each stand based on the species composition of the live trees that formed the canopy of each stand. Our previously described approach of assigning saplings to either the canopy or understory ensured that structure and composition of multi-storied stands was accounted for in the fuel typing process. Conifer dominated stands that did

Table 1 Allometric equation used to estimate the crown fuel (kg) of a tree using its diameter at breast height (DBH, cm) for all conifer species present in the data

Tree species	Foliage expression	Source
Balsam fir (*Abies balsamea*)	$0.0840(DBH)^{1.6695}$	Lambert et al. (2005)
Subalpine fir (*Abies bifolia*)	$0.3894(DBH)^{1.2311}$	Ter-Mikaelian and Korzukhin (1997)
Douglas fir (*Pseudotsuga menziesii*)	$0.0423(DBH)^{1.8619}$	Ter-Mikaelian and Korzukhin (1997)
Tamarack larch (*Larix laricina*)	$0.0801(DBH)^{1.4875}$	Lambert et al. (2005)
White-bark pine (*Pinus albicaulis*)	$0.1168(DBH)^{1.2751}$	Ter-Mikaelian and Korzukhin (1997)
Jack pine (*Pinus banksiana*)	$0.0389(DBH)^{1.7290}$	Lambert et al. (2005)
Lodgepole pine (*Pinus contorta*)	$0.0432(DBH)^{1.7166}$	Lambert et al. (2005)
Engelmann spruce (*Picea engelmannii*)	$0.3346(DBH)^{1.2765}$	Ter-Mikaelian and Korzukhin (1997)
Limber pine (*Pinus flexilis*)	$0.1168(DBH)^{1.2751}$	Ter-Mikaelian and Korzukhin (1997)
White spruce (*Picea glauca*)	$0.1601(DBH)^{1.4670}$	Lambert et al. (2005)
Black spruce (*Picea mariana*)	$0.1648(DBH)^{1.4143}$	Lambert et al. (2005)

not align with any of the FBP System fuel types were assigned a supplementary fuel type label (i.e., mixed conifer) that we created to retain these data.

Fuel type was assigned following the decision path illustrated in Fig. 3. We note that some sampling events could have been labeled as the C-4 Immature Jack or Lodgepole Pine fuel type based on their tree species, but all such stands were classified as C-3 Mature Jack or Lodgepole Pine owing to stand densities that were all below the C-4 standard of 10 000–30 000 stems/ha, with only one exception. Likewise, low-density C-2 stands could have possibly been labeled C-1 Spruce-Lichen Woodland, but none of those stands had a lichen ground cover component > 30%, so the C-2 label was retained.

FBP System fuel types assigned to managed (i.e., fuel-treated) stands were included for consistency, but should be approached with caution given the FBP System was not designed for managed stands and the assigned fuel type may not reflect the pre-treatment stand composition.

2.4.4 Proportion of live trees and proportion of conifer trees
We computed the proportion of canopy trees that were live, and the proportion of those live canopy trees that were conifer. Conifer species in the database are those shown in Table 1.

2.4.5 Understory fuel load
The fuel load (kg · m^{-2}) for the understory trees was calculated using the same allometric equations as for the canopy calculations (Table 1). Seedlings constitute a

negligible contribution to fuel load and were therefore omitted from CFL and understory fuel load calculations.

2.4.6 Stand density and basal area
Basal area (m^2 · ha^{-1}) was estimated from measurements of diameter at breast height (DBH). Four different stand density and basal area calculations were performed, two for each of the canopy and understory strata. Stand density and basal area were computed using all trees and using only live conifer trees.

2.4.7 Canopy tree height and CBH
The canopy tree height (m) and CBH (m) were computed using a weighted average of the average heights of the large trees and saplings in the canopy. The average heights of the large trees and saplings were based on only the live conifer trees; likewise, the weights for the weighted average were the number of live conifer trees.

2.4.8 Canopy bulk density (CBD)
The CBD (kg · m^{-3}) of a sampling event was calculated as follows:

$$CBD = \frac{CFL}{canopy\ tree\ height - CBH}$$

2.4.9 Forb and grass fuel load
Forb and grass fuel loads (kg · m^{-2}) for each destructive sample were calculated as follows:
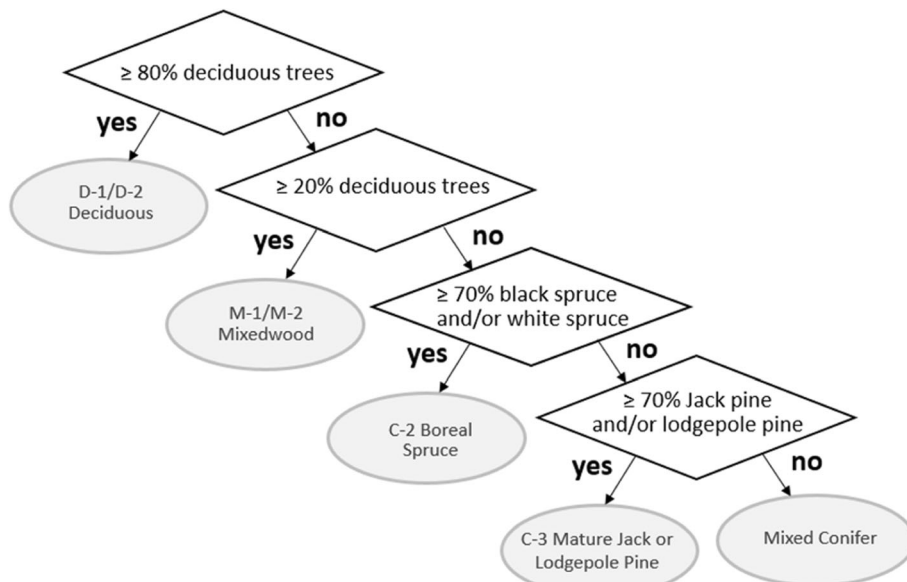
Fig. 3 A diagram outlining how each sampling event was assigned one of four Forest Fire Behaviour Prediction (FBP) System fuel types (Forestry Canada Fire Danger Group 1992) or alternately, if none were applicable, classified as Mixed Conifer. Deciduous trees included narrow-leaf cottonwood (*Populus angustifolia*), trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*), balsam poplar (*Populus balsamifera*), and willow (*Salix spp.*)

