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FUEL AMENDMENT AS A FOREST FUEL REMOVAL TREATMENT

EXPLORATORY TRIALS IN BLACK SPRUCE FUELS AT THE FORT PROVIDENCE WILDFIRE EXPERIMENTAL SITE

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Abstract

A fuel amendment treatment is proposed as a technique that can allow prescribed burning in hazardous fuels during low to moderate fire hazard conditions to minimize the risk of fire escape. In August 2017, a fuel amendment technique was applied at the Fort Providence Wildfire Experimental Site. In October 2019, a burn trial was conducted in a plot treated with the fuel amendment technique and fire spread to adjacent fuels was documented. Future documentation at this site will include assessing crown mortality to determine the effectiveness of the treatment.

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Conducting an experimental burn trial in October in the Northwest Territories is not a normal occurrence. Thanks to Westly Steed and all Environment and Natural Resources staff who remained optimistic and closely watched weather conditions for a suitable burning window. A rapid response to this window of opportunity was crucial. Thank you to all the people that scrambled at the last minute to travel to Fort Providence to make this burn happen.

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Table of contents

BACKGROUND 2

ISSUE 2

OBJECTIVES 3

STUDY SITE 3

METHODS 4

Site selection and preparation 4

Data collection 5

Stand characterization and fuel sampling 5

Imagery 5

Weather and Fire Weather Index values 6

Ignition 6

RESULTS 6

Site description 6

Fuel moisture 7

Weather and Fire Weather Index values 7

Fire behaviour and effects 8

DISCUSSION 9

Fire behaviour 9

Defining prescriptions 9

Weather and fuel moisture 9

Fuel amendment 9

Measuring success 10

Ignition 11

Resource requirements 12

Potential fire behaviour in other fuel environments 12

CONCLUSION 12

REFERENCES 13

BACKGROUND

Alberta Agriculture and Forestry (AAF) has applied a fuel amendment treatment in a mature lodgepole pine forest stand in a subalpine natural subregion. The prescribed fire in the Evan-Thomas area of the Kananaskis Valley was proposed in 2010 as an initiative to reintroduce the natural benefits of wildfire. The primary ecological objectives were to improve and expand wildlife habitat, restore vegetative diversity, and remove prime pockets of mountain pine beetle habitat. Additional land management objectives were to reduce the potential for fire spread into prime recreation areas and to create a control line that would enhance fire suppression strategies in this area.

To achieve the prescribed burn outcomes at a fire hazard level that would minimize the risk of escape fires, a fuel amendment treatment was applied. To create this fuel amendment, a feller-buncher was used to create a fire guard along the perimeter of the prescribed burn area and place the cut stems and branches under the adjacent canopy. This amendment process was also applied within the treatment area to a create a continuous amended surface fuel layer. This resulted in a blended fuel environment made up of the mature lodgepole pine overstorey and a surface fuel layer amended with fine and medium-sized fuels from the cut stems.

The amended fuel strips were ignited under moderate fire hazard conditions. During the prescribed fire, the amended surface fuel layer generated fire intensity sufficient to scorch aerial fuels and cause mortality in the overstorey stems.

ISSUE

Large expanses of black spruce fuels in the Northwest Territories and other parts of Canada pose a major wildfire threat to communities and other values. Conventional fuel removal treatment methods such as manual thinning with debris burning are expensive; fuels managers would like to explore opportunities to mitigate the risk of wildfire through innovations in fuels engineering and prescribed fire. The fuel amendment principle with prescribed burning is proposed as a fuel treatment that could reduce hazardous fuel loading.

Prescribed burning as a fuel treatment in black spruce is problematic. Black spruce fuels burn very well under high hazard conditions but the potential for escape fires is high. Under moderate hazard conditions, fire does not spread well in the surface layer and fire intensity may not be sufficient to achieve the desired objectives of crown consumption and stand mortality. A fuel amendment treatment is proposed as a technique that can allow prescribed burning in hazardous fuels during lower fire hazard conditions that will minimize the risk of fire escape.

At a landscape level, the mechanical fuel amendment applied at the Evan-Thomas prescribed burn site was possible due to the scale of the project and the size of the mature stems. However, at a community level, using harvesting equipment as an amendment tool may not be feasible in dense forest stands such as black spruce fuels. As an alternative, a motor-manual treatment (hand crew with chainsaws) is proposed as a method for creating a fuel amendment treatment within a hazardous fuel stand adjacent to communities.

