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EVALUATING THE RELATIVE FIRE HAZARD OF ORIENTED DEBRIS PILES AND CONSTRUCTED BURN PILES

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ABTRACT:

Oriented residue piles and constructed burn piles have different characteristics, including fuel size, composition, and fuel arrangement. The comparative ignition trials conducted in this proof-of-concept study suggest that these characteristics influence the fuel environment, with a higher potential for ignition and sustained burning and greater resultant fire intensity in constructed burn piles. The intent of this proof-of-concept trial was to determine whether logging residue piles that have been oriented for biomass extraction (placed in parallel piles by the processor operator during primary harvesting activities) is a significant fuel hazard that requires further abatement.

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BACKGROUND

The clean air initiative led by British Columbia's Ministry of Environment and Climate Change Strategy seeks to develop innovative methods to use harvest residues as a means to improve community air quality. Presently, harvest residues are often left at roadside by the primary harvester in a form that makes it economically unfeasible for a secondary user to recover. The current practice is for licensees to burn harvest residues to fulfill their fire hazard abatement obligations. This practice creates negative impacts, including poor regional air quality, loss of potential economic opportunities, and the release of greenhouse gases; it also eliminates any beneficial uses or offsets. To meet the requirements of fire fuel hazard abatement, an alternative to burning may be to pile the residues in an oriented alignment, something that has not yet been investigated.

The intent of this proof-of-concept trial was to determine whether logging residue piles that have been oriented for biomass extraction (placed in parallel piles by the processor operator during primary harvesting activities) are a significant fuel hazard that requires further abatement. Knowing this would help forest managers to determine whether oriented piles can be left at roadside until such time as they are extracted by secondary harvesters. This would enable primary harvesters to avoid immediately having to reduce fuel loads, which would provide secondary users the ability to harvest residues beyond the timeframe that is currently possible.

OBJECTIVES

The overall goal of this study was to investigate the two distinct fuel environments (oriented residue piles and constructed burn piles) and the flammability of each. Specifically, the objectives of this study were to:

- Characterize harvest residue piles that have been left at the roadside in an oriented fashion and haystack piles that have been constructed for burning.
- Evaluate the ease of ignition for each pile type.
- Assess the sustained burning, fire intensity, and consumption rate for each pile type.
- Explore the challenges in fire suppression associated with each configuration.
- Develop evolved research questions and adapted work plans for other geographic areas and fuel types of British Columbia.

SITE DESCRIPTION

The study site was in the CWHxm2 biogeoclimatic subzone located 25 km north of Port Alberni, British Columbia, in the Ash operating area managed by Island Timberlands. Before harvest, the predominant overstory was 80-year-old Douglas-fir, with a minor component of western red cedar and western hemlock. This area was harvested in winter/spring 2018 and processed using a dangle-head processor; the tops were left at roadside in an oriented fashion (all tops aligned in parallel orientation). Long butts and branches were scattered around the oriented pile. Twelve piles along Road CX99-7 were chosen for this study. In fall 2018, contractors reconfigured six of these piles on the southwest side of the road in the traditional haystack fashion, while the remaining six piles on the northeast side of the road were left undisturbed in the oriented fashion.

METHODS

Debris Pile Characterization

Spencer and Röser (2017) provide terminology of harvest residue components and the best practices for piling debris. For the current study, researchers adopted this common terminology and applied the term "oriented pile" to tops that had been left by the processor in a parallel alignment at the roadside (Figure 1). The term "burn pile" was applied to residues piled in a haystack configuration, typical in a post-harvest burning operation (Figure 2).

Figure 1. An oriented pile.

Figure 2. A burn pile.

Characterizing residue piles included measurement of pile height and butt diameter of pieces, classification by species, and relative evaluation of pile size, density, and composition of each component (Appendix 1). A Protimeter moisture meter and calipers were used to measure moisture content and the butt diameter for 20 tops from all piles to determine the differences in moisture content between the two pile types (Figure 3).

Figure 3. Measurement of moisture content.

