Estimates of mortality in areas affected by the 2021 wildfires

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Objective

This document describes the method used to estimate timber mortality in areas affected by wildfires in British Columbia in 2021.

Method

- Ground samples: 95 samples

  Forest attributes collected from ground samples established for Continuous Monitoring Inventory (CMI), Vegetation Resources Inventory phase 2 (VRI), Young Stand Monitoring (YSM), and the National Forest Inventory (NFI) were used to estimate timber volumes within the fire perimeters before the fires occurred.

  Ground samples after 2017 fire: Sixty-eight ground plots were visited. However, seven samples were removed from the analysis since they were harvested before the fires. Therefore, 61 samples were used in this analysis (see Appendix 1). The majority of these samples were in the Quesnel, 100 Mile House, and Williams Lake TSAs since these TSAs accounted for about 80% of the area burned in 2017.

  Ground samples after 2021 fire: Thirty-six ground plots were visited. However, two samples were removed from the analysis since they were harvested before the fires. Therefore, 34 samples were used in this analysis. The majority of these samples were from six TSAs (Kamloops, 100 Mile House, Okanagan, Lillooet, Merritt, and Arrow TSA) which account for about 71% of the area burned in 2021.

- Fire severity classification

  This analysis assumes that because the fire severity classification algorithms for areas within the 2017 and 2021 wildfire perimeters were same, the mortality rates for any given fire severity class in 2017 and 2021were equivalent.

  There were five fire severity classes for the 2017 fires: unburned, low, medium, high, and nuked. There were four fire severity classes for the 2021 fires: unburned, low, medium, and high. To make the 2017 fire severity classes consistent with the 2021 classes, the nuked class in 2017 was combined with the high class.

- Forest inventory information - VRI rank 1 layers for 2017 and 2021

  These layers were used to derive the area within the fire perimeters, by maturity class (young vs. mature) for each fire severity class.

- The area of each fire severity class within the fire perimeters was estimated using the VRI rank 1 layer and the fire severity mapping.

Table 1 shows the area within the fire perimeters of each fire severity class by forest maturity class. For the 2017 fires, the areas were summarized for the three most affected TSAs (Quesnel, 100 Mile House, and Williams Lake). For the 2021 fire, the areas were summarized for the six most affected TSAs (Kamloops, 100 Mile House, Okanagan, Lillooet, Merritt, and Arrow).

Table 1. Summary of area by fire severity and maturity classes

Fire severity	Maturity class	2017 fire		2021 fire		Combined	
		Area (ha)	Number of samples	Area (ha)	Number of samples	Area (ha)	Number of samples
Unburned	Young (SA <= 50)	51,998	7	28,505	6	80,503	13
Unburned	Mature (SA > 50)	86,284	2	80,267	8	166,551	10
Low	Young (SA <= 50)	33,683	5	16,717	1	50,400	6
Low	Mature (SA > 50)	112,848	6	70,536	1	183,384	7
Medium	Young (SA <= 50)	46,642	0	50,574	5	97,216	5
Medium	Mature (SA > 50)	225,919	14	154,188	4	380,107	18
High	Young (SA <= 50)	59,263	12	17,769	3	77,032	15
High	Mature (SA > 50)	368,455	15	147,440	6	515,895	21
		985,092	61	565,996	34	1,551,088	95

Table 2 shows a summary of area by fire severity class for all of the TSAs affected by the 2021 wildfires.

Table 2. Area summary by fire severity class for all TSAs within the 2021 fire perimeters

Fire severity	All TSAs (ha)	Six most affected TSAs (ha)	Other TSAs (ha)
Unburned	189,414	108,772	80,642
Low	121,395	87,253	34,142
Medium	278,726	204,762	73,964
High	209,735	165,209	44,526
Total	799,270	565,996	23,3274

Results

- Area-weighted mean mortality rates by fire severity class were determined.

  The area-weighted mean mortality rate for each fire severity class was computed based on the mean mortality rate for a fire severity class and the proportion of the area of the maturity class to total area within the fire severity class (see Table 1). Table 3 below table summarizes the area weighted mean mortality rates for each fire severity class for the six most affected TSAs in the 2021 wildfires. The mortality attributes used in Table 3 are:

  Stem @7.5 cm (stem/ha for trees in the sample plot with a dbh greater than 7.5 cm);

  BA @7.5 (basal area of trees in the sample plot with a dbh greater than 7.5 cm);

  VSV @7.5 (whole stem volume for trees in the sample plot with a dbh greater than 7.5 cm);

  NTWB @12.5 (merchantable volume, after cruise called decay, waste and breakage for trees in the sample plot with a dbh greater than 12.5 cm).

