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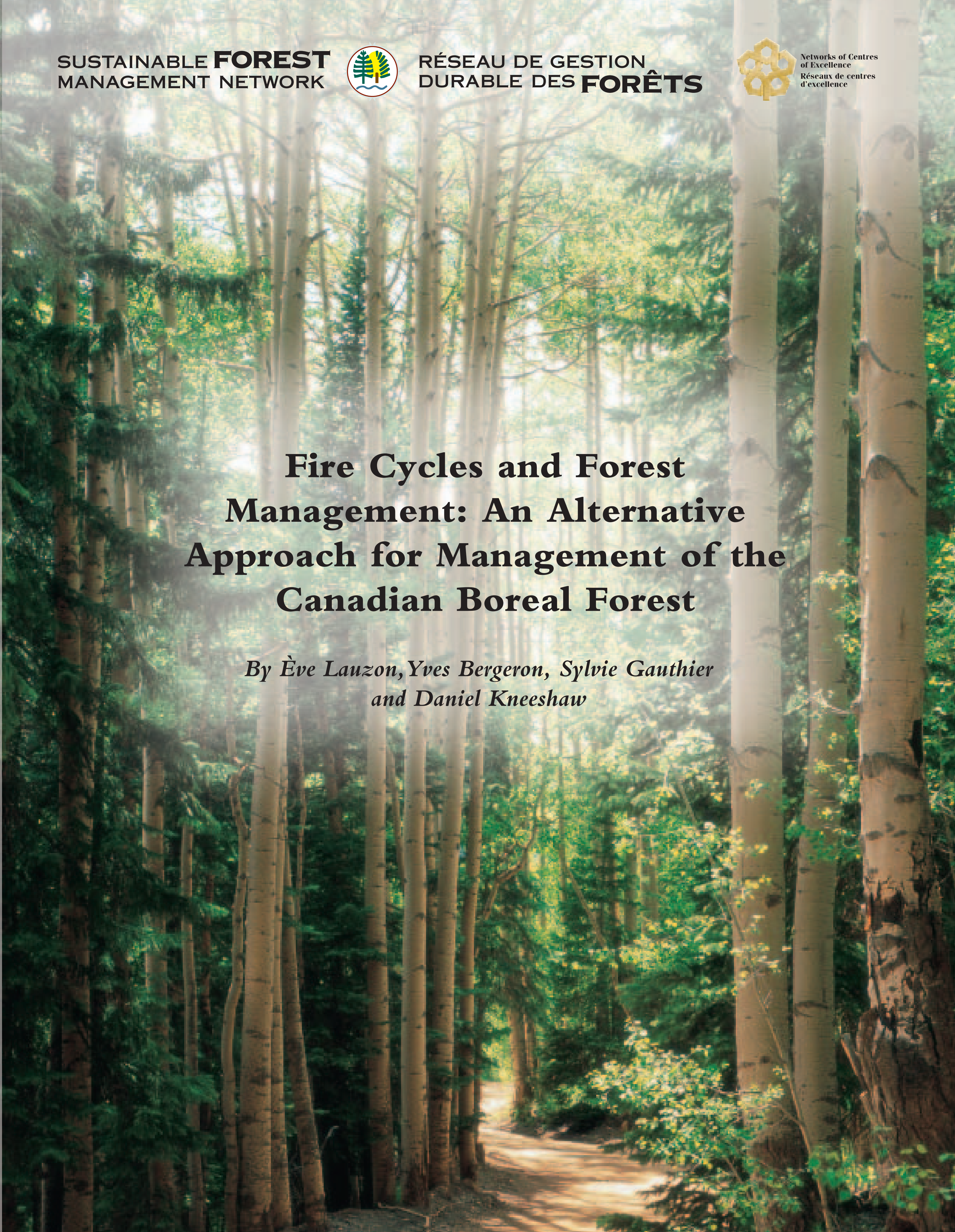

Fire Cycles and Forest Management: An Alternative Approach for Management of the Canadian Boreal Forest

By Ève Lauzon, Yves Bergeron, Sylvie Gauthier and Daniel Kneeshaw

THE SUSTAINABLE FOREST MANAGEMENT NETWORK

Established in 1995, the Sustainable Forest Management Network (SFM Network) is an incorporated, non-profit research organization based at the University of Alberta in Edmonton, Alberta, Canada.

