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 CO_2 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, clear-cutting 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).

Current vs Past fire frequency : the good news

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 *et al*. 2000). 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 CO_2 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 CO_2 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 CO_2 and 3 x CO_2) 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

Angelstam, P.K. 1998. Maintaining and restoring biodiversity in European boreal forests by developing natural disturbance regimes. J. Veg. Sci. 9:593–602.

Attiwill, P.M. 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. For. Ecol. Manag. 63: 247-300.

Bergeron, Y. 2000. Species and stand dynamics in the mixed woods of Quebec's southern boreal forest. Ecology 81(6): 1500-1516.

Bergeron, Y. and Archambault, S. 1993. Decreasing frequency of forest fires in the southern boreal zone of Québec and its relation to global warming since the end of the 'Little Ice Age'. Holocene 3: 255-259.

Bergeron, Y. and Dubuc, M. 1989. Succession in the southern part of the canadian boreal forest. Vegetatio 79:51-63.

Bergeron, Y., Flannigan, M., Gauthier, S., Leduc, A., and P. Lefort. Past, current and future fire frequency in the Canadian boreal forest: implications for sustainable forest mangement. Ambio (in-press).

Bergeron, Y., Gauthier, S., Kafka, V., Lefort, P. and Lesieur, D. 2001. Natural fire frequency for the eastern Canadian boreal forest: consequences for sustainable forestry. Can. J. For. Res. 31: 384-391.

Bergeron, Y. and Harvey, B. 1997. Basing silviculture on natural ecosystem dynamics: an approach applied to the southern boreal mixedwood forest of Quebec. For. Ecol. Manag. 92: 235-242.

Bergeron, Y., Harvey, B., Leduc, A. and Gauthier, S. 1999. Forest management guidelines based on natural disturbance dynamics: Stand- and forest-level considerations. For. Chron. 75: 49-54.

Bergeron, Y., Leduc, A., Harvey, B.D. and Gauthier, S. 2002. Natural fire regime: A guide for sustainable management of the Canadian boreal forest. Silva Fenn. 36:81-95.

Burton, P., Kneeshaw, D. and Coates, D. 1999. Managing forest harvesting to maintain old growth in boreal and sub-boreal forests. For. Chron. 75: 623-631.

Flannigan, M., Campbell, I., Wotton, M., Carcaillet, C., Richard, P. and Bergeron, Y. 2001. Future fire in Canada's boreal forest: paleoecology results and general circulation model – regional climate model simulations. Can. J. For. Res. 31: 854-864.

Flannigan, M.D., Stocks, B.J., Logan, K.A., Bosch, E.M., Wotton. B.M., Amiro, B.D. and Todd, J.B. 2002. Fire and climate change - where are we going. in D.X. Viegas (ed.) Forest Fire Research & Wildland Fire Safety, Proceedings of the IV International Conference on Forest Fire Research/2002 Wildland Fire Safety Summit (Nov. 18-23, 2002, Luso-Coimbra, Portugal). Millpress Sci. Publ., Rotterdam, Netherlands. CD-ROM. 1pp

Foster, D.R. 1983. The history and pattern of fire in the boreal forest of southeastern Labrador. Can. J. Bot. 61: 2459-2471.

Girardin, M.P., Tardif, J., Flannigan, M.D., and Bergeron, Y. Multicentury reconstruction of the Canadian drought Code from eastern Canada and its relationships with paleoclimatic indexes of atmospheric circulation. Climate Dynamics (in-press).

Harper, K. Boudreault, C., de Grandpré, L., Drapeau, P., Gauthier, S., and Y. Bergeron. 2003. Structure, composition and diversity of old-growth black spruce boreal forest of the clay-belt region of Quebec and Ontario. Environ. Rev. 11: s79-s98.

Hunter, M.L. Jr. (editor). 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press, Cambridge, England. 698pp.

Hunter, M.L. Jr., Jacobson, G.L. and T. Webb III, 1988. Paleoecology and the coarse filter approach to maintaining biological diversity. Conserv. Biol. 2: 375-385.

Kneeshaw, D., and Gauthier, S. 2003. Old growth in the boreal forest: A dynamic perspective at the stand and landscape level. Environ. Rev. 11:s99-s114.

Larsen, C.P.S. 1997. Spatial and temporal variations in boreal forest fire frequency in northern Alberta. J. Biogeogr. 24: 663-673.

Lefort, P., Gauthier, S. and Y. Bergeron. 2003. The influence of fire weather and land use on the fire activity on the lake Abitibi area, eastern Canada. Forest science 49: 509-521.