Table 3. Area-weighted mean mortality rate by fire severity class for the six most affected TSAs in 2021

Fire severity	Mortality attribute	Area-weighted mean mortality rate
Unburned	Stem @7.5cm	0.21
Unburned	BA @7.5cm	0.19
Unburned	WSV @7.5cm	0.18
Unburned	NTWB @12.5cm	0.17
Low	Stem @7.5cm	0.26
Low	BA @7.5cm	0.29
Low	WSV @7.5cm	0.33
Low	NTWB @12.5cm	0.35
Medium	Stem @7.5cm	0.65
Medium	BA @7.5cm	0.64
Medium	WSV @7.5cm	0.64
Medium	NTWB @12.5cm	0.62
High	Stem @7.5cm	0.94
High	BA @7.5cm	0.83
High	WSV @7.5cm	0.82
High	NTWB @12.5cm	0.82

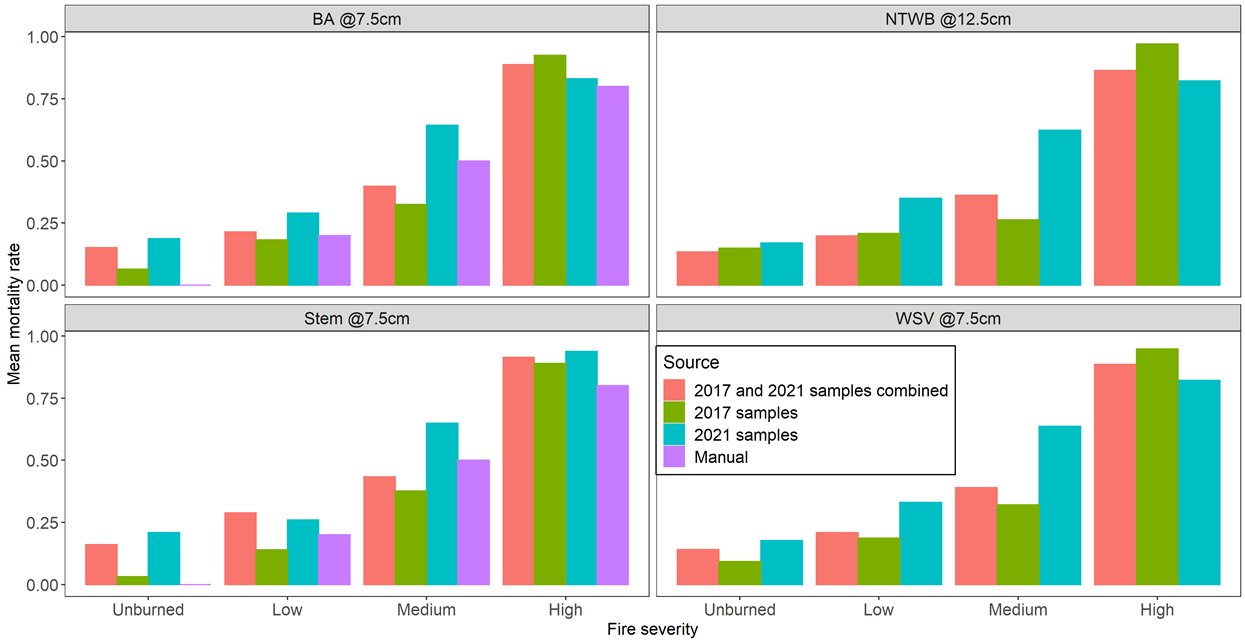
The area-weighted mean mortality rates for the other TSAs affected in the 2021 wildfires were estimated by combining the sample data for the 2021 fires with those from the 2017 fires. Table 4 below shows the area-weighted mean mortality rate by fire severity class for the other TSAs affected by the 2021 wildfires.

