SUSTAINABLE FOREST MANAGEMENT NETWORK

RÉSEAU DE GESTION DURABLE DES FORÊTS

PROJECT REPORTS 2003/2004

The ecological basis of ecosystem management in the eastern boreal forest of Québec

Sylvie Gauthier and Louis De Grandpré

October 2003

Published: 24 October 2003

Related SFM Network Project:
gauthiersdeve6
Development and experimentation of ecosystem management in the eastern boreal forest of Québec

A NETWORK OF CENTRES OF EXCELLENCE
UN RÉSEAU DE CENTRES D'EXCELLENCE

Sustainable Forest Management Network project:
Development and experimentation of ecosystem management in the eastern boreal forest of Québec.

The ecological basis of ecosystem management in the eastern boreal forest of Québec

Project Report

By

Sylvie Gauthier and Louis De Grandpré

Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, P.O. 3800, 1055, rue du P.E.P.S., Sainte-Foy, QC, G1V 4C7; Tel. 418 648 5829 or 418 648 5846; Fax 418 648 5849; e-mail: sgauthier@nrcan.gc.ca and Ldegrandpre@nrcan.gc.ca;

October 2003

Keywords: *boreal forest, old-growth forest, natural disturbances, secondary disturbances, gap dynamics, stand and landscape structure, fire regime, succession, uneven-sized forest, sustainable management strategies.*

Abstract

It has long been considered that secondary disturbances only play a marginal role in boreal forest dynamics, since fire was regarded as the principal disturbance of this ecosystem. However, the variability in fire regimes observed among boreal forest regions suggests that some regions are rather strongly influenced by secondary disturbances. In Quebec's eastern boreal forest, where the fire cycle is relatively long, dynamics seems to be controlled more by secondary disturbances, such as insect outbreaks and windthrows, than by fire. Such a disturbance regime generates gaps of various sizes, small gaps of only a few square meters, resulting from single-tree mortality, as well as gaps of several hectares, ensuing from major windthrows or severe insect outbreaks. This results in a complex mosaic of structures in the forest landscape. The maintenance of such a spectrum of composition and structure in the landscape of Quebec's eastern boreal forest is of prime importance for biodiversity conservation. For instance, the forest caribou could be particularly sensitive to the spatial structure of the forest landscape, since this species moves through immense territories. Therefore, in a sustainable forest management perspective, it has become essential to consider structural diversity in the development of silvicultural scenarios, which should reflect the pattern imposed by secondary disturbances on the landscape. The variability of the disturbance regime requires a diversification of silvicultural approaches.

Introduction

The development of sustainable forest management strategies requires that we consider the forest as a whole, which includes concerns other than wood fibre production. It has been proposed that forest practices inspired by the natural processes controlling forest development could help us to achieve sustainable forest management objectives. An increasing number of studies have shown that the development dynamics of boreal forest, which is dominated by disturbances, principally fires, has a strong influence on biological diversity, forest productivity and ecological processes (Pickett and White 1985; Bergeron 1991; Johnson 1992). Fire regime (cycle, mean interval, size, occurrence, intensity, severity and season) varies across regions and climates, and greatly affects forest stand composition and structure (Attiwill 1994; De Grandpré and Bergeron 1997; Bergeron 2000; Gauthier et al. 2000; Kneeshaw and Gauthier 2003). Thus, when the mean interval between forest fires is shorter than the pioneer species longevity, the landscape will be dominated by even-aged stands and few changes will occur in the canopy. Based on this statement, clearcut practices have been widely used on the boreal forest territories, assuming that fires were thus replaced by clearcuts. However, it has become evident that the mean fire interval in some regions, like in Quebec’s North Shore, greatly exceeds the longevity of pioneer species. Data on recent fires (1941-1992) in this region suggest that the fire cycle could well exceed 300 years. Such long intervals between successive fires could allow compositional changes in the canopy or development of an uneven-aged structure in many stands. Therefore, it is essential to question the generalized use of even-aged management. It was in this context that we started our work in Quebec’s eastern boreal forest. Our research focused on disturbance regime, forest dynamics and structure, and on the implication of this knowledge for boreal forest management in north-eastern Quebec. More specifically, the objectives are: 1) to characterize the disturbance regime of the northeastern boreal forest and its influence on the natural dynamics, 2) to identify the temporal sequences and the factors associated with the change from an even- to an uneven-aged stand, and 3) to contribute to the development of silvicultural scenarios based on the comprehension of the natural dynamics, essentially by developing a typology of structure and composition.

