USING FOREST MANAGEMENT TECHNIQUES TO ALTER FOREST FUELS AND REDUCE WILDFIRE SIZE: AN EXPLORATORY ANALYSIS

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ABSTRACT

During the next few decades, a considerable portion of the productive boreal forest in Canada will be harvested and there is an excellent opportunity to use forest management activities (e.g., harvesting, regeneration, stand tending) to alter the forest fuels for fire management purposes. This process, known as fire-smart forest management, has the potential to reduce the number and size of wildfires and the risk associated with the use of prescribed fire. We describe a landscape-level fire-smart technique in which strategically located fuel treatments, primarily species conversion, are incorporated into a long-term forest management planning model. Using a mechanistic-based fire simulation model, a comparative analysis of projected landscapes in central Alberta showed that fuel treatments could have a considerable impact on fire size. These findings have important implications for sustainable forest management in crown fire-dominated boreal forest ecosystems now and in the future.

keywords: Alberta, boreal forest, climate change adaptation, fire-smart forest management, forest management planning, fuels management, timber supply modeling.

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INTRODUCTION

Fire is an important natural disturbance in boreal forest ecosystems and has significant economic, social, and ecological effects. During the last two decades, there has been an average of about 8,500 fires per year in Canada, and the annual area burned has ranged between 0.3 million and 7.5 million ha (Canadian Council of Forest Ministers 1997). Most (97%) of the area burned is caused by a small proportion (3%) of all reported wildfires (Weber and Stocks 1998). Although forest managers recognize the ecological benefits of fire, wildfires are suppressed in heavily inhabited and industrial forest areas.

Traditionally, Canadian fire management agencies have focused on the prevention and suppression of wildfires in an attempt to protect life, property, and natural resources. This has been effective in some regions, but it is neither economically possible nor ecologically desirable to eliminate fire in most forest ecosystems (Weber and Stocks 1998). This is exemplified by recent fire seasons (e.g., 2002, 2001, and 1998 in Alberta, 1996 and 1995 in Quebec, 1995 in Ontario) during which large areas burned despite unprecedented fire suppression expenditures. The concept of a limit to fire suppression effectiveness is further supported by simulation modeling results for Ontario that showed a small percentage of wildfires (2%–4%) are likely to continue to escape initial attack and have the potential to become large despite increases in suppression spending, due to diminishing marginal returns on suppression investments (McAlpine and Hirsch 1999). To reduce the area burned below current levels and reintroduce fire where it is ecologically desirable, it will be necessary to implement a new, proactive approach to fire management that emphasizes stand- and landscape-level fuels management in conjunction with fire suppression.

Fuels management is the planned manipulation of forest vegetation to decrease the intensity and rate of spread of a wildfire to improve suppression effectiveness and reduce fire impacts. Pyne et al. (1996) identify three types of fuels management: reduction, conversion, and isolation. These activities have generally been associated with the protection of relatively small, high-value areas, such as homes in the wildland–urban interface, but they may also have application at the landscape scale (e.g., Weatherspoon and Skinner 1996, Agee et al. 2000). For example, Finney (2001) conducted a theoretical analysis of the shape and pattern of fuel breaks on a landscape to minimize fire spread. In a more applied approach, Sessions et al. (1999) discuss the effect of different management actions, including the creation of fuel breaks, on achieving multiple resource goals in a portion of the Sierra Nevada forest of California. The present study, initiated at the request of a forest company in Alberta, builds upon these works by exploring how landscape-level fuels management can be integrated into a long-term forest management plan in a region of the western boreal forest.

During the next 30–50 years, a considerable portion of Canada's productive boreal forest will be harvested. Thus, there is a tremendous opportunity to use forest management activities (e.g., harvesting, regeneration, stand tending, prescribed burning) to alter the forest fuels for fire management purposes. Such actions, termed "fire-smart forest management," could reduce both the potential for catastrophic wildfires and the risk associated with the use of prescribed fire (Hirsch et al. 2001). This paper provides an analysis of one of many possible fire-smart forest management techniques. We describe a method for incorporating strategically located, landscape-level fuel treatments into a spatial timber supply model. We also examine the potential effectiveness of these treatments at reducing wildfire size using a mechanistic-based fire simulation model and discuss the implications for sustainable forest management in intensively managed, crown fire-dominated, boreal forest ecosystems.

