# Assessing Future Landscape Fire Behavior Potential in the Duck Mountains of Manitoba

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## SUMMARY DOCUMENT

Mark Johnston and Nick Nicolichuk
Saskatchewan Research Council

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*A forest fire in northern Saskatchewan*

This summary report provides an overview of the findings from the Prairie Adaptation Research Collaborative project, Assessing Future Landscape Fire Behavior Potential in the Duck Mountains of Manitoba. The summary report is at the PARC website (www.parc.ca). Click on the link to "Research Publications" and "Forestry and Biodiversity".

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*A high intensity crown fire in the Canadian boreal forest*

## INTRODUCTION

There is increasing consensus in the scientific community that climate change is a reality (Oreskes 2004). For the forested portions of central Canada, a major concern is that forest fires will increase in size, frequency and severity (Flannigan et al. 1998, 2001, 2005; Parisien 2004). Recent analyses indicate that area burned in Western Canada could increase by up to 250% by 2100 (Flannigan et al. 2005). Forest managers need to be aware of these projections, since results of decisions made today regarding tree species selection, silvicultural investments and fire prevention activities will persist for many years.

The purpose of this study was to develop projections of potential future fire behavior in the Duck Mountains region of SW Manitoba. This region is the operating area of Louisiana-Pacific Canada Ltd. (LP), a forest management and forest products company with headquarters in Swan River MB. The analysis described here will be incorporated into LP's 20-year forest management plan, due to be submitted to the Manitoba government in 2007. We also attempt to identify potential adaptation strategies that could be incorporated into LP's forest management in order to reduce the company's vulnerability to the impacts of future forest fires.

The fire history for the study area is given in Tardif (2004). Briefly, fires in presettlement times occurred on average every 55 years, while the current fire cycle is approximately 200 years due to fire suppression. The last major fire events were associated with an extreme drought in 1885-1895 during which approximately 286,000 ha burned. Since then approximately 61,000 has burned, with the last major fire in 1961 of 21,000 ha. Since 1961, only about 700 ha has burned (Tardif 2004).

## METHODS

### Study Area

The study area was the portion of the Duck Mountains in SW Manitoba lying within the Forest Management Licence Area of LP. This area comprises approximately 500,000 ha and lies at approximately 51.7°N, 101.2°W (Figure 1). The area is a large upland, one of several that form the Manitoba Escarpment along the Manitoba-Saskatchewan border. The upland is a large shale deposit overlain by glacial drift, over 200 m deep in some spots. The Duck Mountains have a moist, micro-thermal climate with mean annual precipitation of about 500 mm. Nearly 70% of the precipitation falls as rain during May through September (Sauchyn and Hadwen 2001). Soils are predominantly Luvisols and support stands of aspen (*Populus tremuloides* Michx.) and white spruce (*Picea glauca* (Moench) Voss) mixedwoods on upland sites. Wetter areas are dominated by black spruce (*Pice mariana* (Mill.) B.S.P.). Hardwood dominated sites include aspen and white birch (*Betula papyrifera* Marsh.), while coniferous dominated sites include white spruce, jack pine (*Pinus banksiana* Lamb) and balsam fir (*Abies balsamifera* (L.) Mill.). The relative importance of the various stand types is shown in Table 1.