Natural dynamics of the North Shore forests

The mean interval between two successive fires is estimated at more than 350 years in a large part of the North Shore forest territory. Historical documents (maps and aerial photographs) allowed us to reconstruct the recent fire history of this area (Fig. 1). Between 1941

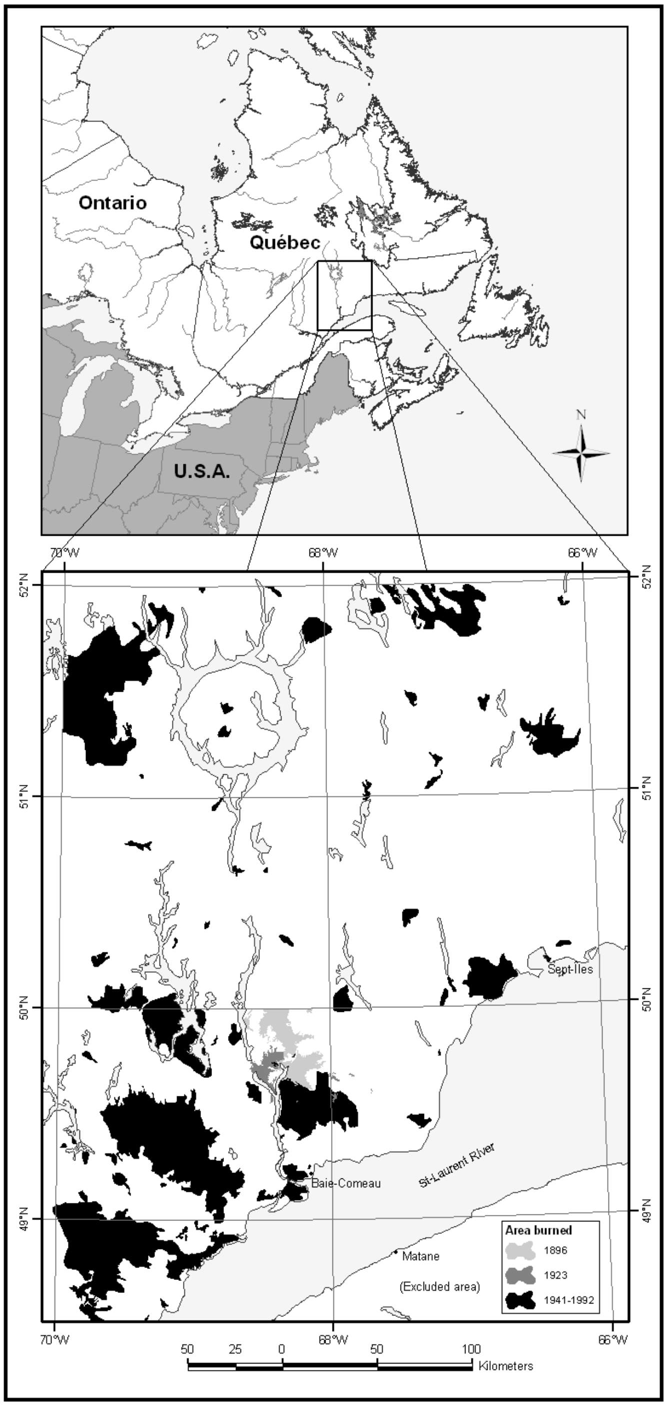

Fig. 1. Fire history map of the study area, showing principal fires that have occurred in the last 50 years. The use of aerial photographs from 1930 allowed us to map some older fires (1923 and 1896).

and 1992, 8 050 km^2 of forest have burned on a total area of 80 000 km^2. These results suggest that nearly 500 years would be required for an area as large as the entire territory to burn. Such a fire cycle widely exceeds the mean longevity of tree species and, thus, allows changes in composition and structure with time. We observed three post-fire successional trends in this area (Fig. 2), which were characterized by the early dominance of intolerant hardwood species (white birch (*Betula papyrifera*) and trembling aspen (*Populus tremuloides*)), jack pine (*Pinus banksiana*) or black spruce (*Picea mariana*) (De Grandpré et al. 2000). With time elapsed since the last fire, composition became dominated by black spruce, balsam fir (*Abies balsamea*), or a mixture of both species.

