Is regulated even-aged management the right strategy for the Canadian boreal forest?

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Abstract

Over the past decade, there has been an increasing interest in the development of forest management approaches that are based on an understanding of historical natural disturbance dynamics. The rationale for such an approach is that management to favour landscape compositions and stand structures similar to those of natural ecosystems should also maintain biological diversity and essential ecological functions. In fire-dominated landscapes, this approach is possible only if current and future fire frequency are sufficiently low, in comparison to pre-industrial fire frequency, that we can substitute fire with forest management. I address this question by comparing current and future fire frequency to historical reconstruction of fire frequency from studies in the Canadian boreal forest. Current and simulated future fire frequencies using 2 x and 3 x CO₂ scenarios are lower than the historical fire frequency for most sites, suggesting that forest management could potentially be used to recreate the forest age structure of fire-controlled pre-industrial landscapes. Current even-aged management, however tends to reduce forest variability: for example, fully regulated, even-aged management will tend to truncate the natural forest stand age distribution and eliminate overmature and old growth forests from the landscape. The development of silvicultural techniques that maintain a spectrum of forest compositions and structures at different scales in the landscape is one avenue to maintain this variability.

Keywords: boreal forest; even age management; fire regime; old-growth forests; climate change; partial cutting
Introduction

Over the past decade, there has been an increasing interest in the development of forest management approaches that are based on an understanding of natural disturbance dynamics (Attiwil 1994; Bergeron and Harvey 1997; Angelstam 1998). The rationale is that management that favours the development of stand and landscape compositions and structures similar to those that characterise natural ecosystems should favour the maintenance of biological diversity and essential ecological functions (Hunter 1999). For the conservation of native flora and fauna, emulation of natural disturbance has been justified by the knowledge that boreal forest species are mostly generalists that are well adapted to the environmental forces that have been acting over thousands of years (Hunter et al. 1988).

Understanding of the fire regimes that characterise the boreal forest is still fragmentary. This lack of understanding has often led to false generalisations. For example, clearcutting has been justified for use throughout the boreal forest based on the assumption that the fire regime is characterised by the presence of large, frequent and severe fires that produced even-aged stands. In fact, it has become increasingly evident that short fire cycles are dominant only in portions of the boreal forest and that the situation is regionally more complex (Bergeron et al. 2001).

In areas where current fire frequency is low, but which historically had more fire, clearcutting might be used as a means to partially emulate natural disturbance. As the length of the fire cycle increases, however, use of clear-cutting to mimic fire becomes more and more difficult to justify. Moreover, in areas where fires are still frequent, logging activities are competing with fire for timber, and even-aged short rotation
management systems may be unsustainable. Most of the productive boreal forest in
Canada lies between these two extreme situations. In the context of climate change,
however, the situation could either improve or degrade because model predictions for
fire frequency vary significantly from region to region (Flannigan et al. 2001).

In this article, I present historical, current, and projected future frequencies of stand-
replacing fires for Canadian boreal forest with an emphasis on eastern boreal forest. I
discuss the extent to which the use of conventional even-aged management
(clearcutting under short rotation) could potentially be used as a means to recreate the
forest age structure of pre-industrial landscapes that were controlled mainly by fire
regimes. I then discuss alternative strategies for managing boreal forest. Finally, I look at
the future in the context of climate change.

Historical fire frequency & its implications for forest age structure: the bad news

Table 1 presents results for published fire history reconstruction along an east-west
gradient in the boreal forest. It includes data from Labrador (Foster 1983), Central and
Western Quebec (Bergeron et al. 2001), Eastern (Bergeron et al. 2001) and Western
(Suffling et al. 1982) Ontario, Saskatchewan (Weir et al. 2000) and Alberta (Larsen
1997). A more extensive data set is presented in Bergeron et al. (in press). Average age
of the forest (time since-fire) or, if not available, fire cycle before large clear-cutting
activities began, were used to estimate historic burn rates. The average age of the forest
was preferred to the historic fire cycle because it integrates climatically induced changes
in fire frequency over a long period, and because it is easier to evaluate than a specific
fire cycle (Bergeron et al. 2001).
Although there are variations in the mean age of the forests, probably caused by changes in climate along our east-west gradient, in all cases there are a significant proportion of forests that are over 100 years. Reported historical mean age are in most cases well above the mean age of similar landscapes under a normal forest rotation. In fact, under a 100-year forest rotation, the mean age of the fully regulated forest would be 50 years while a natural landscape with a 100-year fire cycle would have a mean age of 100 years. (Fig. 1) This is because fire is a random process while forest management is not. With a 100 fire cycle, 37 % of stands in a landscape subject only to fires are, in fact, older than 100 years, while no stands in a fully regulated managed landscape are older than 100 years (van Wagner 1978). This means that a large proportion of the pre-industrial landscape was composed of forests older than the 100-year commercial forest rotation. The distribution of forest age classes over the landscape is the most important factor controlling the structure and composition of the forest, which, in turn, controls its biodiversity.