OBJECTIVES

The objective of a fuel amendment is to create an accumulation of debris that, when ignited, will increase the surface fire intensity sufficiently to initiate crown fire, resulting in crown mortality in the stand.

In 2017, a suitable site was identified at the Fort Providence Wildfire Experimental Site and a motor manual fuel amendment treatment in a black spruce/jack pine forest stand was applied. In October 2019, researchers from FPInnovations and Canadian Forest Service collaborated with Northwest Territories Environment and Natural Resources personnel to conduct a prescribed burn at this site. The objectives of this burn trial were as follows:

- Document the prescribed burn operation.
- Assess the effectiveness of different ignition devices.
- Assess the impact of the fuel amendment on fire behaviour and crown involvement.

STUDY SITE

The Fort Providence Wildfire Experimental Site (previously known as the Canadian Boreal Community FireSmart project) is 50 km northeast of Fort Providence, NWT along Highway 3. The study site is in the northeast corner of the research area as indicated in Figure 1.

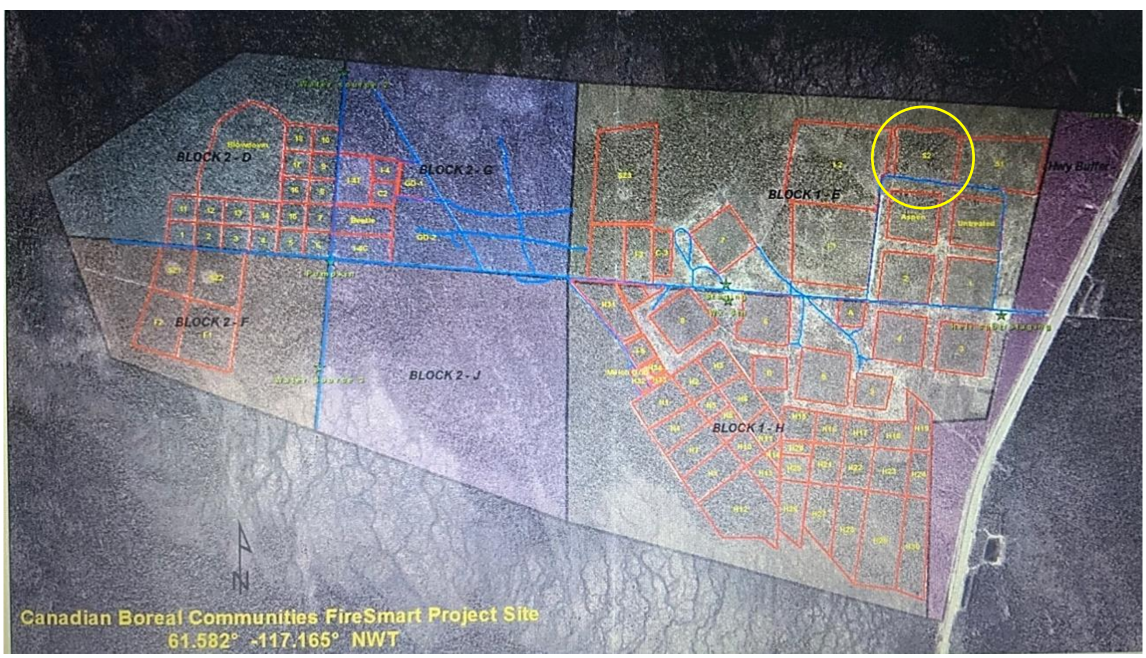

Figure 1. Fort Providence Wildfire Experimental Site with fuel amendment plot shown in northeast corner.

METHODS

Site selection and preparation

This site was chosen because of the ease of access and proximity to a water source. Control operations and barriers to fire spread were also considered. The adjacent dozer guard (Figure 2) was created as part of a suppression operation in 2014 that also involved burning of the dwarf birch bog in the marsh to the north of the research area.

In August 2017, fire crews from Fort Providence applied the fuel amendment treatment by cutting 4- to 5-m-wide corridors in a north/south direction (Figure 3) and piling the cut stems and debris against the remaining standing stems to create a windrow of debris (fuel amendment) (Figure 4). This windrow of amended fuel is referred to as a "wick" and is applied in experimental fires to rapidly generate high intensity surface fire and initiate crown fire.

The southern half of the two strips furthest to the west were not amended but were left with a natural surface fuel layer to serve as a control area. A corridor was cut mid-point on the strips in an east/west direction to separate the treated areas from the control area. This separation was created to minimize the influence that one area might have on the other.