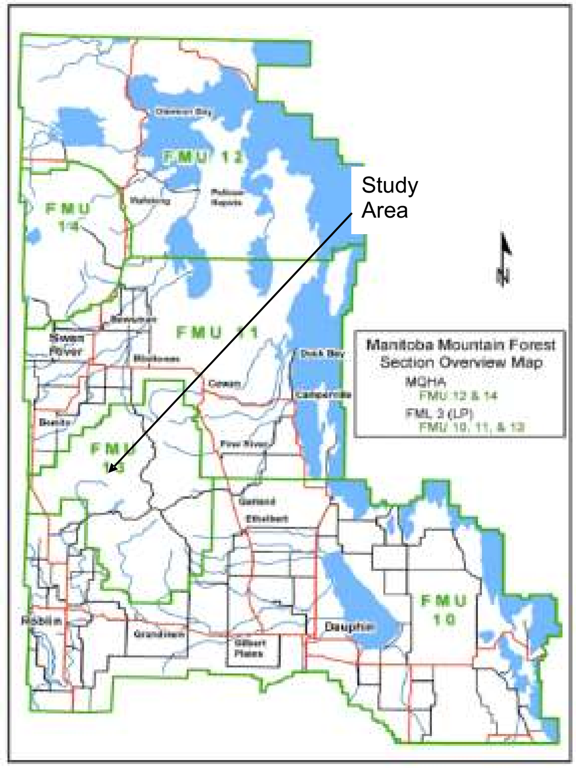


**Figure 1. Map showing the Forest Management Units operated by LP in SW Manitoba. The study area is FMU 13** (source: LP Annual Report, 2003 -2004).

LP has been operating in the area since 1996 and currently harvests approximately 590,000 $m^3$ per year of hardwood, primarily aspen (LP Canada Ltd. 2004). This material is used in the manufacture of oriented strand board at LP's mill in Swan River. White spruce is also harvested and provided to a local sawmill. LP is in the early stages of developing a 20-year forest management plan which includes extensive public involvement and community consultation. In addition, several large research projects support the planning process, including studies of bird populations, small mammals, old growth forest ecology and ecosystem mapping. Results from all of these studies will be incorporated into the 20-year plan by 2007.

**Table 1. Proportion of the Duck Mountains in each stand type** (source: LP's Forest Land Inventory, on file at LP Ltd., Swan River MB).

| Stand Type[1] | Proportion of landscape (%) |
|---|---|
| Aspen | 44 |
| WS-BF mixedwood | 12 |
| lowland BS | 12 |
| Miscellaneous hardwood | 11 |
| BS conifer | 9 |
| JP mixedwood | 5 |
| BS mixedwood | 3 |
| Birch | 2 |
| JP conifer | 1 |

[1] Stand types: WS-BF, white spruce-balsam fir; BS, black spruce; JP, jack pine.

## Future Fire Severity Analysis

The approach used in this study was based on that of Kafka et al. (2001, see also Parisien et al. 2004), who carried out a similar analysis for the forested region of central Saskatchewan. They used weather station observations to determine current values of the Canadian Forest Fire Weather Index System (FWI, Van Wagner 1987). The FWI and its associated Fire Behavior Prediction System (FBP) provide a range of indices useful to fire suppression planning, including fuel moisture, rates of spread and estimates of fire area. Kafka et al. (2001) interpolated these data across the landscape of central Saskatchewan using the Spatial Fire Management System (SFMS, Lee et al. 2002). This system enables the interpolation of weather and fire index values across large landscapes based on weather stations or other climate data distributed within or near the study area. After potential fire behavior was determined for the current climate, they recalculated FBP values for future climate scenarios using output from the first generation Canadian Regional Climate Model (CRCM 1, Caya and Laprise 1999). The CRCM 1 produced output for three 10-year time periods: 1975-1984 (used to compare model output to observed climate for the same time period), 2040-2049 (2040s) and 2080-2089 (2080s). The 1975-1984 data assume current levels of atmospheric $CO_2$ ($1XCO_2$). The 2040s correspond to the estimated time at which atmospheric $CO_2$ will have doubled ($2XCO_2$) and the 2080s the time at which $CO_2$ will have tripled ($3XCO_2$) (Caya and Laprise 1999).

Current and future values of the FBP data were interpolated across the landscape using SFMS. Maps were created showing current and future values of various FBP indices, with potential Head Fire Intensity chosen as the most useful. Head Fire Intensity (HFI) is a measure of heat release along the flaming front of a forest fire, and is a good measure of the difficulty of suppressing a fire (Hirsch et al. 1998). Head fire intensity values and associated fire behavior are given in Table 2.