STUDY AREA

The study area is located in west-central Alberta and comprises the Forest Management Agreement (FMA) area held by Millar Western Industries (Figure 1). Millar Western Industries (MWI) operates both a pulp mill and sawmill in Whitecourt, Alberta, under an adaptive and sustainable forest management philosophy (Millar Western Forest Products Ltd. 2000). The MWI-FMA is about 300,000 ha in area and consists of four separate but adjacent blocks. The topography of this general area, locally known as the Swan Hills, is characterized by low-elevation, rounded hills and plateaus resulting primarily from the last glaciation. Elevation varies from 600 m near the Athabasca River in the southeast portion of the MWI-FMA to over 1,300 m in the northwest and extreme southwest parts of the study area. Soils are characterized by gray luvisols or related podzolic types (Rowe 1972).

The MWI-FMA is located within the Mixedwood (B.18a) and lower Foothills (B.19a) section of the boreal forest (Rowe 1972). It contains four natural regions: Upper Foothills, Lower Foothills, Central Mixedwood, and Dry Mixedwood (Strong 1992). Common tree species in this region are lodgepole pine (*Pinus contorta*), jack pine (*Pinus banksiana*), trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), and black spruce (*Picea mariana*). White spruce (*Picea glauca*), white birch (*Betula papyrifera*), and tamarack (*Larix laracina*) can also be found on specific sites.

The general climate in this region consists of long, cold winters and short, cool summers (Environment Canada 1993). Monthly mean daily temperature can vary from –13 °C in January to 15 °C in July. Precipitation occurs mostly as rain in the summer months and averages about 500 mm per year, but amounts vary spatially due, in part, to topography.

The fire regime in this part of the boreal forest is characterized by frequent, small, low- to moderate-intensity fires and infrequent, large, high-intensity crown fires (Cayford and McRae 1983, Viereck 1983). Between 1961 and 1998, there were 4,695 fires and 613,000 ha burned in the Swan Hills region that surrounds and encompasses the study area, but there was considerable annual variation in fire activity (Figures 2 and 3). Sixty-one percent of all fires were human-caused, most of which ignited in April and May, and 39% were lightning-caused, generally occurring from June through August. Each category of fire accounted for about half of the total area burned. Only 1.6% of all fires exceeded 200 ha in area, but these accounted for 97.1% of the total area burned.

Logging has been occurring in this area since the early 1900s; however, intensive timber production has become common only in the last few decades. Recreation (e.g., camping, hunting, fishing) as well as oil and gas exploration and development are the other major land uses in this area. Mixed farming is commonly practiced along the agriculture–forestry fringe and some grazing occurs in the southeastern portion of the MWI-FMA.

ASSESSMENT OF THE FIRE ENVIRONMENT

Defining and implementing landscape-level fuels management treatments require fire and forest management activities to be integrated and based on a thorough understanding of the fire environment. Fire environment is defined as the surrounding conditions, influences, and modifying forces of topography, fuel, and weather that determine fire behavior (Canadian Interagency Forest Fire Centre 2000). In this study, historical fire weather–danger data, fire incidence information and maps of the area burned, current fuel types, and a digitial elevation model were used to evaluate fire ignition and behavior potential over the