Ignition and Fire Behaviour

To assess the relative ease of ignition and to standardize an ignition process that could be replicated across the 12 piles, fusees (road flares) and fire starter logs (Figure 4) were chosen as ignition devices because they have a relatively consistent burn time (approximately 30 minutes and 2 hours, respectively).

Figure 4. A fusee, or road flare *(left)*, and a fire starter log *(right)*.

These devices alone did not create sufficient heat intensity to drive off enough fuel moisture to allow for successful ignition and sustained burning. Even with intentional placement of the ignition devices in pockets of fine fuels (Figure 5), it was necessary to amend this ignition process by adding branches or other fine fuels to sustain combustion.

Figure 5. Intentional placement of an ignition device in pockets of fine fuel.

On October 25, 2018, researchers commenced paired ignitions at 08:40 in Burn Pile 1 (BP-1) and Oriented Pile 1 (OP-1) in the south end of the trial site. From observations and review of video and photos, the duration from ignition to sustained burning and full involvement of the pile were determined. When sustained burning was achieved, fire intensity was monitored and visually assessed. Post-fire review of imagery provided a relative comparison of peak fire intensity achieved in the two pile types (Figures 6 and 7). The degree of pile involvement for each pile was assessed in relation to time from ignition. A pile was considered to be fully involved when 80% of the pile material was estimated to be engulfed in flames. The overall consumption of each pile (as a percentage) was estimated and the burning time to the final state of consumption or self-extinguishment was recorded. Ignition in the last piles (BP-6 and OP-6) was completed at 13:30.

Figure 6. BP-6, 51 minutes after ignition. **Figure 7.** OP-6, 53 minutes after ignition.

RESULTS

Debris Pile Characterization

The oriented piles created by the processor consisted primarily of tops that were generally aligned in a parallel fashion. Long butts and brush were scattered in a wide area around the tops. In contrast, the burn piles consisted of tops piled above concentrated long butts and branches; they were taller and more dense than the oriented piles, but with little alignment of pieces. The characteristics of individual piles can be found in Appendix 1.

The average moisture content of the oriented piles and burn piles was 19.5% and 20.9%, respectively (Appendix 2). The raw data showed little correlation between piece diameter and moisture content.

Weather and Fire Weather Index values

In the five months before the trial (May 1 to October 24), the Port Alberni area had received 333 mm of precipitation (Table 1). In July and August, a persistent high pressure ridge over Vancouver Island had limited rainfall over the study area, and less than 10 mm of precipitation fell during this time.

Table 1. Monthly precipitation at Port Alberni weather station (Environment Canada)

Monthly precipitation for Port Alberni weather station (2018)							
Month	**May**	**June**	**July**	**August**	**September**	**October (1 to 24)**	**Total**
Precipitation (mm)	14.6	41.9	3.7	4.5	229.6	38.9	333.2

In September, 230 mm of rain was recorded, which reduced the Fire Weather Index (FWI) (Van Wagner, 1987) values from extreme to more seasonal levels. Between October 10 and 24, only 1 mm of rain had fallen in this area, which elevated the Fine Fuel Moisture Code (FFMC) to a level beyond the maximum threshold value for burning debris piles. Island Timberlands uses an FFMC of 70 as the maximum threshold value for burning piles to reduce the chance of unwanted fire spread. With 13.8 mm of rain recorded on October 25, the FFMC was reduced to a level that would permit safe burning of piles with little chance of fire spread.

Table 2. FWI values from the Beaver Creek weather station

FWI values for October 25, 2018						
Precipitation (mm)	**FFMC**	**DMC**	**DC**	**ISI**	**BUI**	**FWI**
13.8	22	6	68	0	10	0

Ease of Ignition and Fire Behaviour

Ignition and sustained burning in the oriented piles was more difficult to achieve than in the burn piles. Ignitions in two oriented piles (OP-1 and OP-3) did not sustain combustion even after 1 hour of attempting to amend the ignition with additional fine and medium-sized fuels. In OP-2 and OP-5, even when sustained ignition was achieved in the heavier fuels (tops), these piles self-extinguished after 1 and 2 hours, respectively. Higher temperature and lower relative humidity in the early afternoon contributed to drying of fine fuels, which contributed to easier ignition and sustained burning in the later piles. Piles OP-4 and OP-6 continued to burn with low intensity or smoulder through the night.