$$Fuel\ Load = \frac{M_S}{A}$$

where M_S is the mass of the oven dry forb or grass sample (kg) and A is the sample area (m^2). It should be noted that a standard sample was 1 m × 1 m, but some sampling events had samples that were 50 cm × 50 cm. The sample area for each sample was not recorded in the database, such that deviations from the default 1 m^2 area were identified solely by reading comments associated with the sampling event. Some samples were assigned a combined forb-grass label on the field datasheet, but not in the database, and were labeled forb as a default. The fuel load for the entire sampling event was computed as the average of the individual fuel loads, including zeros.

2.4.10 Shrub fuel load

Percent cover of shrubs by transect was calculated as follows:

$$Percent\ Cover = \frac{\sum L_{shrub}}{L_{transect}} \times 100$$

where L_{shrub} is the measured length along the transect for a species of interest (m) and $L_{transect}$ is the total length of the transect (m).

Average height of a given shrub species was calculated as follows:

$$Average\ Height = \frac{\sum H_{interval}}{n_{interval}}$$

where $H_{interval}$ is the representative height for a species of interest within a given transect interval (m) and $n_{interval}$ is the number of intervals within the transect containing the species of interest.

Shrub biomass equations suitable for use with the AWFIP data and specific to the geographic area where the data were collected were not available. A coarse approximation of shrub fuel load (kg · m^{-2}) for each species and transect was therefore estimated using a generalized shrub biomass equation reported by Olson and Martin ([1981](#)) for conifer stands in the pacific northwest USA:

$$Fuel\ Load = [-0.62689 + 0.05778(Percent\ Cover)$$
$$(Average\ Height \times 100)] \times M_L \times 0.002$$

where M_L is a multiplier based on the vegetation status of the shrub (1 if the shrub was alive and 0.75 if the shrub was dead), which was based on expert judgment.

For each sampling event, the fuel loads calculated for each species were summed by transect and shrub fuel load for the sampling event was computed as the average of the four transect fuel loads. The equation used to compute shrub fuel load can produce a negative value in some cases. If the resulting fuel load for the entire sampling event was negative, shrub fuel load for the event was assigned a value of zero.

2.4.11 Litter/duff fuel load, bulk density, and depth

Protocols for litter and duff sampling varied during the life of the program. During most sampling events, ground biomass cores were extracted to a maximum depth of 10 cm. Because duff and litter were extracted in one core, litter depth impacted the depth of the duff sampled. In some cases, litter depth was ≥ 10 cm, resulting in omission of the duff sample, which were considered true zeros; however, this protocol was not used for some sampling events in the earlier years of the program. To maintain consistency, both the depth and mass of the sample were adjusted to account for only the portion that existed within 10 cm of the surface.

Litter fuel load (kg · m^{-2}) for each sample was calculated as follows:

$$Fuel\ Load = \frac{M_S}{A}$$

where M_S is the mass of the oven dry litter sample (kg) and A is area of the sample (m^2).

Duff is generally considered a minimal to negligible component of fuels consumed during the passage of a fire front, nonetheless under very dry fuel moisture conditions portions of the upper duff layer may potentially become available for consumption. To represent this potential extra fuel source, we calculated duff fuel load (kg · m^{-2}) using only the top 2 cm of duff. The fuel load for each destructive sample was calculated as follows:

$$Fuel\ Load = \frac{M_s}{A} \times M_D$$

where M_s is the mass of the oven dry duff sample (kg), A is the area of the sample (m^2), and M_D is a multiplier based on the depth of the sample, computed as follows:

$$M_D = \begin{cases} 1\ if\ depth \leq 2\ cm \\ \dfrac{2}{depth}\ otherwise \end{cases}$$

The litter/duff fuel load for the sampling event was the average of the individual fuel loads, including true zeros.

For both litter and duff, the bulk density (kg · m^{-3}) for each sample was computed as follows:

$$Bulk\ Density = \frac{M_S}{AD}$$

where M_S is the mass of the oven dry litter or duff sample (kg), A is area of the sample (m^2), and D is the depth of the sample (m).

The bulk density of the sampling event was the average of the individual samples, with true zero samples omitted. The litter/duff depth of the sampling event was the average of the individual samples as well, but included true zeros.