The SFM Network's mission is to:
- Deliver an internationally-recognized, interdisciplinary program that undertakes relevant university-based research;
- Develop networks of researchers, industry, government, Aboriginal, and non-government organization partners;
- Offer innovative approaches to knowledge transfer; and
- Train scientists and advanced practitioners to meet the challenges of natural resource management.

The SFM Network receives about 60% of its $7 million annual budget from the Networks of Centres of Excellence (NCE) Program, a Canadian initiative sponsored by the NSERC, SSHRC, and CIHR research granting councils. Other funding partners include the University of Alberta, governments, forest industries, Aboriginal groups, non-governmental organizations, and the BIOCAP Canada Foundation (through the Sustainable Forest Management Network/BIOCAP Canada Foundation Joint Venture Agreement).

KNOWLEDGE EXCHANGE PROGRAM

The SFM Network funded approximately 337 research projects from 1995 – 2006. These projects enhanced the knowledge and understanding of many aspects of the boreal forest ecosystem, provided unique training opportunities for both graduate and undergraduate students and established a network of partnerships across Canada between researchers, government, forest companies and Aboriginal communities.

The SFM Network's research program was designed to contribute to the transition of the forestry sector from sustained yield forestry to sustainable forest management. Two key elements in this transition include:
- Development of strategies and tools to promote ecological, economic and social sustainability, and
- Transfer of knowledge and technology to inform policy makers and affect forest management practices.

In order to accomplish this transfer of knowledge, the research completed by the Network must be provided to the Network Partners in a variety of forms. The KE Program is developing a series of tools to facilitate knowledge transfer to their Partners. The Partners' needs are highly variable, ranging from differences in institutional arrangements or corporate philosophies to the capacity to interpret and implement highly technical information. An assortment of strategies and tools is required to facilitate the exchange of information across scales and to a variety of audiences.

The KE documents represent one element of the knowledge transfer process. They attempt to synthesize research results, from research conducted by the Network and elsewhere in Canada, into a systems approach to sustainable forest management to assist foresters, planners and biologists with the development of alternative approaches to forest management planning and operational practices.

Sustainable Forest Management Network

Fire Cycles and Forest Management: An Alternative Approach for Management of the Canadian Boreal Forest

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ABSTRACT

Forest managers in Canada urgently require solutions for achieving the goals of sustainable development and the conservation of biodiversity. To attain these goals, many have suggested the use of landscape pattern resulting from naturally occurring disturbances as a template for forest management. Forest fires constitute one of the main disturbances affecting forest dynamics in the boreal. Fire cycle studies have revealed the high variability of this parameter from one region of boreal forest to the next. Fire cycle is often used as a forest management tool, but since it is highly variable in time and space, using the mean time since fire seems to be a simpler and more realistic approach.

Published literature was used to determine both fire cycle and mean time since last fire of forests across the Canadian boreal forest. Based on the mean time since fire of the stands, the percentage of forest which could be managed to reproduce the fire controlled age structure conditions found for each Canadian region studied was determined. This report provides forest managers with a tool that can be used to help achieve sustainable forest management and the conservation of biodiversity.

HIGHLIGHTS

- Forest management based on natural forest dynamics may help maintain biodiversity
- Using a natural disturbance approach requires knowledge of the local fire cycle and fire cycles vary by region
- The three-cohort model is a tool that can be used to guide forest management to emulate natural forest dynamics
- It may be better to use mean time since fire than fire cycle to define the proportion of the landscape to be managed into the first cohort
- The shorter the fire cycle or mean time since fire, the higher percentage assigned to the first cohort and designated for clearcut harvest.
- Most regions in Canada have seen their fire cycle lengthen over time
- Using the three cohort model may result in an increased level of disturbance if harvest does not replace fire but is additive to it
- Other challenges include a possible decreased timber supply and an increase in road networks and maintenance
- The positive effects of this approach in terms of biodiversity conservation still make it an attractive management option
- Mean time since fire is a good index to use when developing natural disturbance management strategies

Introduction

Forest management based on natural forest dynamics may help maintain biodiversity

Sustainable forest management remains one of the greatest challenges facing forest managers. A better understanding of natural processes and the resultant landscape patterns represents a first step towards conservation of an area's ecological integrity. Scientists currently believe that forest management based on natural forest dynamics may facilitate sustainability and maintenance of biodiversity.