Table 4. Area-weighted mean mortality rate by fire severity class for the other TSAs affected by wildfires in 2021

Fire severity	Mortality attribute	Mortality rate
Unburned	Stem @7.5cm	0.16
Unburned	BA @7.5cm	0.15
Unburned	WSV @7.5cm	0.14
Unburned	NTWB @12.5cm	0.13
Low	Stem @7.5cm	0.29
Low	BA @7.5cm	0.21
Low	WSV @7.5cm	0.21
Low	NTWB @12.5cm	0.20
Medium	Stem @7.5cm	0.43
Medium	BA @7.5cm	0.40
Medium	WSV @7.5cm	0.39
Medium	NTWB @12.5cm	0.36
High	Stem @7.5cm	0.91
High	BA @7.5cm	0.89
High	WSV @7.5cm	0.89
High	NTWB @12.5cm	0.86

- Comparison of mortality rates

  Figure 1 shows a comparison of mortality rates by mortality attribute and by sample year. It also includes the mortality rates obtained from combining the samples from 2017 and 2021. For mortality attributes BA @7.5 and Stem @7.5 the rates for unburned, low, and medium severity classes were higher in 2021 that they were in 2017. Figure 1 also shows a "manual" mortality source which is an estimate of mortality in 2017 based on observations by field staff. It shows that for the medium severity class the manual estimate was higher that the estimate using ground samples from 2017, whereas for the high class, the manual estimate was lower than the estimate using ground samples.



- Scenarios comparing mortality rates by fire severity classes:
  - Scenario 1: mortality rates were derived from 2017 and 2021 ground samples combined;
  - Scenario 2: mortality rates were derived from 2021 ground samples only;
  - Scenario 3: mortality rates were manually assigned for 2017.

Fire severity	Scenario 1		Scenario 2		Scenario 3	
	Stem mortality rate	BA mortality rate	Stem mortality rate	BA mortality rate	Stem mortality rate	BA mortality rate
Unburned	0.16	0.15	0.21	0.19	0	0
Low	0.29	0.21	0.26	0.29	0.2	0.2
Medium	0.43	0.4	0.65	0.64	0.5	0.5
High	0.91	0.89	0.94	0.83	0.8	0.8

For the unburned and high classes, the mortality rates derived from ground samples were higher than the manually assigned mortality rates. However, for the low and medium classes, the mortality rates derived from ground samples were similar to the ones that were manually assigned.

- Effect of applying mortality rates from the different scenarios to adjust the spatial inventory to account for the 2021 wildfires.

  The effect of applying mortality rates from the different scenarios were assessed for three spatial coverages (all TSAs, the six most highly affected TSAs, and other TSAs). For each spatial coverage and scenario, we computed a relative adjustment factor using the equation below for the Stem @7.5 and BA @7.5 mortality attributes.

$$Relative\ adjustment\ factor = \sum \frac{Mortality_i \times Area_i}{Area_{total}}$$

where $Mortality_i$ and $Area_i$ were the mortality rate and area for i^{th} fire severity, respectively. $Area_{total}$ was the total area for a spatial coverage of interest across all the fire severity classes. The relative adjustment factor, to some extent, reflects the intensity of adjustment for a given area.

Spatial coverage	Relative adjustment factor in Scenario 1		Relative adjustment factor in Scenario 2		Relative adjustment factor in Scenario 3	
	Stem	BA	Stem	BA	Stem	BA
All TSAs	0.47	0.44	0.56	0.53	0.41	0.41
Other TSAs	**0.41**	**0.38**	**0.50**	**0.47**	**0.34**	**0.34**
Six most affected TSAs	0.50	0.46	0.59	0.56	0.45	0.45

The results show that when using the mortality rates from 2017 and 2021 combined samples (Scenario 1) to adjust the other TSAs affected in the 2021 fires (highlighted in red in the above table), the adjustment factors are higher than the adjustment factors that were manually assigned (i.e., Scenario 3). Specifically, the factors increased from 0.34 to 0.41 for the Stem @7.5 mortality attribute, while it increased from 0.34 to 0.38 for the BA @7.5 mortality attribute. The adjustment factors using the rates from 2021 samples (Scenario 2) generated the highest relative adjustment factors among the three scenarios.

Conclusions

This study provides a procedure to derive and apply mortality adjustments for areas affected by wildfires in the future. If mortality rates can be derived locally, i.e., have enough ground samples (> 30 samples) in the area, those mortality rates should be used to adjust forest inventory stand volumes in that area.

Although in this analysis we provided mortality rates based on 95 ground samples, this analysis could be improved in the future when more samples are collected after wildfires to address uncertainties in mortality rate estimates. For example, there is uncertainty whether the mortality rates vary with stand composition and stand structure. Mixed stands are believed to be more resilient to wildfire than pure stands, and lodgepole pine dominant stands are more vulnerable to the wildfires than deciduous dominant stands.