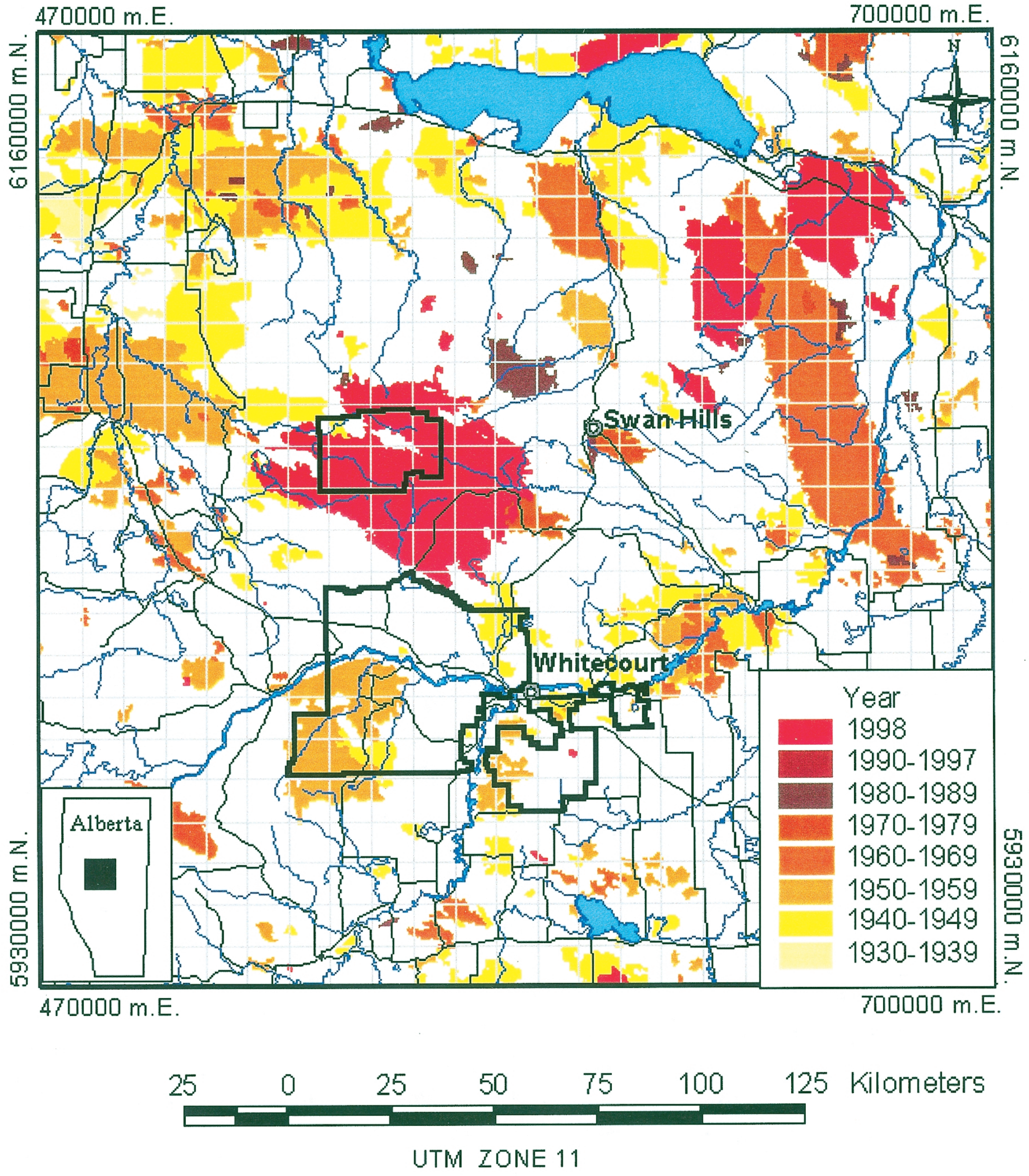

Figure 1. Study area in west-central Alberta (within the black outline) and fires >200 ha in area (shaded areas) between 1931 and 1998 (source data provided by Alberta Sustainable Resource Development).

landscape. Analysis of the fire weather–danger data showed that this area's fire climate is not as severe as some other parts of the boreal forest, but occasionally short periods of extreme fire weather have resulted in major wildfires. For example, the Virginia Hills Fire (May 1998) burned over 163,000 ha and the Lesser Slave Lake Fire (Kiil and Grigel 1969) in May 1968 spread 64 km in a 10-hour period, reaching a final area of 162,000 ha. Such extreme spread rates were also observed on the Chisholm Fire in May 2001 (Chisholm Fire Review Committee 2001). The map of fires in this region between 1931 and 1998 that exceeded 200 ha in area (Figure 1) shows that most fires have burned in a southeasterly or northwesterly direction, which is consistent with the dominant wind directions on days with high fire danger.

Wildfire occurrence patterns since 1961 were analyzed using geographic information system (GIS) coverages of fire ignition data. Lightning fires were most frequent in the higher-elevation areas near Swan Hills, uncommon in the most southwesterly corner of the MWI-FMA, and very rare in the aspen-dominated southeastern block of the MWI-FMA. As expected, human-caused fires were concentrated around communities, roads, recreational areas, and the agriculture–forestry fringe.