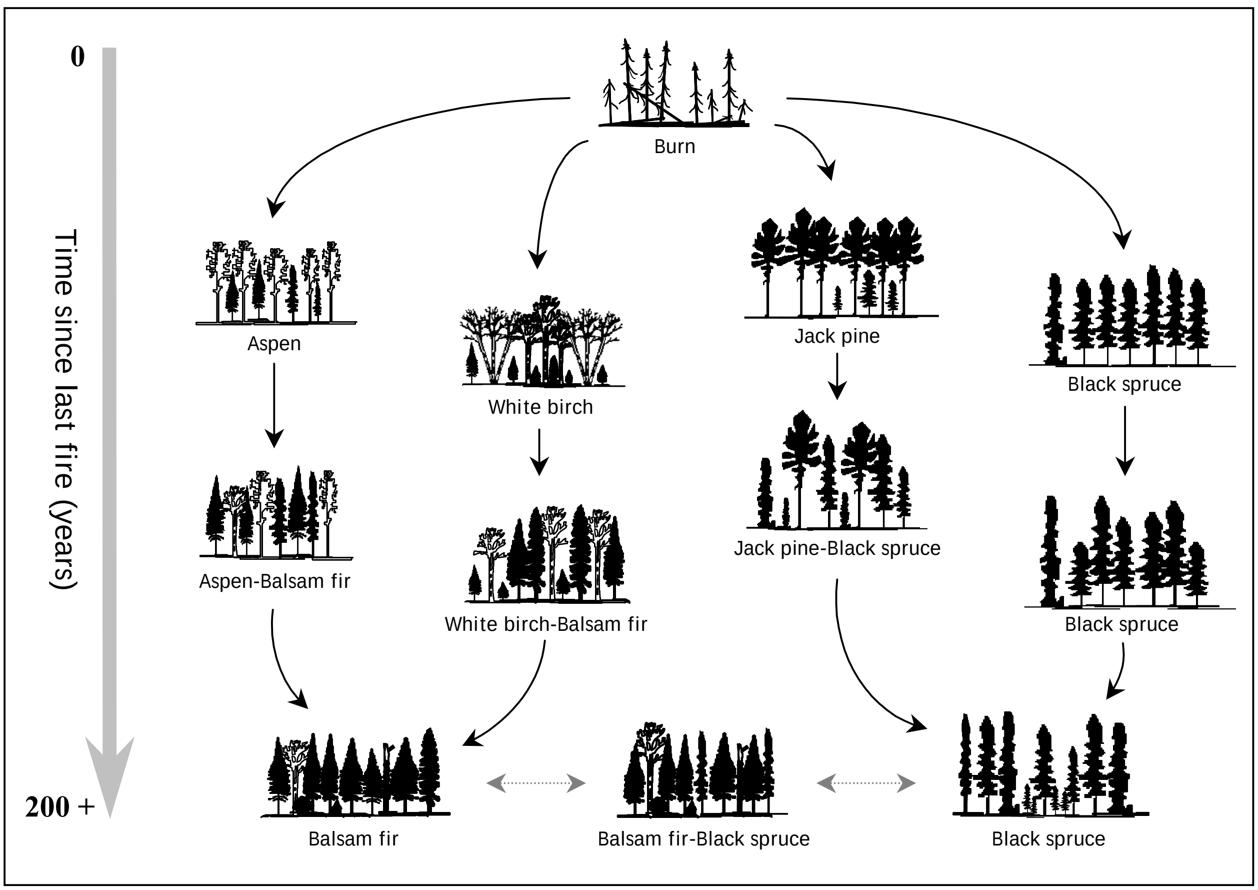

Fig. 2. Three forest successional pathways after fire.

Under such a fire cycle, succession involving canopy tree replacements is highly probable in the region and can be reflected by the development of uneven-sized structures. Like Kneeshaw and Gauthier (2003), we suggest that the start of the old-growth stage of a forest occurs when the initial cohort begins to die. Therefore, it is expected that under a fire cycle over 300 years, more than half of the stands exceed the breakup time (i.e. the time when trees of the initial cohort begin to be replaced by new trees in the canopy), and then have reached old-growth status. The stand structure is an important element for biodiversity and stands should be managed in order to maintain the structural diversity observed over the landscape. With this in mind, we have developed a statistical tool to characterize stand structure that can be used in forest management planning. This tool was developed from forest inventory data gathered by the ministère des Ressources naturelles, de la Faune et des Parcs du Québec, using discriminant analysis. The analysis makes it possible to classify the stands into three types of structure, even-sized, uneven-sized and inverse J-shaped, with an error rate estimated at only 7%. The proportion of these different structure types observed in Quebec's eastern black spruce forest region were compared with those found in the western black spruce forest region, where the fire cycle is short (50-150 yr). Nearly 90% of the western black spruce forest region is composed of pure black spruce stands, in contrast with the eastern black spruce region, where there are more pure fir and mixed spruce-fir stands (Boucher et al. 2003). Most of the western black spruce forest stands are even-sized (62%), while almost 70% of the eastern black spruce forest stands are uneven-sized or inverse J-shaped. Pure black spruce stands are more even-sized than pure fir stands, but regional differences are also found within pure black spruce stands. Our results show that it is possible to develop a robust tool to classify the structure of thousands of stands rapidly. Such tools are required if we want to consider stand structure in developing appropriate management prescriptions in the boreal forest (such as partial or selective cutting).