Fire is the dominant natural disturbance in the boreal forest

One of the goals of forest management based on naturally-occurring disturbances is to adequately reproduce the variety of age-class distributions, stand types, and structural components observed in unmanaged forests (Bergeron & Dansereau, 1993; Weber & Stocks, 1998; Gauthier *et al.* 2001). Forest fire constitutes one of the main disturbances affecting natural forest dynamics and plays an essential role in maintaining biodiversity (Rowe & Scotter, 1973; Attiwil, 1994; Weber & Stocks, 1998; Peltzer *et al.*, 2000; Gauthier *et al.* 2001). In the past, the recurrence and severity of fires in boreal forest were seen as a homogenous phenomenon. Today, it has been clearly established that the fire regime varies substantially from one part of the boreal forests to the next (Bergeron *et al.* 2001). Studies have shown that in Canada, the fire cycle varies from west to east. Fire cycle is defined as the time required to burn a portion of land equivalent to the area being studied. In parts of Alberta, the fire cycle has been estimated to be approximately 50 years, whereas in more humid regions in the east, such as Labrador and Nova Scotia, the cycle varies between 250 and 500 years (Wein & Moore, 1979; Foster, 1983; Lauzon *et al.* in press).

Many studies have shown that the fire cycle varies not only from one region to another, but also over time (Flannigan *et al.* 1998). Climatic changes account for such variations in many regions where the fire cycle has significantly increased since the end of the Little Ice Age (*circa* 1850) (Bergeron & Archambault, 1993; Stocks, 1993; Engelmark *et al.* 1994; Flanningan *et al.* 1998; Bergeron 1998; Bergeron *et al.* 2001)(see Figure 1). Fire cycle length can also be influenced by human activities. For example, the fire cycle has shortened in certain regions due to the prevalence of man-made fires (Johnson *et al.* 1990). In contrast, other locations have seen an increase in fire cycle during well-defined periods following the implementation of fire-control measures (Tandes, 1979; Wein & Moore, 1979).

In the boreal forest, fire cycles vary by region

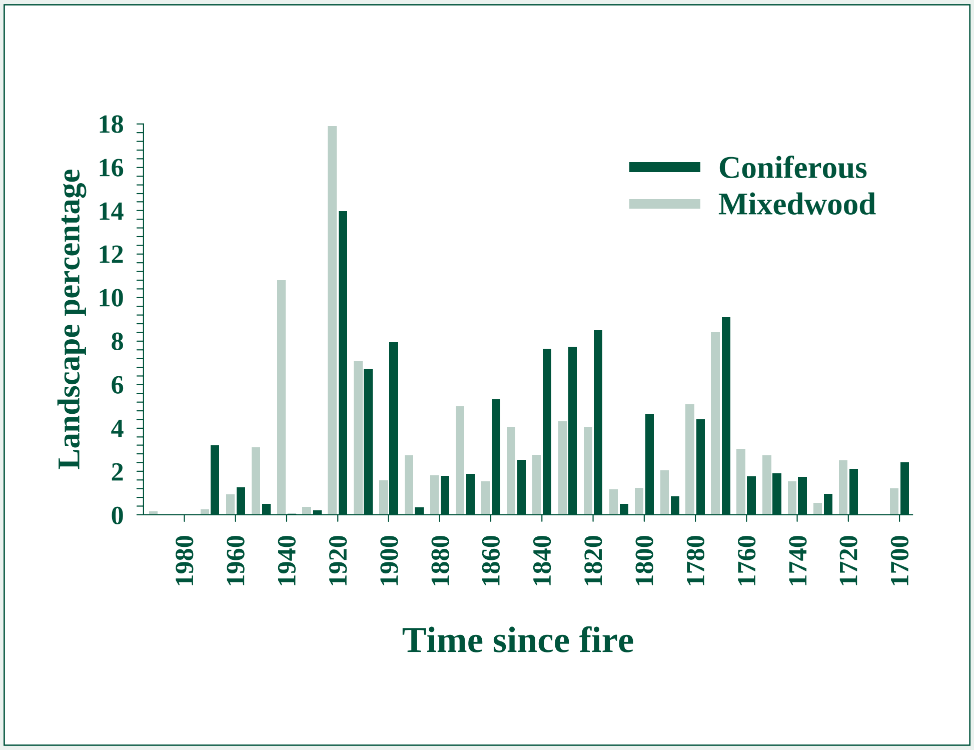

Figure 1. Proportion of landscape by decade of origin for the Abitibi region in Quebec. This illustrates an increase in fire cycle in the region over time (from Bergeron *et al.* 2000).