The current study differs from that of Kafka et al. (2001) only in that we used the newer version of the Canadian Regional Climate Model, CRCM 3.5 (Laprise et al. 2003) and made minor modifications to the SFMS software following consultations with the author (P. Englefield, Canadian Forest Service, personal communication, May 2004). The first step in applying the HFI data to the Duck Mountains was to identify fuel types and how they were distributed across the landscape. The FBP system uses approximately 16 fuel types that differentiate forest stands based on characteristics important to fire behavior. These include tree form, size, fuel arrangement and continuity, and flammability of foliage (Forestry Canada Fire Danger Group 1992). The forest types identified in LP's forest inventory data were reclassified into the FBP fuel types using a decision tree made up for this study. The fuel types and area are shown in Table 3. The fuel type classification was then applied spatially to the forest inventory across the Duck mountains landscape, yielding a map of fuel types based on the original forest inventory polygons (Figure 2). For purposes of mapping, fuel types S1 (jack pine slash) and S2 (white spruce and balsam fir slash) were combined since the amount of jack pine is minimal in the Duck Mountains landscape. The slash fuel types were assigned to all areas in the inventory that had been recently harvested.

**Table 2. Fire behavior characteristics based on head fire in tensity. Units are in kilowatts of heat released per meter of flaming fire front** (from Kafka et al. 2001).

| Head Fire Intensity Class (kW $m^{-1}$) | General Fire Behavior Description |
|---|---|
| 0-9 | Smoldering or subsurface fires with little or no visible flame. |
| 10-499 | Slow moving surface fires with relatively low flame heights. |
| 500-1,999 | Moderately fast spreading fires with low and high flame heights. Isolated torching may occur if ladder fuels are present. |
| 2,000-3,999 | Fast spreading, high intensity surface fires or intermittent crown fires with short range spotting. |
| 4,000-9,999 | Very fast spreading intermittent crown fires with flames extending above the canopy and short to medium range spotting. |
| 10,000-29,999 | Continuous crown fires with extremely fast spread rates. Fire whirls, towering convection columns and medium to long range spotting possible. |
| > 30,000 | Continuous crown fires with extremely fast spread rates and long range spotting. Conflagration or blow-up type fire behavior possible. |

**Table 3. Fuel type and area on the Duck Mountain Forest Management Unit. Fuel types are defined in the Canadian Fire Behavior Prediction System (Forestry Canada Fire Danger Group 1992).** Designations shown in legend of Figure 2.

| FBP Fuel Type | Designation | Area (ha) |
|---|---|---|
| Boreal spruce | C1 | 7,302 |
| Mature Jack Pine | C2 | 14,977 |
| Immature Jack Pine | C3 | 728 |
| Red and White Pine | C4 | 8 |
| Aspen | D1 | 140,764 |
| Boreal Mixedwood | M1 | 102,862 |
| Land outside the inventory area | NA | 153,125 |
| Non-Fuel | NF | 21,606 |
| Grass | O1 | 42,765 |
| Jack Pine Slash | S1 | 1,098 |
| White Spruce – Balsam Fir Slash | S2 | 24,988 |
| Water | WA | 19,774 |

To represent the current climate and associated FBP values, the current (1975-1984) output of the CRCM was used. Past experience with CRCM data indicates that modeled temperatures are often too warm as compared with observations for the same time period and location (e.g. Kafka et al. 2001, Johnston and Williamson 2005). We therefore adjusted the RCM data for the current period by comparing them to the local weather station records for the same time period and location. Only two stations were in or near the study area and had data for the appropriate time period: Yorkton SK and Swan River MB. As expected we found that the RCM temperature data were warmer than the observed values for the two stations, and therefore adjusted the RCM values as suggested by Kafka et al. (2001). This was done by comparing the monthly temperature for the RCM current time period (1975-1984) to that of the observed record for the same time period. The difference between the two was averaged among the 10 years and subtracted from the 2040s and 2080s monthly data produced by the CRCM. In this way the interannual