At the stand level, small-scale mortality events influence forest development (McCarthy 2001). A current study on gap dynamics shows that more than 50% of the surface area of old-growth coniferous stands are occupied by gaps (Table 1), and gap size varies according to stand composition. More than 85% of all gaps cover less than 100 m^2 and are caused by the mortality of less than 10 trees. Replacement probabilities show self-replacement of *Abies* in *Abies* stands as well as self-replacement of *Picea mariana* in *Picea* stands (Pham et al. *in press*). However, in *Abies-Picea* stands, there seems to be a reciprocal replacement of the two species. These results corroborate those obtained from the photo-interpretation project, which allowed us to observe the compositional changes over a 57-year period (Gauthier et al. *in preparation*). These findings on the disturbance dynamics of the region will be useful in developing of silvicultural practices that preserve structural components of older forest stands.

Table 1. Expanded gap fraction and mean number of gaps intercepted by 200 m long transects for different stand types in the northeastern boreal forest of Quebec.

	Gap fraction (%)			No. of gaps /
Stand type	Min.	Max.	Mean	transect
Abies balsamea	30	74	47	10
Abies balsamea-Picea mariana	40	82	53	10
Picea mariana	54	74	60	13
Total			54	11

In addition to small gap-forming events, massive mortality in the forest canopy occurs episodically and leads to the formation of larger openings. These disturbances tend to increase the spatial structure complexity at both the stand and landscape levels. Secondary disturbances, such as windthrow, likely contribute to the development of such structures by increasing the complexity of both stem spatial distribution within the stand and stand spatial arrangement in the landscape. Thus, we observed, using aerial photographs, that 15% of spruce stands, 38% of spruce-fir stands and 78% of fir stands showed recent traces (<30 years) of windthrow or insect damage (Table 2). Being perceptible at 0.5 ha of resolution, these disturbances constitute the driving force of forest dynamics and contribute to shaping the forested landscape. The spatial arrangement of stands in the landscape, ensuing from such disturbance dynamics, is not well defined yet, while this knowledge is essential to the planning of sustainable forest management. Therefore, one of the challenges of sustainable management in the uneven-sized boreal forest is to describe the variability and the spatial arrangement of the different forest structure types at various scales (400 m^2 plots, aerial photographs 1:15 000 and 1:40 000, satellite imagery), and to increase our knowledge of the development dynamics of these structures.

Knowledge implications for forest management

The ecological specificity of the North Shore boreal forest lies in its great proportion of uneven-sized old-growth forests and in the importance of secondary disturbances on forest dynamics. Development of a conservation strategy must be based on this specificity.

Conservation of forests free from anthropogenic disturbances should reflect proportions found under natural disturbance regimes. Therefore, since more than 50% of North Shore forests have an uneven-sized structure, this ratio should be retained within conservation areas. However, conservation alone will not make it possible to attain all sustainable forest management objectives. We have to develop extensive management strategies, in which the effects on stand and landscape structure are similar to those resulting from natural disturbances. It will be essential to describe the variability of gap sizes produced by disturbances, such as windthrow, insect outbreaks and even fires, in order to develop interventions inspired by this spectrum at the landscape level. It is crucial to rapidly develop management strategies that aim at maintaining forest structures and their resulting spatial arrangement.

Table 2. Proportion of coniferous stands affected by secondary disturbances (%) according to aerial photographs of 1987.

	Picea mariana	*Abies balsamea-Picea mariana*	*Abies balsamea*
Spruce budworm	14.8 %	37.5 %	59.0 %
Windthrow	0.3 %	1.4 %	17.9 %

Strategic planning

In terms of strategic planning, the objectives should be the maintenance of forest composition and structure in similar proportions to those observed in the natural landscape. To this end, two options can be considered, as suggested by Bergeron et al. (2002). The first one, proposed by Seymour and Hunter (1999) and Burton et al. (1999), recommends that, for a portion of the territory, forests should be allowed to age well over the usual rotation length, in order to allow time for succession processes to occur (ageing patches). However, other options must be envisaged to avoid important negative socio-economic impacts. A second option proposed is to vary silvicultural treatments in order to maintain forest composition and structure (Bergeron et al. 1999). This last option will likely involve lower economic costs since there is the possibility of harvest at each stage. Such a strategy remains difficult to implement presently since silvicultural methods and allowable cut calculations have yet to be developed.