Figure 2. Strip amendment plot adjacent to dozer guard and marsh.

Figure 3. Firefighters clearing a 4-m-wide corridor.

Figure 4. Cut stems and debris piled up to create a wick for ignition (fuel amendment)

Data collection

Stand characterization and fuel sampling

Stand inventory data from an adjacent untreated forest stand were used to characterize the strip amendment plot. Species composition, stem density, average diameter at breast height, average height, and live/dead composition were processed from this data set.

Fuel amendments were assessed by measuring the width and height of the wick at three points along each strip. Within one hour of starting ignition operations, fuel moisture samples were collected for foliage and size class 1 and 2 (less than 1 cm in diameter) fine woody debris. These samples were weighed, oven dried, and re-weighed to calculate fuel moisture content.

Imagery

Video and still images were captured from several different vantage points prior to and during the ignition of each strip.

Locations and media types were as follows:

- Pre-fire and post-fire still images were captured along the amended strips and control area.
- Video cameras housed in fire-resistant camera boxes were placed upwind from the oncoming fire to capture fire behaviour in each strip.
- A DJI Mavic 2 Enterprise Dual remotely piloted aircraft collected site images and video of the ignition operations.

Weather and Fire Weather Index values

The raw automatic weather station (RAWS) at the Fort Providence Wildfire Experimental Site is 750 m southwest of the fuel amendment site. A Kestrel weather station was also set up at the burn site and recorded weather values for the duration of the burn trials

Ignition

The Northwest Territories' ground-based torch system (Campbell 2012) and two drip torches were used independently to ignite each fuel amendment strip. With a predominant north wind, ignition started at the south end of the plot and proceeded to the north. For the initial trial on the west strip, the ground torch started igniting in the control area (southern half) and then continued through the amended section (northern half).

When the ground torch had moved ahead a safe distance, firefighters commenced ignition with drip torches on the opposite side of the strip. This allowed us to evaluate how each ignition device initiated and sustained ignition in the amended sections and in the natural surface fuel layer. The same ignition process was applied on the remaining strips. Ignition operations were conducted between 14:20 and 15:22.

RESULTS

Site description

The overall strip amendment plot was approximately 70 m long × 60 m wide (0.4 ha). The strips of standing stems were cut in a north/south orientation. They were about 15 m wide and separated by corridors which were 4 to 5 metres wide.

The predominant overstorey species in the strip amendment site was black spruce with a minor component of jack pine (Table 1). The surface fuel layer in this site was not representative of a boreal spruce (FBP C-2) fuel type as described in Hirsch (1996) but is more typical of a jack pine forest type. Characterization of the surface layer from Alexander et al. (2014) was deemed to be representative of this fuel layer.

Table 1. Stand characterization

	Species composition (%)		Density (stems/ha)	Avg. DBH (cm)	Avg. height (m)	Live/dead composition (%)	
	Black spruce	Jack pine				Live	Dead
Overstorey[a]	86	14	4200	6.0	8.8	71	29
Understorey	78	22	1800	2.3	2.3	33	67

[a] Overstorey stems are greater than or equal to 3 cm DBH as characterized in Alexander et al. (2004).

The wicks along the strips varied in width and height as indicated in Table 2.

Table 2. Dimensions of fuel amendments

	Maximum	Minimum	Average
Width (m)	2.2	1.0	1.9
Height (m)	1.3	0.3	0.5

Fuel moisture

The average fuel moisture contents in the foliage and fine woody debris samples were 89.2% and 14.7%, respectively.

Weather and Fire Weather Index values

Weather readings recorded at 13:00 from the RAWS with the forecast Fire Weather Index (FWI) values are shown in Table 3. During the burn trials, wind speed was light with a maximum speed of 5.4 km/h recorded at 15:30. The general wind direction was from the north. For the duration of burning, temperature was steady between 15°C and 18°C while relative humidity dropped to a daily low of 27.1% at the end of the trial (Table 4).

Table 3. Automatic weather station values from the Fort Providence Wildfire Experimental Site

Weather values[a]				Fire Weather Index (FWI) values[b]					
Temp. (°C)	Rh	WS	WD	FFMC	DMC	DC	ISI	BUI	FWI
11.6	39	4.5	338	87	20	708	4	38	9

[a] Rh: relative humidity; WS: wind speed; WD: wind direction.

[b] FFMC: Fine Fuel Moisture Code; DMC: Duff Moisture Code; DC: Drought Code; ISI: Initial Spread Index; BUI: Buildup Index.