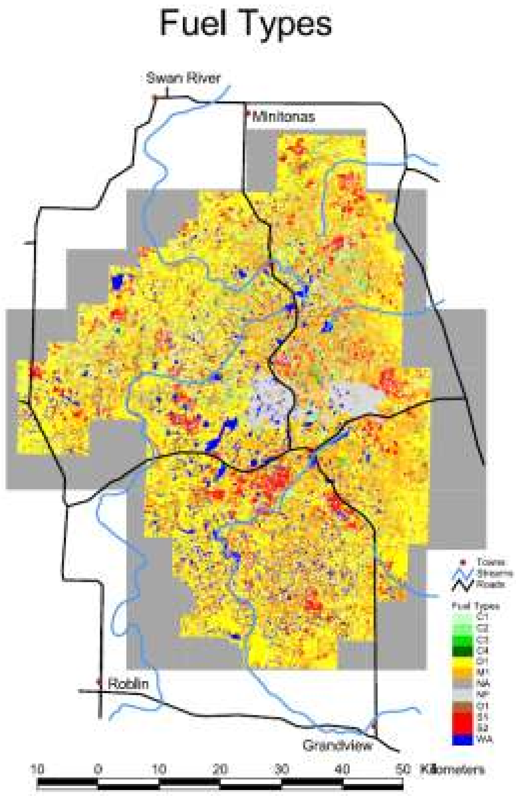


**Figure 2. FBP fuel types on LP's Duck Mountains management unit as reclassified from forest inventory.**

variation in the data was maintained, but the average temperatures were closer to those in the observed record. This was done separately for mean minimum and mean maximum temperatures. As similar procedure was followed for mean monthly precipitation except that future CRCM values were divided by those from the observed record. The result was then multiplied by the CRCM data to adjust the precipitation values.

The CRCM output data are produced on a grid spacing of approximately 45 X 45 km. At this spacing, five CRCM

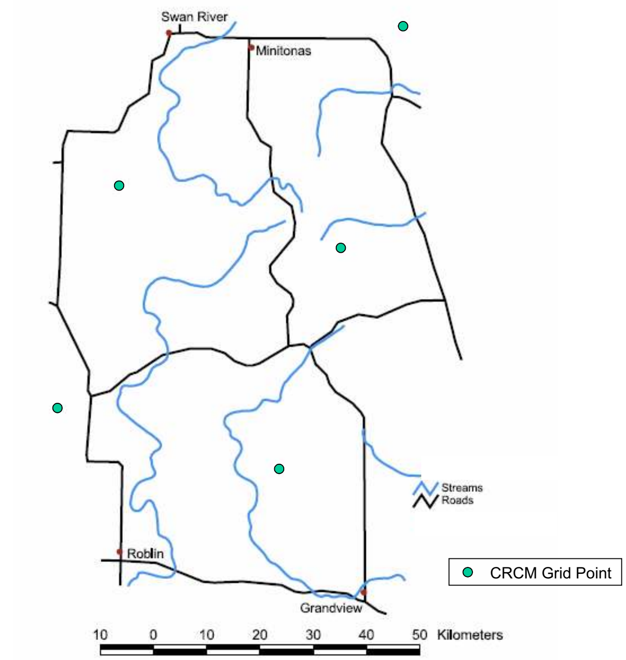


**Figure 3. Location of CRCM grid points in the Duck Mountains study area.**

grid cells cover the area of the Duck Mountains (Figure 3). The SFMS was used calculate the HFI values for each grid cell point for the observed climate during 1975-1984 (historical), the CRCM 1X$CO_2$ output, and for the 2040s (2X$CO_2$) and 2080s (3X$CO_2$). We then used the SFMS to interpolate the HFI values for each time period across the entire Duck Mountains landscape. A total of 72 maps was constructed using ArcView GIS software. These included the calculated values for the historical climate data and the three CRCM time periods, shown separately by season and percentile level. The 80$^{th}$ and 95$^{th}$ percentile values are shown, illustrating moderate and "worst case" scenarios, respectively. Seasons were defined as spring (May), summer (June, July, August) and full (May-September). Earlier spring months (March and April) were not included