Many studies focusing on fire cycles have been carried out using the negative exponential model developed by Van Wagner (1978) (see Figure 2). This model predicts, assuming all stands are equally susceptible to fire, that about one third of stands will be older than the length of the fire cycle. In theory, with a fire cycle of 100 years and an ecological rotation age[1] of 100 years, 63% of stands will be in an age class younger than the fire cycle, and 37% will be older (Van Wagner, 1978). When a fire cycle nears 300 years, and the ecological rotation age remains at 100 years, approximately 60% of stands should be 100 years or older and only 30% should be younger.

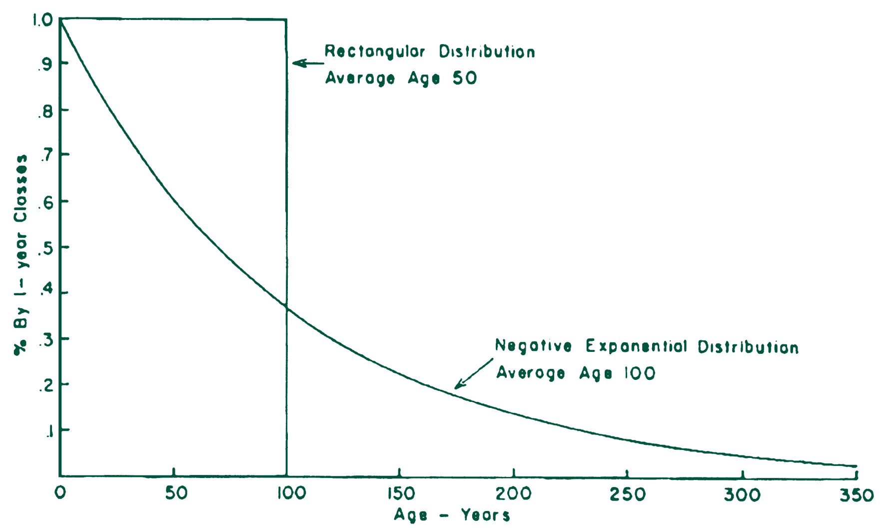

Figure 2. Two age-class distributions, rectangular and negative exponential, compared at same rotation, 100 years (from Van Wagner 1978).

Based on this concept, Bergeron *et al.* (1999) developed the three-cohort model (Figure 3). Using the example above, where both the fire cycle and the ecological rotation age are 100 years, the three-cohort model suggests that 63% of the forest is in the first cohort and could be managed in a manner that emulates the passage of fire. In other words, 63% of the forest area could be clear-cut followed by seeding or planting of pyrogeneous, early successional species. Such a strategy could be used to recreate even-aged stands that naturally follow fire. The second and third cohorts represent, for their part, 37% of stands and should be managed to emulate natural succession. Indeed, these two cohorts should reflect the effects of secondary disturbances that characterize older and uneven-aged stands that have been spared by fire over a long period. For cohorts 2 and 3 extended rotation periods and alternative harvest methods should be considered.

The three-cohort model is a tool that can be used to guide forest management to emulate natural forest dynamics

[1] Ecological rotation age refers to the age at which the stand structure begins to break down and the stand enters into the gap dynamic stage of succession.