Table 4. Weather values recorded at the burn trial site

Time	Temp. (°C)	Relative humidity (%)	Wind speed (km/h)	Wind direction (degrees)
14:00	17.0	25.9	3.0	282
14:30	15.0	32.7	0.0	298
14:56	15.3	33.7	4.3	346
15:00	14.7	33.4	3.0	357
15:30	16.8	30.2	5.4	352
16:00	18.0	27.1	0.0	351

Fire behaviour and effects

The ground fuels (moss, grass, and duff) were moist to the touch. This prevented fire spread in the surface layer unless there was sufficient dead and down debris in that area or a generous application of fuel with the ground torch. Most of the fuel consumption in the strips (surface and overstorey) resulted from heat intensity of the amendments.

The greatest intensity fire and sustained burning of surface fuels was produced with the ground torch in sections that had been amended. Higher volumes of amended fuel resulted in higher intensity fire with greater surface fuel consumption and crown scorch (Figure 5).

There was minimal surface fuel consumption or crown consumption in the control area (no amendment strips). Any sustained burning or surface fuel consumption in the control area was due to a generous application of fuel with the ground torch. However, there was candling along the flaky bark of mature jack pine in the control area with minimal surface fuels.

Drip torches did not produce enough intensity to sustain burning in the control areas due to the moist litter and duff fuels. However, the drip torches ignited the fuel amendments successfully in areas with adequate fine fuels (Figure 6).

Figure 5. Ignition with the ground torch in heavy accumulation in the fuel amendment.

Figure 6. Ignition with drip torches in lighter loading of fuel amendment.

In the areas that had been amended, there was greater scorch on the overstorey stems and foliage. Not surprisingly, in those areas with a greater volume of amended fuels, there were higher intensity fires and greater consumption of overstorey fuels.

DISCUSSION

Fire behaviour

Under the weather and fuel moisture conditions at the time of the burn trials, the fuel amendment was critical to crown fire initiation; without the fuel amendment in the control areas, the surface fire intensity was not sufficient to maintain sustained burning in the surface layer or initiate crown fire. One benefit of the moist ground fuels was that the chance of unwanted fire spread through ember transfer was minimized.

It appeared that most of the scorch on the overstorey was from vertical convective activity generated from the heat intensity from the burning debris. With the light winds during the trials, there was insufficient wind to initiate and support crown-to-crown fire spread.

Defining prescriptions

Weather and fuel moisture

"Latitude, along with time of year, influences the effective daylength and thereby the amount of drying that can be accomplished in any one day" (Van Wagner, 1987). During this burn trial, fewer hours of low-angle sunlight resulted in reduced drying and a shorter daily burning period with the Fine Fuel Moisture Code (FFMC) in prescription for only a few hours of the day.

To put this in perspective, during the planned trials on this site in July the increased daylight hours of direct sunlight increased the drying of fuels such that diurnal FFMC values were outside the prescription for most of the day. Burning during these extreme conditions was not possible.

The warm and dry weather that was encountered on October 1 was likely an anomaly for this time of year. However, the conditions under which the burn occurred during this burn trial were at the lower end of the weather and fuel moisture prescription. More favourable burning conditions would be encountered earlier in the season, and late August or September should be considered for burning in this type of treatment. With drier surface fuels earlier in the season, there may be additional benefits of fire spread and fuel consumption in the surface layer.

As further trials are conducted, the prescribed FFMC should be increased progressively. Stronger winds will be required to evaluate crown-to-crown fire spread. Wind speeds during these trials were in the 0 to 5 km/h range and future trials should attempt to burn with wind speeds of 5 to 10 km/h.

Fuel amendment

Creating a fuel amendment (wick) is a common practice in setting up an experimental fire plot. A wick is used to quickly generate high intensity surface fire and initiate crown fire. This practice is especially useful for accelerating crown fire development in the ignition zone with continued crown fire spread toward a fuel treatment under evaluation.

Creating a wick in preparation for an experimental fire requires something of an intuitive approach; in most cases, the experimental fire is conducted under high to extreme fire hazard conditions and minimal amendment is required. The amount of material used to build a wick is often based on available materials adjacent to the treatment area. However, in some cases extra material is imported to the site to build a more robust amendment.

The volume of fuel in the wick influences the crown engagement and consumption. Other factors such as needle retention and arrangement of fuels will have an impact on the heat intensity generated by the amendment.