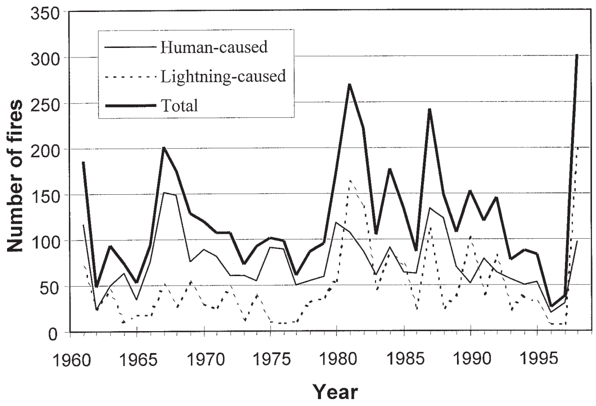

Figure 2. Number of fires per year in west-central Alberta (i.e., area bounded by lat 53.8°–55.5°N and long 114°–117°W) between 1961 and 1998.

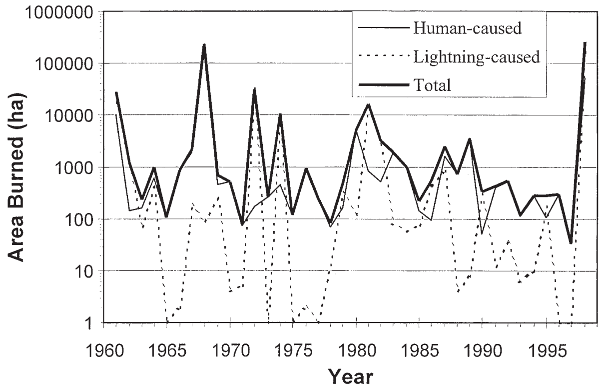

Figure 3. Area burned per year in west-central Alberta (i.e., area bounded by lat 53.8°–55.5°N and long 114°–117°W) between 1961 and 1998.

Fuels, topography, and 10 years (1989–1998) of fire climate data were used to evaluate fire behavior potential over the study area. Following a procedure described by Kafka et al. (2000), head fire intensity (HFI) maps were produced for different fire weather percentiles (e.g., 99th, 95th, 90th, 80th, …, 50th) and seasons (i.e., spring, summer, fall, and entire fire season) using the ArcView-based Spatial Fire Management System (Englefield et al. 2000). Fire intensity is the rate of energy release per unit time per unit length of fire front (Byram 1959) and has been related to fire behavior characteristics, fire effects, and suppression effectiveness. Analysis of the HFI maps showed that the greatest fire behavior potential exists during the spring in the southwest corner of the MWI-FMA because it is dominated by almost continuous stands of dense, immature pine (C4) and boreal spruce (C2) fuel types. Aspen and mixedwood stands had considerably lower HFI values and mature pine stands would support crowning only on the most extreme fire danger days. Recent cutblocks and burns can often have a heavy grass fuel loading (e.g., 3–10 t/ha) and even though HFI values for these areas were relatively low, they remain a hazard because the spread potential is very high when the grass is fully cured.

A simple evaluation of the current fire suppression capability was based on maps of probability of containment (Hirsch et al. 1998) calculated for a range of fire weather–danger conditions and initial attack response times. These maps, along with others showing the distance to permanent water sources and access for heavy equipment, indicated suppression capability was lowest in the extreme southwest and northwest portions of the MWI-FMA.

Combining the results of these separate analyses, we found that the southwest portion of the MWI-FMA is of considerable concern because it had the highest fire behavior potential and lowest suppression capability. Interestingly, from a long-term timber supply perspective, this area is of particular importance because it contains a large portion of semi-mature pine that will be the company's primary source of fiber within a few decades. Few ignitions have occurred in this area in the recent past, but the potential for human-caused ignitions does exist upwind. A high potential for lightning- and human-caused ignitions exists near the town of Swan Hills; however, this poses only a minor threat to the MWI-FMA because of the prevailing wind direction on high hazard days. There are also numerous human-caused ignitions near Whitecourt, but the southeastern section of the MWI-FMA is dominated by aspen stands that have a low fire behavior potential.