Some large samples were divided into multiple portions prior to weighing and thus were entered into the database as multiple samples. These were aggregated before performing computations.

2.4.12 Dead and down woody fuel loads

Dead and down woody fuel loads (kg · m^{-2}) were computed separately for two categories: fine and coarse. Fine woody debris fuel load for each transect was computed as follows:

$$Fuel\ Load = \frac{(n \times c)}{L} \times \left[\left(S_1 \times M_{spp1}\right) + \left(S_2 \times M_{spp2}\right) + ... \right] \times 0.1$$

where n is the number of intercepts over the length of the transect, c is the slope correction factor $\sqrt{1 + \left(\frac{\%slope}{100}\right)^2}$, L is the total length of the transect (m), S is the percent species composition of woody material, and M_{spp} is a multiplier given species, diameter, and condition (i.e., natural or slash). Multipliers were obtained from Nalder et al. (1999). Fine woody debris fuel load was computed for different diameter size classes: < 1 cm, 1–3 cm, and 3–7 cm.

Coarse woody debris fuel load by transect was computed as follows:

$$Fuel\ Load = \frac{c}{L} \times \left[\left(\sum d^2 \times M_{spp1}\right) + \left(\sum d^2 \times M_{spp2}\right) + ... \right] \times 0.1$$

where c is the slope correction factor $\sqrt{1 + \left(\frac{\%slope}{100}\right)^2}$, L is the total length of the transect (m), d is the particle diameter (cm), and M_{spp} is a multiplier given species and condition (i.e., natural or slash). Multipliers were obtained from Bessie and Johnson (1995) and Delisle and Woodard (1988). If the condition was labeled as unassessed, then the particle was excluded.

The fuel load for the sampling event was the average of the transect fuel loads.

2.4.13 Mulch fuel load and depth

For each mulch sample, the depth of the four corners of the sample was recorded. In some cases, the depth of the center of the sample was also recorded. The average depth of a mulch sample (cm) was computed as the average of the recorded depths. The average depth of the entire sampling event was the average of these individual averages.

Following Schiks and Wotton (2015), only the top 2 cm of mulch was considered available for combustion. The mulch fuel load (kg · m^{-2}) for each destructive sample was calculated as follows:

$$Fuel\ Load = \frac{M_s}{A} \times M_D$$

where M_s is the mass of the oven dry mulch sample (kg), A is the area of the sample (m^2), and M_D is a multiplier based on the average depth of the sample, computed as follows:

$$M_D = \begin{cases} 1 \text{ if average depth} \leq 2\ cm \\ \dfrac{2}{average\ depth} \text{ otherwise} \end{cases}$$

A sampling event's mulch fuel load was the average of the fuel loads from the individual samples.

Some large mulch samples were divided into multiple portions before being weighed and thus were entered into the database as multiple samples. These portions were aggregated before performing computations.

3 Access to data and metadata description

The dataset (Phelps et al. 2021) is available at https://doi.org/10.17605/OSF.IO/FZ8E4. The associated metadata is available at https://metadata-afs.nancy.inra.fr/geonetwork/srv/fre/catalog.search#/metadata/527efb49-43b4-43eb-88b2-70535ff99fc5

The dataset contains 476 records of unique sampling events. Each sampling event record consists of 42 different variables. The first column is the sampling event number (SamplingEventNo), which is a unique identifier assigned at the time of field data collection. Next is the sampling event name (SamplingEventName) and date (SamplingDate). A separate column for the sampling year (Year) is included to make grouping/filtering by year more convenient. The treatment status (Treated) and fuel type (FuelType) are the next two columns, followed by plot level features of plot identification (PlotID), latitude (Latitude), longitude (Longitude), and moisture regime (MoistureRegime).

Four stand densities are included: all trees in the canopy (SDCanopyAll), live conifers in the canopy (SDCanopyLiveConifers), all trees in the understory (SDUndAll), and live conifers in the understory (SDUndLiveConifers). Basal area is also included for those four groups (BACanopyAll, BACanopyLiveConifers, BAUndAll, and BAUndLiveConifers respectively).

Information about the stand's trees include the average height (Height) and canopy base height (CBH), both of which are based on only live conifers in the

Table 2 Summary tables describing the minimum, maximum, mean, and standard deviation for several stand level features for each fuel type and treatment status by fuel type: C-2 Boreal Spruce. It should be noted that the number of sampling events for each category is not necessarily the number of sampling events contributing to the computation. For example, a sampling event might not have any deciduous trees and therefore would not contribute to the computation of statistics about the age of deciduous trees. A value of NA indicates that there were zero—or possibly one in the case of standard deviation—sampling events contributing to the computation. Values were rounded to four significant figures, up to four decimal places