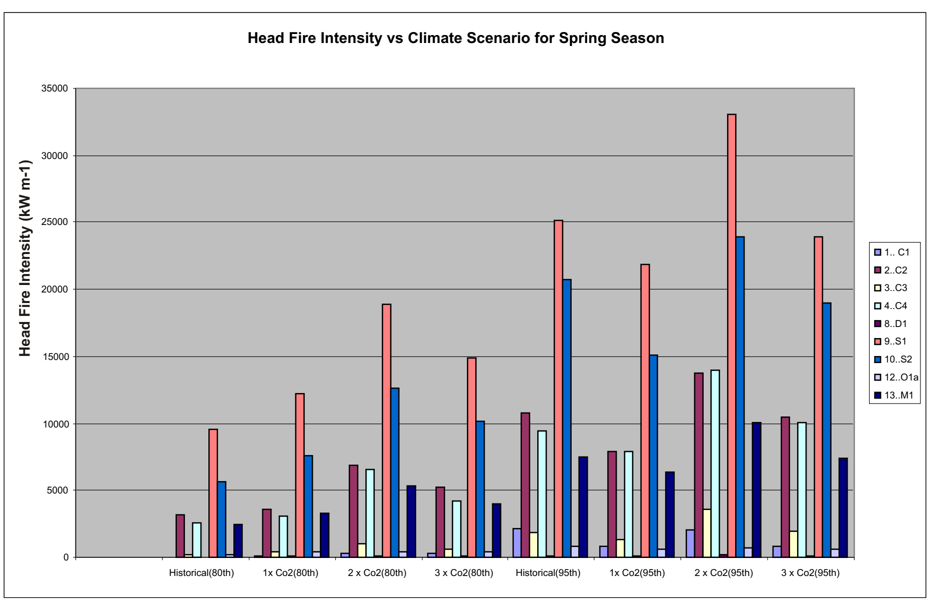


**Figure 4.**
HFI values for fuel types by CRCM scenarios for the spring fire season.

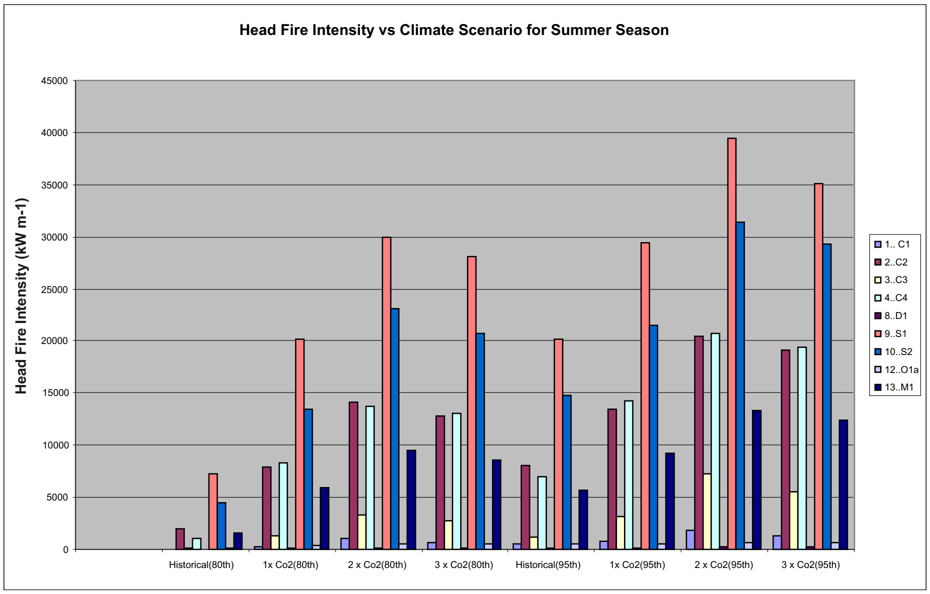


**Figure 5.**
HFI values for fuel types by CRCM scenarios for the summer fire season.

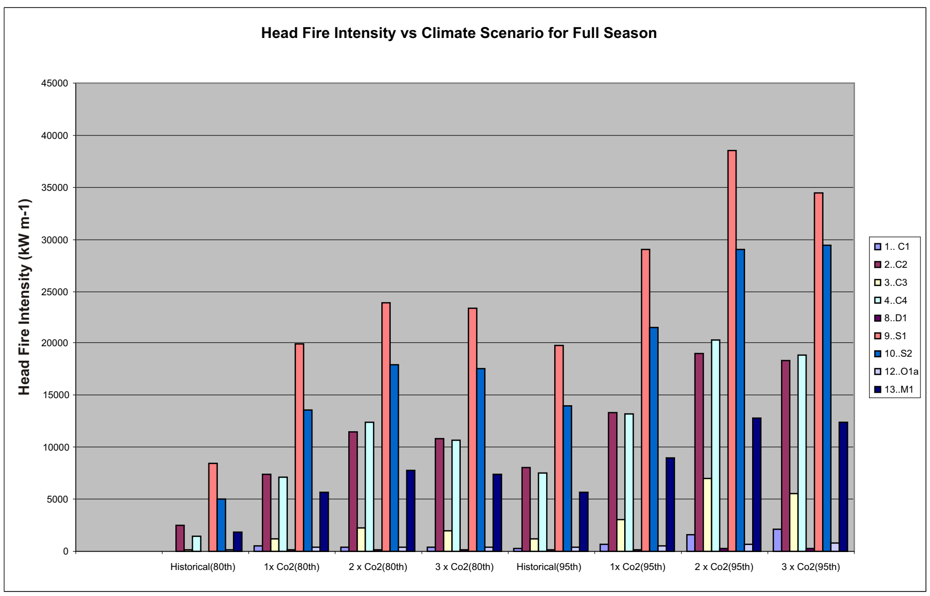


**Figure 6.**
HFI values for fuel types by CRCM scenarios for the full fire season.

due to unavailability of data. In addition, maps showed comparisons among these results in terms of the absolute difference, the percent change and the change in HFI class value as shown in Table 2. We summarized these results by the variation in mean HFI values among fuel types and season (Figures 4-6) and the variation in HFI class area among the CRCM scenarios by season (Figures 7-9).

## RESULTS AND DISCUSSION

### Fuel Types

The Duck Mountains are dominated by the D1 (aspen) fuel type which is generally less flammable than the coniferous fuel types. Before leaf-out in late spring, flammability can be significant under high fire hazard conditions, but generally requires associated grass or woody debris fuels to carry fire. In addition, patches of snow in shaded areas tend to limit fire spread. After leaf-out, high foliar moisture contents and relatively sparse foliage (compared to coniferous canopies) prevent fire spread under all but the most hazardous conditions (Forestry Canada Fire Danger Group 1992). Mixedwood and conifer fuel types are distributed across the study area, particularly in the central and eastern portions. Slash fuel types are also distributed widely, with a concentration in the south-central area. These fuel types are the most hazardous, as discussed in the following sections.

### Fuel Type and HFI Value

Figures 4-6 show how HFI values varied among fuel types for the various CRCM scenarios for the spring, summer and full fire seasons, respectively. In general, fire behavior potential is greater in spring than in the summer or full season analysis. This is because precipitation levels are higher in summer than in spring.