In the mixedwood forest located in the southern portion of the eastern boreal forest we generally observe a post-fire invasion of shade-intolerant hardwoods (birch and poplar) that are gradually replaced in the canopy by shade-tolerant conifers (Bergeron and Dubuc 1989; Bergeron 2000). Thus, successive replacement of hardwood stands by mixed stands then by softwood stands occurs over a 200-year period. Further north, in the coniferous boreal forest dominated by black spruce, stand establishment following fire is often dominated by an initial cohort of spruce which gives rise to a dense forest principally of seed origin. At maturity, this even-aged stand structure is gradually replaced by a more open forest containing stems originating from the fire and regeneration partly of layer origin. In the prolonged absence of fire, these stands develop
a very open and heterogeneous uneven-aged structure, maintained by layering. The
presence and abundance of birds, insects, vascular and non-vascular species changes
gradually along the time-since-fire sequence, with very few species restricted to a
particular stand age (Harper et al. 2003).

In light of these results it has become clear that in comparison with natural landscapes,
even-aged forest management under short rotations will lead to an important decrease
of overmature and old-growth stands important for the maintenance of biodiversity
(Kneeshaw and Gauthier 2003).

Table 2 presents the current burn rates for the same locations as in Table 1. Current
burn rates were estimated from the Canadian large-fire database (Stocks et al. 2002).
The large-fire database includes all fires 200 ha and larger and represents over 97 % of
the total area burned in Canada. For each site, the average annual area burned was
calculated within a 100 km radius using the large fire database for the period 1959-1999
(Table 1). The inverse of average age (or fire cycle) was used as an estimator of the
annual historic burn rate.

All study areas show current burn rates significantly lower than their associated historical
burn rates. The observed shift from short fire cycles in the past to longer cycles over the
last 50 years is probably due to a combination of climate change and more effective fire
protection. Many studies from the Canadian boreal forest report a general decrease in
fire frequency since the mid-nineteen century (Bergeron et al. 2001; Larsen 1997; Weir
As most of the forest was still unexploited at that time, it is very likely that the decrease in fire frequency was driven by changes in climate. In northwestern Quebec, the decrease in fire frequency was related to a reduction in the frequency of drought events since the end of the Little Ice Age (Bergeron and Archambault 1993). It is hypothesized that the warming that started at the end of the Little Ice Age is associated with an important change in the circulation of global air masses (Girardin et al. in press).

While the firefighting tools available during the first part of the twentieth Century seem to have been insufficient to deal effectively with large fires (Lefort et al. 2003), active fire suppression has increased during the last 50 years. Moreover, with the introduction of water bombers, firefighting methods have probably been improved continuously through enhanced fire detection and initial response systems. Fire suppression has very likely become more efficient due to increased landscape fragmentation from land clearing and a well-developed road system which increases the number of firebreaks and improves firefighting capacity.

Whatever its causes, the recent decrease in fire frequency favours management strategies that use even-age management on a proportion of the landscape to create forest age structures that would exist under shorter fire-return intervals. Considering the good side and the bad side of even-aged management, what should we do?

A new way to manage the boreal forest

Use of rotations of variable length in proportions similar to those observed under the natural fire regime is a possible alternative (Burton et al. 1999). However, this approach
may be applicable only in ecosystems where species are long-lived and can thus
support longer rotations. In boreal forests composed of relatively short-lived species
such an approach will probably lead to fibre loss and a decrease in allowable cut. This
dilemma is not without a solution, however. Silvicultural practices aimed at maintaining
structural and compositional characteristics of overmature stands within treated stands
could, in boreal regions, guarantee maintenance of habitat diversity while only slightly
affecting allowable cut. Thus, it is possible to treat some stands by clear-cutting followed
by seeding or planting (or another even-age silvicultural system whose outcome
resembles the effect of fire), other stands with partial cuts which approximate the natural
development of overmature stands, and still other stands with selection cuts in order to
reflect the dynamics of old growth stands (Figure 2).

In a forest system under a natural fire regime, not all stands survive to a mature or old
growth stage before again succumbing to fire. Similarly, in the proposed strategy, not all
stands should develop to the latter, advanced cohorts. Thus, the reinitiation to a first
cohort forest type can occur when forest types in any of the three cohorts are clear-cut
and either naturally or artificially regenerated. Figure 2 provides an example of a
possible forest age structure where maximum harvest age and fire cycle are both 100
years. The approach provides a means of covering a forest management area with
zones of regulated, even-aged forests with proportions of each decreasing in relation
with time since the last stand-initiating clear-cut. It should be noted here that the third
cohort includes all age classes greater than 200 years. It would thus be possible to
partially recreate not only the natural composition and structure of stands, but also to
reproduce a forest age structure (proportions of each cohort) that approaches the typical
distribution produced by fires (Fig.1b).
This approach can easily be applied to a variety of different situations; it is only necessary to know the natural fire cycle and maximum harvest age to determine the relative area of each cohort to be maintained over the forest landscape. Silvicultural practices are varied according to the cohort distribution and the disturbance regime of a given forest region. Bergeron et al. (1999) present a framework for determining the proportion of cohorts based on fire cycle and maximum harvest age.