INCORPORATING FUEL TREATMENTS INTO A FOREST MANAGEMENT PLANNING MODEL

One of many possible fire-smart forest management techniques is to use fuels management to create areas with reduced fire spread potential in strategically significant locations. The idea of landscape-level fuel treatments is conceptually similar to installing fire doors in a building to reduce the possibility of a fire spreading between compartments. The need to consider such treatments arose after an analysis of MWI's initial forest management strategies (i.e., business-as-usual, adjusted spatial pattern, intensive two-pass, and enhanced timber production) showed that those approaches that focused solely on maximizing timber production would increase the fire behavior potential of the landscape over time (Millar Western Forest

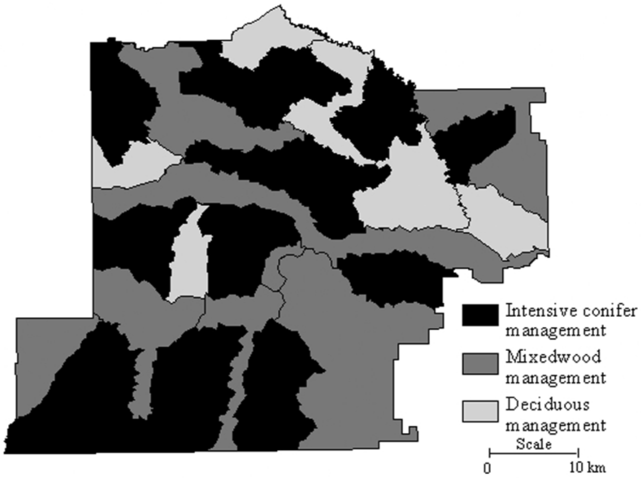

Figure 4. Compartments within the Millar Western Industries Forest Management Agreement area identified for landscape-level fuel treatments (mixedwood or deciduous management) and intensive conifer management.

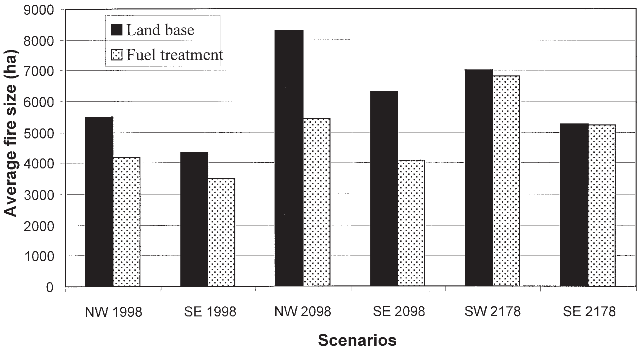

Figure 5. Average size of simulated fires on the current, hypothetical and projected landscapes within the Millar Western Industries Forest Management Agreement area for a 12-hour run under spring conditions (i.e., leafless deciduous–mixedwood fuels and 90% cured grass) for northwest (NW) and southeast (SE) wind directions.

Products Ltd. 2000). Given that MWI has a relatively small FMA and a limited wood supply, the company was very concerned about the potential impact of fire on the amount and flow of wood fiber.

The specific type and location of the fuel treatments were determined during a 2-day workshop with planning and timber supply foresters working with MWI. Insights obtained from the fire environment analysis were used extensively in conjunction with the participants' local knowledge of the MWI-FMA and values at risk (e.g., current and future timber values, site productivity, important infrastructure, critical wildlife and fisheries habitat, key archaeological sites). Through consensus, the workshop participants identified numerous compartments suitable for fuel treatments, especially species conversion and, to a lesser extent, fuel reduction. The result was a spatial forest management plan aimed at creating a landscape consisting of areas with low flammability (e.g., low rates of spread and fire intensities) adjacent to larger compartments of valuable or highly productive conifer stands suitable for intensive management (Figure 4). To be conservative, the fuel treatments were designed to be relatively large (e.g., at least 1 km wide) to minimize the probability they would be breached by spotting, although smaller treatments could be effective when considered in conjunction with fire suppression action (e.g., backburning, airtankers, etc.).

For different types of stands within each compartment, a specific set of regeneration, stand tending, and succession rules were developed to emphasize the establishment of fuel treatments and/or fiber production. These rules were incorporated into Woodstock (Feunekes and Coswell 1997) and Stanley (Remsoft 1996), the aspatial and spatial timber supply models used by MWI. The timber supply models used locally derived growth and yield functions, made no allowance for future fire loss (in accordance with the policy in Alberta), and had no adjacency, green-up, or cutblock size constraints. The objective was to maximize fiber production from the MWI-FMA in a sustainable manner over a 200-year planning horizon and therefore included harvesting stands within the fuel treatments (Millar Western Forest Product Ltd. 2000).