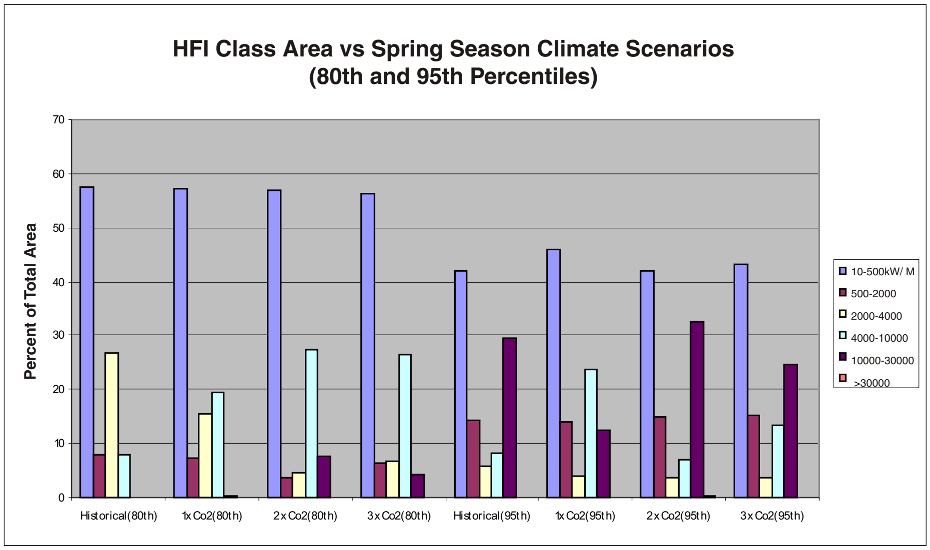


**Figure 7.**
HFI class area for CRCM scenarios for the spring fire season.

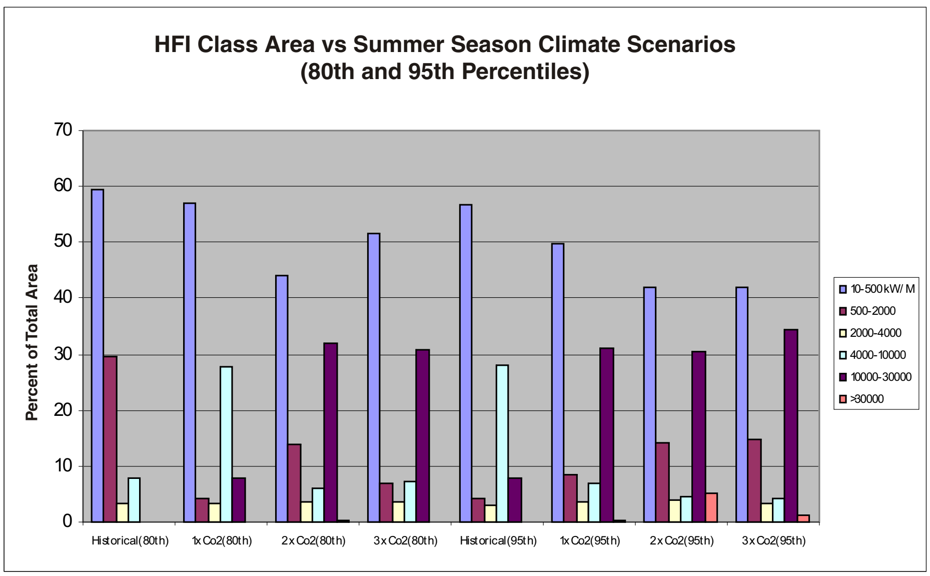


**Figure 8.**
HFI class area for CRCM scenarios for the spring fire season.

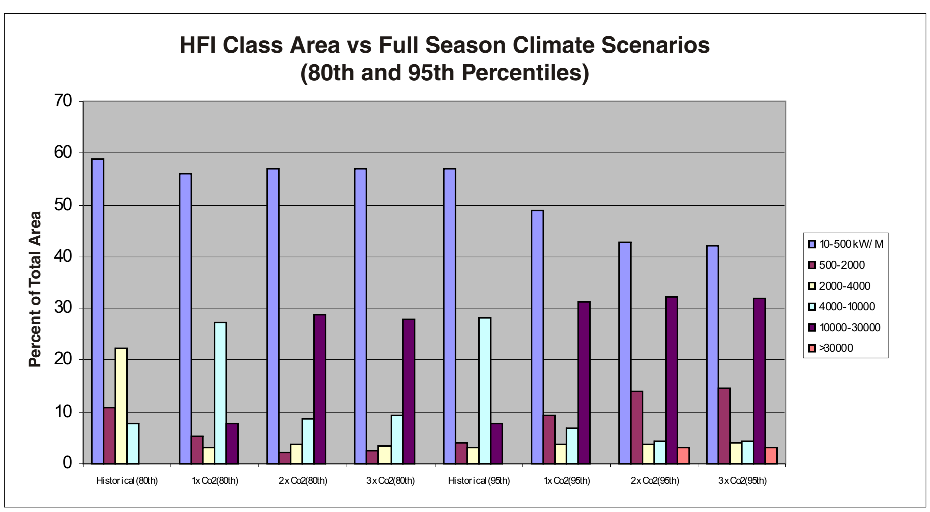


**Figure 9.**
HFI class area for CRCM scenarios for the full fire season.

For the spring season, there were notable increases in HFI for the slash fuel types (S1, S2). For the 80th percentile data, HFI values for S1 increased from < 10,000 kW $m^{-1}$ in the historical scenario to nearly 20,000 kW $m^{-1}$ in the 2XCO2 scenario. Values then declined to about 15,000 kW $m^{-1}$ in the 3XCO2 scenario. For the 95th percentile data, values increased from about 25,000 to > 33,000 kW $m^{-1}$. In both cases, values decreased from the $2XCO_2$ to the $3XCO_2$ scenarios. The reason for the decline is not clear, although there is some speculation that wind speeds may be less under the $3XCO_2$ scenario. This could be due to a reduction in the pressure gradient between the tropics and the northern hemisphere, because in future climate scenarios the tropics warm proportionally less than high latitudes (M. Flannigan, Canadian forest service, personal communication, January 2006). Wind speeds calculated for this project show that they are 5-10% less in the 2080s than those of the 2040s. Fire behavior is extremely sensitive to wind speed and is therefore less severe when wind speeds are lower. Similar relative increases occurred for the M1 fuel type, also important on the Duck Mountains landscape. Mature jack pine (C2) also showed substantial increases over the historical scenario. Red and white pine (C4) increased as well but it makes up only a tiny fraction of the Duck Mountains landscape (Table 2). It is clear from these data that the potential increase in potential head fire intensity is very large for the slash fuel types. Patterns were similar for summer and full fires seasons, with relatively large increases in potential fire behavior for the slash and mature jack pine fuel types.