Recommendations

We recommend that:

- Scenario 1 mortality rates (2017 and 2021 sample data combined) are used to adjust the VRI basal area and density estimates for all the other TSAs affected by wildfires in 2021.
- Scenario 2 mortality rates (2021 sample data) are used to adjust the VRI basal area and density estimates for the six most highly affected TSAs in the 2021 wildfires.
- The specific mortality rates for each fire intensity class are presented in the table below.

Fire severity	Scenario 1		Scenario 2	
	Stem adjustment rate	BA adjustment rate	Stem adjustment rate	BA adjustment rate
Unburned	0.16	0.15	0.21	0.19
Low	0.29	0.21	0.26	0.29
Medium	0.43	0.40	0.65	0.64
High	0.91	0.89	0.94	0.83

Appendix 1. Mortality rates of 95 visited ground samples

CLSTR_ID	Fire year	Age class	Burn severity	Stem mortality	BA mortality	WSV mortality	NTWB mortality
1424431-M1	2021	Mature (SA > 50)	Unburned	0.00	0.00	0.00	0.00
2069116-Q1	2021	Mature (SA > 50)	Unburned	0.55	0.29	0.20	0.14
2081116-Q1	2021	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
1403816-M1	2021	Mature (SA > 50)	Unburned	0.47	0.69	0.72	0.74
2085118-Q1	2021	Mature (SA > 50)	Unburned	0.58	0.53	0.51	0.49
6001591-Q1	2021	Mature (SA > 50)	Medium	0.98	0.85	0.81	0.80
2077127-Y1	2021	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
2073128-Q1	2021	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
6006439-M2	2021	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
2073124-Q1	2021	Mature (SA > 50)	Medium	0.68	0.88	0.89	0.90
6001584-Q1	2021	Mature (SA > 50)	High	0.67	0.71	0.75	0.77
2075128-Q1	2021	Mature (SA > 50)	Medium	0.28	0.23	0.21	0.20
2073126-Q1	2021	Young (SA <= 50)	Medium	0.17	0.13	0.09	0.09
1424446-M1	2021	Mature (SA > 50)	High	0.90	0.12	0.06	0.02
1438221-M2	2021	Young (SA <= 50)	Medium	0.46	0.59	0.67	0.78
2067113-Y2	2021	Young (SA <= 50)	Unburned	0.02	0.03	0.02	0.07
1424486-M2	2021	Young (SA <= 50)	Unburned	0.79	0.73	0.73	0.74
6000922-M5	2021	Mature (SA > 50)	Medium	1.00	1.00	1.00	1.00
1451976-M4	2021	Young (SA <= 50)	Unburned	0.02	0.02	0.02	0.00
2058083-Y2	2021	Mature (SA > 50)	Unburned	0.00	0.00	0.00	0.00
2029091-Y2	2021	Mature (SA > 50)	Low	0.00	0.00	0.00	0.00
2026091-Y1	2021	Young (SA <= 50)	Medium	0.24	0.18	0.13	0.12
3000912-M1	2021	Mature (SA > 50)	Unburned	0.08	0.05	0.05	0.05
3000329-Y2	2021	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
3000359-Y3	2021	Mature (SA > 50)	Unburned	0.04	0.03	0.04	0.04
2050097-Y2	2021	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
2052101-Y1	2021	Young (SA <= 50)	Medium	0.40	0.33	0.31	
1507026-F2	2021	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
3000027-Y2	2021	Young (SA <= 50)	Unburned	0.25	0.11	0.07	0.03
3000040-Y2	2021	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
2049123-Y2	2021	Young (SA <= 50)	Low	0.53	0.59	0.67	0.70
1465731-M1	2021	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
1465726-M1	2021	Mature (SA > 50)	Unburned	0.00	0.00	0.00	0.00
1479551-M2	2021	Young (SA <= 50)	Medium	0.62	0.53	0.57	
024Y-0212-YO1	2017	Young (SA <= 50)	Low	0.00	0.00	0.00	0.00
CMI1-0501-FR1	2017	Mature (SA > 50)	Medium	0.10	0.10	0.10	0.10
026M-0010-YR1	2017	Young (SA <= 50)	High	0.39	0.37	0.36	0.14
CAR1-9356-MO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
026M-0005-MR1	2017	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
026M-0009-YR1	2017	Young (SA <= 50)	Low	0.00	0.00	0.00	0.00
CMI1-0327-MR1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00