McRae, D.J., Duchesne, L.C., Freedman, B., Lynham, T.J. and Woodley, S. 2001. Comparisons between wildfire and forest harvesting and their implications in forest management. Environ. Rev. 9: 223-260.

OMNR. 2001. Forest management guide for natural disturbance pattern emulation, Version 3.1. Ont. Min. Nat. Res., Queen’s Printer for Ontario, Toronto. 40 p.

Stocks, B.J., Mason, J.A., Todd, J.B., Bosch, E.M., Wotton, B.M., Amiro, B.D., Flannigan, M.D., Hirsch, K.G., Logan, K.A., Martell, D.L. and Skinner, W.R. 2002. Large forest fires in Canada, 1959-1997. J. Geophys. Res. – Atmospheres, December 20 vol. 107.

Suffling, R., Smith, B. and Dal Molin, J. 1982. Estimating past forest age distributions and disturbance rates in North-western Ontario: a demographic approach. J. Environ. Manag. 14: 45-56.

Van Wagner, C.E. 1978. Age-class distribution and the forest fire cycle. Can. J. For. Res. 8: 220-227.

Weir, J.M.H., Johnson, E.A. and Miyanishi, K. 2000. Fire frequency and the spatial age mosaic of the mixed-wood boreal forest in western Canada. Ecol. Appl. 10: 1162-1177.

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

Study area	Study area (km^2)	Time period	Mean age	% >100 years
Wood Buffalo Park	44807	1750-1989	71	24
Prince Albert	3461	< 1890	97	36
Northern Ontario	24000	~1870-1974	52	15
LAMF	8245	1740-1998	178	78
Western Quebec	15793	~1750-1998	139	57
Central Quebec	3844	1720-1998	102	35
Southeastern Labrador	48500	1870-1975	500	81

Table 2 Geographic location and burn rates for each study area.

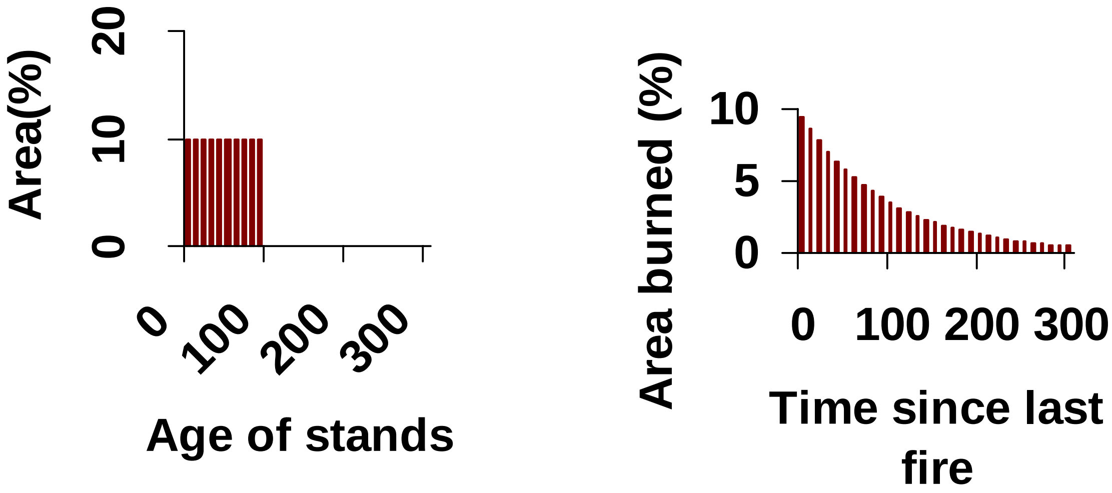
Study area	Study area (km^2)	Time period	Past burn rate (%)	Current burn rate (%) (1959-1999)	2xCO2 (CCC) % variation	3xCO2 (CCC) % variation
Wood Buffalo Park	44807	1750-1989	1.41	0.6603	15.2	11.2
Prince Albert	3461	< 1890	1.03	0.4697	-1.9	1.4
Northern Ontario	24000	~1870-1974	1.92	0.4615	153.7	219.7
LAMF	8245	1740-1998	0.58	0.0456	1.5	1.9
Western Quebec	15793	~1750-1998	0.72	0.0322	0.1	1.6
Central Quebec	3844	1720-1998	0.79	0.1109	-11.1	-11.1
Southeastern Labrador	48500	1870-1975	0.20	0.0379	1.9	3.0

Figure captions

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.

1 BERGERON FIGURE 1



BERGERON FIG 2