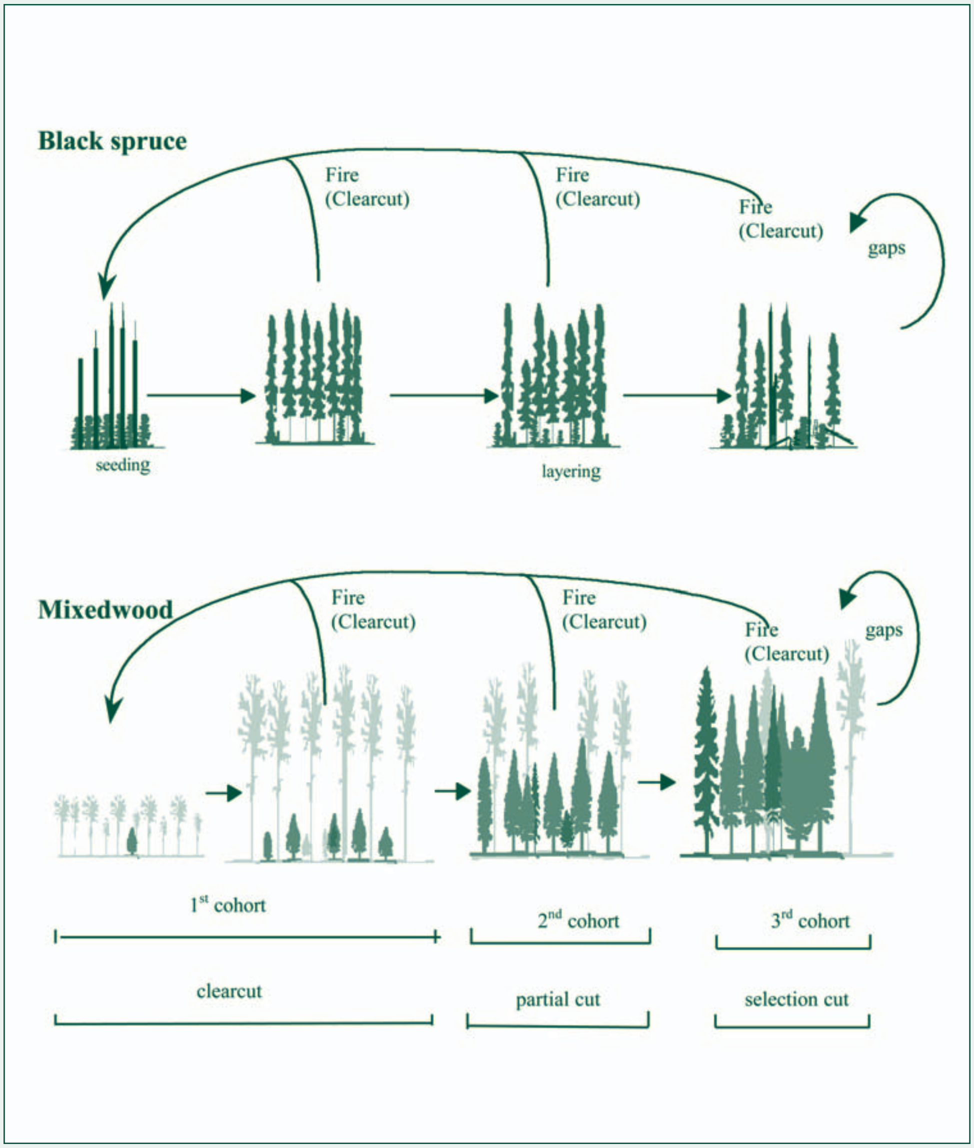

Figure 3. Example of natural dynamics and associated silviculture treatments for mixedwood and black spruce forests (from Bergeron *et al.* 2000).

This document will:

(1) compare fire cycle to mean time since fire of stands to determine which measure is more stable and more realistic;

(2) measure the percentage of the Canadian boreal forest which falls into the first cohort and could therefore be managed to reproduce the large even-aged stands that follow fires; and

(3) provide an approach for the implementation of the natural disturbance model in each of the Canadian regions studied.

Fire Cycles

A review of the published literature was conducted to determine the fire cycle and the factors that influence fire cycle in many Canadian regions (see Table 1 and Figure 4). Various studies examined coniferous and mixed forests of Canada by vegetation zones: tundra (T); boreal (B); subalpine (SA); Great Lakes/St-Lawrence (L); and Acadian (A) (Rowe 1972). Because the fire cycle varies greatly in frequency and from one region of the boreal forest to another, the mean time since fire is also presented. The mean time since fire of stands can also be employed to characterize average fire interval in order to define the proportion of the landscape to be managed in the first cohort. This measure is more stable than the fire cycle and directly informs us of the proportion of forest that has succumbed to fire (Bergeron *et al.* 2000; Bergeron *et al.* 2004; Gauthier *et al.* 2002). It may therefore serve as a better reference for comparison of different regions[2].