Fuel type: C-2 Boreal Spruce	Natural (158 sampling events)				Treated (37 sampling events)			
	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
SDCanopyAll (trees hectare^{-1})	50.03	5595	1911	1157	324.8	2249	1164	621.5
SDCanopyLiveConifers (trees hectare^{-1})	49.99	4996	1634	1080	274.8	2249	1045	584.5
SDUndAll (trees hectare^{-1})	0	31 970	5958	6461	0	2248	397.2	518.1
SDUndLiveConifers (trees hectare^{-1})	0	30 720	5286	6477	0	2248	336.4	497.1
BACanopyAll (m^2 hectare^{-1})	0.5216	86.75	25.72	18.89	1.210	47.82	17.78	12.56
BACanopyLiveConifers (m^2 hectare^{-1})	0.4328	62.72	20.55	14.96	0.7676	36.15	15.87	10.69
BAUndAll (m^2 hectare^{-1})	0	30.96	5.992	5.691	0	5.796	0.7410	1.097
BAUndLiveConifers (m^2 hectare^{-1})	0	30.79	5.080	5.549	0	5.796	0.5934	1.049
Height (m)	5.022	22.27	11.09	3.529	5.857	22.33	11.96	4.146
CBH (m)	0.3615	12.27	4.333	2.033	1.417	13.43	4.681	2.602
ConiferProportion	0.8125	1.000	0.9793	0.0484	0.8333	1.000	0.9858	0.0393
LiveProportion	0.0455	1.000	0.8648	0.1532	0.5000	1.000	0.9068	0.1099
ConiferousAge (years)	23.75	184.3	77.60	27.91	47.67	184.0	80.59	29.09
DeciduousAge (years)	30.00	101.0	62.95	18.01	19.00	63.00	38.33	22.48
CanopyFuelLoad (kg m^{-2})	0.0229	2.380	0.9209	0.5825	0.0550	1.723	0.6750	0.3961
CanopyBulkDensity (kg m^{-3})	0.0024	0.4005	0.1441	0.0910	0.0122	0.2319	0.0954	0.0526
UnderstoryFuelLoad (kg m^{-2})	0	2.646	0.4555	0.5030	0	0.4135	0.0445	0.0741
ForbFuelLoad (kg m^{-2})	0	0.0288	0.0043	0.0047	0	0.0149	0.0033	0.0045
GrassFuelLoad (kg m^{-2})	0	0.0679	0.0058	0.0100	0	0.1164	0.0093	0.0211
ShrubFuelLoad (kg m^{-2})	0	1.923	0.3004	0.3056	0.0002	3.073	0.2844	0.5728
FWDFuelLoad1cm (kg m^{-2})	0.0008	0.0635	0.0201	0.0156	0.0036	0.1200	0.0287	0.0285
FWDFuelLoad3cm (kg m^{-2})	0	0.3115	0.0635	0.0546	0.0026	0.4441	0.0754	0.0807
FWDFuelLoad7cm (kg m^{-2})	0	0.8608	0.1447	0.1427	0.0103	0.5078	0.1408	0.1262
CWDFuelLoad (kg m^{-2})	0	10.75	0.8359	1.772	0	1.759	0.3300	0.4772
LitterFuelLoad (kg m^{-2})	0.1226	2.674	0.7493	0.4618	0	1.891	0.6707	0.4733
LitterAvgBulkDensity (kg m^{-3})	4.771	161.9	32.49	25.79	0	257.2	45.89	51.43
LitterAvgDepth (cm)	0.4583	5.688	2.948	0.9893	0	8.313	2.194	1.718
DuffFuelLoad (kg m^{-2})	0	3.498	1.160	0.6042	0.2792	4.980	1.526	1.021
DuffAvgBulkDens (kg m^{-3})	0	209.1	61.69	35.78	16.52	417.0	88.89	73.91
DuffAvgDepth (cm)	0	8.475	6.256	1.665	0.2500	10.00	6.283	2.157
MulchFuelLoad (kg m^{-2})	0	0	0	0	0	4.2619	0.7209	1.256
MulchAvgDepth (cm)	NA	NA	NA	NA	0.2500	9.750	4.303	2.642

canopy, as well as proportion of conifers (ConiferProportion), proportion of live trees among the conifers (LiveProportion), age of conifer trees (ConiferousAge), and age of deciduous trees (DeciduousAge). The stand's canopy and understory fuel loads are available (CanopyFuelLoad and CanopyBulkDensity respectively), as is the bulk density of the canopy (CanopyBulkDensity).

Several other fuel loads are in the dataset as well. These include fuel loads of forb (ForbFuelLoad), grass (GrassFuelLoad), shrubs (ShrubFuelLoad), coarse woody debris (CWDFuelLoad), and fine woody debris in three different diameter classes: < 1 cm (FWDFuelLoad1cm), 1–3 cm, (FWDFuelLoad3cm), and 3–7 cm (FWDFuelLoad7cm).

Phelps *et al. Annals of Forest Science*   (2022) 79:28

Page 11 of 16

Table 3 Summary tables describing the minimum, maximum, mean, and standard deviation for several stand level features for each fuel type and treatment status by fuel type: C-3 Mature Jack or Lodgepole Pine. It should be noted that the number of sampling events for each category is not necessarily the number of sampling events contributing to the computation. For example, a sampling event might not have any deciduous trees and therefore would not contribute to the computation of statistics about the age of deciduous trees. A value of NA indicates that there were zero—or possibly one in the case of standard deviation—sampling events contributing to the computation. Values were rounded to four significant figures, up to four decimal places