While some of the burn piles were difficult to ignite, sustained ignition was achieved in all burn piles. On average, the burn piles took 51 minutes to become fully involved in fire. Most of the burn piles were fully consumed within 4 to 5 hours. In comparison, the oriented piles displayed slower and less consistent consumption.

Table 3. Fire behaviour characteristics

Sustained burning and fire growth					
Pile	Time after ignition (HH:MM)			Final pile consumption (%)	Comments
	Sustained burning[a]	Average for group	Full pile involvement[b]		
OP-1	N/A	00:31	N/A	0	Three ignitions attempted. Fuel amendments could not sustain burning in residue.
Op-2	00:47		N/A	<5	Low-intensity fire initiated in residue but self-extinguished 1 hour after ignition.
OP-3	N/A		N/A	0	No fine fuels available in pile; amendments could not sustain burning in residue.
OP-4	00:39		N/A	80	Continued flaming combustion through afternoon, with smouldering through evening.
OP-5	00:15		N/A	<10	No flaming combustion 2 hours, 4 minutes after ignition.
OP-6	00:23		N/A	85	Continued flaming combustion through afternoon, with smouldering through evening.
BP-1	00:40	00:24.5	01:10	100	
BP-2	00:20		00:50	95	
BP-3	00:20		00:30	100	

BP-4	00:46		01:13	100	
BP-5	00:50		01:02	100	
BP-6	00:11		00:20	100	

[a] Sustained burning was achieved when no further amendments or interventions were required to maintain ignition.

[b] Full pile involvement was achieved when 80% of the pile was in a flaming state.

During the trial, researchers observed that ignitions in the burn piles grew more rapidly and resulted in a higher intensity fire, with more rapid fuel consumption, compared to ignitions in the oriented piles. As post-harvest residues are rearranged into burn piles, tops, branches, and some butts are concentrated into a reduced footprint (relative to the oriented piles). Burn piles were characterized as having a higher, more compact vertical structure composed of tops, branches, and long butts. Therefore, more fuels were directly exposed to radiant and convective energy during ignition and were pre-heated more rapidly toward a state of sustained combustion. With a larger volume of fuels combusting in a smaller area, the burn piles exhibited higher fire intensity and more challenging fire behaviour (Figure 6) than the oriented piles (Figure 7).

DISCUSSION

During this trial, the ignition potential of two different pile configurations was explored and potential fire behaviour was documented during conditions of low to moderate fire hazard conditions. At an FFMC of less than 70 (the maximum threshold value that Island Timberlands uses for burning debris piles), the ignition probability of fine fuels was considered low (Lawson & Dalrymple, 1996). It is important to repeat these trials during lower fuel moisture conditions to better understand the ignition potential and potential fire behaviour during higher fire hazard conditions.

The Drought Code (DC) is an FWI fuel moisture value that indicates fuel moisture in deep ground fuel layers or heavy fuels. The peak DC value in July and August was 733. This is an extreme value relative to the DC of 68 observed during these trials. Moisture content in the residue piles during the period of drought in 2018 was not measured; however, Baxter (2009) indicates that minimum moisture content during the month of August can drop to as low as 11%. It is important to explore moisture content and potential fire behaviour of these two pile configurations in the months when precipitation is minimal and fuel moisture content drops to very hazardous levels. Even though these trials were conducted during low fire hazard conditions, they provided valuable insight into the differences in fuel characteristics between oriented and burn piles and how these different configurations influence ignition and sustained burning potential. The absence of fine to medium-sized fuels in the oriented piles (Appendix 1) created difficult ignition conditions, and there was limited sustained burning in these piles. Conversely, the burn piles had a greater amount of branches mixed into them, which was more conducive to ignition and fire spread to larger fuels.