Development needs

Research will continue in order to develop and implement management strategies adapted to uneven-sized boreal forest. The development of such strategies necessitates the description of vegetation distribution (age, diameter, height, space) at multiple scales (stand, landscape, region), elements that will also serve in the development of a structural typology. The typology must reflect the forest structure variability (spatial, diameter and height structure) observed at different scales. Such a typology should serve as a basis for the development of various silvicultural scenarios adapted to different forest types, jointly with the ministère des Ressources naturelles, de la Faune et des Parcs du Québec and other research teams. Such scenarios should take into account forest yield hypotheses, ecosystem productivity and biodiversity characteristics. Moreover, allowable cut simulation models must be modified to include the new proposed treatments. Finally, it will also be essential to develop new diagnostic tools which would facilitate cartographic localization of the various stand types (structure and composition) and their quick identification in the field. It is important that the implementation of these new strategies begins rapidly, even though all the information is not yet available. Obviously, to ensure continuous improvement of the strategies, new knowledge elements have to be integrated as soon as they become available.

Conclusion

Québec's North Shore forests differ from the generalized assumption that the boreal forest is essentially composed of even-sized stands. The great proportion of uneven-sized stands in this vast forest territory brings into question our management approach in this area. Otherwise, social pressures and commitments with the international community on sustainable forestry development lead us to review our harvesting methods in the boreal forest. Finally, we can wonder if current silvicultural treatments really optimize long-term fibre production and yield. Traditional silvicultural systems assume and prescribe the homogeneity of boreal forests in order to optimize and predict tree growth. However, it is rather the heterogeneity that characterizes the structure and composition of the North Shore forests. Therefore, the maintenance of this heterogeneity following a silvicultural intervention is certainly desirable in an ecosystemic management perspective, indeed even in a fibre yield perspective.

Acknowledgements

This project is a common initiative of the Sustainable Forest Management Network (SFMN), the Canadian Forest Service and the NSERC-UQAT-UQAM Industrial Chair in

Sustainable Forest Management, in collaboration with the ministère des Ressources naturelles, de la Faune et des Parcs du Québec (North Shore region), scierie Norbois and Uniforêt. We are also grateful to our colleagues Dominique Boucher, Jacques Morissette and Ahn Thu Pham.

References

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

Bergeron, Y. 1991. The influence of island and mainland lakeshore landscapes on boreal forest fire regimes. Ecology 72: 1980-1992.

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

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. and Gauthier, S. 2002. Natural fire regime: a guide for sustainable management of the Canadian boreal forest. Silva Fenn. 36: 81-95.

Boucher, D., De Grandpré, L. and Gauthier, S. 2003. Développement d'un outil de classification de la structure des peuplements et comparaison de deux territoires de la pessière à mousses du Québec. For. Chron. 79: 318-328.

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

De Grandpré, L. and Bergeron, Y. 1997. Diversity and stability of understorey communities following disturbance in the southern boreal forest. J. Ecol. 85: 777-784.

De Grandpré, L., Morissette, J. and Gauthier, S. 2000. Long-term post-fire changes in the northeastern boreal forest of Quebec. J. Veg. Sci. 11: 791-800.

Gauthier, S., De Grandpré, L. and Bergeron, Y. 2000. Differences in forest composition in two boreal forest ecoregions of Quebec. J. Veg. Sci. 11: 781-790.

Johnson, E.A. 1992. Fire and Vegetation Dynamics. Studies from the North American Boreal Forest. Cambridge Studies in Ecology, Cambridge University Press, Cambridge, UK.

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.

McCarthy, J. 2001. Gap dynamics of forest trees: A review with particular attention to boreal forests. Environ. Rev. 9: 1-59.

Pham, A.T., De Grandpré, L., Gauthier, S. and Bergeron, Y. Gap dynamics and replacement patterns in gaps of the northeastern boreal forest of Québec. Can. J. For. Res. *In press*.

Pickett, S.T.A. and White, P.S. 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York, USA.

Seymour, R.S. and Hunter, M.L. Jr. 1999. Principles of ecological forestry. In: Hunter, M.L. Jr. (Ed.). Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge, UK. pp. 22-61.