Future fire frequency what should we expect?

Flannigan et al. (2002) and Bergeron et al. (in press) calculated future burn rates using relations developed between observed annual area burned and observed weather and fire weather indexes. We then substituted weather and fire weather indexes from General Circulation Models (GCMs) into our calculations to obtain an estimate of the future area that would burn. We used the Canadian first generation coupled GCM for the 2 x CO2 and 3 x CO2 scenarios. This model included both greenhouse gas and sulphate aerosol forcing contributing to a 1 % increase in CO2 per year. At this rate, the time periods 2040-2060 and 2080-2100 roughly correspond to a 2 x CO2 and 3 x CO2 scenario, respectively. The grid spacing around each specific areas shown in table 2 is approximately 3.75 longitude by 3.75 latitude.

The 2 x CO2 simulation (Table 2) shows a high degree of variability between regions with increases in burn rates such as northern Ontario (154 %) and Wood Buffalo (15 %). Except for central Quebec where a decrease of 11 % is predicted, all other regions show slight decreases or increases. The directional changes in the 3 x CO2 scenario are generally similar to those in the 2 x CO2 scenario (Table 2). Exceptions are Prince Albert and Wood Buffalo for which a 3 to 4 % change in the opposite direction is observed.
Even in a 3 x CO₂ scenario most of the regions still have future burn rates that are lower than their historical burn rates. Under these circumstances, the use of even-age management should still be allowable to make up differences between historical and predicted (2 x CO₂ and 3 x CO₂) burn rates. However, our results have to be interpreted with caution. First, simulations based on different GCM scenarios often give a range of results. Moreover, it is dangerous to extrapolate from our study of specific locations. For one thing, regions in the same ecozone showed wide variability in the effects of climate change. For another, certain regions (Northwestern Ontario) showed a significant increase in burn rates. In cases where current or future fire frequency is high, logging competes with forest fires for timber. Thus, logging might not be sustainable without a large investment in fire suppression (active and passive), and extensive use of salvage logging. However, fire suppression has its limitations, and is increasingly recognized as not really effective in large tracts of natural forest where access is limited, and in years of extreme fire weather. Our belief in the efficacy of fire suppression may have been biased by the fact that fire suppression began during a period when climate change was already responsible for a decrease in fire activity.

Conclusions

The answer to the question Is even-aged management the right strategy for the Canadian boreal forest? is neither a clear yes nor a clear no. Our results show that even-aged management could potentially be used to recreate pre-industrial, fire-controlled landscapes over a large part of the Canadian boreal forest. There are, however, important limitations to the use of clearcut systems for this purpose. Clear-
cutting and fire are obviously not the same process (McRae et al. 2001) and a careful examination of their respective effects on pattern and processes should help define clear-cutting guidelines (OMNR 2001; Bergeron et al. 2002). Moreover, clear-cutting is unable to emulate the overmature and old growth forests that comprised a large part of our natural forests. There is an urgent need to develop alternative silvicultural systems for boreal forests. Experience in uneven aged management in the Canadian boreal forest is limited but it would be a mistake to wait until we have all the answers. The rate at which the virgin forest is disappearing demands us to adopt an adaptive management strategy.

References


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Table 1. Geographic location and burn rates for each study area.

<table>
<thead>
<tr>
<th>Study area</th>
<th>Study area (km²)</th>
<th>Time period</th>
<th>Mean age</th>
<th>% &gt;100 years</th>
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<td>Wood Buffalo Park</td>
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<td>1750-1989</td>
<td>71</td>
<td>24</td>
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<tr>
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<td>&lt; 1890</td>
<td>97</td>
<td>36</td>
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<td>1740-1998</td>
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<td>78</td>
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<td>~1750-1998</td>
<td>139</td>
<td>57</td>
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<td>1870-1975</td>
<td>500</td>
<td>81</td>
</tr>
<tr>
<td>Study area</td>
<td>Study area (km²)</td>
<td>Time period</td>
<td>Past burn rate (%)</td>
<td>Current burn rate (%) (1959-1999)</td>
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</table>
Figure 1. A fully regulated forest with a rotation of 100 years has an equal distribution of stand ages that do not exceed 100 years. During a 100 year cycle, fires may burn some sites many times and leave some sites unburned. A significant proportion of the forest (36.9 %) will live for more than 100 years.

Figure 2. As opposed to the exclusive use of clear-cutting which leads to a fully regulated, even-aged forest, the use of partial and selection cutting in a proportion of the stands permits the recreation of natural stand composition and structure as well as a forest age structure that approaches the typical distribution produced by fire. The proposed approach does not imply lengthening the forest rotation but only varying silvicultural practices.
BERGERON FIGURE 1

Age of stands

Time since last fire

Area burned (%)
BERGERON FIG 2

Clear-cutting

63%

Partial cutting

23%

Selection cutting

14%