The differences in fuel arrangement (pile height and alignment of fuels) between the two pile types had a strong influence on fire growth within the pile and the resultant fire intensity. The rate of fire growth will have an impact on effective initial attack response times, and fire intensity will impact resistance to control and the resources required for fire suppression. Compared to burn piles, the longer time to sustained burning and lower fire intensity in oriented piles may result in more successful initial attack and suppression of fire in oriented piles. This hypothesis will need to be tested under higher fire hazard conditions.

Fuel arrangement also influenced the overall consumption of the piles. The fuel concentration and the height of the haystack contributed to continuous fire spread and more thorough consumption. The burn piles were more efficiently consumed; in contrast, the larger footprint and lower height of the oriented piles resulted in partial pile consumption. This may have been due to the inability of fire to spread horizontally to the adjacent heavy fuels (tops) in this oriented pile configuration.

NEXT STEPS

It is understood that fire activity can vary greatly from site to site, and the methods in this study may not be repeated easily in other sites across the province. This proof-of-concept trial provided valuable insight into fire behaviour in harvest residue piles in coastal areas under low to moderate fire hazard. These observations and results will contribute to an adapted work plan to address research questions through continued trial replications across diverse provincial variables.

Research Fundamentals

The document called *A Guide to Fuel Hazard Assessment and Abatement in British Columbia* (Ministry of Forests, Lands and Natural Resource Operations, 2012) defines fire hazard assessment as "the exercise of analysing the ignition potential and predictable fire behaviour based on fuel hazards (i.e. physical fuel characteristics) and site-specific and probable weather conditions. It includes a consideration of the risk of a fire starting, the difficulty of controlling the fire and the potential impact on identified values." The guide defines fire hazard as:

(a) the risk of fire starting, and

(b) the hazard associated with an industrial activity; and

(c) if a fire were to start,

(i) the volatility of the fire's behaviour,

(ii) the difficulty of controlling the fire, and

(iii) the potential threat to values at risk.

Furthermore, a fuel hazard is considered to mean "the potential fire behaviour, without regard to the state of weather or topography, based on the physical fuel characteristics, including fuel arrangement, fuel load, condition of herbaceous vegetation and the presence of ladder fuel."

These statements that define fire hazard and fuel hazard provide a valuable framework for formalizing relevant research questions and developing a project plan with applicable research activities to address these questions.

Ignition Potential and Predictable Fire Behaviour

Harvest residue piles are a unique fuel environment, with physical fuel characteristics that influence ignition potential and fire behaviour. Similarly, scattered harvest residues resulting from harvest operations have different fuel characteristics, which create another unique fuel environment, with varying ignition and fire behaviour potential. These fuel characteristics lead to the first research question, which addresses relative ignition potential and fire behaviour potential in three fuel environments: oriented residue piles, harvest debris fields, and natural forest stands. The following is a list of relevant research questions:

1. What is the probability of ignition in oriented residue piles relative to adjacent harvest debris fields and forest stands?
2. What type of fire behaviour can be predicted in oriented residue piles relative to adjacent harvest debris fields and forest stands?
3. How will the probability of ignition and potential fire behaviour change with fuel environments in different geographic areas and weather conditions?
4. Will fire intensity in oriented piles be sufficient to generate firebrands and contribute to fire spread through firebrand transfer and spot fire development?

Difficulty of Fire Control

From the observations of fire behaviour in this trial, it would be very difficult for typical ground-based response units (1-ton truck with water tank and 4 persons) to suppress fire in a single fully involved burn pile. The average time to full fire involvement in the burn piles was 51 minutes; however, none of the oriented piles actually achieved full fire involvement. To assess the probability of control and developing appropriate response strategies and resources, it is important to understand the growth rate of fire in oriented piles under higher fire hazard conditions. Fire control strategies and tactics vary based on fire intensity, wind speed, and adjacent fuels. Under very low or very high fire hazard conditions, the response strategies and tactics may be straightforward (aggressive direct attack under low hazard conditions or indirect attack in adjacent fuels under high hazard conditions). These issues can be addressed through the following research questions:

1. Under what conditions (fire hazard and degree of pile involvement) would it be possible to suppress fire in oriented residue piles?
2. What are some viable suppression strategies that can be used in harvest areas (limiting spread from piles to adjacent fuels or direct attack)?