Measuring success

Fuel removal is a fundamental goal of most fuel treatments (Agee & Skinner, 2005) and through the fuel amendment technique, this goal was achieved in two ways. Firstly, cutting the strips to create corridors resulted in a reduction of crown fuel. This fuel was removed when the amendment strips were ignited. Secondly, during the experimental fire, crown fuels directly above and adjacent to the amendment strip were also consumed. The portion of crown fuel removed across the treatment site was variable with no crown fuel consumed in the control area (Figure 7), and extensive crown consumption in areas of heavy amendments (Figure 8).

Figure 7. Minimal surface consumption with no crown scorch in the control area.

Figure 8. Extensive consumption of surface and crown fuel with larger amendments.

A coarse estimate of canopy removal suggests that approximately 20% of the crown fuel in the overall treatment area was removed when cutting the corridors and building the amendments. An additional 10% to 15% of the crown fuel was removed during the burn. A more accurate estimation of crown consumption and stand mortality can be made in the summer of 2020.

Visual aesthetics and long-term stand conditions should also be considered when evaluating treatment success. In sensitive areas that are visible to the public, aesthetics may be an issue due to the extent of burned standing stems. A social benefit of the corridors in this treatment may be better access to a firewood source. With strips cut in a treatment area, ongoing maintenance may be easier to plan and execute.

A high-intensity fire with complete stand mortality may not be a desirable end result of a prescribed burn since this would perpetuate a homogeneous black spruce forest stand. A mixed-age class forest stand would likely be a healthier and easier-to-manage stand.

Establishing a metric of treatment success, such as crown mortality, will be important in determining how a treatment prescription should be adjusted to achieve the treatment goals. A prescription could be adjusted in several ways including wick size, fuel moisture, and weather conditions.

Ignition

During these trials, the ground torch was essential for generating sufficient fire intensity for rapid ignition of the wick and transfer of heat intensity to the crown fuels (Figure 9). On the amendment strips where the drip torches were used, the fire behaviour was less intense with relatively less consumption of amendment strips and crown fuels.

Figure 9. Intermittent crown fire generated by the ground torch in heavy accumulations of debris.

In this trial, approximately 200 m of wick were ignited using the ground torch. The amount of fuel required for an ignition operation is an experience-based piece of knowledge that should be explored; documentation in future trials should be considered to develop a “rule of thumb” or operational guideline for fuel consumption.

The ground torch may not always be available for prescribed burning of fuel amendment treatments. Provisions should be developed that would allow the use of drip torches for ignition. These provisions may be modifications to the fuel amendment (larger volume) or changes in the burn prescription. Applying gel (Flash 21) to the amendment strip may be a viable option for quickly building intensity in the amendments when using drip torches.

Resource requirements

Cutting the corridors and creating the fuel amendment treatment areas was achieved by an eight-person fire crew in 3 days. Chainsaws were the primary tool used for falling trees and clearing brush and shrubs in the corridors. Brush saws would be useful tools for clearing small shrubs or saplings in the corridors.

Relative to other experimental fires in this research area, the burn operation on October 1 was conducted with a small crew. This was partly due to the late-season timing of the burn and the limited availability of personnel. With a low fire hazard and minimal chance of fire escape at the time of the burn trial, few suppression resources were required. A Northwest Territories Environment and Natural Resources suppression response vehicle (Ford F-550 one-ton truck) with slip tank was adequate as a water supply. The ignition team consisted of three people committed to the ground torch operation and two people using drip torches. Two researchers who were documenting the operation were available for suppression.

Potential fire behaviour in other fuel environments

With a broad area of boreal spruce fuels in the south end of the Fort Providence Wildfire Experimental Site, several repetitions of the fuel amendment treatment can be applied and tested under different burn prescriptions.

The surface fuel layer in these plots is more representative of the C-2 (Boreal Spruce) Canadian Forest Fire Behavior Prediction (FBP) System fuel type described as continuous feather moss and reindeer lichen (Hirsch, 1996). Ignition and sustained burning at a moderate FFMC are typically difficult and these areas will be a good testing ground for the fuel amendment treatment in boreal spruce fuels.

CONCLUSION

This burn trial using an innovative fuel amendment technique demonstrated that fuel removal objectives can be achieved using a ground torch under low to moderate fire weather hazard conditions. The prescriptions for this fuel amendment burn trial were appropriate for the weather conditions and fuel moisture conditions at this research site in early October. Modifications to a fuel amendment prescription will be required for other research areas at different times of the season.

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