Three Cohort Model

Bergeron *et al.* (1999) developed a three-cohort model that separates the landscape into 3 silviculture approaches:

The three-cohort model designates areas for clearcut harvesting and varying degrees of partial retention harvesting

1) clearcut harvesting (used to emulate natural disturbance),

2-3) varying degrees of partial cutting to reflect dominant disturbances (used to emulate natural succession and gap dynamics).

Using this model, recommended percentages for each cohort was determined for each of the forest regions based on their fire cycle (see Table 2). For this project the percentage of forest assigned to the first cohort was determined using the mean time since fire and the ecological rotation age was arbitrarily set at 80 years. Ecological rotation age varies according to species and region and this procedure can easily be reproduced by employing the results of the mean time since last fire presented in Table 1 and Table 2.

[2] For more information about the methods used to determine fire cycles and mean time since fire, please refer to the original articles highlighted in the reference section with an asterisk.

Table 1. Fire cycle calculated for different regions of Canada, as well as the mean time since last fire, which was used to determine the percentage of forest included in the first cohort (percentage of forest area which could be harvested by clear-cutting followed by seeding or planting).

Geographic Regions	Forest Regions**	References	Area Studied (km^2)	Period Studied to Determine Fire Cycle	Fire Cycle (year)	Period Studied to Determine Mean Time Since Last Fire	Mean Time Since Last Fire (year)	% of Area in 1st Cohort
Labrador	T-B	Foster 1983	48 500	1870-1980	500	n. c.	n. c.	n. c.
Nova-Scotia	A	Wein and Moore 1979	province	1915-1975	1000	n. c.	n. c.	n. c.
New-Brunswick	A	Wein and Moore 1977	Province	1920-1975	625	n. c.	n. c.	n. c.
Gaspesia	B	Lauzon *et al.* in press	4600	1925-2003	650	1680-2003	140	44%
Central Quebec	B	Lesieur *et al.* 2002	3844	1920-1999	273	1700-1999	127	47%
Abitibi East	B	Bergeron *et al.* 2001	3294	1920-1999	191	1700-1999	111	51%
Abitibi West	B	Bergeron *et al.* 2001	15 793	1920-1999	325	1530-1999	139	44%
LAMF	B	Bergeron *et al.* 2001	8245	1920-1999	521	1750-1999	172	37%
Ontario (St-Joseph Lake)	B	Suffling *et al.* 1982	≈11 250	1920-1982	100	1820-1980	47	82%
Ontario/Minnesota	B-L	Heinselman 1973	4170	1595-1971	100	1595-1971	106	53%
Manitoba (Duck Mountain)	B	Tardif 2004	3760	1914-2001	486	1914-2001	115	50%
Saskatchewan (Boreal Shield)	B-SA	Parisien *et al.* 2004	18 716	1945-2002	99	n. c.	n. c.	n. c.
Saskatchewan (Prince Albert)	B	Weir and Johnson 1998	3461	1900-1995	100	1745-1995	97*	56%
Alberta (Kananaskis)	SA	Johnson and Larsen 1991	495	1730-1980	90	1730-1980	132†	45%
Alberta (Wood Buffalo)	B	Larsen 1997	44 870	1870-1989	89	1750-1989	71‡	68%
British-Columbia (Glacier)	SA	Johnson *et al.* 1990	600	1880-1980	110	n. c.	n. c.	n. c.
British-Columbia (Kootenay)	SA	Masters 1990	1400	1928-1988	>1000	1508-1984	172	37%

** Forest Region: T: tundra; B: boreal; SA: subalpine; L: Great Lakes/St-Lawrence; A: Acadian
* Mean time since last fire obtained from Weir *et al.* 2000.
† Mean time since last fire obtained from Johnson *et al.* 1995.
‡ Mean time since last fire obtained from Larsen, 1996.
n.c.: Not calculated, this was usually due to insufficient information in the published paper.