Project Design

Evaluating ignition potential and fire intensity under higher fire hazard conditions is important for producing relevant research findings. However, future burn trials need to be conducted initially under moderate fire hazard conditions and then progress to higher hazard conditions, with appropriate measures implemented for preventing fire spread.

It is possible to achieve lower moisture content in residue piles by covering these piles with tarps during the summer and early autumn to prevent moisture absorption during rain events. This will allow for burn trials to be conducted under low fuel moisture content conditions at a safe fire hazard level when there is no chance for fire spread to adjacent fuels and forest stands. Covering piles with tarps is not a perfect surrogate for drought conditions since solar radiation and wind do not have the same influence under a tarp.

Ignition of harvest residue piles can occur in three ways: fire spread from adjacent surface fuels, human-caused ignition (arson), and firebrand transfer. Each of these ignition mechanisms can be evaluated through representative test methods under varying hazard conditions. To simulate the first ignition method, it may be possible to use existing harvest areas and initiate line ignition in harvest debris adjacent to oriented piles and allow the fire to accelerate and build in intensity before it reaches the pile. Fire behaviour at the time it reaches the pile and the success of pile ignition should be documented.

Simulations of human-caused ignitions can be conducted using the same methods used in this study; however, results will be improved with more robust ignition devices.

The match drop test is a standard test procedure used to evaluate ignition potential in fine fuels such as grass or mulch. To simulate firebrand transfer and evaluate ignition potential in residue piles or debris fields, it will be necessary to use ignition devices such ember generators or plastic sphere dispensers,[1] which produce consistent simulated firebrands with greater mass and longevity. The same ignition potential test can be conducted in adjacent debris fields and forest stands to compare the potential for ignition in these fuel environments.

In conjunction with the ignition potential test, fire behaviour in these fuel environments can be compared. Spread rate, fire intensity, and degree of pile involvement can be used as metrics for assessing fire behaviour.

Continued trials should be conducted under progressively higher hazard conditions. Ideally, these would consist of comparative trials in all three fuel environments. However, under very high fire hazard conditions, ignitions in debris fields and forest stands may not be prudent.

Support Resources

Continued burn trials under higher fire hazard conditions will require engagement with British Columbia's Wildfire Services, licensees, and industry operators to plan and execute appropriate site preparations to reduce the possibility of escaped fires. In addition, under moderate to high fire hazard conditions, sufficient fire suppression resources will be required to ensure quick and effective response to fire behaviour that may result in unwanted fire spread to adjacent forest values.

Study Sites

Because there is only one data set for ignition and fire behaviour potential in a coastal area, it is worthwhile to expand this data set with continued trials in this area. Additionally, it is important to conduct trials in other geographic areas to determine how pile characteristics are influenced by different mixes of fine and medium-sized fuels associated with different species. A different mix of fuel sizes will impact ignition potential and fire intensity in the adjacent debris fields and in the piles.

Finding optimum trial sites will be a challenge. Ideally, these sites should have good road access for site preparation and suppression resources. Access to an adequate water source is critical for sprinkler deployments and other water delivery systems. Trial sites can be improved with constructed fire guards and/or sprinkler set-ups to reduce the potential of escaped fires.

[1] https://www.sei-ind.com/products/green-dragon/

Harvested areas within recent burns may provide a good opportunity to conduct trials where there is a reduced chance of escaped fires. Sort yards may provide an opportunity to construct and burn oriented piles in a controlled environment; however, attention to pile composition will be critical in replicating these piles.

Based on the findings from the trials in this exploratory study, this section provides some preliminary opportunities for continued trials. Conducting further trials, especially under higher fire hazard conditions, will require consultation with stakeholders to gain support in principle and in practice.

CONCLUSION

Oriented piles and burn piles have different characteristics, including fuel size, composition, and fuel arrangement. The comparative ignition trials conducted in this proof-of-concept study suggest that these characteristics influence the fuel environment, with a higher potential for ignition and sustained burning and greater resultant fire intensity in burn piles.