## HFI Class Area

Figures 7-9 show the area that falls into the various HFI classes shown in Table 2 and how this changes among the scenarios. Patterns are relatively similar among the three seasons. In the 80th percentile data, nearly 60% of the area falls into the lowest HFI class in all scenarios. However, the area in the 10,000-30,000 kW $m^{-1}$ class increases from less than 10% to nearly 30%, resulting in a large proportional increase in area of high potential fire severity. There is a corresponding decrease in area in the lowest HFI classes. For the 90th percentile data, there is an even larger increase in the 10,000-30,000 kW $m^{-1}$ class, and a decline in area in the lowest HI class. Up to 35% of the Duck Mountains landscape could be subject to conditions which generate large, rapidly moving crown fires and other severe fire behavior.

## Adaptation Options

The importance of the slash (S1) fuel type is apparent and will obviously increase as harvesting progresses. An important adaptation option for these areas is slash management. LP may want to consider a practice known as "lop and scatter", in which slash is spread across the harvest area and cut into smaller pieces. This reduces the hazard by distributing the fuel over a large area and avoiding large concentrations, and also increases the speed of organic matter decomposition which will reduce the fuel loading. Adopting Fire-smart landscape planning is another important adaptation option for reducing potential fire spread. Fire-smart planning (Hirsch et al. 2001) is a set of techniques for reducing fuel continuity and interspersing less flammable hardwood species (e.g. aspen) among more flammable coniferous species. This landscape-level transition in species composition will occur slowly as stands are harvested and replanted but over several decades the fire hazard will be reduced.

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