Figure 4. Map depicting the fire cycle for the different regions of Canada

Table I indicates the percentage of forest that could be in the first cohort – the area available for clearcut harvest to emulate natural disturbance. The shorter the fire-cycle or the mean time since fire, the higher the first cohort percentage. Inversely, the greater the fire cycle or mean time since fire, the smaller the first cohort area will be. For example, in the Gaspesia region 44% of the forest area is composed of young stands (less than 80 years) suggesting that under a natural fire regime a significant amount of forest was undisturbed by fire for long periods of time. In central Quebec, young stands account for less than 50% of the forest. In Ontario, where regional variations are more pronounced, young stands range from 50% to ~80% of forest cover. The prevalence of young stands in Manitoba is similar to that of Abitibi east and Central Quebec. In Saskatchewan and Alberta, young stands vary from 45% to 68%. And finally, only 37% of British Columbia's forest is made up of young stands.

The shorter the fire cycle or mean time since fire, the higher percentage assigned to the first cohort and designated for clearcut harvest

Table 2. Proportion of the three cohorts that could be subjected to different silvicultural treatments as a function of mean time since fire and rotation age. Note: The third cohort is the summation of the proportion of all subsequent cohorts (adapted from Bergeron *et al.* 1999).

	Disturbance Cycle (years)																	
	50			75			100			125			150			200		
	Cohort (%)			Cohort (%)			Cohort (%)			Cohort (%)			Cohort (%)			Cohort (%)		
Rotation Age (years)	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
50	63	23	14	49	25	26	39	24	37	33	22	45	28	20	51	22	17	61
60	70	21	9	55	25	20	45	25	30	38	24	38	33	22	45	26	19	55
70	75	19	6	61	24	15	50	25	25	43	24	33	37	23	39	30	21	50
80	80	16	4	66	23	12	55	25	20	47	25	28	41	24	34	33	22	45
90	83	14	3	70	21	9	59	24	17	51	25	24	45	25	30	36	23	41
100	86	12	2	74	19	7	63	23	14	55	25	20	49	25	26	39	24	37
110	89	10	1	77	18	5	67	22	11	59	24	17	52	25	23	42	24	33
120	91	8	1	80	16	4	70	21	9	62	24	15	55	25	20	45	25	30
130	93	7	1	82	15	3	73	20	7	65	23	12	58	24	18	48	25	27
140	94	6	0	85	13	2	75	19	6	67	22	11	61	24	15	50	25	25
150	95	5	0	86	12	2	78	17	5	70	21	9	63	23	14	53	25	22
160	96	4	0	88	10	1	80	16	4	72	20	8	66	23	12	55	25	20
170	97	3	0	90	9	1	82	15	3	74	19	7	68	22	10	57	24	18
180	97	3	0	91	8	1	83	14	3	76	18	6	70	21	9	59	24	17
190	98	2	0	92	7	1	85	13	2	78	17	5	72	20	8	61	24	15
200	98	2	0	93	6	0	86	12	2	80	16	4	74	19	7	63	23	14

Fire cycles vary in Canada from east to west (Table I) and with climate and geography. The maritime climate of eastern Quebec limits the spreading of fire therefore fire cycles are longer in this region (Wein & Moore, 1977; Foster, 1983; Lauzon *et al.* in press). Central Canada is subject to much dryer air masses. In these provinces, and in the mountains of the west, the cycle is generally shorter (Johnson & Larsen, 1991; Parisien *et al.* 2004). However, the wet mountainous regions of western Canada are more humid and have a greater fire cycle. In these mountainous regions fires are more destructive despite having a lower frequency of occurrence (Masters, 1990; Bessie & Johnson, 1995). Geographic differences are noteworthy as they have a direct impact on the fire cycle.

Most regions in Canada have seen their fire cycle lengthen over time

When considering the use of the three cohort model in forest management it is important to recognize that most regions have seen their fire cycle lengthen over the course of the last century (see Table 3). However, southern Alberta has witnessed an increase in fire frequency as has Quebec's subarctic region.

Table 3. Observed tendencies of fire cycles in the 20th century in different regions of Canada.