Fuel type: C-3 Mature Jack or Lodgepole Pine	Natural (61 sampling events)				Treated (12 sampling events)			
	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
SDCanopyAll (trees hectare^{-1})	500.3	4300	1913	856.1	375.3	2502	1369	823.1
SDCanopyLiveConifers (trees hectare^{-1})	249.9	4300	1578	806.0	375.3	2302	1244	808.3
SDUndAll (trees hectare^{-1})	0	7742	1175	1399	0	999.0	279.2	300.9
SDUndLiveConifers (trees hectare^{-1})	0	2902	621.4	709.0	0	499.5	108.3	167.6
BACanopyAll (m^2 hectare^{-1})	9.177	79.05	44.34	15.40	7.776	53.02	31.61	13.73
BACanopyLiveConifers (m^2 hectare^{-1})	7.691	67.38	38.01	13.76	6.355	47.97	29.37	12.76
BAUndAll (m^2 hectare^{-1})	0	23.32	2.772	3.848	0	3.403	1.003	1.089
BAUndLiveConifers (m^2 hectare^{-1})	0	9.676	1.448	1.897	0	1.569	0.4289	0.6174
Height (m)	6.558	23.34	15.69	3.347	14.31	22.82	17.68	2.844
CBH (m)	0.4938	15.30	8.760	2.891	6.407	14.21	9.832	1.951
ConiferProportion	0.8214	1	0.9812	0.0490	0.8750	1.000	0.9740	0.0422
LiveProportion	0.3529	1	0.8305	0.1590	0.7368	1.000	0.9134	0.1034
ConiferousAge (years)	31.00	169.7	80.16	29.78	55.50	90.67	68.59	9.972
DeciduousAge (years)	31.00	70.50	56.00	13.55	132.0	132.0	132.0	NA
CanopyFuelLoad (kg m^{-2})	0.1792	1.538	0.9285	0.3139	0.1624	1.207	0.6973	0.3266
CanopyBulkDensity (kg m^{-3})	0.0282	0.2879	0.1469	0.0634	0.0308	0.1820	0.0996	0.0601
UnderstoryFuelLoad (kg m^{-2})	0	0.4290	0.0817	0.1101	0	0.0558	0.0148	0.0215
ForbFuelLoad (kg m^{-2})	0	0.0251	0.0040	0.0050	0	0.1169	0.0136	0.0330
GrassFuelLoad (kg m^{-2})	0	0.0438	0.0073	0.0091	0	0.0140	0.0049	0.0054
ShrubFuelLoad (kg m^{-2})	0.0009	0.7966	0.1987	0.2173	0.0007	0.6332	0.1251	0.1846
FWDFuelLoad1cm (kg m^{-2})	0.0026	0.0679	0.0276	0.0153	0.0094	0.1036	0.0475	0.0281
FWDFuelLoad3cm (kg m^{-2})	0.0068	0.4482	0.0746	0.0670	0.0279	0.1979	0.1061	0.0555
FWDFuelLoad7cm (kg m^{-2})	0.0095	1.404	0.2640	0.2591	0.0451	0.5669	0.2165	0.1889
CWDFuelLoad (kg m^{-2})	0	6.430	1.526	1.449	0.0819	1.762	0.5768	0.4943
LitterFuelLoad (kg m^{-2})	0.3540	2.531	0.9795	0.3612	0.0181	1.362	0.8741	0.3783
LitterAvgBulkDensity (kg m^{-3})	17.26	228.8	51.84	36.28	19.49	102.0	53.86	28.01
LitterAvgDepth (cm)	0.7000	5.688	2.613	1.120	0.0625	3.813	2.168	1.145
DuffFuelLoad (kg m^{-2})	0.5112	4.411	1.962	0.8373	0.8695	3.018	2.006	0.6604
DuffAvgBulkDens (kg m^{-3})	38.99	387.3	115.7	60.20	58.28	269.3	125.6	53.63
DuffAvgDepth (cm)	1.188	7.000	3.863	1.453	0.7000	7.438	3.888	1.934
MulchFuelLoad (kg m^{-2})	0	0	0	0	0	1.776	0.3312	0.6252
MulchAvgDepth (cm)	NA	NA	NA	NA	1.268	9.771	5.555	4.2519

For litter, fuel load (LitterFuelLoad), bulk density (LitterAvgBulkDensity), and depth (LitterAvgDepth) are included. The same three features (DuffFuelLoad, DuffAvgBulkDensity, and DuffAvgDepth respectively) are available for duff. For mulch, fuel load (MulchFuelLoad) and depth (MulchAvgDepth) are present.

4 Technical validation

Technical validation consisted of the exhaustive cleaning and filtering process detailed in the Methods section. The resulting accuracy-checked dataset consists of 476 sampling event records. A series of reference tables (Tables 2, 3, 4, 5, and 6) contain descriptive statistical summaries of a variety of stand level features by assigned

Table 4 Summary tables describing the minimum, maximum, mean, and standard deviation for several stand level features for each fuel type and treatment status by fuel type: M-1/M-2 Boreal Mixedwood. It should be noted that the number of sampling events for each category is not necessarily the number of sampling events contributing to the computation. For example, a sampling event might not have any deciduous trees and therefore would not contribute to the computation of statistics about the age of deciduous trees. A value of NA indicates that there were zero—or possibly one in the case of standard deviation—sampling events contributing to the computation. Values were rounded to four significant figures, up to four decimal places