Impact on Potential Wildfire Size

To assess the impact of the fuel treatment scenario on fire size, it was compared with a business-as-usual forest management scenario, which served as a baseline for all of the MWI analyses (Millar Western Forest Products Ltd. 2000). "Business-as-usual" refers to a two-pass system where cutblocks cannot exceed 50 ha in area and cut-over areas must be sufficiently stocked with new trees before the adjacent stand can be harvested. For both scenarios, the timber supply models provided a "snapshot" of the vegetation for the MWI-FMA every 10 years over the 200-year planning horizon. Based primarily on species composition and average tree height, Canadian Forest Fire Behavior Prediction (FBP) System fuel type maps were created for each time period. Initially two different pairs of maps (i.e., fuel treatment versus business-as-usual in 2098 and 2178) for the largest portion of the MWI-FMA (200,000 ha) were selected for comparison because the fuel treatments in these time periods were relatively well defined. In addition, a hypothetical third landscape was created by superimposing the well-established fuel treatments of 2178 on the original 1998 land base. This was done to test the effectiveness of the fuel treatments in isolation of the effects of the timber harvesting rules and objectives. However, it was not possible to evaluate the whole MWI-FMA and the surrounding region due to a lack of accessible fuels data.

To test the potential effectiveness of the fuel treatments on fire size, wildfire behavior was modeled under extreme burning conditions. The point of origin of each fire was determined randomly within a set of 5 × 5-km grid cells. This resulted in a total of 71 free-burning wildfires being simulated over the landscape for each scenario. This semi-systematic approach was preferred to a completely random or historically weighted ignition procedure as it ensured an even spatial distribution of large fire ignitions thereby providing a more uniform and comprehensive test of the fuel treatments. Fire spread was simulated using an hourly time-step, 8-point cellular fire growth model (Kourtz et al. 1977). This model incorporates the impact of spotting on the rate of spread through the FBP System equations (Forestry Canada Fire Danger Group 1992) but does not model the probability of a spot fire breaching a fuel treatment. Given the size of the treatments (e.g., minimum of 1 km wide) relative to the maximum spotting distances generally observed in this part of the boreal forest (e.g., Kiil and Grigel 1969, Chisholm Fire Review Committee 2001), the likelihood of a fire jumping a fuel treatment was considered relatively low. Eight simulations were conducted for each landscape using selected extreme weather conditions for two seasons (spring and summer), two dominant wind directions (NW and SE), and two fire periods (6 hours and 12 hours to represent a 1-day and 2-day fire run, respectively). The fire weather–danger inputs were based on the independently derived 80th percentile values for a representative weather station in the study area (i.e., Windfall station: lat 54°19′N, long 16°25′W; elevation 808 m). The spring season values for the Fine Fuel Moisture Code, Buildup Index, and wind speed were 90, 50, and 15 km/h, respectively, and the frequency of all three of these values being equaled or exceeded simultaneously was <2 days per fire season on average (based on the period 1989–1998).

A quantitative comparison of all 71 fires simulated on the current land base and the hypothetical fuel treatment landscape for the springtime conditions and northwest winds showed a considerable decrease (about 25%) in the average fire size (Figure 5). A paired *t*-test found this difference to be statistically significant ($P = 0.0056$) at the 95% confidence level. Analysis of the fire size distribution also showed that those fires >20,000 ha in area were eliminated on the fuel treatment landscape while the number of fires <5,000 ha increased. Similar relative results were obtained for the summer weather conditions, 6-hour fire run period, and for two other replications of the simulations using different random ignition locations.

This exploratory analysis showed that the fuel treatments can certainly have an impact on the size of individual fires (e.g., Figure 6), but we caution against directly equating the 25% reduction in the average size