These exploratory trials were conducted under low fire hazard conditions, and future trials conducted with lower fuel moisture conditions will be necessary to make relevant conclusions about the relative flammability of oriented residue piles and burn piles. Additionally, comparative trials that evaluate ignition potential in adjacent debris fields can help to inform fuels managers on the relative fuel hazard of each fuel environment.

With any exploratory trials, future directions and next steps are important components of developing relevant data sets. These trials provided an opportunity to experiment with preliminary research methods and adapt these methods in response to results and evolving research questions.

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APPENDIX I. PILE CHARACTERIZATION

Pile	Size	Height (m)	Tops	Long butts	Brush	Alignment	Length (m)	Density	Species	Butt diameter (cm)	Standard deviation
Oriented piles											
OP-1	M	1.00	9	1	0	4	8	2.5	100Fd	14.48	2.33
OP-2	L	1.40	8	2	0	4.5	8	3.0	90Fd10Hw	14.12	3.19
OP-3	S	1.10	7	3	0	4	9	1.0	100Fd	13.83	2.19
OP-4	L	2.20	9	1	0	5	8	3.5	80Fd10Cw10Hw	14.80	3.29
OP-5	S	1.40	7	3	0	4	8	2.0	90Fd10Dr	15.37	3.63
OP-6	M	1.50	9	1	0	5	9	3.0	100Fd	16.76	7.01
Average		1.43	8.17	1.83	0.00	4.42	8.33	2.50		14.89	4.00
Burn piles											
BP-1	L	5	10	0	0	1.5	6	3.5	80Fd10Hw10Dr	15.63	4.42
BP-2	L	4	10	0	0	1	5	2.5	100Fd	16.21	2.93
BP-3	M	3	9	0	1	2	5	3.5	100Fd	15.18	3.52
BP-4	M	2.8	10	0	0	2	5	3.5	100Fd	14.50	3.54
BP-5	L	5	8	1	1	1	5	3.5	100Fd	14.56	2.42
BP-6	L	4	9	1	0	1	5	3.0	100Fd	15.44	3.89
Average		3.97	9.33	0.33	0.33	1.42	5.08	3.25		15.29	3.52

Size: S = Small, M = Medium, L = Large

Brush components (tops, long butts, and brush): Identified by a ratio of weights within the pile, rounded to the nearest 10%.

Alignment: Scale of 1 to 5:
1 = Poor alignment (typically seen in haystack piles).
5 = Pieces are parallel to each other, with minimal airspace between pieces.

Length: Average length of the tops component of the pile.

Density: Scale of 1 to 5:
1 = Loose material, with lots of airspace between pieces; pieces are typically not parallel.
5 = Neatly stacked pieces, with minimal airspace between pieces, OR compacted brush, with minimal airspace between pieces.

Species: Ratio based on weight, rounded to the nearest 10%.

APPENDIX II. FUEL MOISTURE CONTENT

Pile	Average diameter (cm)	Standard deviation	Maximum	Minimum	Average moisture content (%)	Standard deviation	Maximum	Minimum
Oriented piles								
OP-1	18.25	7.25	41	12	19.44	5.78	42	6
OP-2	15.80	6.55	35	6	16.47	2.03	20	10
OP-3	15.03	4.05	24.5	10	17.85	2.24	20.8	8
OP-4	16.98	5.99	34	8	20.38	3.93	32.7	11
OP-5	17.00	5.14	35	11	21.73	3.93	29.9	8.5
OP-6	19.68	10.67	48	8.5	21.45	3.22	26.2	12
Average	17.12				19.54			
Burn piles								
BP-1	15.95	4.87	27	8	18.96	4.43	35	9
BP-2	18.60	6.49	33	9	18.71	3.69	32	7.5
BP-3	11.95	3.33	18	7.5	22.73	5.19	36.4	9.5
BP-4	16.78	5.73	30.5	9.5	21.51	2.86	25.9	10
BP-5	15.35	2.97	23	10	21.83	11.13	56	8
BP-6	16.68	5.48	29	8	22.09	4.62	31.6	12
Average	15.88				20.90			

For each pile, 20 pieces of were measured (moisture content and diameter).

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