CLSTR_ID	Fire year	Age class	Burn severity	Stem mortality	BA mortality	WSV mortality	NTWB mortality
026M-0008-YR1	2017	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
CAR1-6241-MO1	2017	Mature (SA > 50)	Medium	0.17	0.14	0.12	0.04
026M-0007-YR1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
CAR1-6246-MO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
CAR1-6251-MO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
CMI1-0559-FR1	2017	Mature (SA > 50)	Low	0.08	0.14	0.14	0.15
029M-0238-MO1	2017	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
CAR1-3121-MO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
CAR1-3126-MO1	2017	Mature (SA > 50)	Medium	0.00	0.00	0.00	0.00
CAR1-3131-MO1	2017	Mature (SA > 50)	Unburned	0.00	0.00	0.00	0.00
026M-0019-YR1	2017	Young (SA <= 50)	Low	0.00	0.00	0.00	0.00
CAR1-3141-MO1	2017	Mature (SA > 50)	Medium	0.81	0.79	0.79	0.70
026M-0024-YR1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
029M-0202-MO1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
029M-0220-MO1	2017	Young (SA <= 50)	High	0.20	0.24	0.25	0.00
029M-0225-MO1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
CAR1-6911-MO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
029M-0267-MO1	2017	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
029M-0263-MO1	2017	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
029M-0264-MO1	2017	Mature (SA > 50)	Medium	0.10	0.08	0.06	0.00
CAR1-3781-MO1	2017	Mature (SA > 50)	Medium	0.19	0.15	0.14	0.00
029M-0243-MO1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
029M-0211-MO1	2017	Young (SA <= 50)	Low	0.00	0.00	0.00	0.00
CAR1-0626-MO1	2017	Mature (SA > 50)	Medium	0.34	0.26	0.22	0.20
CAR1-0656-MO1	2017	Mature (SA > 50)	High	0.46	0.42	0.40	0.00
CAR1-0661-MO1	2017	Mature (SA > 50)	High	0.92	0.91	0.95	1.00
029M-0207-MO1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
029M-0258-MO1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
0231-0306-QO1	2017	Mature (SA > 50)	High	0.79	0.78	0.80	0.81
029M-0223-MO1	2017	Young (SA <= 50)	Low	0.08	0.12	0.13	0.00
0231-0045-QO1	2017	Mature (SA > 50)	Low	0.31	0.24	0.24	0.23
029M-0247-MO1	2017	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00
029M-0208-MO1	2017	Young (SA <= 50)	High	0.65	0.39	0.29	0.10
0231-0070-QO1	2017	Mature (SA > 50)	Medium	0.70	0.54	0.47	0.45
0231-0080-QO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
0231-0253-QO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
CMI1-0513-FR1	2017	Mature (SA > 50)	Medium	1.00	1.00	1.00	1.00
0231-0091-QO1	2017	Mature (SA > 50)	Low	0.27	0.14	0.11	0.12
0231-0242-QO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
CAR1-1331-MO1	2017	Mature (SA > 50)	Medium	0.50	0.38	0.34	0.24
0231-0227-QO1	2017	Mature (SA > 50)	High	0.67	0.80	0.80	0.80
KMHY-0218-YO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00

CLSTR_ID	Fire year	Age class	Burn severity	Stem mortality	BA mortality	WSV mortality	NTWB mortality
0231-0226-QO1	2017	Mature (SA > 50)	Low	0.63	0.53	0.54	0.53
CAR1-1336-MO1	2017	Mature (SA > 50)	High	1.00	1.00	1.00	1.00
0231-0110-QO1	2017	Mature (SA > 50)	Medium	0.10	0.23	0.25	0.28
0231-0213-QO1	2017	Mature (SA > 50)	Medium	0.70	0.50	0.46	0.47
0231-0111-QO1	2017	Mature (SA > 50)	Low	0.35	0.10	0.06	0.00
0231-0112-QO1	2017	Mature (SA > 50)	Unburned	0.31	0.29	0.28	0.26
0231-0113-QO1	2017	Mature (SA > 50)	Low	0.74	0.52	0.55	0.53
0231-0205-QO1	2017	Mature (SA > 50)	Medium	0.00	0.00	0.00	0.00
0231-0117-QO1	2017	Mature (SA > 50)	Medium	0.40	0.31	0.29	0.29
KMHY-0212-YO1	2017	Young (SA <= 50)	High	1.00	1.00	1.00	1.00
CAR1-8211-MO1	2017	Mature (SA > 50)	High	0.90	0.90	0.90	0.90
KMHY-0211-YO1	2017	Young (SA <= 50)	Unburned	0.00	0.00	0.00	0.00