Fuel type: M-1/M-2 Boreal Mixedwood	Natural (94 sampling events)				Treated (24 sampling events)			
	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
SDCanopyAll (trees hectare^{-1})	250.2	4149	1365	741.0	175.12	1799	805.3	457.6
SDCanopyLiveConifers (trees hectare^{-1})	50.03	2699	540.8	418.7	50.03	1249	434.4	358.9
SDUndAll (trees hectare^{-1})	0	13 990	1674	1980	0	1701	418.7	501.8
SDUndLiveConifers (trees hectare^{-1})	0	2902	553.1	656.0	0	800.5	91.69	206.3
BACanopyAll (m^2 hectare^{-1})	6.158	80.83	41.58	15.72	1.620	46.56	27.07	12.39
BACanopyLiveConifers (m^2 hectare^{-1})	0.0542	51.91	14.86	10.93	0.0237	42.07	13.20	9.269
BAUndAll (m^2 hectare^{-1})	0	8.408	1.195	1.582	0	4.525	0.4543	0.9960
BAUndLiveConifers (m^2 hectare^{-1})	0	3.770	0.5208	0.7053	0	1.265	0.0973	0.2786
Height (m)	1.850	27.05	14.00	5.283	1.500	27.05	15.57	5.074
CBH (m)	0.2333	10.36	4.138	2.415	0.9500	9.113	5.301	2.238
ConiferProportion	0.2069	0.800	0.5241	0.1922	0.2083	0.800	0.5226	0.1907
LiveProportion	0.1667	1.000	0.7712	0.2062	0.5385	1.000	0.9158	0.1118
ConiferousAge (years)	24.50	140.0	64.35	22.85	30.00	92.00	63.46	17.37
DeciduousAge (years)	20.75	118.0	60.21	22.88	37.00	101.0	70.38	21.86
CanopyFuelLoad (kg m^{-2})	0.0100	1.887	0.5275	0.3673	0.0046	0.9512	0.4290	0.2795
CanopyBulkDensity (kg m^{-3})	0.0055	0.2185	0.0560	0.0413	0.0057	0.1172	0.0436	0.0305
UnderstoryFuelLoad (kg m^{-2})	0	0.2677	0.0450	0.0546	0	0.0961	0.0089	0.0229
ForbFuelLoad (kg m^{-2})	0	0.0327	0.0087	0.0075	0.0015	0.0515	0.0135	0.0112
GrassFuelLoad (kg m^{-2})	0	0.0758	0.0115	0.0140	0.0001	0.1657	0.0287	0.0364
ShrubFuelLoad (kg m^{-2})	0	2.854	0.4142	0.5792	0.0232	0.7564	0.1425	0.1673
FWDFuelLoad1cm (kg m^{-2})	0.0072	0.1160	0.0281	0.0201	0.0062	0.1447	0.0330	0.0316
FWDFuelLoad3cm (kg m^{-2})	0.0182	0.3069	0.0950	0.0613	0.0105	0.2478	0.0837	0.0595
FWDFuelLoad7cm (kg m^{-2})	0.0266	0.7650	0.2457	0.1645	0.0077	0.4117	0.1461	0.1094
CWDFuelLoad (kg m^{-2})	0	6.614	2.007	1.541	0	3.219	0.6965	1.003
LitterFuelLoad (kg m^{-2})	0.2451	2.059	0.8471	0.3357	0.2005	3.862	0.9870	0.7913
LitterAvgBulkDensity (kg m^{-3})	13.45	148.9	48.15	26.27	10.18	154.0	54.08	33.46
LitterAvgDepth (cm)	0.5625	4.500	2.232	0.7840	0.4375	4.714	2.214	1.133
DuffFuelLoad (kg m^{-2})	0	6.678	1.941	0.8732	0.4964	9.092	2.210	1.663
DuffAvgBulkDens (kg m^{-3})	0	333.9	103.8	44.08	55.83	454.6	128.5	81.51
DuffAvgDepth (cm)	0	9.238	5.628	1.878	0.5625	8.438	4.685	2.050
MulchFuelLoad (kg m^{-2})	0	0	0	0	0	2.849	0.4405	0.9346
MulchAvgDepth (cm)	NA	NA	NA	NA	2.200	8.833	4.414	2.577

FBP System fuel type and treatment status (i.e., treated or natural). These tables were scrutinized for irregularities, and none were found.

5 Reuse potential and limits
This dataset has been used to cluster forest stands into groups with similar modeled crown fire behavior (Phelps

N, Beverly JL: Classification of forest fuels in selected fire-prone ecosystems of Alberta, Canada - implications for crown fire behaviour prediction and fuel management, in review). Other studies have used data from the AWFIP database in conjunction with other data to estimate fuel characteristics using airborne laser scanning (Cameron et al. 2022b) and hemispherical and nadir photography

Phelps *et al. Annals of Forest Science*   (2022) 79:28

Page 13 of 16

Table 5 Summary tables describing the minimum, maximum, mean, and standard deviation for several stand level features for each fuel type and treatment status by fuel type: Mixed Conifer. It should be noted that the number of sampling events for each category is not necessarily the number of sampling events contributing to the computation. For example, a sampling event might not have any deciduous trees and therefore would not contribute to the computation of statistics about the age of deciduous trees. A value of NA indicates that there were zero—or possibly one in the case of standard deviation—sampling events contributing to the computation. Values were rounded to four significant figures, up to four decimal places