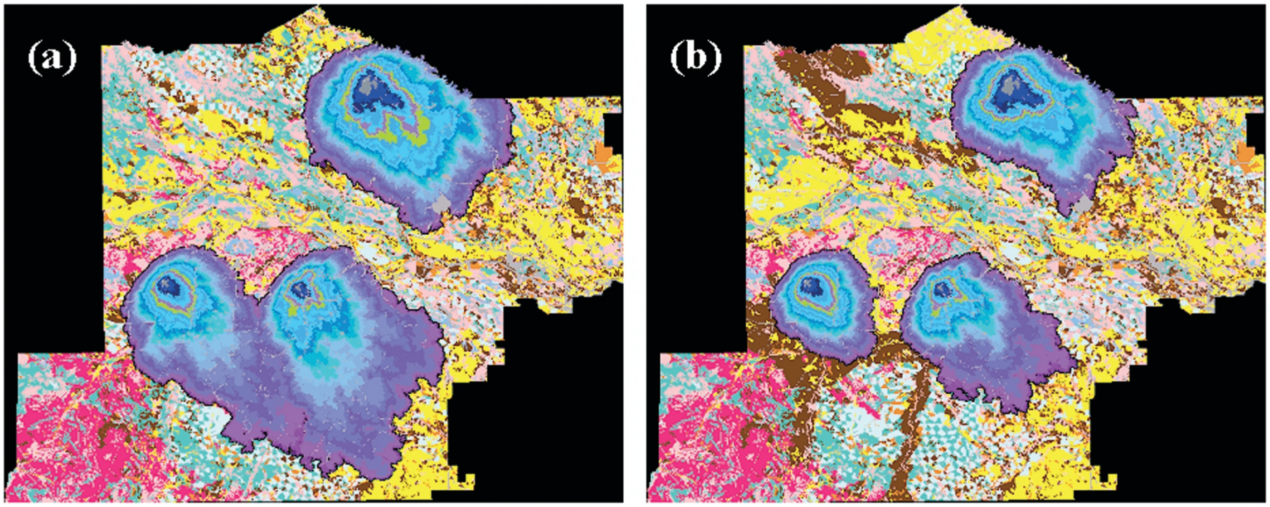

Figure 6. Size of three simulated fires on the current (a) and hypothetical fuel treatment (b) landscapes within the Millar Western Forest Management Agreement area after 20 hours under severe fire weather conditions.

of the simulated fires to an equivalent reduction in area burned on the MWI-FMA over time. This is because the amount of area burned will also depend on many other factors including fire occurrence risk, frequency of extreme fire weather conditions, fire suppression effectiveness, land-use changes, and the state of completeness of the fuel treatments when a fire occurs.

Another key result arising from the comparison of the business-as-usual and fuel treatment scenarios was that future landscapes influenced by harvesting may become more prone to rapidly spreading fires due to the extensive invasion of grass into cutover areas and an increase in the number of immature conifer stands. This finding is contrary to the commonly held belief that wildfire problems can be eliminated simply by harvesting the trees (although it is recognized that grasslands may produce lower-intensity fires that are easier to suppress). The 1998 spring fires had high spread rates in grass that resulted in rapid increases in fire size and made suppression impossible (H. Stegehuis, Alberta Sustainable Resource Development, personal communication). The presence of grass was also the primary reason for the smaller difference between the business-as-usual and fuel treatment simulation results for the 2178 landscape (Figure 5). This implies that vegetation management after harvesting is an important aspect of fire-smart forest management.

Impact on Potential Timber Supply and Biodiversity

The rules used to include the fuel treatments into the timber supply models were relatively simple but a qualitative assessment of the type and arrangement of fuels every decade identified the need for further refinement. More specifically, in some time periods the fuel treatments were well-established, but in other periods they were almost completely eliminated. This was due to the timber supply modeling objective of maximizing wood volume and the absence of rules to constrain harvesting activities in the treatment areas in any one time period. The lack of green-up and adjacency constraints also contributed to the creation of some large, continuous cutblocks, which may be socially unacceptable or ecologically undesirable. From a fire suppression perspective, a large cutblock can be either positive or negative, depending on its location and flammability at a particular point in time relative to the surrounding area. In comparison, the business-as-usual approach resulted in many small (≤50 ha), disjointed cutblocks over the whole landscape that would do little to limit the spread of large fires.

The timber supply analysis conducted by MWI found the fuel treatment scenario caused a moderate (20%) increase in the total annual allowable cut in comparison to the business-as-usual case (Millar Western Forest Products Ltd. 2000). This was due, in part, because MWI could offset the increase in aspen and mixedwood production in one location with intensive conifer production in another. The reason the annual allowable cut did not rise even more under the fuel treatment scenario was because future fire loss was not included in the annual allowable cut calculations (a policy in Alberta); however, the forest managers realize the fuel treatments could reduce the fire behavior potential of the landscape in some time periods and further increase the annual allowable cut.

Millar Western Industries also conducted an evaluation of the impact of the fuel treatments on biodiversity using the Biodiversity Assessment Program (Duinker et al. 2000) and found positive and negative results. The fuel treatment scenario increased the habitat suitability index for many species because of an increase in the amount of deciduous forest. On the other hand, the intensive logging required to maximize fiber production resulted in a considerable reduction in the amount of older forest stands, which can have a detrimental impact on some species. Overall the modeled biodiversity impacts for the fuel treatment scenario were near the median when compared with the other forest management strategies tested by MWI (Millar Western Forest Products Ltd. 2000).