Provinces/Regions	Reference	Length of Fire Cycle
Gaspesie	Lauzon *et al.* in press	↑
Central Quebec	Lesieur *et al.* 2002	↑
Western Quebec	Payette *et al.* 1989	↓
East Abitibi	Bergeron *et al.* 2001	↑
West Abitibi	Bergeron *et al.* 2001	↑
Ontario (LAMF)	Bergeron *et al.* 2001	↑
Ontario	Cwynar 1977	↑
Ontario/Minnesota	Heinselman 1973	↑
Manitoba	Tardif 2004	↑
Saskatchewan (Prince Albert)	Weir *et al.* 2000	↑
Alberta (Kananaskis)	Johnson and Larsen 1991	↓*
Alberta (Wood Buffalo)	Larsen 1997	↑
Alberta (Glacier)	Johnson *et al.* 1990	↓*
BC (Kootenay)	Masters 1990	↑

*Obtained from Johnson *et al.* 1998

Management Implications

As part of a biodiversity conservation strategy, managers may consider a natural disturbance-based model in their forest management planning. Given that fire is the primary disturbance in Canada's forests, using the three-cohort model developed by Bergeron *et al.* (1999) enables managers to emulate natural disturbance patterns and maintain heterogeneity across the landscape. This model considers the regional fire regime and determines the amount of forest that could be harvested through clearcut, partial cutting and selective methods.

Using a natural disturbance approach requires knowledge of the local fire cycle

Using a natural disturbance approach to forest management requires knowledge of the mean time since fire for the region. For example the forests of central Canada have a short fire cycle and contain a greater percentage of young stands. This percentage of young stands can then be used by managers to determine the amount of forest that could be managed in a manner reflective of the natural disturbance regime (Bergeron *et al.* 1999).

It is important to consider that the effect of using the three cohort model may be additive to fire and could result in an increased level of disturbance (fire plus harvesting). The strategy is to use forest harvesting to *replace* natural forest disturbance rather than add to it. Extreme fire events still occur naturally and appropriate contingency measures should be incorporated in the management strategy.

Using the three cohort model may result in an increased level of disturbance if harvest does not replace fire but is additive to it

As indicated in Table 3, certain regions have seen an increase in fire cycle length over this last century, which under the three cohort model, increases the possibility of substituting harvesting for the effects of fire. In regions where the fire cycle has shortened, using the three-cohort model may restrict the quantity of forest available for harvest. Again, the objective of using this approach is not to cut more forest than fire would burn but to harvest what would potentially burn – thus serving as a replacement disturbance agent.

Other forest management challenges resulting from the implementation of this approach include a possible decrease in available timber supply. This could occur in the short term while making the transition from traditional forest management to one based on landscape patterns and forest dynamics resulting from natural disturbances. It may be necessary to constrain the total amount of area disturbed and an attempt to mimic the natural heterogeneity of the landscape in terms of patch size distribution – having a designated number of patches in identified patch size classes – may likewise result in a reduction in timber supply.

Other challenges include a possible decreased timber supply and an increase in road networks and maintenance

Forest management based on the natural disturbance template may also see a related challenge involving the road networks required to harvest areas. In general, an increase in the number of patches to be harvested requires a greater amount of roads to support the harvest of those areas. Depending on the fire regime for the region, more road networks may be required, along with a corresponding increase in maintenance. Challenges aside, the positive effects the use of this approach may have in terms of biodiversity conservation still makes it an attractive management option.

The positive effects of this approach in terms of biodiversity conservation still make it an attractive management option

Conclusion

Variation in fire cycle over time presents a challenge to managers. The fire cycle has changed in many regions of Canada within a short timeframe (Table 3). For instance, in Saskatchewan, Weir *et al.* (2000) found that the fire cycle changed significantly over a period of 55 years. Before 1890, it was estimated to be 15 years; between 1890 and 1945, 75 years; and from 1945 to today, it has jumped to 1745 years. This illustrates how large variations in fire cycles can occur during short time periods. This instability affects the usefulness of fire cycle length in the development of natural disturbance management strategies.

Mean time since fire may be a better index to use when developing natural disturbance management strategies

In light of these observations, mean time since fire may be a better index of comparison since it is more stable in time and space (Bergeron *et al.* 2001; Bergeron *et al.* 2004; Gauthier *et al.* 2002). Mean time since fire directly represents the percentage of forest affected by fire and facilitates the determination of percentage which lies in the first cohort. Mean time since fire also has the advantage of encapsulating the variation of fire recurrence that occurred over time and is therefore considered a more realistic index to use when developing natural disturbance management strategies.

It is important that today's forest managers work towards sustainable forest management and the conservation of biodiversity. With information about local or regional fire regimes, the implementation of a three-cohort forest management approach to conserve the natural heterogeneity of the region may help forest managers achieve these goals.

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