Fuel type: Mixed Conifer	Natural (47 sampling events)				Treated (9 sampling events)			
	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
SDCanopyAll (trees hectare^{-1})	250.2	2802	1386	732.4	349.8	3497	1347	945.1
SDCanopyLiveConifers (trees hectare^{-1})	200.1	2802	1130	688.6	349.8	3247	1225	863.8
SDUndAll (trees hectare^{-1})	100.1	12 740	2364	2900	0	7243	1754	2478
SDUndLiveConifers (trees hectare^{-1})	0	12 740	1675	2252	0	6244	1532	2181
BACanopyAll (m^2 hectare^{-1})	2.294	86.12	40.88	22.04	1.913	53.27	28.47	18.77
BACanopyLiveConifers (m^2 hectare^{-1})	2.294	84.04	33.06	20.99	1.913	53.27	26.56	18.29
BAUndAll (m^2 hectare^{-1})	0.0282	15.35	3.097	3.153	0	5.986	2.004	2.383
BAUndLiveConifers (m^2 hectare^{-1})	0	9.798	2.290	2.438	0	5.986	1.864	2.390
Height (m)	7.200	21.67	14.62	3.502	7.620	17.71	13.14	3.713
CBH (m)	1.707	10.98	6.178	2.415	1.886	7.767	5.001	2.068
ConiferProportion	0.8125	1.000	0.9553	0.0649	0.8235	1.000	0.9525	0.0692
LiveProportion	0.2800	1.000	0.8231	0.1704	0.8889	1.000	0.9770	0.0391
ConiferousAge (years)	32.25	177.0	79.37	26.69	47.50	102.8	64.11	18.76
DeciduousAge (years)	19.00	160.0	75.35	37.22	60.00	73.50	66.75	9.546
CanopyFuelLoad (kg m^{-2})	0.1394	2.627	1.021	0.6269	0.0985	1.782	0.8637	0.5336
CanopyBulkDensity (kg m^{-3})	0.0244	0.3149	0.1265	0.0785	0.0312	0.1885	0.1039	0.0587
UnderstoryFuelLoad (kg m^{-2})	0	0.9695	0.1626	0.1906	0	0.4344	0.1497	0.1895
ForbFuelLoad (kg m^{-2})	0	0.0375	0.0065	0.0080	0.0007	0.0258	0.0087	0.0092
GrassFuelLoad (kg m^{-2})	0	0.0267	0.0069	0.0076	0.0002	0.0229	0.0118	0.0072
ShrubFuelLoad (kg m^{-2})	0	1.220	0.1748	0.2229	0.0767	1.125	0.4375	0.3773
FWDFuelLoad1cm (kg m^{-2})	0.0057	0.0917	0.0331	0.0203	0.0153	0.0886	0.0335	0.0249
FWDFuelLoad3cm (kg m^{-2})	0.0050	0.2105	0.0697	0.0479	0.0172	0.1864	0.0684	0.0507
FWDFuelLoad7cm (kg m^{-2})	0	0.5442	0.1716	0.1378	0	0.3933	0.0970	0.1313
CWDFuelLoad (kg m^{-2})	0	8.724	1.718	2.035	0	2.558	0.6239	1.048
LitterFuelLoad (kg m^{-2})	0.2571	1.756	0.8426	0.3434	0.3908	1.998	0.9879	0.5803
LitterAvgBulkDensity (kg m^{-3})	12.42	96.00	42.71	20.52	14.45	63.68	36.88	16.39
LitterAvgDepth (cm)	1.063	4.438	2.441	0.8019	1.325	4.538	2.901	0.9854
DuffFuelLoad (kg m^{-2})	0.3479	4.331	1.706	0.8770	0.7050	6.383	2.294	1.924
DuffAvgBulkDens (kg m^{-3})	17.39	315.5	89.12	51.72	35.25	319.1	115.7	97.35
DuffAvgDepth (cm)	1.413	8.338	5.633	1.549	3.500	8.063	6.374	1.483
MulchFuelLoad (kg m^{-2})	0	0	0	0	0	0.6188	0.0688	0.2063
MulchAvgDepth (cm)	NA	NA	NA	NA	0.8250	0.8250	0.8250	NA

(Cameron et al. 2021, 2022a); as well as to analyze the effects of thinning on the spread rate and fuel consumption of wildland fire (Thompson et al. 2020) and of thinning and mulching on peat depth of burn (Wilkinson et al. 2018). The data has also been used in numerous technical reports to support fire behavior documentation including investigations of fire behavior in thinned stands (Hvenegaard et al. 2016) and mulched fuels (Hvenegaard 2020) and to support productivity studies for informing fuel management treatments (Hvenegaard and Hsieh 2017; Hvenegaard 2019). The dataset is also useful for informing inputs used for high resolution fire growth models (e.g., Marshall et al. 2020). We envision this dataset can be reused with other data for similar studies as well as for training purposes.