MANAGEMENT IMPLICATIONS

The results of this study have shown it is possible to incorporate strategically located, landscape-level fuel treatments into long-term forest management planning. Acknowledging that fuels management may not be possible across the whole boreal forest (Amiro et al. 2001), that in rare instances the treatments may still be somewhat flammable (e.g., due to very extreme fire weather conditions), and that fuel conversions will take time to develop, the treatments could have a considerable impact on the fire behavior potential in some industrial forest areas. Converting highly flammable coniferous stands to less flammable deciduous or mixedwood stands will reduce fire spread potential. It will also create predetermined anchor points suitable for direct and indirect attack that could increase suppression effectiveness for large fires and reduce the likelihood of catastrophic wildfires. This, in turn, would decrease the risk associated with timber management in fire-dominated forests and the threat of wildfire to people and infrastructure.

Once in place, such fuel treatments would also lower the risk associated with prescribed burning, thus making it easier to use fire as a site-preparation tool for the enhancement of biodiversity and forest health, and to reduce forest fuels. Landscape-level fuels management may also be an important adaptation strategy to offset the impacts from increasing fire activity projected under a changing climate.

This study has provided a few key insights and also generated a number of questions that require further investigation. 1) Grass management is very important in locations where it aggressively invades cutovers. Forest managers who have been trying to deal with grass from a regeneration perspective must also consider ways to reduce the presence, loading, and spatial dispersion of grass to reduce fire spread potential. 2) Greater benefit would be gained by planning and evaluating fuel treatments on larger landscapes (e.g., regionally) because fires igniting outside the MWI-FMA could influence areas within it. It would also be of interest to determine if the optimal location of fuel treatments could be derived mathematically. 3) There were limitations to the rules used in the timber supply modeling as they resulted in some of the fuel treatments being completely harvested in a 10-year time period. These rules could be modified to prevent the periodic elimination of the fuel treatments; however, it may be even more advantageous if the fuel treatments were spatially dynamic through time (i.e., move over the landscape throughout a rotation to protect the constantly changing areas that are of the most value). 4) The fuel treatments are intended to reduce, but not eliminate, the risk of catastrophic wildfire, and so a better understanding of the limits of their effectiveness under various fire environment conditions is essential. For example, more information on when deciduous stands may be prone to extreme fire behavior is needed (e.g., Quintilio et al. 1991). 5) To accurately estimate landscape flammability and potential reduction in area burned resulting from the fuel treatments, it is necessary to model treatment effects on both ignition potential (e.g., Kourtz and Todd 1991) and fire spread in an integrated manner. 6) It is necessary for the timber supply analysis to consider the influence of harvesting, fire, and other natural disturbances simultaneously (e.g., Johnson et al. 1996, Sessions et al. 1996). 7) Further work is needed to evaluate various fire-smart forest management strategies on forest health, biodiversity, and other market and non-market forest amenities. 8) Landscape-level fuels management is a strategy that could be used by forest companies and other land-management organizations to adapt to the potential increases in wildfire activity (Grissom et al. 2000) that are projected under a changing climate (Flannigan et al. 1998, Stocks et al. 1998).

CONCLUSION

This was an applied research study aimed at exploring ways of integrating fire and forest management in Canada and even though further research is required it has led to a number of new, practical initiatives. For instance, Millar Western Industries has begun incorporating fire concepts into their short-term operational forest management activities and are planning to make fire-related issues a major part of their next detailed forest management plan. Alberta Sustainable Resource Development has initiated a landscape fire assessment pilot project that draws upon the techniques described in this study to evaluate fire environment conditions on a regional basis. They, in conjunction with the Canadian Forest Service, have also created and conducted an annual 4-day professional development course on techniques for integrating fire and sustainable forest management.

Implementing sustainable forest management in fire-dominated ecosystems will require balancing the short- and long-term economic, social, and ecological effects of fire. This will be extremely challenging and may require a paradigm shift in both fire management and forest management planning and operations. Creating strategically located, landscape-level fuels treatments is one possible fire-smart forest management technique; however, over the next few years many other approaches will undoubtedly be discovered, evaluated, and applied by forest and fire management professionals across Canada.

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