Table 6 Summary tables describing the minimum, maximum, mean, and standard deviation for several stand level features for each fuel type and treatment status by fuel type: D-1/D-2 Deciduous. It should be noted that the number of sampling events for each category is not necessarily the number of sampling events contributing to the computation. For example, a sampling event might not have any deciduous trees and therefore would not contribute to the computation of statistics about the age of deciduous trees. A value of NA indicates that there were zero—or possibly one in the case of standard deviation—sampling events contributing to the computation. Values were rounded to four significant figures, up to four decimal places

Fuel type: D-1/D-2 Deciduous	Natural (28 sampling events)				Treated (6 sampling events)			
	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
SDCanopyAll (trees hectare^{-1})	525.4	4099	1580	907.6	350.2	1250	745.7	395.5
SDCanopyLiveConifers (trees hectare^{-1})	25.02	749.3	180.3	179.8	25.02	199.9	87.49	62.72
SDUndAll (trees hectare^{-1})	0	12 990	1312	2468	0	2747	641.1	1104
SDUndLiveConifers (trees hectare^{-1})	0	12 740	878.0	2450	0	249.8	41.63	102.0
BACanopyAll (m^2 hectare^{-1})	21.06	115.4	46.27	21.99	10.11	38.21	30.23	10.20
BACanopyLiveConifers (m^2 hectare^{-1})	0.1830	14.17	4.111	3.709	0.4417	5.721	3.434	1.932
BAUndAll (m^2 hectare^{-1})	0	5.875	0.6620	1.175	0	1.200	0.3180	0.4659
BAUndLiveConifers (m^2 hectare^{-1})	0	5.771	0.4629	1.132	0	0.0708	0.0118	0.0289
Height (m)	2.167	25.15	13.33	5.781	7.100	20.50	14.93	4.431
CBH (m)	0.1000	13.20	2.656	2.873	1.525	5.800	3.079	1.837
ConiferProportion	0.0270	0.2000	0.1245	0.0542	0.0714	0.1818	0.1373	0.0433
LiveProportion	0.2778	1.000	0.8009	0.1626	0.4783	1.000	0.8545	0.1979
ConiferousAge (years)	20.00	135.0	53.71	27.72	44.00	74.00	50.30	13.26
DeciduousAge (years)	24.00	87.75	54.69	19.45	48.50	87.75	63.61	15.10
CanopyFuelLoad (kg m^{-2})	0.0097	0.3913	0.1359	0.0956	0.0255	0.2070	0.1067	0.0652
CanopyBulkDensity (kg m^{-3})	0.0020	0.0327	0.0133	0.0080	0.0035	0.0158	0.0087	0.0045
UnderstoryFuelLoad (kg m^{-2})	0	0.6740	0.0468	0.1284	0	0.0032	0.0005	0.0013
ForbFuelLoad (kg m^{-2})	0.0018	0.0251	0.0106	0.0062	0.0007	0.0691	0.0151	0.0267
GrassFuelLoad (kg m^{-2})	0	0.0983	0.0171	0.0227	0.0012	0.0676	0.0256	0.0242
ShrubFuelLoad (kg m^{-2})	0.0066	4.171	0.5776	0.8867	0.0044	0.2437	0.0910	0.0961
FWDFuelLoad1cm (kg m^{-2})	0.0077	0.0816	0.0244	0.0199	0.0119	0.0196	0.0139	0.0029
FWDFuelLoad3cm (kg m^{-2})	0.0305	0.2074	0.0872	0.0447	0.0405	0.0964	0.0612	0.0197
FWDFuelLoad7cm (kg m^{-2})	0.0590	1.269	0.3264	0.2546	0.0705	0.4162	0.2092	0.1386
CWDFuelLoad (kg m^{-2})	0.2209	5.250	2.068	1.240	0.3856	3.691	1.447	1.270
LitterFuelLoad (kg m^{-2})	0.2695	1.532	0.6927	0.2526	0.1581	1.014	0.7733	0.3220
LitterAvgBulkDensity (kg m^{-3})	19.43	171.9	43.99	34.54	24.32	91.86	48.58	23.41
LitterAvgDepth (cm)	1.000	3.500	2.194	0.6749	0.3750	3.188	2.060	0.9745
DuffFuelLoad (kg m^{-2})	0	3.748	1.757	0.7671	1.617	3.092	2.428	0.6614
DuffAvgBulkDens (kg m^{-3})	0	214.1	102.7	43.11	80.87	178.9	130.3	37.72
DuffAvgDepth (cm)	0	8.250	5.156	2.480	3.563	6.375	5.223	1.185
MulchFuelLoad (kg m^{-2})	0	0	0	0	0	3.139	0.8148	1.225
MulchAvgDepth (cm)	NA	NA	NA	NA	3.333	8.797	5.757	2.783

There remain some known deficiencies, for example errors in tree entries and shrub fuel loads computed with a general equation not specific to the species in our study area. Likewise, the readily-available allometric equations we used to compute CFL could lead to over- or underestimates depending on how closely the stand conforms to those used to develop the applied equations.

Further, we have not accounted for the effects of pruning in treated stands on CFL due to the lack of pre-treatment measurements of LCBH. Our use of statistical models to estimate missing LCBH values is another limitation of the data.

There are also most certainly errors that were not detected. For example, we know some tree data were not

entered; however, we believe our data cleaning and filtering process has sufficiently reduced errors and that the computations provide reasonable estimates of fuel loads that can be used with confidence in future scientific studies.

Code availability
N/A

Availability of data and materials
Data have been deposited to the Open Science Framework repository: https://doi.org/10.17605/OSF.IO/FZ8E4.

Declarations

Ethics approval and consent to participate
N/A

Consent for publication
All authors gave their informed consent to this publication and its content.

Competing interests
The authors declare that they have no competing interests.

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